Usability of disaster apps: Understanding the perspectives of the public as end-users

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ABSTRACT

Multiple smartphone applications (apps) exist that can enhance the public's resilience to disasters. Despite the capabilities of these apps, they can only be effective if users find them usable. Availability does not automatically translate to usability nor does it guarantee continued usage by the target users. A disaster app will be of little or no value if a user abandons it after the initial download. It is, therefore, essential to understand the users' perspectives on the usability of disaster apps. In the context of disaster apps, usability entails providing the elements that effectively facilitate users in retrieving critical information, and thus enabling them to make decisions during crises.

Establishing good usability for effective systems relies upon focussing on the user whereby technological solutions match the user's needs and expectations. However, most studies on the usability of disaster context technologies have been conducted with emergency responders, and only a few have investigated the publics' perspectives as end-users. This doctoral project, written within a 'PhD-thesis-with-publication' format, addresses this gap by investigating the usability of disaster apps through the perspectives of the public end-users.

The investigation takes an explicitly *perceived usability* standpoint where the experiences of the end-users are prioritised. Data analysis involved user-centric information to understand the public's context and the mechanisms of disaster app usability. A mixed methods approach incorporates the qualitative analysis of app store data of 1,405 user reviews from 58 existing disaster apps, the quantitative analysis of 271 survey responses from actual disaster app users, and the qualitative analysis of usability inquiries with 18 members of the public.

Insights gathered from this doctoral project highlight that end-users do not anticipate using disaster apps frequently, which poses particular challenges. Furthermore, despite the anticipated low frequency of use, because of the life-safety association of disasters apps, end-

users have an expectation that the apps can operate with adequate usability when needed. This doctoral project provides focussed outcomes that consider such user perspectives.

First, an app store analysis investigating user reviews identified new usability concerns particular to disaster apps. It highlighted users' opinion on phone resource usage and relevance of content, among others. More importantly, it defined a new usability factor, *app dependability,* relating to the life-safety context of disaster apps. *App dependability* is the degree to which users' perceive that an app can operate dependably during critical scenarios.

Second, the quantitative results from this research have contributed towards producing a usability-continuance model, highlighting the usability factors that affect end-users' intention to keep or uninstall a disaster app. The key influences for users' intention to keep disaster apps are: (1) users' perceptions as to whether the app delivers its function (*app utility*), (2) whether it does so dependably (*app dependability*), and (3) whether it presents information that can be easily understood (*user-interface output*). Subsequently, too much focus on (4) *user-interface graphics* and (5) *user-interface input* can encourage users to uninstall apps.

Third, the results from the qualitative analysis of the inquiry data provide a basis for developing guidelines for disaster app usability. In the expectation of low level of engagement with disaster app users, the guidelines list recommendations addressing information salience, cognitive load, and trust.

This doctoral project provides several contributions to the body of knowledge for usability and disaster apps. It reiterates the importance of investigating the usability of technological products for disasters and showcases the value of user-centric data in understanding usability. It has investigated usability with particular attention to the end-users' perspectives on the context of disaster apps and, thus, produces a theoretical usability-continuance model to advance disaster app usability research and usability guidelines to encourage responsible design in practice.

PREFACE

I was nine months into my PhD, and nine months new to New Zealand, when the 7.8M Kaikōura earthquake struck at two minutes past midnight on November 14, 2016.

The shaking I felt on that night, in Wellington, was nothing like I have ever encountered in all my years living in the Philippines. During the two-minute-long shaking, I crouched under my study desk. It felt like our two-storey wooden house became a small boat, waiting to be torn apart by the waves of rough seas.

When the shaking subsided, I left my room. Seeing my housemates in the hallways, we all quickly evacuated to our back garden, unsure whether the severity of the ground motion damaged the structural integrity of our home.

Despite the mild and clear spring night, it still felt cold to be out in the open, especially since we went out only wearing our sleeping clothes. None of us brought jackets, blankets, emergency bags, or torches with us. However, all of us brought out one thing: our smartphones.

Despite the gravity of the event, mobile and internet connectivity was still intact. Huddled outside in the dark, reeling from the aftershocks, all of us got onto our devices. With my hands shaking, I used whatever relevant apps I had at the time to figure out the details of the earthquake and to connect with my family and friends to let them know I was alright.

The Kaikōura earthquake killed two people, destroyed infrastructure, disrupted local economies, and unsettled many lives. I would rather the event had not happened, but, at the moment we all used our smartphones in the dark, I knew I needed to continue to pursue my

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My PhD story is not one without challenges, but I thoroughly enjoyed the entirety of the experience thanks to the support and love I received from so many people.

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It was challenging to be away from family while doing this PhD. However, I found different 'families' in New Zealand that sustained me. The Kia Maia International Student Hostel was my home for three years under the loving care of Rosemary and Graeme Wallis, and Naomi Afoa. I am grateful for the gifts of friendship from: Ye Tingting (Lindsay), Laura and Ed Holden, Pravin Thayaparan, Transi Phu, Naoto Shiota, Janice Liaw, and Teh Meng Hing. I also want to thank the New Zealand Focolare Movement, particularly to Miriam Vender, Philip Wakelin, and Cris Sebold. Not by deliberate intention but just by their loving presence they shone light in some of my darkest moments. I started practising aikido mid-way through the PhD, and I am thankful to Riai Aikido for providing me respite from academic life. My special thanks to Victor Sugijarta and Marceau Bole-Richards for their friendship off the mat. I am grateful to my 'Stress-Free Living' friends, Dr John Guilaran, Hanny John Mediodia, Jofferson Gonzales, Janeca and Gian Miranda, and Geo Robrigado, for opening a space for me to share both my joys and disappointments.

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1 INTRODUCTION

At the onset of, and during, a disaster situation, many people will feel uncertain and will seek information that could answer questions, such as: “What is happening? What should I consider? Who can help? What are the possible courses of action?” (Karl, Rother, & Nestler, 2015, p. 19). Research and commercial efforts have sought to answer these questions for the general public by building disaster apps that will collect, curate, and disseminate emergency information (Bachmann, Jamison, Martin, Delgado, & Kman, 2015). The term ‘disaster apps’ is defined in this research project as mobile apps that help the public to retrieve, understand, and use time- and location-critical information to enhance their decision-making processes during a disaster.

The large-scale use of new technologies, such as mobile apps, by ordinary people has given an opportunity for improving communications with the public during disasters (Foresti, Farinosi, & Vernier, 2015). Effective disaster communication in today’s socio-technological world, however, requires sufficient comprehension of how people interact with these technologies (Chan, Killeen, Griswold, & Lenert, 2004; Meum, 2014). Moreover, it is vital that these technologies are designed in the context of their end-users (Nurse, Creese, Goldsmith, Craddock, & Jones, 2012). Lack of usability can dissuade users from using or trusting technology-based solutions for disasters (Mentler, 2017). Furthermore, in acute situations, seemingly minor usability issues can result in delayed or improper actions, thus becoming critical safety concerns (Kwee-Meier, Wiessmann, & Mertens, 2017). A disaster app is of little or no value if a user abandons it after the initial download or finds it unusable when interacting with it during crises (Appleby-Arnold, Brockdorff, Fallou, & Bossu, 2019; Bopp, Douvinet, & Serre, 2019).

While disaster apps are becoming increasingly available (Gómez, Bernardos, Portillo, Tarrío, & Casar, 2013), only a limited number of scientific publications have looked into understanding the users, their perceptions, and how to improve the usability of these disaster apps (Tan et al.,

2017). This doctoral project seeks to contribute to the academic discourse by investigating the usability of disaster apps from the perspectives of the public as end-users.

1.1 USABILITY

Usability is "the degree to which something is able or fit to be used" (Stevenson, 2010). Usability is differentiated from functionality. Functionality centres on the product, and it answers the question, "What does the product do?" (McNamara & Kirakowski, 2007, p. 26). Usability, on the other hand, looks into the interaction of the user and the product. It answers the question, "Can the user make the product do what it is intended to do?" (McNamara & Kirakowski, 2007, p. 27). Formally, usability is defined by the International Organization of Standards (ISO, 1998) as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

Historically, usability studies have anchored on the ISO's seven general principles, Nielsen's ten usability heuristics, or Shneiderman's eight golden rules on interactive design (Kwee-Meier et al., 2017). These general usability concepts began as principles derived from stationary workplace-based website or software contexts. For example, the ISO 9241-11 (1998) focusses on the ergonomic requirements for the visual display at an office work setting. Nielsen's (1994b) heuristics for software and website assessments were developed in the 1990s when technological systems were primarily used in stationary settings. Shneiderman's (n.d.) golden rules originated in 1985 and have been subjected to further refinement, extension, and interpretation to adapt to modern contexts.

Although the usability principles from ISO, Nielsen, and Schneiderman are still applicable to current times, they do not fully capture the mobility contexts that prevalently characterise new technologies. Multiple studies (Harrison, Flood, & Duce, 2013; Hoehle & Venkatesh, 2015; Zhang, Mowafi, & Adipat, 2009) have argued that software or website-based usability models may be insufficient to account for the contexts of mobile technologies and mobile apps. Mobile

app interfaces provide a set of usability challenges different from their stationary counterparts. Using mobile technologies provides unique and often unpredictable operational conditions as, for example, weather, lighting, safety hazards, and connectivity (Mentler, 2017). Research efforts on designing and developing apps must consider how users will effectively interact with apps given their contexts of use.

Moreover, it must also be considered that people's behaviour towards technologies for emergencies may be different from those in the general domain (Prasanna & Huggins, 2015). Usability of systems becomes especially important during crises as conditions, such as time pressure and high stress, can cause individuals to experience degradation in information-processing and decision-making abilities (Kwee-Meier et al., 2017; Sarna, 2002). Users will rely on the usability of the technologies to facilitate critical decisions during disaster situations (Sarshar, Nunavath, & Radianti, 2015). Special design attention is thus needed for technologies in critical contexts.

1.1.1 Technologies in critical contexts

The importance of usability has been acknowledged in the field of safety-critical systems as the lack of usability can lead to product discontent and users' compromised safety (Kwee-Meier et al., 2017). Multiple studies have looked at the usability of technologies in the context of responders as, for example, the police force (Kuula et al., 2013), firefighters (Nurse et al., 2012), and medical responders (Elmasllari & Reiners, 2017). In crisis situations, well-designed technological systems have aided responders and agencies to retrieve information, aiding them to make better decisions on the potential threats and response options (Dorasamy, Raman, & Kaliannan, 2013; Yang, Prasanna, & King, 2009). Despite the capabilities of these technological systems, they can only work when the interface between machines and the users are in reciprocal alignment with each other (Mentler, Berndt, Wessel, & Herczeg, 2017). Taking

account of the users and their contexts is essential when designing systems for disaster management.

Most usability studies in the disaster and crisis management field have focussed on tools for responders, like firefighters and emergency responders, and not on technologies that are available to the public, such as mobile apps (Tan et al., 2017). Despite the existence of public-facing disaster apps in the markets, most app usability studies view users as consumers situated in a normal casual or business-as-usual situation. Usability studies have focussed on social media apps (for example Hoehle & Venkatesh, 2015), banking apps (for example Mohan, Mathur, & Reddy, 2015), or health and fitness apps (for example O'Malley, Dowdall, Burls, Perry, & Curran, 2014). However, the conditions in which disaster apps are used may be different from ordinary everyday use apps. Disaster apps may be used less regularly (Reuter, Kaufhold, Leopold, & Knipp, 2017) and, when used, the users may be in a high-risk environment (Sarshar et al., 2015).

In the small number of disaster app studies where the target users are the public, the interpretation of the citizens' perspectives have been limited. A study by Gómez et al. (2013) of 250 apps for emergencies in the Google Play market confirms that most disaster apps were designed for users in the capacity of passive victims. However, the public should not be constrained to simply being endpoints of information systems. Gunawan, Fitrianie, Brinkman, and Neerincx (2012, p. 1) state that even though there is a "… growing awareness of untapped potential of affected population in a disaster situation, their inclusion in disaster management is extremely limited." Therefore, engagement with the public can provide valuable perspectives that can improve the use of technological systems for disaster management.

1.2 Research gaps, questions, and objectives

This project recognises that there are two main gaps in the study of usability in the disaster apps domain. First, studies on the usability of mobile apps often look into products assuming frequent or regular use in casual environments, such as social media, fitness tracking, and banking. There

is a limited understanding of apps that are expected to be used irregularly, and, when used, the users may find themselves in critical-context events. Second, only a small number of academic publications on critical-context technologies have taken the perspective of the general public as end-users. This doctoral project seeks to address these gaps by studying the perspectives of the public to understand disaster app usability. The project also aims to develop usability guidelines for disaster apps that take into account the users' perspectives and their contexts of use.

This dissertation is written under the 'PhD thesis with publications' format under the Massey University Guidelines (Massey University, n.d.). Taken as whole, the research project builds towards gaining an understanding of the usability of disaster apps from the perspectives of the users. The doctoral project seeks to answer the following research questions:

RQ1. How does usability influence citizens' perception of disaster apps?

RQ2. What guidance can end-user insights provide for the design of usable disaster apps?

To answer these questions, the following are the objectives of this research:

RO1. To understand the state of research on mobile apps for public use in crisis management;

RO2. To capture current perspectives on the usability of existing disaster apps from users;

RO3. To establish which usability factors are important to citizens in their use of disaster apps; and

RO4. To develop a set of usability guidelines from the insights of the end-users.

The thesis has four stages, demarcated through four manuscripts, designed sequentially to chronologically address the research objectives and questions. Table 1-1 illustrates the alignment of the manuscripts to the research questions and objectives. Each manuscript can stand alone as an independent article intended for publication. Due to the format, there will be repetition of ideas, especially in the introduction sections of the different chapters.

Table 1-1. Paper and research alignment.

Research questions	Research objectives	Manuscript and outputs	Chapter
RQ1. How does usability influence citizens' perception of disaster apps?	RO1. To understand the state of research on mobile apps for public use in crisis management	1st Manuscript • To understand past studies and research direction on disaster apps • To find existing framework and theories (if any) as a basis to build future work	3
	RO2. To capture current perspectives on the usability of existing disaster apps from users	2nd Manuscript • To scope existing disaster apps and their usability characteristics • To understand current users' perceptions of the usability of existing disaster apps • To present a set of distinctive usability constructs on the use of disaster apps	4
	RO3. To establish which usability factors are important to citizens in their use of disaster apps	3rd Manuscript • To quantitatively assess the usability constructs • To identify and test a dependent variable that is influenced by usability factors • To test the robustness of usability factors using structural equation modelling • To provide detailed insights into the relationships identified in the model	6
RQ2. What guidance can end-user insights provide for the design of usable disaster apps?	RO4. To develop a set of usability guidelines from the insights of the end-users	4th Manuscript • To integrate results from previous papers and present a set of usability guidelines for disaster apps	7

1.3 SCOPE OF THE THESIS

At the outset, it is important to identify and understand the scope of the thesis. The following explanations lay out the boundaries of this thesis.

- When considering apps, it can be challenging to differentiate usability from functionality. However, it is beyond the scope of this study to examine the functionalities of disaster apps in detail. Discussions on functionality will be minimal and will only be used to contextualise the discourse on disasters apps' usability.
- In this thesis, usability is considered from a 'perceived usability' standpoint – the usability of a system is taken from the experience of its users (Hertzum, 2010). The thesis thus moves

away from a purely positivist perspective of usability. The positivistic approach to usability may limit the studies to measures of the ease of use of interfaces (Lin, 2013; Richter & Flückiger, 2014) where usability is defined only through observable and quantifiable metrics. Measures, such as error rates, the number of clicks required, and time to complete tasks, are used and usually investigated in controlled laboratory settings (Acton, Golden, Gudea, Scott, & Change, 2004; Richter & Flückiger, 2014). In contrast, this study tries to understand usability through the perception of the users. Capturing perceived usability can be conducted through questionnaires, interviews, and observations, and analysing user-generated content (Balapour & Walton, 2017; Hedegaard & Simonsen, 2013; Nielsen, 1994a). Using a perceived usability standpoint definition has its strengths: it puts focus on the users, and it provides perspectives that are paramount to whether systems are liked, disliked, adopted, used, or rejected (Hertzum, 2010). It fits the purposes of the study in (1) understanding how usability influences citizens' outlook of disaster apps and (2) developing guidance from the perspectives of users for designing usable disaster apps.

- This doctoral research focusses on apps that are built specifically for disaster management purposes—namely, disaster apps—and moves away from general apps, such as social media apps. As will be discussed in Chapter 3, different types of apps can be used by the public during disasters. Using social media apps has been proven to provide benefits for communication during disasters (Houston et al., 2015). However, there are limitations to social media as many have raised concerns, such as distrust due to misinformation, privacy, and quality and timeliness of information (Fallou, Petersen, & Roussel, 2019; Schimak, Havlik, & Pielorz, 2015). Appleby-Arnold et al.'s (2019) study found that the public perceive disaster apps to be more reliable than social media as a communication platform between citizens and authorities. Despite disaster apps' potential to be used as an effective medium for disaster communication, comparably, only a small number of the population uses disaster apps (Spielhofer, Hahne, Reuter, Kaufhold, & Schmid, 2019). There is a need for

more detailed research into citizens' perceptions towards disaster apps (Appleby-Arnold et al., 2019). This doctoral study aims to contribute the body of knowledge by choosing to investigate disaster apps that are built specifically to provide targeted information to the public about natural hazards.

1.4 CHAPTER OUTLINE

This thesis has eight chapters. Each of the four manuscripts is an individual chapter in the thesis. Additionally, the thesis contains an introductory chapter, a research philosophy and framework chapter, a chapter on the prototype built for the doctoral project, and an overall discussion.

- **Chapter 1** introduces the rationale behind the research. It provides underlying concepts of usability and the use of technology in critical contexts, and it also outlines the research questions and objectives.
- **Chapter 2** discusses the research framework adopted in this study. It covers the overarching philosophy and the subsequent methods used in the entire research process.
- **Chapter 3,** the first manuscript, reviews the interdisciplinary literature to provide an understanding of the use of mobile apps in the disaster communications world.
- **Chapter 4,** the second manuscript, investigates the apps on the market to provide a level of understanding of how actual users of existing apps perceive the usability of disaster apps.
- **Chapter 5** discusses the disaster app prototype built for, and used in, the succeeding stages of the research.
- **Chapter 6**, the third manuscript, presents a usability–continuance model, studying in detail the relationships between usability factors and the continued use of disaster apps.
- **Chapter 7**, the fourth manuscript, provides a set of usability guidelines for disaster apps.
- **Chapter 8** provides an overall discussion that integrates the entire thesis. The narrative returns to the questions and objectives of the research. It concludes the thesis by covering the significance, impacts, limitations, and areas for future research.

2 RESEARCH PHILOSOPHY AND FRAMEWORK

> *The way we think the world is (ontology) influences: what we think can be known about it (epistemology); how we think it can be investigated (methodology and research techniques); the kinds of theories we think can be constructed about it; and the political and policy stances we are prepared to take.* (Fleetwood, 2005, p. 197)

This chapter provides the overarching philosophical approach to the study and the framework adopted for the research process. The first part of the chapter shows the dominant philosophical viewpoints in the field of information systems and rationalises the philosophical underpinnings chosen for this study. The second part of the chapter discusses the mixed method strategy and summarises the methods adopted for this research project.

2.1 RESEARCH PHILOSOPHY IN INFORMATION SYSTEMS

This doctoral research falls broadly into the field of information systems (IS). IS research involves a range of disciplines that studies the activities of gathering, processing, storing, and using information, and the associated technologies, in organisations and society (Avison & Elliot, 2006). The field of IS may study technological systems and social systems, both in parallel or the interaction between the two (Lee, 2001).

Information systems research has a practical approach to inquiry where the focus is on 'what works' (Dobson, 2012). Adapting a research philosophy is not contrary to practicality as philosophical reflection can lead to a more consistent, rational, and logical research process (Dobson, 2002, 2012). How a researcher views the world and knowledge will shape and influence a coherent design of the study.

2.1.1 Positivism and interpretivism

Most IS literature adheres to two main philosophical paradigms: (1) positivism and (2) interpretivism (Smith, 2006; Wynn & Williams, 2012). Positivists view reality as objectively given,

and knowledge of reality can be readily acquired through empirical observations of objects' measurable properties (Myers, 1997). Positivism has a deterministic approach to explaining phenomena (Orlikowski & Baroudi, 1991). As Smith (2006) explains, positivists have a Humean[1] view of causality where scientific laws are perceived as a constant conjunction of events. In IS research, most positivist studies often involve formal propositions, quantifying variables, testing, confirmation and falsification, drawing inferences, and prediction using generalisable theories (Myers, 1997; Orlikowski & Baroudi, 1991; Wynn & Williams, 2012).

Interpretivism, on the other hand, perceives reality to be socially constructed where reality is accessed only through subjective consciousness. Interpretivists explain phenomena through interpreting subjective meanings, recognising motivating actions, and understanding contexts (Myers, 1997; Wynn & Williams, 2012). From an interpretivist's standpoint, causal relationships are phenomenological rather than theoretical (Smith, 2006). Thus, interpretivist studies often involve the study of emergent situations from experiences and perceptions of participants involved rather than assessing a priori hypotheses using predefined variables (Myers, 1997; Orlikowski & Baroudi, 1991; Smith, 2006). Walsham (1993, pp. 4–5) notes that IS interpretive research is "aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context".

The two opposing dichotomies of positivism and interpretivism, as applied in IS research, have contributed to long-standing theory–practice inconsistencies in the field (Smith, 2006). Positivism has been criticised for holding a limited realist ontology that reduces causality as an empirical conjunction of events (for example, event 'A' is consistently followed by event 'B'), ignoring the deeper and more complex transpiring mechanisms of reality (Mingers, 2004; Smith, 2006). Interpretivism, on the other hand, has been criticised for rejecting the notion of

[1] Following the philosopher David Hume. "For Hume, causality is nothing more than a constant conjunction of events. In other words, there is no necessity connecting cause and effect" (Smith, 2006, p. 194)

regularities or of the causal powers of the natural and social worlds (Mingers, 2004; Wynn & Williams, 2012). Interpretivism denies the concept of generalisation and limits knowledge within a subject and its experiences (Mingers, 2004; Smith, 2006).

The contradictions of the extreme ends of the philosophical spectrum to IS research have caused IS researchers to seek, adapt, and develop alternative paradigms. Three worldviews stand in the middle ground: pragmatism, transformative–emancipatory, and critical realism (Venkatesh, Brown, & Bala, 2013). The next section briefly discusses two alternatives: pragmatism and transformative–emancipatory. Then, the succeeding section presents critical realism as the research philosophy of choice for this research and its fundamental underpinnings.

2.1.2 Pragmatism and transformative–emancipatory

The pragmatism paradigm places primary importance on the research question (Creswell & Plano Clark, 2011; Venkatesh et al., 2013). Pragmatism supports both positivist and interpretivist standpoints (Jokonya, 2016), and pragmatic research allows for mixed methods use in a single study (Creswell & Plano Clark, 2011; Venkatesh et al., 2013). It has a practical standpoint and chooses methods, not on the basis of worldviews but on 'what works' to answer the research question (Creswell & Plano Clark, 2011; Venkatesh et al., 2013).

Many scholars are cautious about pragmatism because of methodological eclecticism. The 'what works' mind-set requires little theoretical commitment and may be used by researchers to mix different methods without consideration of theoretical contradictions, incompatibility, or implications (Biddle & Schafft, 2015). Furthermore, pragmatism assumes the usefulness of methods to be known in advance. However, knowing 'what works' can sometimes only be decided when the findings are interpreted and the project completed (Hall, 2013). Pragmatism's principle of practicality and 'what works' also asks the question, practical for whom and to what end? (Biddle & Schafft, 2015; Shannon-Baker, 2016).

The transformative–emancipatory paradigm, on the other hand, tries to focus on the question 'to what end' and argues for goal-oriented research (Mertens, 2007). The transformative–emancipatory paradigm treats the research process as a means for reaching social justice by adopting explicit related goals (Creswell & Plano Clark, 2011; Venkatesh et al., 2013).

Transformative–emancipatory researchers recognise that they take on implicit value assumptions and have 'transformative' roles, aware that knowledge is not neutral, and power and social relationships shape the context of their research (Creswell & Plano Clark, 2011). Mixed methods research design is appropriate in the transformative–emancipatory paradigm as it provides more flexibility in bridging inquiry and practice (Venkatesh et al., 2013). In this perspective, the researcher involves the communities under study and tries to understand their history and their positionality in the research (Shannon-Baker, 2016). One of the main criticisms of the transformative–emancipatory paradigm is that its philosophical application becomes limited to a small range of social scientific research (Hall, 2013).

2.1.3 Critical realism

Critical realism (CR), as developed by Bhaskar (1975), is an alternative philosophical perspective that IS researchers have adopted (Dobson, 2012). Multiple disciplines, such as the social sciences, economics, organisational and management research, health, and education, have argued the usefulness of critical realism as a philosophical underpinning in their respective fields (Smith, 2006). Critical realism overcomes the positivist and interpretivist contradictions and provides a coherent philosophy for information systems (Mingers, 2004; Mingers, Mutch, & Willcocks, 2013; Smith, 2006). Table 2-1 compares CR with the other research philosophies.

Table 2-1. Comparison of philosophies

	Positivism	Interpretivism	Pragmatism	Transformative–emancipatory	Critical realism
Ontology	Single reality; objective	Multiple; socially constructed	Single and multiple realities	Multiple realities	Single reality; intransitive and stratified
Epistemology	Knowledge is gained through what can be empirically captured. Conducts testing and validates theories through deductive means	Knowledge is gained through subjective interpretations of meanings, actions, and contexts.	Knowledge is based on practicality (for example, researchers collect data by 'what works')	Knowledge is not neutral but reflects the power and social relationships within the societies we construct	Knowledge of reality is shaped by various influences; therefore, different viewpoints are valid yet also fallible
Axiology	The researcher takes an objective and independent stance. They are value-free	The researcher takes a subjective stance and accepts that they cannot be separated from the study. They are value-bound	The researcher takes multiple stances (both biased and unbiased perspectives). Values can be appropriately used in research, but they are not predetermined	The researcher has an awareness of power differentials and their role in enhancing social justice. They are value-aware	The researcher is conscious that their context, such as worldviews or experiences, influences the research; therefore, they are value-laden

(Adapted from Biddle & Schafft, 2015; Creswell & Plano Clark, 2011; Jokonya, 2016; Sweetman, Badiee, & Creswell, 2010; Wynn & Williams, 2008)

Bhaskar (As cited in Smith, 2006, p. 200) characterises CR as "ontologically bold but epistemologically cautious". CR takes on the *realist* stance where reality is believed to exist intransitively outside human perception. However, it also takes on a *critical* outlook where knowledge of reality can only be perceived through *transitive* human experiences (Mingers et al., 2013). CR, similar to transformative–emancipatory, accepts that social, cultural, and political influences shape knowledge; therefore, different viewpoints are valid yet also fallible (Zachariadis, Scott, & Barrett, 2013). However, CR allows for generalisability as it treats reality as both (1) intransitive and (2) stratified.

An intransitive reality is where objective existence is independent of our perceptions but can be objects of our knowledge (Mingers et al., 2013). Intransitive reality asserts a world of things and structures with non-deterministic causal powers or tendencies—whether physical, social, or conceptual—that operate independently from human knowledge (Mingers et al., 2013; Smith, 2006). CR assumes that the formation of knowledge of the intransitive entities occurs in the transitive dimension where researchers are mediated and contained in their social structures (Wynn & Williams, 2012). The practice of science, therefore, is a social process built on transitive objects to generate improved knowledge of the intransitive reality (Mingers et al., 2013).

CR also views reality in a stratified structure: (1) the real, (2) the actual, (3) and the empirical (see Figure 2-1). In the domain of the real, there are inherent powers and tendencies of things that result in *generative mechanisms* (Mingers, 2004; Zachariadis et al., 2013). The myriad of interacting mechanisms generates the phenomena of events, observed or unobserved, of the actual domain (Smith, 2006; Zachariadis et al., 2013). The actual is a subset within the real as the empirical is the subset of the actual. The empirical domain, then, is where we acquire our knowledge and where we get to measure and to perceive the experienced events (Smith, 2006).

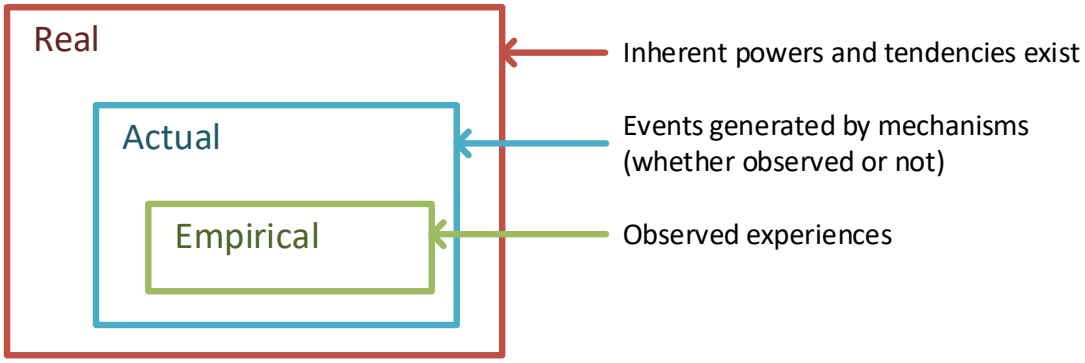

Figure 2-1. Stratified ontology. Adapted from Mingers, 2004.

The CR ontology transcends the positivist's view of causality (Smith, 2006). Causality is not merely the constant conjunction of observed events (for example, event 'A' is consistently followed by event 'B'), rather CR acknowledges and seeks to understand the causal process and conditions to which 'A' brings about 'B' (Zachariadis et al., 2013). CR provides an ontology that asserts the role of meanings, interpretations, and context, as does the interpretivist philosophy (Smith, 2006). Moreover, it allows researchers to pursue a generalisation agenda that is beyond the subjective scope of the interpretivist epistemology as it acknowledges the existence of mechanisms that puts the subject in an existence with inherent regulating mechanisms (Mingers et al., 2013; Smith, 2006; Zachariadis et al., 2013).

Despite a realist ontology, CR allows for epistemological relativity (Zachariadis et al., 2013). Our human experiences shape our knowledge in the transitive domain where knowledge is "historically emergent, political and imperfect" (Zachariadis et al., 2013; p.857). CR acknowledges that to understand different epistemological characteristics of different types of objects, we can use a range of research methods (Mingers et al., 2013). With a relative epistemological stance, CR supports different methods (quantitative, qualitative, or both) but is likely to use mixed methods as it produces more robust inferences than in using a single method (Mingers et al., 2013; Zachariadis et al., 2013). This study takes on a critical realist approach using mixed methods to try to build an understanding of the context and mechanisms of usability of disaster apps.

2.2 MIXED METHODS

Creswell (2003) identifies multiple purposes in conducting mixed method research; these include complementarity, completeness, developmental, expansion, corroboration, compensation, and diversity purposes. This study has a developmental purpose and uses a sequential mixed methods approach to understand usability of disaster apps. Table 2-2 summarises the developmental purpose and its methodological implications to a CR philosophy.

Table 2-2. Conducting developmental mixed methods research.

Purpose	Description	Implications from CR
Developmental	Sequential mixed method research; one type of research uses inferences from another research type	Part of the retroductive approach of CR, inferences need to hypothesise about the causal mechanisms whose recovery will then inspire sequential research

Source: Zacharadias et al. (2013)

This research project starts with understanding the context related to the usability of disaster apps by studying the literature. It then proceeds to observe, hypothesise, and test via multi-method user-centred data collection phases. Finally, generalisations are formed from the observations to form a set of guidelines.

2.2.1 Retroduction

For the realist, the driver for deciding the methodological approach will always be to unearth mechanisms and structures of events—to understand the 'why' and 'how' of causality (Dobson, 2012). To do so requires a retroductive inquiry—the movement between observed events and underlying mechanisms. The retroductive approach takes a phenomenon of interest and proposes possible mechanisms that would generate relevant events. The inquiry moves between regularities from the empirical domain to the possible generative mechanisms of the real domain (Mingers et al., 2013). The retroductive process involves four general steps (Zachariadis et al., 2013):

1. **Description** – asks the question, *What is happening?* It involves the appreciation of the research situation and focusses on the phenomena under study. For this research project, the description stage involves studying existing literature as well as observing the user sentiments from the markets to understand the usability of disaster apps.
2. **Retroductive analysis** – asks the question, W*hy is it happening?* It involves hypothesising about the possible structures of the phenomena under study through iterative phases of investigation. For this research project, the retroductive analysis stage involves measuring and observing user sentiments through various user-centred data sources.
3. **Assessment and elimination** – asks the question, *How could the explanation be different?* It entails critical assessment and comparison of inferences from a combination of different methods. For this research project, this stage involves testing a usability model quantitatively, finding explanations through analysing observations with the end-users and assessing the findings with other stakeholders other than the end-users.
4. **Action** – asks the question, *So what?* It involves circulating the research to see if the research findings from the previous stages are satisfactory to an audience with background knowledge and expertise. For this research project, the action stage involves presenting a set of usability guidelines to app stakeholders (developers, designers, and owners) that reflect the end-users' perspectives.

Figure 2-2 summarises how the chapters in this research project align with the retroductive process. A similar figure will be shown at the beginning of each chapter to pinpoint the positionality of the manuscript to the thesis.

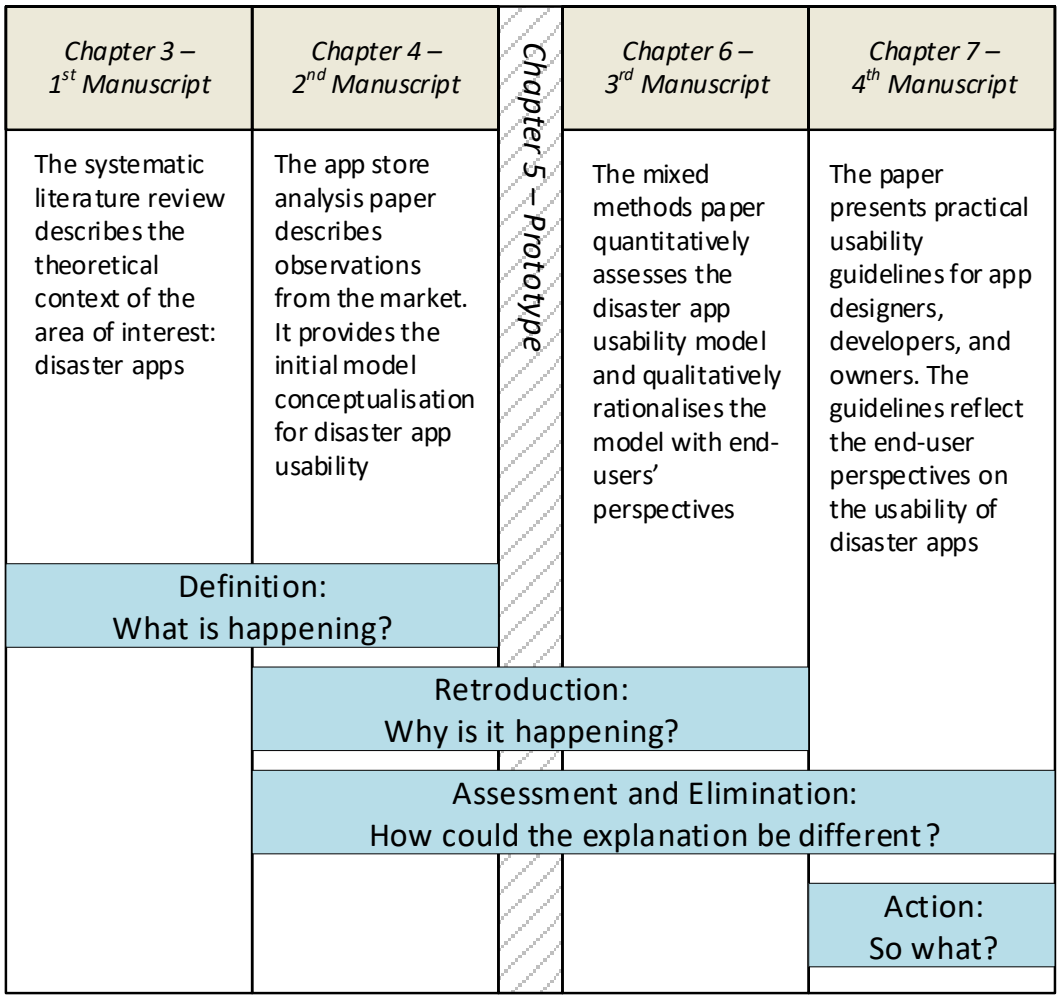

Figure 2-2. Retroductive process as applied to the research.

This doctoral project has four developmental stages taking on the retroductive approach. The retroductive process in the context of IS research encourages the exploration of *why* and *how* an IS initiative has the potential to cause desired changes. Furthermore, it seeks to explore the context as it also asks the questions *for whom* and in *what circumstances*. In short, this retroductive process seeks to explain phenomena but also defines contextual components within which such mechanisms work. A part of this research project investigates the end-user's perspectives on the usability of disaster apps through the use of a prototype. It looks at the phenomena with the public as users and in the context of retrieving hazard information from disaster apps. The next section summarises the manuscripts and methods.

2.2.2 Manuscripts and methods

The research project employs a mixed method approach that uses both quantitative and qualitative techniques. The project has four manuscripts addressing each of the four research objectives (as stated in Section 1.2). Each study builds upon the other towards the creation of a set of proposed usability guidelines.

2.2.2.1 *1st Manuscript (Chapter 3)*

The research project first describes the mobile app phenomena in disaster management through a study of academic publications. The first study is a systematic literature review of 49 crisis informatics articles. The study scopes relevant disaster app literature, highlighting the gaps and opportunities for research in this area. The method for this study follows the scoping review process by Arksey and O'Malley (2005).

2.2.2.2 2nd Manuscript (Chapter 4)

The research project then describes the market setting for disaster apps through an app store analysis paper. App store analysis uses publicly available data from the app markets to learn about trends and behaviours (Martin, Jia, Sarro, & Harman, 2016). The second study utilises 1,405 user-reviews gathered from 58 disaster apps from the iOS and Google Play app stores (Apple Inc., n.d.-b; Google, n.d.-b). Analysis of the user-reviews follows Braun and Clarke's (2006) process for thematic analysis. The study proposes a conceptual model for the usability of disaster apps using the insights from the app markets.

2.2.2.3 Prototype (Chapter 5)

Best practice guidance on crisis communication advises development and utilisation of technologies through "know[ing your] audience" (Kain, de Jong, & Smith, 2010, p. 305). To have an in-depth understanding of the users' perspectives of usability, this doctoral project includes the development and utilisation of a disaster app prototype for data gathering. As the doctoral project is situated in New Zealand, the prototype (as discussed in Chapter 5) reflects the hazards

context and alerting and warning needs of the New Zealand public. The prototype was used as a tool for the usability inquiries to stimulate conversations with the participants on their perspectives of disaster apps and usability. Data gathered from the usability inquiries are used in the 3rd and 4th Manuscripts.

2.2.2.4 3rd Manuscript (Chapter 6)

After gaining an appreciation of the phenomena through the academic literature (1st Manuscript – Chapter 3) and the app markets (2nd Manuscript – Chapter 4), this chapter uses a mixed methods approach to understand the structures and mechanisms of disaster app usability. An online survey with 271 disaster app users provides insights into usability factors and their relationship to users' intentions to use disaster apps. The use of structural equation modelling (SEM) re-frames and validates a usability–continuance model. SEM is particularly compatible with critical realism as it looks to evaluate theoretical hypotheses involving mechanisms and structures that seek to reflect real processes, and SEM includes analysing unobserved variables, cross-influences, as well as contextual effects (Pratschke, 2003).

The quantitative assessment of the usability factors and their relationship to continuance intention is qualitatively complemented with the data gathered from the usability inquiry using the prototype developed for this thesis (Chapter 5). The participation of target users through usability inquiry allows for in-depth understanding through the users' experiences and preferences (Nielsen, 1994a; Zapata, Fernández-Alemá, Idri, & Toval, 2015). The analysis of qualitative data follows Braun and Clarke's (2006) process for thematic analysis.

The third manuscript highlights the benefits of the critical realism philosophy as applied to this research project. The combination of mixed methods allows for generalisability through quantitative modelling as well as emphasising the importance of meaning and context through the qualitative inquiry.

2.2.2.5 4th Manuscript (Chapter 7)

The final manuscript translates the research findings gathered from the end-users into actionable guidelines that can be used by app stakeholders, such as developers, designers, managers, or owners. The fourth manuscript scrutinises the results from the usability inquiry. The same data set from the third manuscript was used, but a separate implementation of thematic analysis was conducted. The theoretically driven thematic analysis followed Braun and Clarke's (2006) process by looking into overarching usability considerations that are critical for disaster apps. The statements were then presented to 17 experts for feedback, through a combination of focus group discussion (FGD), interviews, and a structured survey, to develop the usability guidelines for disaster apps.

The inclusion of the stakeholders as part of the research process provides for a lens of criticality from a perspective different from the end-users. Furthermore, the engagement with the experts also fulfils the action stage of the retroductive process of critical realism. It allows the development of a concrete outcome from the research that can appropriate change in research and practice.

2.2.2.6 Ethics

This doctoral research project involves different data sets and uses various methods with parts requiring participation from end-users and app stakeholders. Where necessary, peer-reviewed ethical approval was sought under the Massey University code of ethical conduct for research, teaching, and evaluations involving human participants (Massey University, 2017). The first two manuscripts did not undergo the ethical approval process for human participation as the studies only used secondary data through the literature and the app store markets. The methods for the third and fourth manuscripts utilised an online survey, the usability inquiry, and the expert feedback (using FGD, interviews, and a structured survey). All of these involved human participation and received peer-reviewed approval under the Massey University code. Although

the topic of disaster can cause some discomfort, there was no reason to expect any harm to the participants as the focus of the data gathering methods was on the matter of usability rather than on disasters. The nature of the discomfort is "minimal and no more than is normally encountered in daily life" (Massey University, 2015, p. 1). The ethics notifications on the peer-reviewed approvals can be found in Appendix A.

2.2.2.7 Summary of research methods for the thesis

The research methods used in this doctoral research project are summarised in Table 2-3. Each of the manuscripts (Chapters 3, 4, 6, and 7) will provide the details for each.

Table 2-3. Summary of data sets and methods for each of the manuscripts.

Manuscript	Data gathering method/ instrument	Data set	Methods for data analysis
1st Manuscript	Systematic selection of articles	49 academic articles	Scoping literature review (Arksey & O'Malley, 2005)
2nd Manuscript	Systematic selection of apps and user reviews	1,405 user reviews	Thematic analysis (Braun & Clarke, 2006)
3rd Manuscript	Online questionnaire + usability inquiry using a prototype	271 survey responses + 18 inquiry interviews	Structural equation modelling + thematic analysis (Braun & Clarke, 2006)
4th Manuscript	Usability inquiry using a prototype + FGD, interviews, and a structured survey	18 inquiry interviews + 17 experts' feedback	Iterative design process

3 [1ST MANUSCRIPT] MOBILE APPLICATIONS IN CRISIS INFORMATICS LITERATURE: A SYSTEMATIC REVIEW

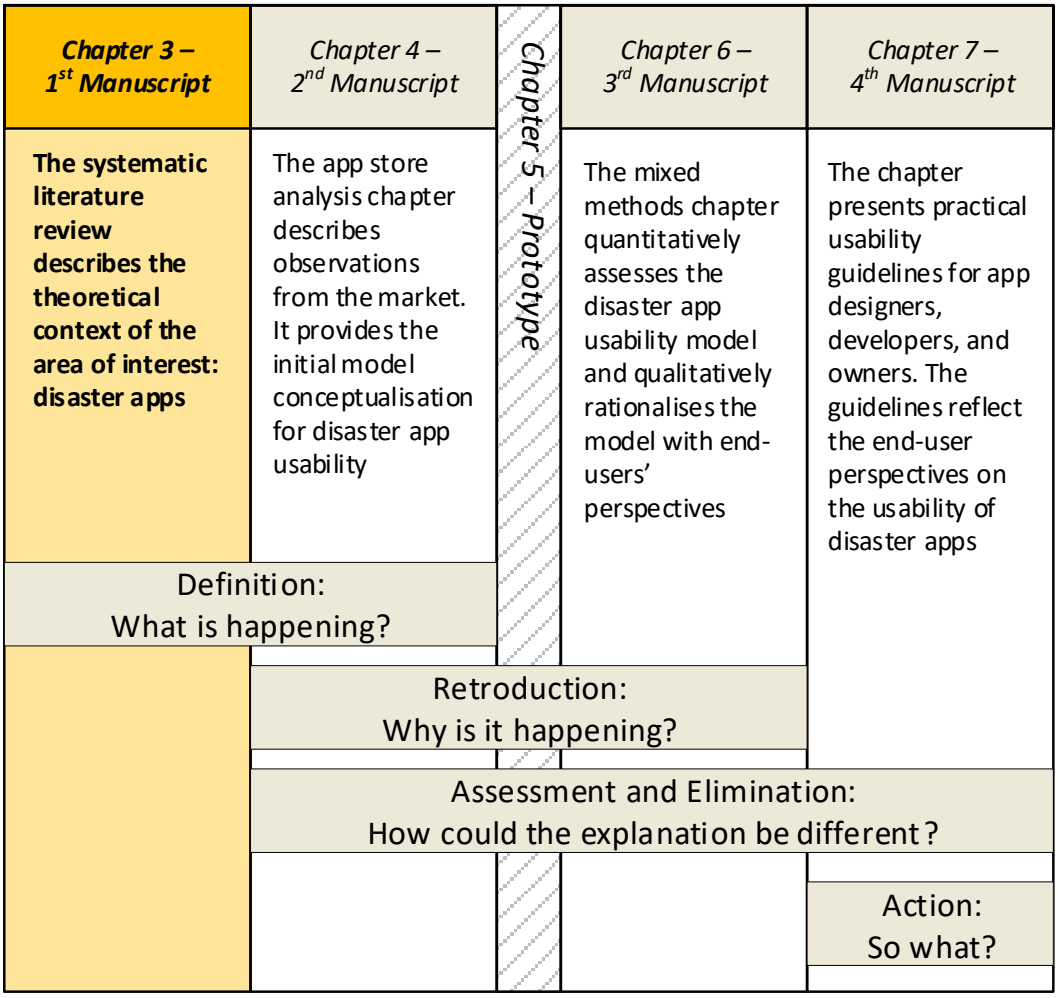

Figure 3-1. Positionality of the 1st manuscript to the thesis.

ABSTRACT

How members of society interact during disasters has significantly changed because of technological innovations and new media evolution. The modality changes in crisis communications, such as the popular rise of mobile application use, may pose risks to the public if not properly studied, adopted, and utilised. Crisis informatics, as an emerging field of research, studies the socio-technical advancements in disaster management. The purpose of this review is to summarise the involvement of mobile applications (apps) in crisis informatics literature and to scope opportunities for further research on citizens' use of mobile apps during disasters. This

review uses a scoping process to identify and analyse 49 crisis informatics articles that focus on mobile apps in disaster situations. The study also investigates the various mobile apps that engage with the crowd during disaster situations. Findings from literature show that apps used in disasters can be general-purpose apps or built-for-disaster-purpose apps. This review further focusses on the built-for-disaster-purpose apps and shows the various interactions these apps foster with the public and the apps' value-added contributions throughout the disaster life cycle. Due to the varying detail the articles provide, comprehensive appraisal of the technical functionalities of these apps are not within the scope of this review. Communication during disasters between the public and authorities has become more dispersed. To fully augment disaster resilience through technology, it is important that future research should engage in user-centred studies to gain more insights into citizens' needs, motivations, expectations, experiences, and limitations when using mobile apps. This study highlights three areas for future research: (1) engagement of apps prior to the disaster response stage; (2) public behaviour and motivation towards the use of apps; and (3) usability of mobile apps.

MANUSCRIPT PREPARATION AND PUBLICATION

I prepared the manuscript as the primary author with my supervisors, Dr Prasanna, Dr Stock, Dr Hudson-Doyle, Dr Leonard, and Professor Johnston, as co-authors. I conducted the data collection, analysis, and drafted the initial manuscript. The co-authors provided guidance on the systematic review analysis, gave insights into patterns in the data collected, and offered feedback on the content and structure of the manuscript. I prepared the final manuscript for submission to the journal. The manuscript, published in 2017 by the International Journal of Disaster Risk Reduction, was accepted with minor revisions by the journal (Tan et al., 2017).

3.1 INTRODUCTION

Communication is a crucial component in managing disasters as communication can aggravate or alleviate the impact of disaster situations (Haddow & Haddow, 2014b; Rodriguez, Diaz, Santos, & Aguirre, 2007). In disaster scenarios, numerous people and agencies become linked, creating complex information demands in constrained supply capacities, thus generating large and unique problems (Andersen & Spitzberg, 2009). How members of society interact during disaster situations has significantly changed because of technological advancements and new media evolution (Andersen, 2016). With the ubiquitous presence of social media and mobile devices in our networked world, the influence of Information and Communications Technology (ICT) on social phenomena cannot be ignored (Ngai, Tao, & Moon, 2015).

Crisis informatics, as termed by Hagar (2010, p. 10), is "broadly defined as the interconnectedness of people, organisations, information and technology during crises. Informatics often relates to the development of new uses for information technology and focusses on how people transform technology and how technology transforms people." Two important movements in communications have given rise to crisis informatics: (1) the shift from a top-down approach to bottom-up interaction, and (2) the growth of socio-mobile capacities (Lopatovska & Smiley, 2014). The increasing interconnectedness of our society challenges the traditional one-way dissemination of disaster communications (Andersen, 2016; Purohit et al., 2014). The rising trend of social media has created a communications world that has become "more complex rather than linear" (Andersen, 2016, p. 128).

In line with the growth of social media usage for disaster communications, mobile inventions and applications have also expanded. It is through these mobile technologies that users have unparalleled access to information (Haddow & Haddow, 2014a, 2014b). This chapter seeks to contribute to current research by reviewing the role of mobile applications (apps) in the crisis

informatics literature and by framing opportunities for further research on citizens' use of mobile apps during disasters.

This literature review followed the scoping review process devised by Arksey and O'Malley (2005). The review process started with a broad question: *Are mobile applications represented in crisis informatics literature?* Through the scoping process, the following questions were raised:

- *What purpose do mobile apps serve in disaster situations?*
- *What interactions do mobile apps foster?*
- *What are the roles of the public when using these apps?*
- *In which stage of the disaster management cycle do the apps contribute?*

Findings from the 49 articles included in this review provide insights into the above questions. Furthermore, this review highlights three areas for future research: engagement with apps before the disaster response stage, public behaviour and motivation in the use of apps, and usability of mobile apps.

This chapter is structured into five sections. First, the chapter contextualises the review by providing a background to the study, briefly discussing (1) the change in the communication landscape and (2) crisis informatics as a field of study. Second, the chapter then presents the methodology, and, third, the findings from the literature follow. Fourth, the discussion section examines the findings in context to current and future research trends for mobile apps in crisis informatics. Fifth, the chapter concludes with a summary of recommendations for future research.

3.2 BACKGROUND OF THE STUDY

3.2.1 Communication during disasters

Most practices in disaster communication, whether stemming from crisis communication or risk communication traditions, have centred on an authority-centric *push* culture where messages

come from authorities and are principally distributed through mass media to the public (Houston et al., 2015; Rodriguez et al., 2007). Traditionally, communication is understood "as a planned activity conducted through the use of established strategies, regulations, and standardised plans" (Olsson, 2014, p. 115). A top-down approach is one in which the focus is on the transmission (Olsson, 2014).

In this traditional *push* culture, the authorities act as the focal point where they treat communication as an intentional activity (Andersen, 2016; Olsson, 2014). Authorities can be the government or official organisations that have a mandate over the management of disaster situations; they can be international, national, regional, or local in scale (Ghersetti & Odén, 2014). People assume authorities are ready to: take responsibility, maintain order, and safeguard society from the effects of disasters (Dressel & Pfeil, 2014; Ghersetti & Odén, 2014). Traditional mass media during disaster communication uses one-to-many transmission (Andersen, 2016). The public has often relied on news media (for example, radio and television) as their main source of detailed information on disaster situations; however, for alerting to reach the widest audience possible, news media alone is not sufficient (Ghersetti & Odén, 2014). In strategic alerting, as good practice, multiple channels are needed to promote reinforcement and redundancy (Ghersetti & Odén, 2014).

However, the one-way disaster communication paradigm has been challenged by the changing media landscape. Through the years, different media channels allow people to communicate with each other in various ways during crises (see Table 3-1). Reuter, Marx, and Pipek (2012) point out that social technologies are already integrated into our societal infrastructure. According to Reuter et al. (2012), social-software-assisted cooperation has aided in crisis management in four categories: (1) crisis communication – quickly communicating with citizens for individual needs; (2) self-help communities – cooperation through emergent groups; (3) integration of citizen-generated content – integration of information from various social

software sources; and (4) inter-organisational crisis management – cooperation among professional organisation communities. These various types of social-software-assisted cooperation, along with emerging technologies, such as mobile phones and location-based media, have the potential to enhance crisis management (Reuter et al., 2012).

Table 3-1. Communication paradigms.

Interactions	Description	Examples
One-to-one	Individuals communicate with each other	Telephone call, SMS messaging
One-to-many	A single source distributes information broadly	TV broadcast, radio broadcast
Many-to-many	Participants can publish and receive broadly with one another	Social media platforms: Facebook, Twitter

Communication during disasters is moving towards the crowd (Auferbauer, Ganhör, & Hilda, 2015). 'Movement towards the crowd' means that members of the public no longer act simply as passive recipients of information but, rather, the crowd can self-organise, communicate as a network, and provide ongoing assistance amongst each other during disaster events (Palen, Hiltz, & Liu, 2007). This movement is a great opportunity to improve independent community resilience. However, multiple complexities arise with this many-to-many interaction from the crowd. For example, too much information can cause strain on the collective or authority-based capacity to manage the disaster (Manoj & Baker, 2007). Despite the increased complications, the presence of social media technologies may be advantageous during disaster events because such technologies also have many beneficial attributes, such as greater capacity and interactivity (Houston et al., 2015).

3.2.2 Crisis informatics

Crisis informatics, as a growing research field of interest, seeks to understand online behaviour in social computing during disaster events (Palen, Anderson, et al., 2010). The 2010 Haitian earthquake acted as the tipping point for demonstrating the value of ICT and new media in crisis communications (Fraustino, Liu, & Yan, 2012; Yates & Paquette, 2011). Crisis informatics looks into the socio-technical aspects of disaster management with a particular focus on the

interaction between the people and organisations involved (Hughes, Peterson, & Palen, 2014). The study of crisis informatics aims to contribute to scientific knowledge and society by updating theories, developing informed policies, and innovating technologies to better improve disaster resilience (Palen, Vieweg, & Sutton, 2007; Pipek, Liu, & Kerne, 2014).

Even before the 2010 Haitian earthquake, some studies already noted the changing media landscape. As early as the 2005 Hurricane Katrina, researchers observed the emergence of online forums following the disaster (Palen, Hiltz, et al., 2007). Further interest in crisis informatics emerged as social media platforms, such as Facebook, gained in popularity. For example, after the 2007 Virginia Tech Shooting, many of those affected sought social media information during and after the mass shooting event (Vieweg, Palen, Liu, Hughes, & Sutton, 2008). Early academic publications on crisis informatics also emerged from the 2007 Southern California Wildfires (Sutton, Palen, & Shklovski, 2008), the 2009 Red River Valley Flood (Palen, Starbird, Vieweg, & Hughes, 2010), and the 2009 H1N1 pandemic (Boulos et al., 2011; Palen, Vieweg, & Anderson, 2010).

However, crisis informatics gained more traction as the Haitian 2010 earthquake amassed a vast scale of spontaneous digital volunteerism (Liu, 2014). Partly because of the Haitian diaspora, volunteers across the world came together with technology skills through social media to collaboratively work on crisis maps to aid relief efforts. For the first time, the United States government agencies used social media extensively to gain and coordinate knowledge for disaster management (Yates & Paquette, 2011). The public's and authorities' wide-scale acceptance of new media technologies legitimised crisis informatics as an area of research. Since 2010, an increased volume of academic research has explored crisis informatics. For example, the initial search for relevant crisis informatics articles for this review resulted in 356 publications between the years 2007 to 2015, of which the most publications (93%) occurred after the year 2010 (See Figure 3-2).

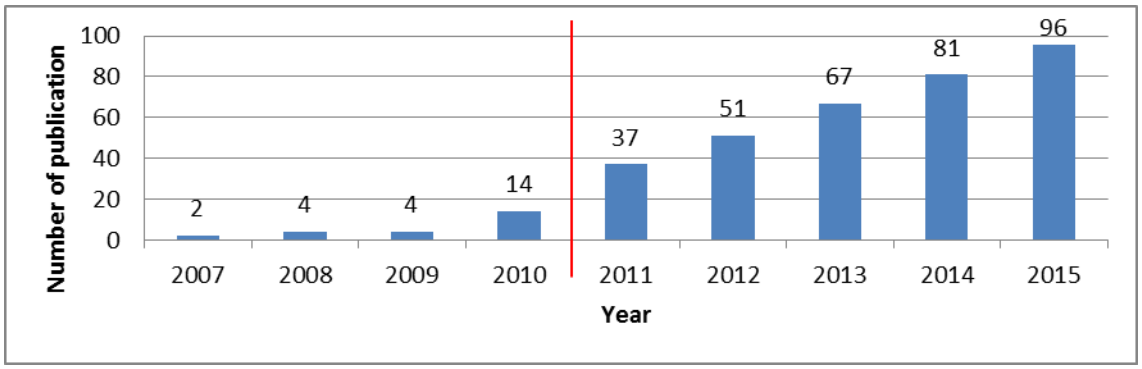

Figure 3-2. Increase in crisis informatics publications post-2010.

In addition, since the 2010 Haitian earthquake, research has more frequently integrated the varied fields of technology, society, and disasters. Some articles have systematically analysed and compared studies from different focus areas, including collective behaviour and social media in disasters (Eismann, Posegga, & Fischbach, 2016); crowdsourcing and emergency management (Liu, 2014); Twitter communication and stakeholder expectation in various disaster situations (Olteanu, Vieweg, & Castillo, 2015); and on algorithms for processing social media messages (Imran, Castillo, Diaz, & Vieweg, 2015). Similarly, this review contributes to the literature by providing insights from systematically analysing mobile apps in crisis informatics research.

Crisis informatics integrates three main topics: (1) disaster management, (2) ICT, and (3) socially generated and processed content. Crisis informatics covers a broad scope of disciplines, and it branches into several themes of study although, currently, there are no demarcated boundaries on these themes. Depending on the discipline lens, different research areas are highlighted (see, for example, Pipek et al., 2014). From a thematic analysis of 373 unique publications, we have identified broad themes (See Table 3-2). These themes are not mutually exclusive and may overlap.

Table 3-2. Crisis informatics themes of study

Themes	Description	Examples of papers
Social media analytics	Literature quantitatively or qualitatively assesses data produced by the public through social media to understand socio-behavioural phenomena. These studies often involve recommendations on improving quality mining of social media data (such as Twitter tweets or Facebook posts) during the immediate timeframe of the disaster.	• Barrenechea, Anderson, Aydin, Hakeem, & Jambi, 2015 • Cameron, Power, Robinson, & Yin, 2012 • Bruns & Stieglitz, 2012
Adaptation and utilisation	How individuals and organisations adopt and use social media and technologies during disaster situations	• Hughes, St. Denis, Palen, & Anderson, 2014 • Kavanaugh et al., 2012 • Lindsay, 2011
Information sharing behaviour	Looks at the socio-behavioural aspect of information sharing of people and organisations during disasters. It looks at the motivations behind information seeking and sharing to allow crowdsourcing to work	• Shaw, Burgess, Crawford, & Bruns, 2013 • Secretan, 2011 • Palen, Hiltz, et al., 2007
Improving technical capacities	Focusses on technological aspects. These papers present technological developments and innovations to improve disaster management capabilities. The studies look at a wide technical range: from infrastructure to modalities that will be resilient during disasters.	• Soden, Budhathoki, & Palen, 2014 • Adam, Shafiq, & Staffin, 2012 • Shih et al., 2013

3.3 METHODOLOGY

This review used the scoping typology. Scoping reviews, also known as mapping reviews, aim to frame the nature of existing literature on a particular topic (Paré, Trudel, Jaana, & Kitsiou, 2015). Scoping reviews have been conducted and accepted in the information systems field. For example, Sjøberg et al. (2005) and Venkatesh et al. (2007) published well-cited scoping studies that have helped frame the literature in their respective fields of software engineering and technology adoption (Kitchenham, Budgen, & Brereton, 2011; Paré et al., 2015). The scoping review usually starts at a broad level, follows the research trend, and develops inclusion/exclusion criteria to scope the size and nature of a particular topic (Kitchenham et al., 2011; Paré et al., 2015). This study followed Arksey and O'Malley's (2005) five-step scoping

review process: (1) defining the research question, (2) identifying relevant studies, (3) selection of articles, (4) charting the data, and (5) analysing and collating the results.

The purpose of the review was to find research opportunities for mobile apps in the crisis informatics literature. Unlike other systematic literature typologies, in scoping reviews, the research questions are allowed to be generic (Kitchenham et al., 2011). The review started with an overarching question: *Are mobile apps represented in the crisis informatics literature?*

The scan for relevant academic publications started with using the EBSCO Discovery Service—a unified indexed search service that simultaneously searches through multiple indexed databases and collections. The search covered the period starting at the year 2000 until the end of the first quarter of 2016. Additional searches were conducted on Scopus and Web of Science to ensure coverage of major publications on the topic. Only peer-reviewed journals and conference proceedings in English were considered. Table 3-3 summarises the literature search results. Search criteria included the keywords 'crisis informatics' and 'mobile' but also included variants of these keywords. Alternate searches for 'crisis informatics' used a search combination of 'disaster management' (or 'emergency management' or 'crisis management') and 'social media' (or 'web 2.0', or 'citizen science', or 'crowdsourcing'), without 'crisis informatics'. Substitute keywords for 'mobile' included the words platform, device, instrument, tool, and phone. The initial search produced 1,166 results.

Table 3-3. Summary of literature search results

	EBSCO Discover	**Scopus**	**Web of Science**	**Total**
Initial search criteria results				
'crisis informatics' AND 'mobile'	19	75	23	117
('disaster management' or 'emergency management' or 'crisis management') AND ('social media' or 'web 2.0' or 'citizen science' or 'crowdsourc*')	348	495	206	1049
Total	**367**	**570**	**229**	**1166**
Total articles after removal of duplicates	93	259	21	373
Total articles after Exclusion Criteria 1	44	189	13	246
Total articles after Exclusion Criteria 2	**6**	**43**	**0**	**49**

Further filtering removed duplicates within and between databases, reducing the number to 373 unique publications. We then employed two rounds of inclusion–exclusion criteria to filter relevant documents. Figure 3-3 summarises the inclusion–exclusion process. While the numbers of articles are listed, we are of the view that the qualitative aspects reported in the articles regarding the usability and utility of the disaster apps to be more important than the number of articles.

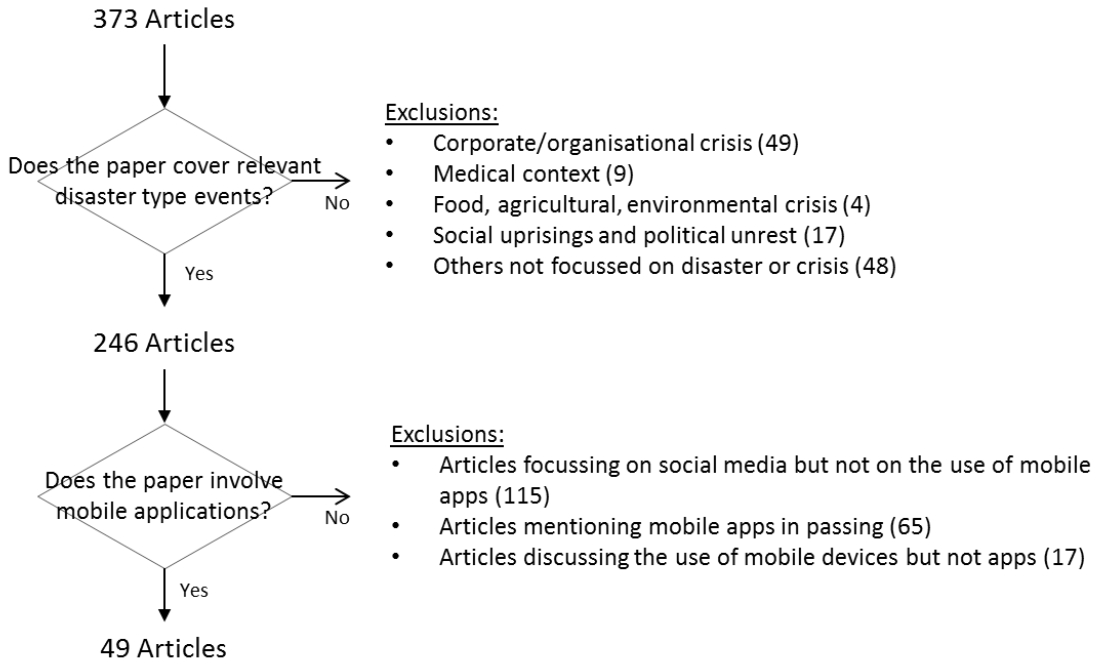

Figure 3-3. Inclusion and exclusion criteria.

The first inclusion–exclusion criteria looked at the types of disasters discussed in the literature. The definition of 'disaster' adopted in this review comes from the crisis informatics perspective: "Disaster situations are a result of hazards with varying predictabilities in a time-pressured environment. The increase in uncertainty during crises often leads to complex response efforts with broad societal consequences." (Liu, 2014, p. 392)

Differentiating disasters from non-disaster crises, crises are usually seen from the perspective of an organisation (Fraustino et al., 2012), but this review considers disasters from a societal perspective rather than that of a single organisation. Based on this criterion, this review excluded articles relating to corporate crises, such as those of public relations problems, social

media fiascos, and product recall situations. This review also excluded articles that were in the medical organisational context where articles focussed on hospital management and social media use in the medical community.

Furthermore, the disruptions included in this study were those characterised by short-term, imminent time pressures rather than slow catastrophes characterised by long emergent time spans. As such, articles on food shortages, and agricultural and environmental problems were excluded from the review. The study also excluded articles delving into political unrests and uprisings where the articles focussed on using technology for the purposes outside disaster management, such as for election campaigning, tracking political unrest, propaganda dissemination, and pushing for political change.

Any other articles that did not put emphasis on disasters were also excluded. The disregarded articles had an array of topics too varied to discuss in detail, but some excluded topics involved e-learning, smart cities, and web design, among others. In total, 127 articles were excluded. The 246 articles included for further review related mostly to natural disasters and terrorism.

The second inclusion–exclusion criteria determined whether the materials contained sufficient mobile app content. On occasion, the articles mentioned mobile apps only in passing and did not dwell on the apps in the discussion. For example, Twitter is a popular topic of interest in crisis informatics literature and has been highly accessible through the web and mobile apps. Journal articles would mention ‘mobile apps' as a context for the use of Twitter, but the focus of the article would be on the analytics of the content of the tweets rather than on the use of the app; this review excluded such publications. Some articles, on the other hand, discussed the role of mobile phones during disaster situations but, again, do not explicitly delve into the apps; the review also excluded such publications. Only articles that discussed the use of mobile apps in disaster situations were included. After subjecting the materials to two rounds of inclusion–exclusion criteria, the total number of articles was reduced to 49.

The 49 articles were subjected to thematic analysis. Through thematic analysis, the data collected were coded in a structured and comparable manner according to emerging themes (Flick, 2009). Thematic coding makes it possible to gather new insights and perspectives related to the themes throughout the review process, and the coding process involves sequentially building summaries for each article but allows for continuous rechecking and modification as further coding and interpretation is conducted (Flick, 2009). The thematic analysis revealed how mobile apps are situated in the crisis informatics literature. The analysis prompted significant sub-questions: What purpose do mobile apps serve in disaster situations?; What interactions do the mobile apps foster?; What are the roles of the public when using these apps?; and in which stage of the disaster management cycle do the apps contribute? The next section presents the answers to these questions.

3.4 FINDINGS FROM THE LITERATURE

This chapter presents the findings regarding mobile applications in the 49 articles selected from the crisis informatics literature. First, an overview of the articles included in the study is provided. Then, this chapter focusses the discussion towards the nature of the apps: (1) the different mobile apps encountered and the interaction these apps foster between the public and authorities; (2) the public's multiple roles as users of these mobile apps; and, finally, (3) the various contributions of mobile apps in the disaster cycle.

3.4.1 Summary of the articles

The 49 articles included in the review showed a varying level of detail in their discussion of mobile apps for disasters (see Figure 3-4). Twenty-two of the 49 articles focussed on presenting a particular mobile app, discussing in detail the app's system architecture or its critical disaster management features. The next 14 articles discussed overarching theories and concepts on mobile apps during disasters without focusing on any particular mobile app. Also, 13 articles named and compared multiple disaster-focussed apps, highlighting some key observations

between various applications. Appendix B summarises the apps mentioned in each of the articles.

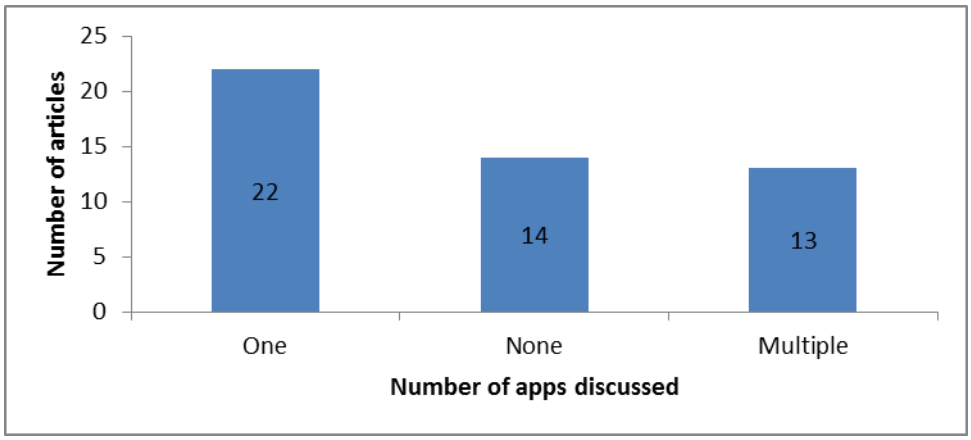

Figure 3-4. Number of apps discussed per article.

The findings in the study display a comparable pattern to Poblet et al.'s (Poblet, García-Cuesta, & Casanovas, 2014a) review of web-based and mobile-based disaster crowdsourcing platforms. According to Poblet et al. (Poblet et al., 2014a), there are two technology approaches in platform functionality development: data-oriented and communication-oriented. Similarly, In the 49 articles reviewed, multiple papers concentrate on providing a proof of concept of data-oriented functionalities and communication-oriented functionalities for the apps. For example, on data-oriented functionalities, some discussion focusses on technical data capacities, such as enhancing geo-referenced data quality (for example, Szczytowski, 2015) as well as systems for mining and processing of multimodal data (for example, Adam et al., 2012). On the other hand, other papers discuss communication-oriented functionalities where the focus is on building seamless interaction between stakeholders. These include resilient alerting/notification services (for example, Romano, Onorati, Aedo, & Diaz, 2016), structures for bridging seeker-supplier information (for example, Shih, Han, & Carroll, 2015), and systems for streamlined crowdsourcing (for example, Ludwig, Siebigteroth, & Pipek, 2015). In most of the papers, however, data- and communication-oriented functionalities are discussed complementarily as part of a whole architecture (Meissen & Fuchs-Kittowski, 2014).

The articles have varying depths of discussion based on the objectives of the papers. Objectives of the papers vary: some provide a detailed analysis of an app, some present a prototype app, some compare different apps, and some discuss theoretical concepts of a disaster app. Appendix B lists the papers included in this review and the objectives of each paper. Because of the varying depth of discussion of the articles (detailed analysis of an app, broad comparison of apps, or theoretical discussion of apps), comprehensive appraisal of the technical functionalities of these apps or the apps' effectiveness are not within the scope of this review. However, the study provides categorisations, descriptions, interactions, and purposes of these apps.

3.4.2 Mobile apps and interactions fostered

Mobile apps used in disaster situations may be made specifically for disaster purposes and may also be apps used for normal day-to-day activities. Apps used during disasters can be broadly categorised as general-purpose apps or built-for-disaster-purpose apps.

3.4.2.1 General-purpose apps in disasters

During disaster situations, the public uses various apps that are not built solely for the purpose of disaster management. For example, the public uses social media apps or news apps to find information pre-, during, and post-disaster events. Table 3-4 describes the nature of the general-purpose apps mentioned in the review—apps that have facilitated communication or information dissemination during disasters.

Table 3-4. Interaction and description of general-purpose apps used during disasters

Interaction	General-purpose apps
One-to-one	Messaging apps where a person can send personal message to another
One-to-many	News apps where a news agency publishes news to the public Weather apps where a meteorological agency publishes weather information
Many-to-many	Social media apps, such as Twitter or Facebook Messaging apps where a group of people can send messages to each other

During disasters, social media apps like Twitter and Facebook are popularly used to gather and communicate information as people tend to favour familiar platforms that they have frequently

used before the disaster occurrence (Haddow & Haddow, 2014b; Nilsson & Stølen, 2011). However, disaster management authorities have concerns in promoting the use of general-purpose platforms for emergency situations as many issues arise, such as privacy, information quantity, and content quality (Schimak et al., 2015). To circumvent these difficulties, multiple efforts have been made to create apps specifically to channel curated emergency information needs of the public and authorities (Schimak et al., 2015).

3.4.2.2 Built-for-disaster-purpose apps

From the 49 articles considered in this review, 35 articles discussed apps built specifically for disaster management purposes. From the 35 articles, a total of 57 built-for-disaster-purpose apps were named, ranging from the popularly used Ushahidi mobile-version mapping platform, to experimental or prototype apps, to tested but discontinued apps. Appendix C lists the apps included in this review.

3.4.2.2.1 Purposes of the built-for-disaster-purpose apps

These built-for-disaster-purpose mobile apps usually have an array of multiple features; however, the apps typically serve a primary objective. The purposes of the apps revolve around operations and activities that arise when disasters occur. The review finds five purposes for built-for-disaster-purpose apps, as summarised in Table 3-5: (1) crowdsourcing, (2) collaboration, (3) alert and information dissemination, (4) information collation, and (5) user-generated notification during disasters. Appendix C lists the purpose of apps included in this review: the first three purposes focus on enriching situation awareness through gathering information with the public's involvement while the last two focus on resilient delivery of critical information between authorities and the public. These five purposes are not mutually exclusive for the built-for-disaster-purpose apps. Some apps may incorporate multiple purposes; for example, CrowdMonitor (Ludwig et al., 2015) gathers information from social media as well as

incorporating volunteered information. Most of the apps, however, adhere to an identifiable primary purpose.

Table 3-5. Purposes of built-for-disaster-purpose apps

Purpose	Description	N*
Crowdsourcing	To organise and collect disaster-related data from the crowd	16
Collaborating platform	To serve as a platform for collaboration during disasters	13
Alerting and information	To disseminate authorised information before and during disasters	13
Collating	To gather, filter, and analyse data to build situation awareness	9
Notifying	For users to notify others during disasters	6
**Number of built-for-disaster-purpose apps in the review. ∑N = 57*		

The purpose of the largest group of apps (16 of the 57 found in the review) is to facilitate crowdsourcing during disaster situations. The apps are usually intended as part of a system to organise crowdsourcing efforts. Most of these apps were designed for crowdtasking activities with the crowdtasking process starting with a call for defined action where participants are asked to perform tasks (Schimak et al., 2015). Examples of such apps include TweetClicker and ImageClicker, which both helped assess the typhoon situation in the Philippines by requesting volunteers to tag the relevance of tweets and images of the disaster (Poblet, García-Cuesta, & Casanovas, 2014b). Crowdtasking apps can be used for post-disaster damage assessment or pre-disaster risk assessment as well; as an example, Damage Tracker collects damage information for evaluation after a disaster (Hodapp, Robbins, Gray, & Graettinger, 2013).

Another purpose for disaster apps is to act as a collaborating platform. Collaboration apps, in contrast to crowdsourcing apps, provide an open avenue for communities to work together during disasters. Apps are used as platforms to foster “self-help communities,” as defined by Reuter et al. (2012, p. 46) , to collaborate from public to public. Examples from this review include a platform where donation seekers can link up with suppliers (Shih et al., 2015) and open-source platforms for crisis mappers, such as OpenStreetMaps mobile (Soden et al., 2014).

Providing alerts and information is also a common purpose for a built-for-disaster-purpose app. The objective of such apps is to disseminate information. The primary interaction is one way, usually originating from the authorities to the public. Examples of such apps are the American Red Cross Apps and the Federal Emergency Management Agency (FEMA) App, which were developed by their respective agencies.

Built-for-disaster-purpose apps' purpose can also be for collating information. Academic publications explore how mobile apps can improve and enrich disaster information by utilising information already provided by the public. Apps collate publicly available social media data without necessarily engaging the public and then repackage the information for easier consumption. For example, XHELP gathers data across social media platforms, and the app monitors, filters, analyses, and presents cross-platform social media data using dashboards (Reuter, Ludwig, Kaufhold, & Pipek, 2015).

Finally, the last purpose is more localised to the user and their network: the app affords users the capability to notify others of their situation when a disaster occurs. The origin of the notification comes from the user to disseminate information to another person, organisation, or network. Usually, it is a common characteristic of these apps to have the ability to retrieve the user's GPS position automatically so users can quickly communicate this information to others (Romano et al., 2016). HelpBridge, ELERTS, and Emergency Alert are examples of notification apps. Appendix C lists more examples of the apps and their purposes.

3.4.2.2.2 Interactions of built-for-disaster-purpose apps

Similar to the general-purpose apps, the built-for-disaster-purpose apps foster interaction between and within the public and the authorities. Table 3-6 shows the various interactions the built-for-disaster-purpose apps provide. Aside from fostering one-to-one, one-to-many, and many-to-many communication, we observed that the built-for-disaster-purpose apps also promote other types of information flow between the authorities and the public. For example,

some apps start with a single source's call for information from the public to contribute data, which will then be processed centrally to gain a better awareness of the disaster situation. In this case, the interaction is 'one-to-many-to-one'. In some instances, the apps data mine publicly displayed information via social media sites to make it usable for the authorities. In this case, the app cultivates a 'many-to-one' processing of information from the public for the benefit of the agency collecting the data. The 'many-to-one' is a one-way interaction also known as crowd harvesting: the app harvests crowd data with or without the public's consent (Liu, 2014). Other apps, on the other hand, try to foster mutual interaction by redistributing the aggregated information to the public, making it a 'many-to-one-to-many' interaction corroborated by the app.

Table 3-6. Interactions and descriptions of built-for-disaster-purpose apps

Interaction	N*	Built-for-disaster-purpose apps
One-to-one	2	Notification apps where a person can send information to authorities
One-to-many	17	Alert and information apps where authorities communicate to the public Notification apps where a person can send emergency information to their contacts
One-to-many-to-one	8	Crowdtasking apps where a source requests volunteers to send information; information is then processed centrally
Many-to-one	12	Processing apps where a central source gathers information from the public
Many-to-one-to-many	8	Crowdsourcing apps where information from the public is aggregated then redistributed to the crowd
Many-to-many	11	Community apps where interest groups (for example, neighbours, firefighters, or mappers) can share information with each other
**Number of built-for-disaster-purpose apps in the review. ∑N = 57*		

3.4.3 The public as app users

The increasing interconnectedness of our society challenges disaster communications, requiring them to become more complex because of the evolving dynamics between the authorities and the public in their various roles (Andersen, 2016; Purohit et al., 2014). Communication tools contribute to the interaction between stakeholders during disasters. Officials are sometimes wary of social media and new technologies, primarily because of the concern for information

integrity (Adam, 2012; Besaleva & Weaver, 2013). Despite this apprehension, according to Adam et al. (2012), authorities (agencies, organisations, and responders) find benefit in using smartphones during disasters. Mobile apps provide the authorities additional capabilities to receive real-time situation awareness reports, request updates from citizens, and provide a timely response.

In earlier literature, the public is often only seen as information recipients, who request assistance or receive updates and advisories through their mobile phones (Adam et al., 2012). As social media evolves and as technologies become more mobile, the citizens are now also seen as potential participating sensors that could give information or perform tasks to aid in disasters. From the various articles we have reviewed, the public is usually perceived to take on the following functions: (1) as victims, (2) as targeted receivers of information, (3) as in-situ sensors, and (4) as offsite volunteers (see Table 3-7).

Table 3-7. Cross-tabulation of public's role and apps interaction.

Interaction	N*	Public as victims	Public as information receivers	Public as in-situ sensors	Public as offsite volunteers
One-to-one	2	•			
One-to-many	17	•	•		
One-to-many-to-one	8		•	•	•
Many-to-one	12			•	•
Many-to-one-to-many	7	•	•	•	•
Many-to-many	11	•	•	•	•
**Number of built-for-disaster-purpose apps in the review. ∑N = 57*					

The apps foster various multiple interactions from simple one-way communication to the complex interactions between the public and the authorities. The level of complexity of the interactions relates to how the app recognises the public as its users. For example, if the app treats users only as disaster victims or as passive recipients of information, then the app focusses on strengthening its one-to-one or one-to-many communication capabilities. If the app fosters a one-to-many-to-one or a many-to-one interaction, the main objective of the app is to support

capabilities for gathering or crowdsourcing of information; it treats the public primarily as sensors or volunteers rather than simply as receivers of information or as victims needing help. Other apps try to foster an enriched interaction that supports complex connections between many stakeholders, and these apps interact with the public in multiple roles during disasters.

3.4.4 Apps in the disaster cycle

ICT developments, such as mobile apps, look to improve disaster management by fostering interactions to minimise uncertainty and to augment capabilities. Improving disaster resilience can happen throughout the various stages of the disaster cycle. Houston et al. (2015) conducted a comprehensive review of academic and non-academic literature and found that social media use exists throughout the disaster life cycle. A similar finding has been observed in this review of mobile app use in disasters, and 49 articles discuss app use throughout the various stages of the disaster life cycle. Table 3-8 summarises the various contributions mobile apps provide at the stages of the cycle found in this review.

Table 3-8. Apps' contributions in the disaster cycle.

Disaster cycle	%*	Mobile apps' contributions
Mitigation/Reduction	26%	Crowdsourced damage assessment Crowdsourced hazards monitoring
Preparedness/Readiness	26%	Disaster risk education and preparedness learning Gathering of digital volunteers prior to disaster occurrence Providing early warning notifications
Response	82%	Fast and wide distribution of information Diffused data gathering – crowd as sensors Fast and timely processing – crowd as microtaskers Localised distribution of alerts and warnings
Recovery	26%	Seeker–supplier interaction for donation/information Providing recovery information post-crisis Crowdsourced disaster effects/damage assessment
*% of total 49 articles discussing the role of mobile apps at the particular stage		

Articles were not limited to discussing just one stage of the disaster cycle as, often, the discussion overlaps between phases. However, the majority of the literature focusses on the response stage, mainly because of interest in the data generated during disaster response.

3.5 DISCUSSION

The 49 documents reviewed include different descriptions, purposes, interactions, and contributions of built-for-disaster-purpose mobile apps. All the apps try to foster better information exchange between and within the public and authorities during the disaster life cycle. However, from the review, there are still research gaps in advancing complex interaction between public and authorities through these built-for-disaster-purpose apps. To ensure that these apps will be valuable to the public-at-large, there are three fundamental areas of further research needed: (1) engagement with apps before the disaster response stage; (2) public role, behaviour, and motivation towards app use; and (3) usability of mobile apps.

3.5.1 App engagement prior to disasters

Existing literature in crisis informatics revolves mostly around the response and recovery stages (Palen, Vieweg, et al., 2007; Poblet et al., 2014a). The reviewed publications have highlighted how the use of mobile apps can improve situation awareness during disaster response. Some of the articles have also emphasised that building disaster resilience capacities should be integrated not only during the response stage but throughout the disaster life cycle. Various stages of disaster management from preparation to mitigation need the involvement of information, communication, and technologies (Hagar, 2010).

In particular, this study highlights the importance of the preparedness phase where awareness of, and familiarity with, the apps must be established before a disaster to ensure full utility. For apps to be useful to the public in the succeeding phases of the disaster management cycle, the users must already be acquainted with the apps before the disaster event. Disasters and their management scale differ depending on the type, size, and complexity of the situation. Any technology meant for disaster management must be familiar to users on a regular basis; otherwise, it will be of limited use during larger and more complex disaster situations (Nilsson & Stølen, 2011). It must be acknowledged that the potential user population of disaster tools

may or may not be familiar with the technology when the need arises (Antoniou & Ciaramicoli, 2013).

From this review, we have observed that during disasters, the public can potentially interact through existing general -purpose apps or through specially built apps for disaster purpose. As such, research on engaging the public to use apps before disaster occurrence has two general directions (see Figure 3-5): integrating disaster management capacities into existing and popular platforms or attracting interest and retaining continued use for built-for-disaster-purpose apps.

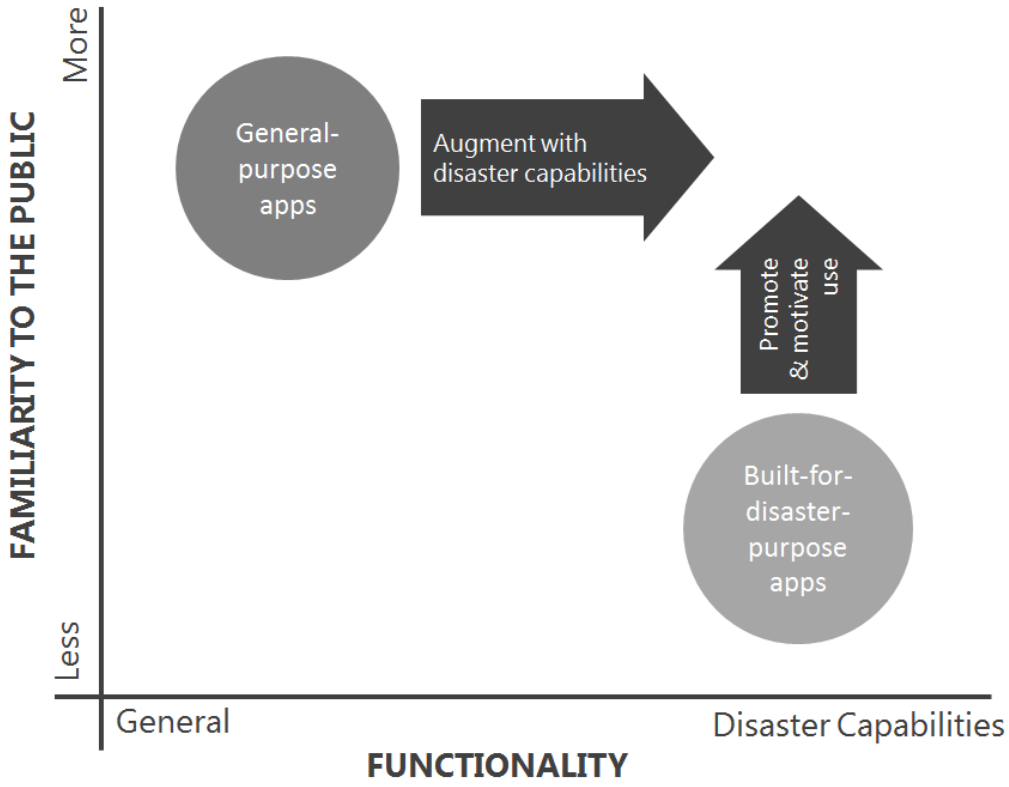

Figure 3-5. Research directions on engaging apps for disasters.

3.5.1.1 Augmenting disaster capability on popular platforms

The public tends to use platforms that are familiar and trusted (Haddow & Haddow, 2014b). Various publications have researched the use of general-purpose apps, such as Google, Twitter, and Facebook, in disaster situations (Cameron et al., 2012; Chauhan & Hughes, 2015; Puras & Iglesias, 2009).

The increased frequency of traffic during disasters to popular online sites, such as Facebook, Twitter, and Google, has driven these entities to consider and integrate disaster functionalities in their respective web and mobile platforms. For example, Google Public Alerts, a platform for disseminating emergency information, seamlessly integrates with Google Search, Google Maps, and Google Now (Google, n.d.-a). Subscription to 'Twitter Alerts' helps Twitter users receive relevant and reliable information during disasters (Pena, 2013). The Facebook 'Safety Check' feature allows Facebook users near a major crisis to publish a notification regarding their safety status (Facebook, n.d.).

These disaster features are only adjuncts to the main functionality of the apps. General- purpose apps are not built for disaster purposes, but they may have extended functions that can be activated during disasters. For example, the main intention of the Facebook app is not for a Safety Check but, rather, for social media purposes. Despite not being designed specifically for disaster context use, Google, Twitter, and Facebook may be deemed more useful when disasters strike as users are familiar with these apps. People tend to favour familiar platforms that they have frequently used before the disaster occurrence (Fraustino et al., 2012).

This review did not find any content from the 49 articles that investigates these extended disaster functionalities by Google, Twitter, and Facebook. Further, it has not considered the discussion on general-purpose apps as the findings from the literature show that the majority of academic publications on mobile apps for crisis informatics literature concentrate on built-for-disaster-purpose apps. The prominence of popular apps—in particular, with the pioneering disaster functionalities executed by Google, Twitter, and Facebook—is a noteworthy area for further disaster research exploration.

3.5.1.2 Promoting the built-for-disaster-purpose apps

In the past few years, the level of use and acceptance of social media platforms during disasters has been established. Often, during disasters, the public uses readily available platforms (such

as Twitter or Facebook) due to their ease of use, simplicity, and familiarity (Antoniou & Ciaramicoli, 2013). The use of built-for-disaster-purpose apps is less common. Despite the plethora of available apps in the market, only a few have been deemed good enough to be downloaded and used by the public. Hoehle and Venkatesh (2015) add that "Only 1 percent of all mobile applications have been downloaded more than one million times and, once downloaded, one in four mobile applications are never used again" (p. 435).

Multiple built-for-disaster-purpose apps are currently being developed to address the emergency information needs of the public and authorities (Schimak et al., 2015). All stakeholders should be aware of, and exposed to, such tools, even before a disaster. If the built-for-disaster-purpose apps are to be useful during disasters, the app must be supported and endorsed by authorities and also promoted to, and accepted by, the public as a preparedness tool.

Efforts must then be carried out in the preparedness phase to facilitate the access, knowledge, and use of technology for disaster situations (Antoniou & Ciaramicoli, 2013). It is a challenge to gain the interest of both the authorities and the public. On the one hand, the authorities must overcome possible apprehension about adapting to new technologies and be invested enough to put their resources behind a complex information communication channel. On the other hand, the apps also need to be attractive enough to the public to achieve critical mass appeal for maximum impact.

So far, research has focussed on the theoretical concepts and technical structures of mobile apps during disasters. In the future, research must transcend this to study societal acceptance of such technologies. For example, after presenting the proof-of-concept of their mobile app, Auferbauer et al. (2015) highlighted the need to ensure the full utility of their mobile app by studying user uptake and acceptance further and finding barriers of entry to user involvement.

3.5.2 The public's motivation and role in using apps

Most of the articles reviewed (23 of the 49) presented theoretical or model app systems, and the majority of these studies recruited participants for experimentation or prototyping with the assumption that users have accepted the technology. However, the studies recognise possible issues of testing in isolated situations. In actual conditions, there is a possibility of low acceptance of the technology systems, especially if the technology does not function in a way that is predictable to the user (Boulos et al., 2011). However, limited literature has looked into the public's behaviour towards disaster mobile apps.

In information systems research, studies of technology acceptance for emergency purposes usually focus on authorised responders as intended users and not the general public as, for example, police in Finland (Kuula et al., 2013), firefighters in the United Kingdom (Nurse et al., 2012; Prasanna, Yang, & King, 2011), and emergency centre operators in New Zealand (Prasanna & Huggins, 2015). Only a handful of studies (see, for example, Al-Akkad & Zimmermann, 2011; Iwasaki, 2013) evaluate technology applications from the perspective of civilians as the targeted users. Gunawan et al. (2012) add that, "despite the growing awareness of untapped potential of affected population in a disaster situation, their inclusion in disaster management is extremely limited"(p. 1).

The premise for ICT developments in disasters has been moving towards the crowd. Members of the public are no longer seen as helpless and unpredictable agents; rather, citizens may have the capability to do life-saving work (Crawford & Finn, 2014). Although multi-modal disaster communication is becoming more popular, the information direction flow for most disaster mobile applications still flows one way (Poblet et al., 2014a). As also seen in this review, a significant proportion of the apps still employs one-way communication (see Table 3-9).

Table 3-9. Communication emphasis and authority–public interactions of reviewed apps.

	Interactions	Public as victims	Public as information receivers	Public as in-situ sensors	Public as offsite volunteers	N
Traditional	One-to-one	•				2
	One-to-many	•	•			17
Authority centric	One-to-many-to-one		•	•	•	8
	Many-to-one			•	•	12
Public centric	Many-to-one-to-many	•	•	•	•	7
	Many-to-many	•	•	•	•	11
Total number of apps						**57**

A large proportion of the articles still approaches apps from an authority-centric and command-and-control perspective. Apps with limited interactions (one-to-one and one-to-many) still retain the traditional one-way communication paradigm, which limits the public to the role of victims or passive information receivers. The many-to-one and one-to-many-to-one interactions, on the other hand, try to utilise information from the public but still centralise on the authorities' interest in gathering information, without adequately fostering two-way communication with the public. Only 17 of the 57 apps mentioned in the review focussed on citizen-centred communication, in which the apps promote complex two-way interaction and treat the public with multiple possible roles during disaster situations.

The partiality towards traditional communication and authority centredness of the articles in this review contrasts with the general crisis informatics literature. Crisis informatics acknowledges the redefined approach to crisis information from "the top-down control and command approach […] towards community-based grassroots strategies" (Hagar, 2010, p. 12). Research on mobile apps for crisis informatics must acknowledge the change in communication paradigm in order to advance research that integrates the public's interests. With mobile apps, the authorities' intentions, interests, and involvement are significant; however, the public's motivation behind downloading, adapting, and the use of the technology are also critical to ensure the full realisation of the apps' purpose.

Academic research on the public's use of mobile technologies for crisis communication is fairly young. Mobile app distribution to the public, in general, is a recent phenomenon. Both the iTunes Apps Store and Android's Google Play (formerly known as Android Market) were launched in 2008 (Martin et al., 2016). Comparatively, more considerable research has been conducted on mobile technologies used in the health industry. Bean et al. (2015) comment that "… health communication colleagues have conducted considerable research on more broadly defined mobile health (mHealth) communication processes, technologies, and campaigns" (p. 70). The field of mHealth provides a parallel body of literature that could provide insight into research on disaster apps. Some examples from the mHealth literature include user-centred design of apps (Schnall et al., 2016) and the socio-technical approach to technology evaluation (Oroviogoicoechea & Watson, 2009). Further research is needed to look into the public's motivation and adaptation of disaster mobile applications.

3.5.3 Usability of mobile apps interface

The built-for-disaster-purpose apps support activities and operations that arise when disasters occur, such as crowdsourcing, collaborating, alert and information dissemination, information collating, and notifying. The majority of the papers in the literature have focussed on (1) data-oriented functionalities: how dispersed data is produced, gathered, and processed; or (2) communication-oriented functionalities: how interaction will be fostered between various stakeholders; or both. This review observes an orientation in the literature (See Figure 3-6) that is not discussed as frequently. Only a few papers have addressed the visualisation and interface capacities of mobile apps. Eighteen of the 49 articles reviewed mention 'user interface' but only to a limited extent. Only Estuar et al.'s (2014) paper discussed app user interface as the main topic.

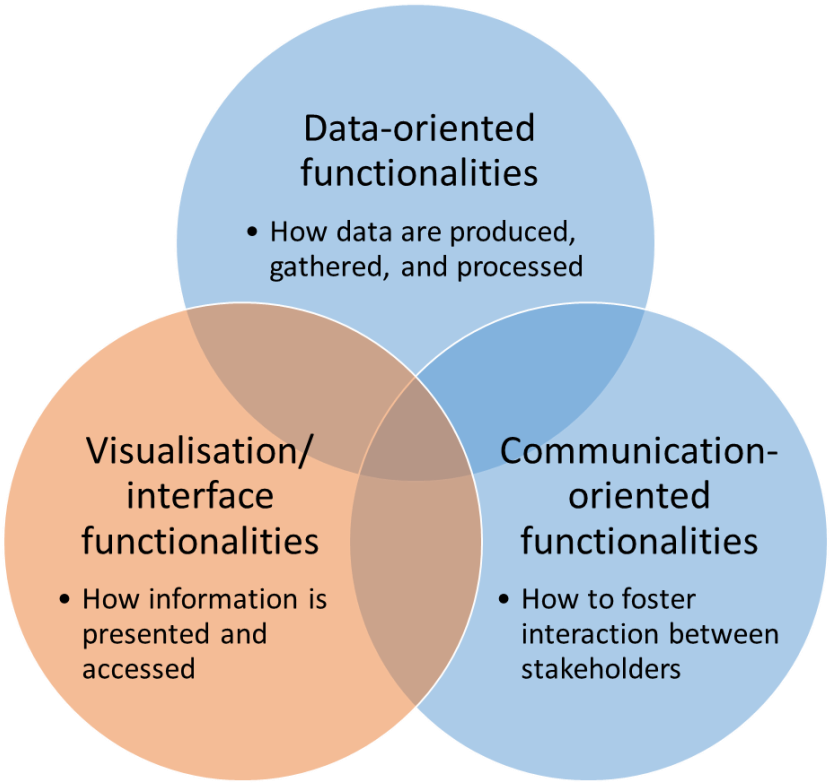

Figure 3-6. Disaster mobile apps main functionalities.

Even if data- and communication-oriented functionalities are in place, mobile apps for disasters must be intuitive at first usage as users must be able to operate the device and access information in complex disaster situations (Nilsson & Stølen, 2011; Romano et al., 2016) and often while under stress. For example, using maps and images may enhance users' awareness as opposed to using text formats (Ludwig et al., 2015; Reuter, Ludwig, Funke, & Pipek, 2015). Veil, Buehner, and Palenchar (2011) state that, "new media tools have much potential for encouraging preparedness, knowledge, and involvement in crisis response by making the topic visual and interactive" (p. 112). An ideal built-for-disaster-purpose app should have data, communication, and also interface functionalities working seamlessly.

Academic research on the usability of mobile apps, in general, has just recently started (Hoehle & Venkatesh, 2015). Furthermore, most of the usability literature centres on social media apps as these are the applications that are most frequently used by the public (Hoehle, Zhang, & Venkatesh, 2015). However, effective interface design is of immediate and relevant concern for

disaster apps, especially as Romano et al. (2016) note that designers of emergency response mobile apps do not particularly focus on usability.

However, good interface design is even more relevant in crisis situations. Taking account of the decision-making qualities of users in stressful scenarios is important when designing information systems for emergency management. Individuals may react differently when under high stress (Hiltz, Van de Walle, & Turoff, 2010). Extreme time pressure and high stakes create conditions of high stress where individuals may experience degradation in information-processing and decision-making abilities (Sarna, 2002).

In disaster situations, users may be put in scenarios where the apps may influence life-critical outcomes; therefore, a sound basis for design and development plays a critical role in the success of the system (Humayoun et al., 2009). Mobile platforms, such as iOS and Android, provide user experience guidelines that help developers to create applications with a user-friendly common interface (Apple Inc., n.d.-a; Google, n.d.-c). Numerous studies have been conducted on adoption and usability of mobile applications but mostly in a context outside disaster apps (for example, Hoehle et al., 2015). However, the dynamic disaster management environment imposes particular demands, requiring that users can operate apps as intuitively and accurately as possible while under stress. Ensuring usability of disaster apps is another area of research that needs to be further explored.

3.6 CONCLUSION

Disaster communication is shifting from the authority-centric archetype and moving towards a paradigm that integrates and engages with the public. Mobile technology is at the frontier of innovation in improving public preparedness and in strengthening the engagement link between citizens and authorities during disasters. This literature review found 49 articles that discussed mobile applications in the crisis informatics literature.

The findings from this review answered a number of questions. In response to the purpose mobile apps serve in disaster situations, the articles revealed five thematic purposes for built-for-disaster-purpose apps: Crowdsourcing, Supporting collaboration, Alerting and providing information, Collating information, and Notifying. The mobile apps fostered different interaction dynamics between one and many. However, the largest proportion of apps focussed on the one-to-many authority-centric flow. The public also had multiple roles as users of mobile apps during disaster events: as victims, information receivers, in-situ sensors, or as offsite volunteers. Finally, mobile apps can assist in various parts of the disaster management cycle, but the majority of the apps discussed in the articles covered in this review are designed for the response stage.

A comprehensive appraisal of the technical functionalities of these apps was not within the scope of the review due to the varying detail the articles provide and the variability of their approach from reviewing existing apps to developing their own proof-of-concept apps. However, the findings reveal some areas for future research. Three of these research directions are highlighted in this paper.

First, future research needs to acknowledge that apps used during disasters can be general-purpose or built-for-disaster-purpose. As such, research on engaging the public to use apps before disaster occurrence has two general directions: (a) integrating disaster management capacities into general-purpose apps, as well as (b) attracting interest and retaining continued use for built-for-disaster-purpose apps.

Second, the use of social technologies, such as social media and mobile apps, is already integrated into our societal structure. Research on mobile apps for crisis informatics must acknowledge the current authority-centric communication paradigm but also the recent changes to a more citizen-centric communication. To fully realise the potential of mobile apps for disasters, it is important that future research engages in citizen-centred studies to gain more

insights into users' needs, motivations, expectations, experiences, and limitations when using disaster apps.

Third, the majority of the literature has focussed on data-oriented and communication-oriented functionalities. However, just as significant as these two orientations is the presentation and visualisation of information in the mobile apps' interface. In the dynamic disaster environment, the usability of these disaster apps is critical. Research is needed to investigate and ensure the usability of mobile apps for disasters.

4 [2ND MANUSCRIPT] USABILITY OF DISASTER APPS: A CONCEPTUAL FRAMEWORK FROM A QUALITATIVE THEMATIC ANALYSIS OF USER REVIEWS

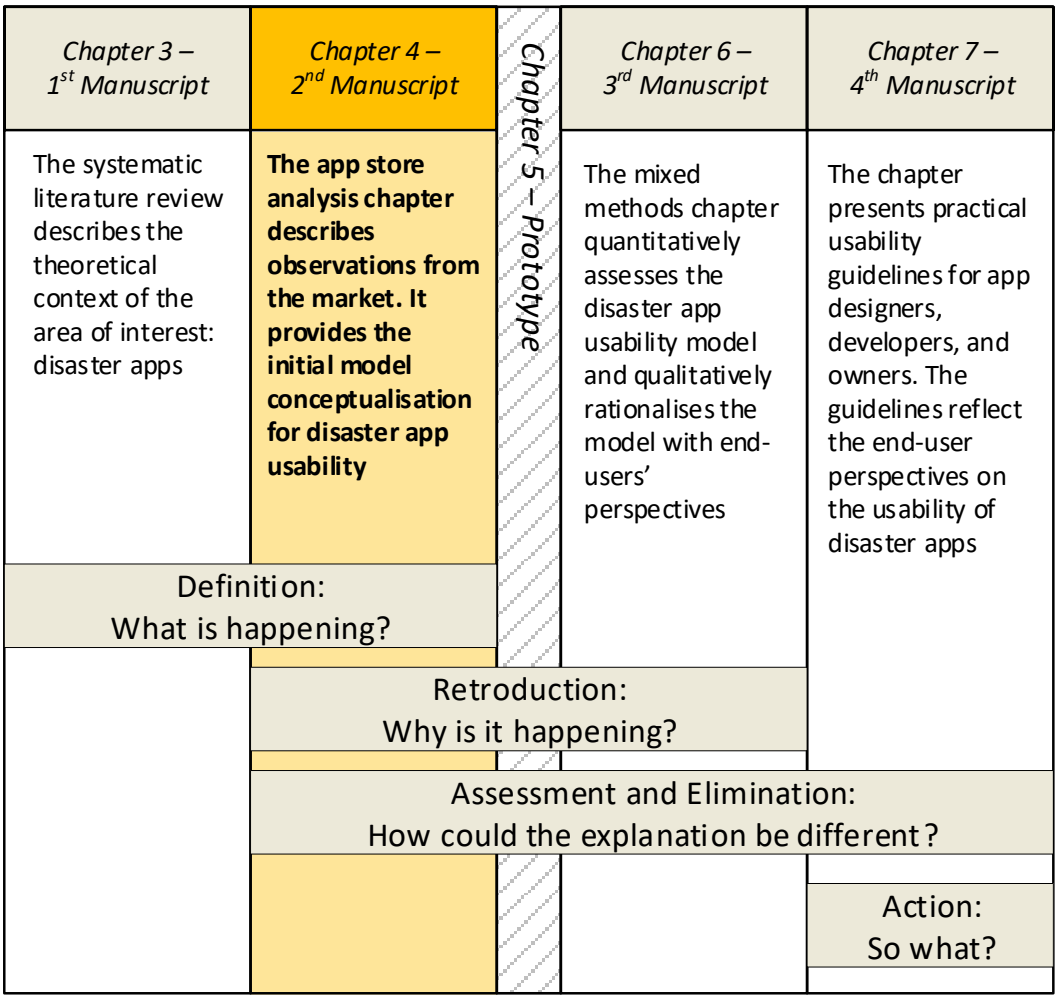

Figure 4-1. Positionality of the 2nd manuscript to the thesis.

ABSTRACT

The public has access to a range of mobile applications (apps) for disasters. However, there has been limited academic research conducted on disaster apps and how the public perceives their usability. This study explores end-users' perceptions of the usability of disaster apps. It proposes a conceptual framework based on insights gathered from thematically analysing online reviews. The study identifies new usability concerns particular to disaster apps' use: (1) content relevance depends on the app's purpose and the proximate significance of the information to the hazard

event's time and location; (2) app dependability affects users' perceptions of usability due to the life-safety association of disaster apps; (3) users perceive advertisements to contribute to their cognitive load; (4) users expect apps to work efficiently without unnecessary consumption of critical phone resources; (5) appropriate audio interface can improve usability as sounds can boost an app's alerting aspect; and, finally, (6) in-app browsing may potentially enhance users' impression of the structure of a disaster app. As a result, this study argues for focussed research and development on public-facing disaster apps. Future research should consider the conceptual framework and concerns presented in this study when building design guidelines and theories for disaster apps.

MANUSCRIPT PREPARATION AND SUBMISSION

I prepared the manuscript for journal publication as the primary author with my supervisors, Dr Prasanna, Dr Stock, Dr Hudson-Doyle, Dr Leonard, and Professor Johnston, as co-authors. I conceptualised the utilisation of user reviews from the app stores as a source of data to gain users' perceptions on usability. I conducted the data collection and analysed the data with the support of my supervisors. My supervisors aided in the thematic analysis of the data through providing insights to patterns and gave suggestions for the visualisation of data presentation. My supervisors also guided me in the structuring and editing of the manuscript. The final manuscript was submitted to an international journal in September, 2019. Earlier versions of this research were presented as posters in the following avenues:

- 14th International Conference on Information Systems for Crisis Response and Management Conference, May 21–24, 2017, Albi, France.
- 2017 QuakeCoRE (New Zealand Centre for Earthquake Resilience) Annual Meeting, September 4–6, 2017, Taupo, New Zealand.

4.1 INTRODUCTION

Well-designed technological systems can aid users in making informed decisions in times of crises. However, technologies can hinder users if they are not designed in the context of their end-users. The importance of usability is acknowledged in the field of safety-critical systems as the lack of usability can lead to product discontent and compromised safety (Kwee-Meier et al., 2017). Usability is "the degree to which something is able or fit to be used" (Stevenson, 2010). Most usability studies in the disaster and crisis management field often focus on tools for responders (for example, firefighters and emergency responders) and not on technologies that are available to the public, such as mobile apps (Tan et al., 2017).

Populations are already using mobile apps as communication tools to get information during disasters (Reuter & Spielhofer, 2017). Apps used by the public during disasters can either be general apps—familiar and popular apps (for example, Twitter, Facebook, and Google), or disaster apps—apps designed specifically for use during crises (Tan et al., 2017). This study investigates the latter. Disaster apps are formally defined in this study as mobile apps that help members of the public in retrieving, understanding, and using time- and location-critical information to enhance their decision-making process during a disaster.

Hundreds of disaster apps already exist, and they are becoming increasingly popular among the general public (Bachmann et al., 2015; Gómez et al., 2013). For example, a large proportion of the British population indicated their willingness to use disaster apps in the future to receive information during emergencies (Spielhofer et al., 2019). While disaster apps have the potential for improving the public's preparedness and response to disasters, the usability of these apps from the perspective of the public as end-users is an understudied topic (Tan et al., 2017).

This study seeks to contribute to the literature by investigating usability from the perspectives of the end-users in the disaster apps domain, asking the question: *What usability concerns are particular to disaster apps?* This chapter is structured as follows. It starts by providing an

overview of past studies on disaster apps and usability, and then explains the methods employed to acquire insights on usability from disaster app users. The chapter then presents the findings, highlighting new insights through a conceptual framework for usability in the disaster apps domain. Finally, the discussion and conclusion underline the relevance and significance of the study.

4.2 DISASTER APPS AND USABILITY

Studies on disaster apps mostly focus on evaluating operational capabilities with only a few assessing usability (Tan et al., 2017). Several studies (Bachmann et al., 2015; Gómez et al., 2013; Ridler-Ueno, 2013) have conducted investigations into large numbers of disaster apps available in the markets. These provided insightful typologies and feature descriptions of the apps, but they did not cover the apps' usability. Only a few academic studies have investigated the usability of disaster apps from the perspective of the public as end-users.

The few studies that do focus on usability concentrate on one or two use-cases or proofs-of-concept (for example, Estuar et al., 2014; Sarshar et al., 2015). The usability study on the eBayanihan app by Estuar et al. (2014) highlights that designing disaster apps requires both an understanding of the functional requirements as well as of the user. Similarly, the evaluation of the apps GDACSmobile and SmartRescue emphasise the need to consider human–computer interaction when designing disaster apps and the need for future research to explore various ways to gauge usability (Sarshar et al., 2015). Beyond the studies about technical and functional aspects of the apps, research should look into the use and usability of these apps (Karl et al., 2015; Reuter, Kaufhold, Leopold, et al., 2017).

4.2.1 Usability of mobile applications

Mobile application usability theory has anchored on general usability literature, which is heavily based on software and website contexts (Hoehle & Venkatesh, 2015). The concepts are primarily defined by the International Organization for Standardization (ISO) and Nielsen (Coursaris &

Kim, 2011; Zahra, Hussain, & Mohd, 2017). ISO (1998) describes usability in three parts: effectiveness, efficiency, and satisfaction, and Nielsen (1994a) identifies five attributes to usability: efficiency, satisfaction, learnability, memorability, and errors.

However, software- or website-based usability models may be insufficient for the context of mobile application use as issues such as mobility and limited screen size are often neglected (Harrison et al., 2013; Zhang & Adipat, 2005). Addressing these mobile app context issues, multiple studies have reconceptualised mobile application usability by combining and extending the usability dimensions from ISO's and Nielsen's concepts. Table 4-1 lists examples of mobile application usability models that have combined and added dimensions to address the context of mobile application use. Although these mobile application usability models (Coursaris & Kim, 2011; Harrison et al., 2013; Zhang & Adipat, 2005) have consistently used traditional usability dimensions, such as effectiveness, efficiency, and satisfaction, there is no consensus on what constitutes mobile application usability.

Table 4-1. Summary of usability dimensions from various usability models.

				Mobile application usability models		
		Nielsen (1994a)	**ISO Standard (1998)**	**Zhang and Adipat (2005)**	**Coursaris & Kim (2011)**	**Harrison et al. (2013)**
Usability dimensions	**Conventional dimensions**		Effectiveness	Effectiveness	Effectiveness	Effectiveness
		Efficiency	Efficiency	Efficiency	Efficiency	Efficiency
		Satisfaction	Satisfaction	Satisfaction	Satisfaction	Satisfaction
		Learnability		Learnability	Learnability	Learnability
		Memorability		Memorability	Memorability	Memorability
		Errors		Errors		Errors
	Extensions for mobile application usability			Simplicity	Accessibility	Cognitive load
				Comprehensiveness	Workload	
				Learning performance	Enjoyment	
					Acceptability	
					Quality	
					Security	
					Aesthetics	
					Utility	
					Playfulness	
					Content	
					Flexibility	

At present, standard usability evaluation measurements, such as task completion, error rate, and time, are the most commonly used to measure efficiency and effectiveness as parts of usability (Balapour & Walton, 2017; Zhang & Adipat, 2005). Although these standard metrics provide useful means to understand the interaction between the user, technology, task, and context, there is a limited understanding of the factors that contribute to the desired result of usability (Balapour & Walton, 2017). The current usability models do not sufficiently provide dimensions that will help guide the development of usable mobile application designs and interfaces (Zahra et al., 2017).

A holistic conceptualisation of mobile app usability developed by Hoehle and Venkatesh (2015) tries to address the gap in the literature by introducing a model that moves away from the website–software usability stream. Furthermore, their model includes antecedents of usability that can guide the development of apps. The model demonstrates six constructs that represent mobile application usability: *app design*, *app utility*, *user interface (UI) graphics*, *UI output*, *UI input*, and *UI structure*. However, one of the limitations of Hoehle and Venkatesh's model is that it has only been applied to social media mobile applications. Further research on their usability conceptualisation is encouraged to see whether the model translates to other types of applications, such as disaster apps.

4.2.2 End-users' perspectives

Disaster management tools can lead to negative consequences if they lack usability, and it is essential to consider the target audience's perspectives when building interventions for emergency management (Cosgrove, 2018). This study considers usability from a perceived usability standpoint where the usability of a system is taken from the experience of its users (Hertzum, 2010). End-users' can provide valuable insights into their behaviour of use (McCurdie et al., 2012). Perceived usability has been traditionally solicited from users through questionnaires, interviews, and observations, but it can also be gathered through analysing user-

generated content (Balapour & Walton, 2017; Hedegaard & Simonsen, 2013; Nielsen, 1994a). For example, interpreting user reviews from online systems can help unfold the experience of the users of real-time applications, especially in obtaining aspects that are important to users that might otherwise be uncaptured through solicited means (Gebauer, Tang, & Baimai, 2008).

4.3 METHODS

This study aims to gain insights into what comprises usability for disaster apps from the perspectives of their end-users. We acquired the end-users' viewpoint through an app store analysis approach. This study investigates feedback from users of disaster apps that can be found in the two most prominent app markets: the iOS App Store (Apple Inc., n.d.-b) and Google Play (Google, n.d.-b). The app stores provide convenient platforms for users to freely convey their experiences through writing reviews (McIlroy, Ali, Khalid, & Hassan, 2015). Analysing large volumes of self-reports, such as user reviews, makes it possible to draw inferences regarding usability that otherwise may not be gathered through structured surveys (Gebauer et al., 2008; Hedegaard & Simonsen, 2013). This study analysed app store data, specifically user reviews, to infer usability aspects that are important to disaster app users. The app store analysis process involves (1) selecting the appropriate apps, (2) collecting the user reviews from the selected apps, and (3) analysing the collected data.

4.3.1 App selection

The research process started with selecting the disaster apps available from the iOS App Store and Google Play markets. Our search strategy employed various iterations of keywords. First, the search used the base keywords: 'disaster', 'emergency', and 'hazards'. The succeeding searches attached extended words to the base words, such as 'management', 'tools', and 'utilities'. Iterations of the base words and extended words were employed such that the combined results from both stores produced a total of 4,024 app results (1,033 from iOS App

Store and 2,991 from Google Play and). Duplication removal reduced the number to 3,003 apps in total. We employed three rounds of inclusion–exclusion criteria to filter relevant apps:

1. We only considered apps using the English language;
2. We included apps purposefully designed for the public to use in the context of disaster preparedness and response. We excluded the following categories: games, references and study guides, lifestyle and entertainment, legal services, insurance services, business continuity apps, and radio scanners; and
3. We excluded tools that can be used during emergencies but do not provide information on the impending or ongoing event. Examples of such apps would be light and sound makers, apps that only provide checklists for emergencies, apps that store vital information on a user's phone, and apps that allow easy dial access to emergency numbers.

After the exclusions, 353 apps remained. Among these, only a few apps have significant analysable content. Some apps had less than 1,000 downloads or had no reviews. Since the purpose of this study was to gather insights from the users, significant user content was needed. We observed that the apps that had at least 35 user reviews had a minimum download count of 1,000, with most having download counts in the range of 10,000 to 50,000. Thus, to ensure we had enough user content to analyse, we set a threshold of reviewing apps that had at least 35 user reviews. Fifty-eight apps met this requirement.

Included in these 58 (See Table *4-2*) are apps that provide warnings and information on hazard threats. Some apps cater towards specific hazards such as earthquakes (for example, Earthquake Alert), extreme weather (for example, Tornado by American Red Cross), wildfires (for example, FireReady), and other apps offer information on multiple hazards (for example, FEMA). Although the 58 apps differ in the scope of hazards, they share the common purpose of providing the public with information on potential hazards at the onset, during, and after an event.

Table 4-2. *List of apps included in the study.*

App#	Android Apps	App#	iOS Apps
1	Adelaide South Australia Alert	36	Alabama SAF-T-Net
2	Alabama SAF-T-Net	37	ALERT FM
3	Alberta Emergency Alert	38	CodeRED Mobile Alert
4	Brisbane & Queensland Alert	39	Disaster Alert
5	CodeRED Mobile Alert	40	Earthquake
6	Disaster Alert	41	Earthquake -American Red Cross
7	Disaster Management (MCGM)	42	Earthquake Lite
8	Earthquake Alert!	43	Earthquake+
9	Earthquake -American Red Cross	44	Emergency - American Red Cross
10	Earthquake Lite	45	Emergency AUS
11	Earthquakes	46	FEMA
12	Earthquakes - RTW	47	FireReady
13	Emergency - American Red Cross	48	FlashAlert Messenger
14	Emergency AUS	49	FloodWatch
15	FEMA	50	GeoNet
16	FireReady	51	Hazards - Red Cross
17	Flood - American Red Cross	52	Hurricane - American Red Cross
18	GeoNet	53	Lancaster County Emergency Radio
19	Hazards - Red Cross	54	ping4alerts!
20	Hurricane - American Red Cross	55	SD Emergency
21	Latest Quakes	56	Tornado - American Red Cross
22	Melbourne & Victoria Alert	57	ubAlert - Disaster Alert
23	PH Weather And Earthquakes	58	Wildfire - American Red Cross
24	ping4alerts!		
25	Project NOAH		
26	Ready Georgia		
27	Ready TN		
28	RSOE EDIS Notifier Lite		
29	Saskatchewan Emergency Alert		
30	SD Emergency		
31	Sydney & NSW Alert		
32	Tornado - American Red Cross		
33	ubAlert - Disaster Alert		
34	Wildfire - American Red Cross		
35	Yurekuru Call		

4.3.2 Data collection

The purpose of this chapter is to draw qualitative concepts of usability as experienced by the users inferred through their reviews rather than to focus on frequencies or to claim statistical significance. Analysis of user reviews reveals recurrent issues as well as extreme sentiments that provide valuable information on instances where the products perform well or poorly (Hedegaard & Simonsen, 2013). Negative comments help identify potential problems while positive comments identify good practices in usability.

We scraped the app stores and collected user reviews from the 58 apps. Non-proportional quota sampling of 35 reviews from each of the 58 apps resulted in 2,030 reviews. We used non-proportional quota sampling (the quota size is not proportional to the size of the entire set of reviews for a given app) because we wanted the corpus of reviews to represent the sentiments from all the 58 apps adequately. When sampling for data mining, non-proportional strategies become appropriate when the primary concern of the study is not the precision of estimates but having "enough to assure that we will be able to talk about even small groups in the population" (Gu, Hu, & Liu, 2000, p. 11). By using non-proportional sampling, we avoid the bias of reflecting just the reviews from popular apps and ensure that the sentiments of users from the less popular apps are adequately represented.

We appraised the 2,030 user reviews to determine whether they contained valuable content. The reviews had an average length of 132 characters but range between 1 to 1,579 characters. Reviews containing less than nine characters were eliminated as they did not contain significant content to be analysed. For example, comments such as '*ok*', '*good*', or '*great*' do not provide valuable insights. We also employed the same removal criteria for reviews longer than nine characters that did not provide useful content. We excluded remarks of general praise, general complaint, sarcasm, or mockery. See Table 4-3 for examples of eliminated reviews. In total, we excluded 625 user reviews, resulting in 1,405 user reviews with meaningful content.

Table 4-3. Examples of eliminated reviews.

Eliminated reviews	Examples
General praise	• *I think this is such a good idea for everybody as we all use technology today. It's more effective, thank you.* • *Works as said. Great work was put into this app. Thank you so much.*
General complaint	• *All this app is worth is giving you a false* [sense] *of security. Complete garbage. Shame on you* […] • *Less than impressed; will most likely delete this app.*
Promotion	• *Floods kill more people than tornadoes. This app can save lives. Download it today.* • *Everyone* […] *should have this app; it's a major enhancement to personal safety.*
Sarcasm/mockery	• *Eventually, when cannibalism breaks out.* […] *now I can be ready.* • *Add some info on what to do in case of zombies and it will be perfect.*

The review system in app markets provides an avenue for users to provide feedback without any predefined structure (Palomba et al., 2015). Users give reviews in app stores in an open-ended format where they can share many commendations or complaints within one entry as they wish. The user reviews we found in this study contained one to eight separate comments. To systematise the analysis, we broke each of the reviews into further coding units. The coding units are the various comments contained within user reviews. Table 4-4 illustrates an example of one user review dissected into four coding units. The 1,405 user reviews yielded 2,082 comments (coding units) for data analysis.

Table 4-4. Illustration of a sampling unit and its coding units

Sampling unit: User review	Coding units: Comments
Worked on first use, and I set up my regions etc. Then received an alert today for my region, and tried to open the app, but got 'setting up initial user' message, all my settings were lost, and all subsequent app loads crash immediately. Pretty flaky.	1. Received an alert today for my region
	2. Tried to open the app, but got 'setting up initial user' message
	3. All my settings were lost
	4. All subsequent app loads crash immediately

4.3.3 Data analysis

We used thematic analysis to examine the 2,082 comments. Thematic analysis is a "method for identifying, analysing and reporting patterns within data" (Braun & Clarke, 2006, p. 80), which begins with familiarisation of the data. For this research, we initiated familiarisation through the app selection and data collection process described in the preceding sections.

The initial coding of the comments was theoretically driven using Hoehle and Venkatesh's (2015) model. The model was chosen as the basis of initial coding because it provides a holistic picture that captures the context of mobile applications. It includes antecedents for usability that can help guide the development of usable mobile app designs and interfaces. The model defines mobile application usability with six higher level constructs, and each of these constructs is detailed further with respective formative lower level constructs (See Figure 4-2).

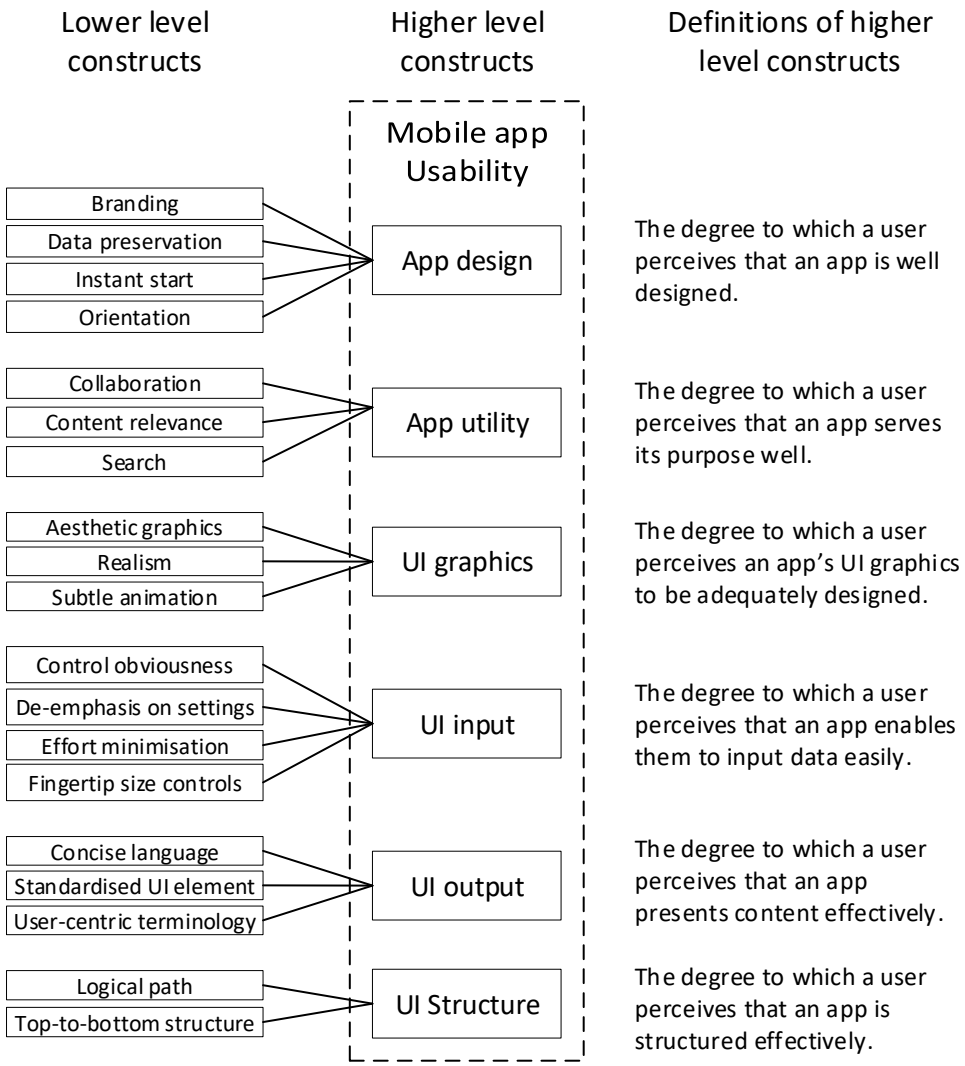

Figure 4-2. Mobile app usability conceptualisation by Hoehle and Venkatesh (2015).

In Figure 4-2, *App design* is formed by *branding, data preservation*, *instant start*, and *orientation*, while *App utility* is formed by *collaboration*, *content relevance*, and *search*. *UI graphics* is formed by *aesthetic graphics*, *realism*, and *subtle animation*; *UI input* is formed by *control obviousness*,

de-*emphasis on settings*, *effort minimisation*, and *fingertip size controls*; and *UI output* is formed by *concise language*, *standardised UI element*, and user-centric *terminology*. *UI structure* is formed by *logical path* and *top-to-bottom structure*.

The initial coding involved categorising the comments based on the Hoehle and Venkatesh's (2015) model's lower level constructs. Through the coding process, we found comments that did not fall within the existing constructs, and we coded these inductively to form new themes. As an example, Table 4-5 illustrates the initial coding results of one user review.

Table 4-5. An example: Initial coding results of a user review

Sampling unit: User review	**Coding units: Comments**	**Initial coding**	
		Higher level construct	Lower level construct
Worked on first use, and I set up my regions, etc. Then received an alert today for my region, and tried to open the app, but got 'setting up initial user' message, all my settings were lost, and all subsequent app loads crash immediately. Pretty flaky.	1. Received an alert today for my region	App utility	Content relevance
	2. Tried to open the app, but got 'setting up initial user' message	App design	Instant start
	3. All my settings were lost	App design	Data preservation
	4. All subsequent app loads crash immediately	Other*	Other*
**Those that did not fall under the initial codes were subjected to inductive coding*			

From this point forward, the term 'themes' refers to newly formed concepts, and the term 'constructs' refers to the items from Hoehle and Venkatesh's (2015) model. Each succeeding comment analysed was compared to the existing constructs and newly developed themes. Themes were subsequently developed and refined as more comments were interpreted. After coding the 2,082 comments, we looked at the patterns from the constructs and themes. We analysed and reorganised the groupings to ensure that the higher level constructs reflect a consistent essence. As a result of these steps, we built a conceptual framework for disaster app usability. Figure 4-3 shows a visual summary of the coding process from the user reviews to yield the conceptual framework.

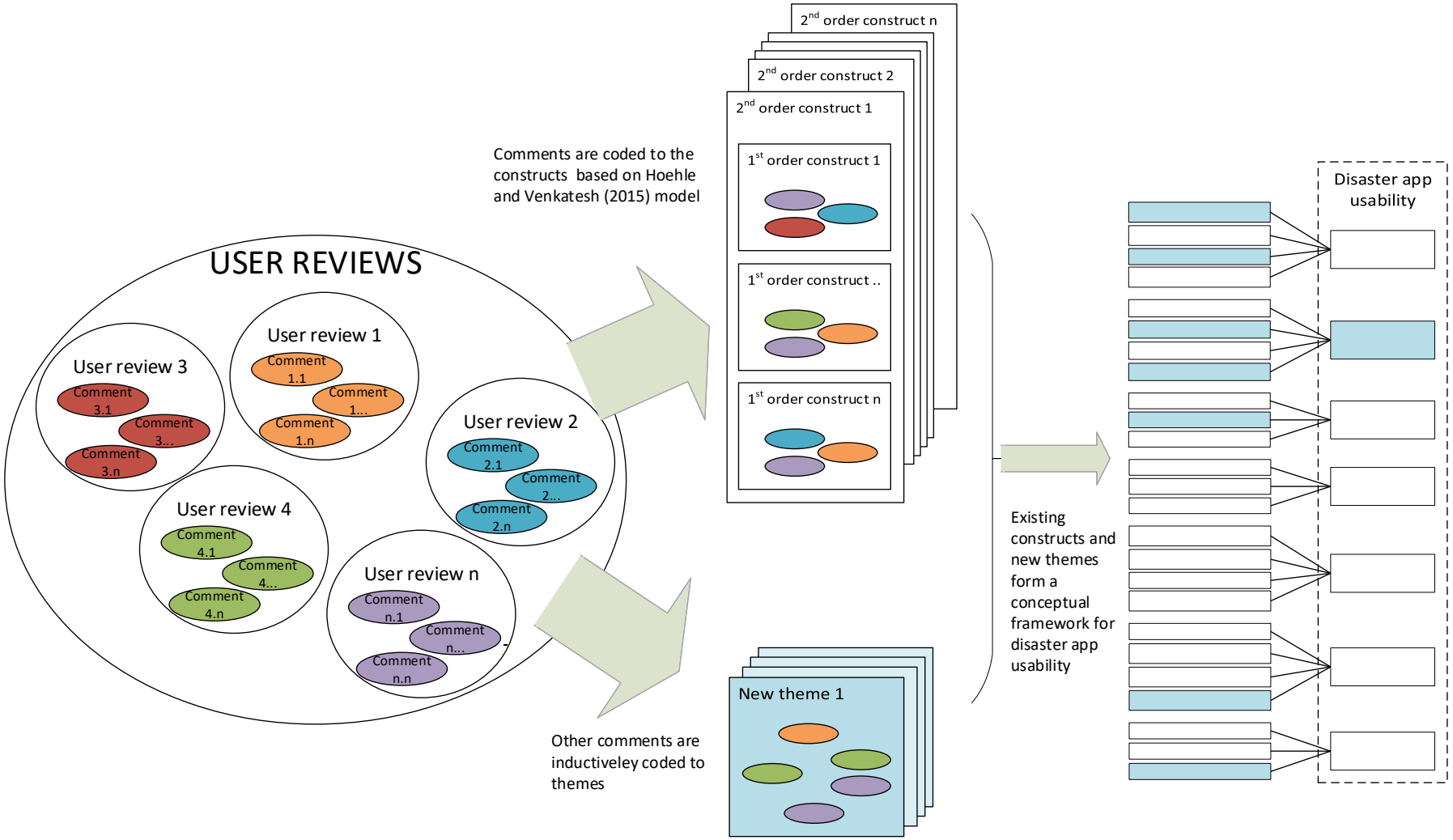

Figure 4-3. A visual summary of the coding process from the user reviews to the framework.

4.3.4 Validity

We ensured validity in this study by exercising rigour, achieved by applying triangulation throughout the process. We incorporated investigator triangulation by documenting the entire coding process conducted by a primary coder and by continuously updating a coding manual. Furthermore, a research assistant independently coded a sample dataset (n=247) to check the validity of the coding. We ran Cohen's kappa to determine if there was an agreement between the primary coder and the secondary coder: $\kappa = 0.613$ (95% confidence interval, 0.546 to 0.680), $p < 0.0005$. Kappa greater than 0.60 indicates that there was a substantial agreement between the two coders' judgements (Landis & Koch, 1977).

4.4 FINDINGS

This study aimed to capture the end-user perspectives on the usability of disaster apps through the analysis of comments made in the app stores' markets. Figure 4-4 shows the observed frequency counts of comments per construct and theme. Appendix D details the spread of codes mentioned in every app. All the lower level constructs from Hoehle and Venkatesh's (2015) model, except for *subtle animation* and *realism*, were observed from the comments. Notably, *content relevance* had the largest proportion of observations with 897 comments.

We acknowledge that there are no observations for the constructs for *subtle animation* and *realism*. Although there is no means to interpret unreported issues in qualitative data, it does not indicate that these are unimportant (Braun & Clarke, 2013b). Since the nature of these constructs is that they are relatable yet subtle, the users are less likely to comment on these. *Subtle animation* is about using effects subtly but effectively to aid users in transitions and actions (Hoehle & Venkatesh, 2015). The construct, *realism,* on the other hand, is about incorporating realistic icons or pictures, such as the rubbish-bin symbolising the delete action (Hoehle & Venkatesh, 2015). We retain these two constructs in the conceptual framework to be further validated in future studies.

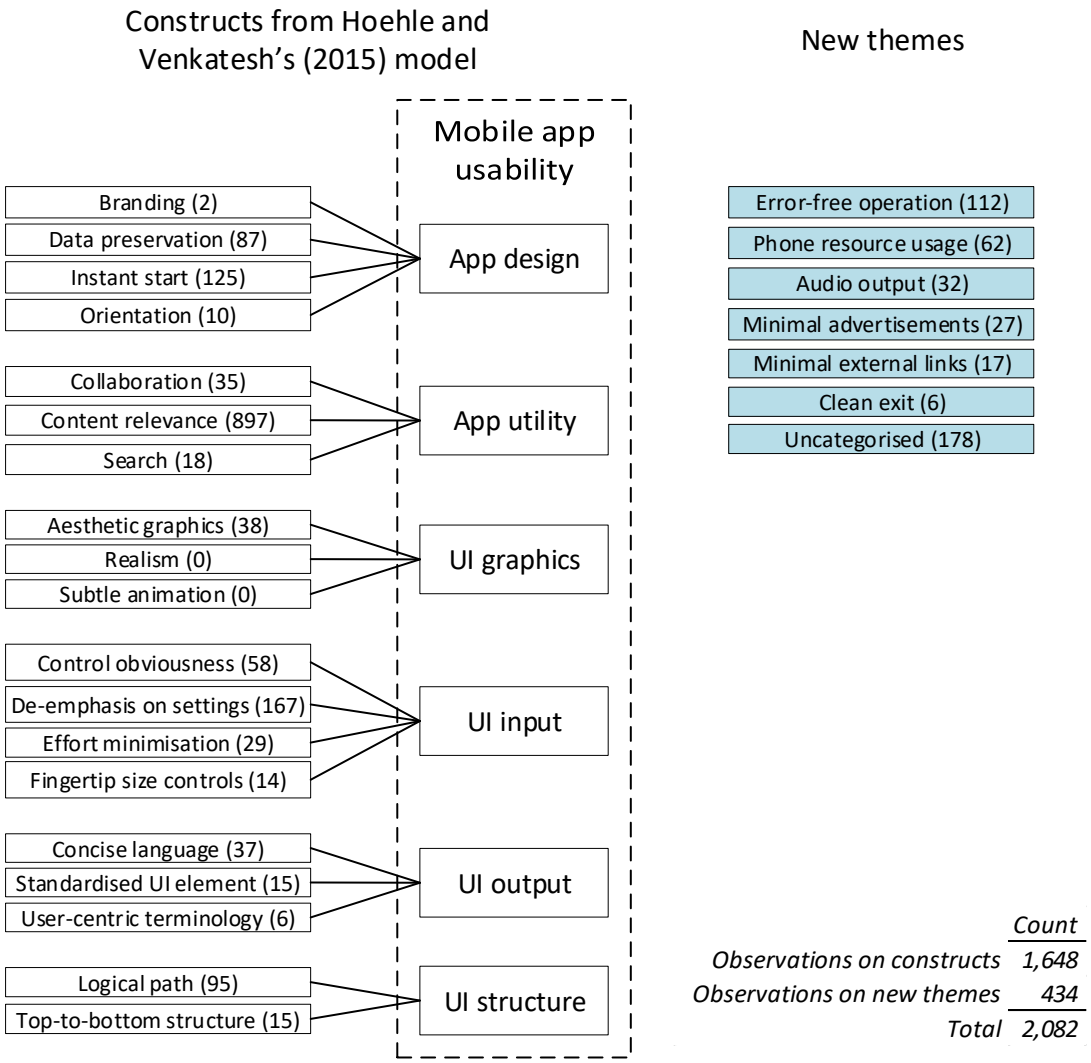

Figure 4-4. Frequency counts of comments observed on the constructs and new themes.

More importantly, 21% of the user comments (434 of 2,082) are new observations that are not yet clearly captured by the Hoehle and Venkatesh (2015) mobile app usability framework. The observations formed six new lower level themes.

4.4.1 Six new observations relating to usability

The following six new themes were observed in reviews multiple times across the set of 58 apps and never detected in isolation to just a single app. We found the theme *error-free operation* in 47 of 58 apps and the theme *phone resource usage* in 29 out of the 58 apps. Even the themes with lower frequency were observed across several apps: *audio output* (18 of 58 apps), *minimal*

advertisements (16 out of 58 apps), *minimal external links* (11 of 58 apps), and *clean exit* (4 out of 58 apps). Below, we discuss the users' insights on these new themes.

- ***Error-free operation***: There were 112 comments that discussed the reliability of the app. The comments narrated the users' experiences of crashes and errors. Some of the users articulated dissatisfaction and lack of trust when the apps exhibited critical errors. There is an expectation of seamless operation for disaster apps to support use.
- ***Phone resource usage***: Users expect the app to be designed efficiently. Sixty-two comments mentioned the amount of battery power consumed by the app or interference of the app with other essential functionalities of the phone. Given that a disaster app is designed for use during emergencies, there is an expectation that it should be able to achieve its purpose without using too much battery power or memory.
- ***Audio output***: Thirty-two comments highlighted the importance of the audio interface, particularly for alerting. The comments paid particular attention to how the notifications sounded. The users commented on the notifications being too loud, too quiet, too frequent, or too similar to sound effects used by other installed apps.
- ***Minimal advertisements***: Twenty-seven comments expressed negative views regarding the inclusion of advertisements in the apps. The comments raised users' concerns about advertisements interfering with the actual use of the app.
- ***Minimal external links***: Seventeen comments emphasised the need to reduce external browsing. Aside from page layout and inter-page navigation, users also remarked on the tendency for an app to direct users to read the content using an external app or browser. Users questioned an app's usefulness if it did not provide essential information internally and forced the user to seek content elsewhere.
- ***Clean exit***: Many comments described the app's ability to start instantly, but a few users also commented on how the app exits. Six comments expressed their expectations that the app should close seamlessly without interfering with the phone's other functions.

Some uncategorised comments (178 observations) did not relate to usability directly. For example, some comments pertained to the costs of purchasing the app, the developer's response to the reviews, and the apps' susceptibility viruses/malware.

4.4.2 The conceptual framework

After identifying the six new themes, we looked at patterns on how the six fit into the existing model. We refined the groupings, developing one new higher level theme and integrating the six into the lower level to form the conceptual framework. Figure 4-5 shows the proposed conceptual framework, highlighting the new themes juxtaposed with the original model.

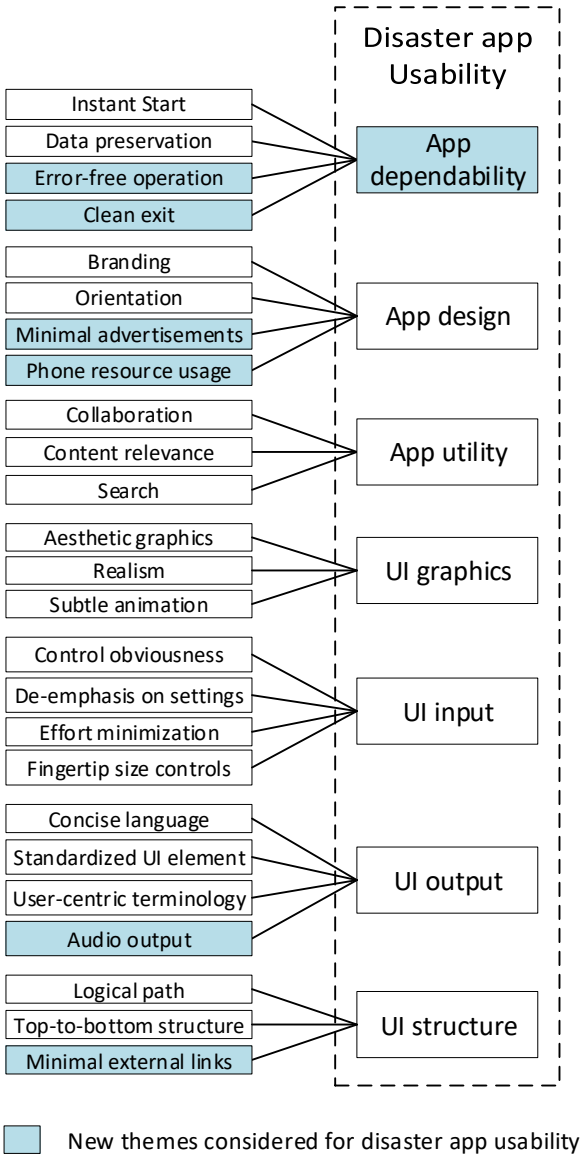

Figure 4-5. Conceptual framework for disaster app usability

In this conceptual framework, we propose a new higher level theme, *app dependability*. Patterns from the comments showed that four newly identified themes, along with four existing constructs at the lower level, form into two distinct thematic groups: *app dependability* and *app design* (See Figure 4-6).

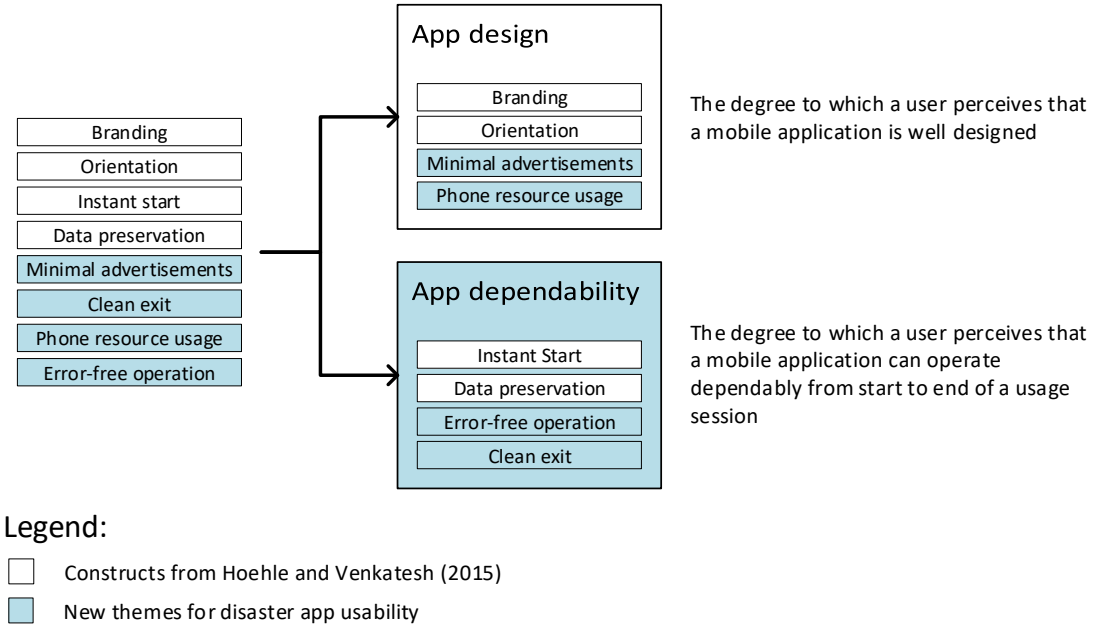

Figure 4-6. Formation of app dependability and app design as two thematic groups.

We observed that the new themes, *error-free operation* and *clean exit,* correspond with the existing constructs, *instant start* and *data preservation,* to form a thematic group. These four themes relate to users' distinct perception of operational dependability through a usage life cycle. Overall, the group covers users' expectation that the app will start instantly, will preserve data automatically, will function dependably without crashing, and will close without any problems. *App dependability* forms an overarching theme that unites *instant start, data preservation, error-free operation,* and *clean exit*. *App dependability* is defined as the degree to which a user perceives that an app can operate dependably from start to end of a usage session.

App design maintains its definition as "the degree to which a user perceives that a mobile application is generally designed well" (Hoehle & Venkatesh, 2015, p. 447). Existing constructs *branding* and *orientation* only had a few mentions but were observed as concerns for users (2

and 10 observations, respectively). However, the comments raised two new distinctive concerns on *app design*: on *minimal advertisements* and *phone resource usage*. Twenty-seven comments challenged the design decision on incorporating advertisements in disaster apps, and 62 comments narrated frustration with an app's design when users experienced exhaustion of their phone's resources (for example, battery and memory). Grouping these two new themes with *branding* and *orientation* frames the concept of *app design* for disaster apps. A disaster app's overall design should consider branding, design for horizontal/vertical orientation, design decisions on including advertisements, and design resolutions affecting phone resource usage.

4.5 DISCUSSION

From the insights from the app market, we have shown a conceptual framework contextualising usability to the disaster apps domain. In the process, we highlight end-users' usability concerns for disaster apps. In this section, we answer the research question: *What usability concerns are particular to disaster apps?* We discuss six items. First, we look into the construct that had the highest frequency of observations to reveal what *content relevance* means to disaster app users. Second, we discuss the applicability of the new higher level theme *app dependability* to disaster apps because of life-safety associations. The last four items discuss new themes at the lower level of the framework: *minimal advertisements*, *phone resource usage*, *audio output*, and *minimal external links*. The discussion cites some quotes gathered from the user reviews to emphasise the user opinions. We also align the discussion with existing research from other technologies, such as from Web2.0, websites, mHealth, and mobile device literature.

4.5.1 Content relevance for disaster app users

The highest percentage of comments (43% of total) in the review was on *content relevance*. Hoehle and Venkatesh (2015, p. 447) loosely define *content relevance* as "the degree to which a user perceives that the app focusses on the most relevant content." The reviews provided

deeper insights as to what relevance meant for disaster app users, who demand three forms of relevance from their disaster apps:

(1) Spatial proximity – Disaster app users seek information that is most relevant to their location. The comments showed that users expect the apps to reduce information overload by showing content related to their current location or a particular selected location. One comment indicated:

> *Need to be able to set a relevance radius—otherwise information overload. (*App# 28, RSOE EDIS Notifier Lite, Date: 27/08/2013*)*

(2) Temporal proximity – Content should also portray relevance to time. A few of the comments expressed the expectation that disaster apps should provide the most recent information. Some comments voiced dissatisfaction and viewed the apps to be unusable when the information provided was not timely.

> *The app gives you warnings about the weather in your area, but they're always 2 to 3 hours late! It's completely useless.* (App#56, Tornado by American Red Cross, 15/06/2015)

(3) Purpose proximity (significance to the app's purpose) – Relevance also means that the app provides content that matches the user's expectations of the app's purpose. Comments from the users often described whether they viewed the app capable of fulfilling its primary purpose, such as alert or information. Also, the comments provided insights into the form of content users expect, such as level of detail, the frequency of alert, sound effects, and information through images or maps. One comment expressed this sentiment:

> *I really like that you can have all the info concerning weather and traffic in one place. Very helpful when travelling. I would like to see the developers put an optional warning system that would pop up when there was a warning in your area.* (App#27 ReadyTN, Date: 26/02/2012)

4.5.2 App dependability

The conceptual framework shows that *app dependability* is an essential aspect of how users perceive the usability of disaster apps. This finding matches earlier studies on technologies for disasters. Mills and Chen's (2009) study on Web2.0 and disasters note that a crash in the system would be critical, prohibiting the use of the technology entirely. When users encounter errors during the usage life cycle, they can lose confidence that the app can dependably deliver. As we found from the comments in this study, users tended to gain confidence in their app when they did not encounter errors. The following sample comment showcased this sentiment:

> *App has got better and better over the last year with updates making the app more and more easy to use and adding more and more features.* […] *Never crashes and does as it says.* (App#18, GeoNet, Date: 26/01/2015)

Users can also lose confidence when the disaster app does not operate as expected. Improved perception of usability may be a result of avoiding negative experiences, such as crashes (Ding & Chai, 2015). The users' perception of usability is not only influenced by the look and feel of the interface but also by dependability. A comment from a user highlighted this:

> *I think, in principle, this app is a good idea. It needs some solid makeovers though. Nice user interface but crashes after 40 seconds. That doesn't sound so useful.* (App#56, Tornado by American Red Cross, 25/05/2015)

The finding of *app dependability* as a new theme is important as the consequences of errors may raise life-safety concerns. In mobile health (mHealth) literature, a study raises concerns on the possible harm an app could cause if it had usability problems (Ettinger, Pharaoh, Buckman, Conradie, & Karlen, 2016). For mHealth apps, clinician users must be able to trust that the app will perform reliably to help them with their jobs (Ettinger et al., 2016). Similarly, disaster app users must be able to perceive that the app will operate dependably during the entire duration of use, especially in the context of critical situations.

4.5.3 Advertisements in disaster apps

Past literature on web usability shows that advertisement integration contributes to the overall perception of the site's usability (Brajnik & Gabrielli, 2010; Dou, Lim, Su, Zhou, & Cui, 2010). In web design, and similarly in app design, this involves subtle advertising or strategic product positioning (Dou et al., 2010). However, usability problems can occur due to the presence of advertising. Adverse effects of advertising include reduced usability that affects reading and information-seeking tasks (Brajnik & Gabrielli, 2010). Users of disaster apps, as observed in the analysis of reviews, can also find advertisements a hindrance to the app's usability. An extracted comment shows this:

> *Useful but far too many advertisements are appearing. If they continue, I'll uninstall.* (App#4, Brisbane & Queensland Alert, Date: 9/10/2015)

The possible negative impact of advertisements on users' information processing capabilities must be considered for disaster apps. Advertisements could contribute to information overload when users are trying to retrieve critical details about a hazard event. Crisis information systems must focus on designing human processes and information systems in an optimal configuration for human cognition (Hiltz et al., 2010). Disaster app design, therefore, should reduce cognitive load to enable its users to process information to enhance life-safety effectiveness. Advertisements are counterproductive for disaster apps. The objective, considering life safety, should be to minimise the use of advertisements so as not to burden users' cognitive load when receiving information.

4.5.4 Phone resource usage efficiency

For disaster app usability, it is critical to consider the app performance within the smartphone itself. Resources, such as battery life and memory, are necessary for the phone and its apps to work during disasters. In an emergency, the smartphone could be used in a variety of ways aside from the use of the disaster app itself as, for example, for making phone calls, SMS messaging,

and lights and sounds. The minimum expectation is that the app can operate efficiently without draining too much of the phone's capacity for the user to perform other functionalities. Sample user comments from the analysis mentioned the practicality of the disaster app concerning phone resource use:

> *Had to uninstall it because it drained my battery – couldn't make it through a day without charging.* (App#38, CodeRED Mobile Alert iOS, Date: 26/01/2014)

> *I don't care how good it is – it isn't worth 6MB of system memory.* (App#5, CodeRED Mobile Alert Android, 5/09/2012)

Unintentional software design decisions can make apps power hungry and rely on operating systems for power management (Ferreira, Dey, & Kostakos, 2011). Users take steps to preserve the battery life of their devices, and battery consumption is a critical usability issue for app usage (Ferreira et al., 2011). Other resource limitations to consider for mobile devices are disk space and memory. For a disaster app to be considered usable, it has to operate efficiently in the possible context of use during disasters and needs to deliver its purpose without draining the phone's resources. An app that overuses resources could prevent the user from using other smartphone functions during emergencies. Given that disaster apps are likely to be used infrequently, they risk being uninstalled if users perceive them to be too resource hungry.

4.5.5 Auditory output for disaster apps

UI output refers to "the degree to which a user perceives that the app presents content effectively" (Hoehle & Venkatesh, 2015, p. 450). Most of the comments on *UI output* focussed on the visualisation aspect of the apps. However, we found 32 comments that highlighted the importance of audio interface in disaster apps, in particular to alerting.

Often, users of general apps disable or mute audio as they may not deem it useful (Korhonen, Holm, & Heikkinen, 2007). However, for disaster app users, audio UI adds value to the app's usability. Sounds can act as prompts that draw the user's attention to an alert for an oncoming,

recently occurred, or an ongoing situation. Some comments from the users expressed the opinion that the notification sound coming from the disaster app should be distinct from other apps' sounds. For example, one comment indicated that the audio effect should be distinguishable when heard:

> *It's missing one critical option: notification sound. Being able to set a different sound for each type of alert would be ideal. You should be able to tell whether that was a tornado warning or if it's your turn in a game* […] *without having to look at your phone.* (App#2, Alabama SAF-T-Net. Date: 22/05/2013)

On user acceptance of audio notifications, Westermann (2017) affirms that the content of the application dictates the sound settings users anticipate. Users may want the most noticeable sound for thunderstorm alerts and less so for notifications from apps that contain less critical information, such as games.

Consequently, setting the default volume on disaster apps stands out as one of the significant challenges in audio UI. App notifications are designed to make users aware of an event. However, excessiveness can cause disruption or annoyance that could lead users to uninstall an app or to ignore notifications (Felt, Egelman, & Wagner, 2012). The comments on audio UI showed that users appreciate high volume audibility when messages contain critical information. However, users can find the app irritating if the sounds are too loud for warnings that are not imminent or significant. One comment expressed this annoyance:

> *Can't change the alert sound or volume* […] *The alert component still seems to run, though, which results in the app waking me up with an annoyingly loud noise in the middle of the night to* [only] *let me know it's raining or windy. Pity. Uninstalled.* (App#19, Hazards - Red Cross, 28/07/2016)

Audio UI influences the disaster app user experience. The comments expressed that for audio UI to positively affect usability, it must be explicitly designed to have a distinctive sound as well

as have appropriate volume settings. Users' volume inclinations are constantly changing, which provides a challenge in setting audio preferences for apps (Rosenthal, Dey, & Veloso, 2011). The audio interface of disaster apps is an important area for potential future research.

Aside from audio UI, the use of haptic cues may be an area for further investigation for disaster apps. In this study, none of the user reviews mentioned vibration. However, it is worth noting that in other studies on notifications and disruptions, the auditory modality often accompanies other sensory outputs (see for example Mashhadi, Mathur, & Kawsar, 2014). A study by Westermann (2017) shows that users associated audio and vibration cues with critical messages. Furthermore, the use of vibration as sensory cues may influence users to see notifications earlier. The overall usability of an app can be improved by enhancing audio UI (Korhonen et al., 2007) and, possibly, other sensory UI.

4.5.6 External browsing

UI structure is defined as "the degree to which a user perceives that the app is structured effectively" (Hoehle & Venkatesh, 2015, p. 450). From the user comments regarding disaster apps, whether or not apps are perceived to be effective structurally mostly depends on the page layout (top-to-bottom structure) and navigation between pages (logical path).

Furthermore, 17 comments emphasised a new theme relating to interface structure: *minimal external links*. Aside from page layout and inter-page navigation, users also remarked on the tendency for an app to direct users to read content on an external source (that is through another app or web browser).

Usually, criticism arises when the content of the app is insufficient, prompting users to seek more information. Users want to see information internally rather than finding the information elsewhere. For example, a user can find an app useless if the app diverts the users to a different source:

> *Real time alerts replaced with links to other sites... this is an improvement... seriously? Uninstalling.* (App#34, Wildfire - American Red Cross, 21/08/2013)

Some of the comments conveyed the preference to have access to the supplementary information within the app:

> *Also, I like the capability to automatically surf over to the USGS web page without leaving the app.* […] *The app* […] *takes you to the website and gives the ability to email the page to others. I use this app every day – is tremendous with great potential.* (App#49, FloodWatch, Date: 3/05/2011)

Improving usability means that disaster apps should minimise the need to open another app or browser to display content. Recent trends in popular apps, such as Facebook and Twitter, show increased use of in-app browsing, in which the browsing of external content occurs within the app, taking away the need to open a separate browser. For disaster app users, this may provide added value, allowing the app to display more content while staying within the app. It may reduce the stress of opening and relying on a separate browser to deliver pertinent information, so in-app browsing has the potential to contribute to usability. It can also help the perceived structure of the user interface; however, further investigation is needed to make this finding conclusive.

4.5.7 Limitations

The new themes resulting from this analysis may potentially apply to different typologies of apps outside the disaster context. However, since the insights were drawn from the analysis of reviews from disaster apps, we can only relate the discussion of these concerns into the domain of disaster apps. It would be worth exploring in future studies whether the new usability themes can apply to any other app typologies. We recommend that researchers, designers, and developers of disaster apps consider these emerging insights for future disaster app projects.

We also acknowledge that this study is exploratory in nature as it aimed to gain an understanding of usability through the lens of user reviews from disaster apps. Future research planned by the authors will look to strengthen this conceptual framework through quantitative validation and actual engagement with users. It would also be beneficial to investigate how this conceptual framework can translate into a set of guidelines for developing disaster apps.

4.6 CONCLUSION

Even though the broader field of safety-critical systems sees the topic of usability as an essential area of research, only a small number of academic studies has investigated the usability of disaster apps that are accessible for public use. From the insights drawn from the app market, we have identified new themes and have proposed a conceptual framework for the usability of disaster apps. The existence of new themes provides an argument that the approach to the research and development of disaster apps is different from general everyday use apps. The identification of *app dependability* shows consideration to users' perception that an app can operate dependably during critical scenarios. The study also provided other usability concerns to investigate, such as the users' expectation on *content relevance*, *minimal advertisements, phone resource usage*, *audio output*, and *minimal external links*. Researchers, designers, and developers should make an effort to consider these new themes, along with other existing usability constructs, when conceptualising, building, and evaluating disaster apps. Future research should further investigate the conceptual framework proposed in this study and consider the themes with a life-safety lens to develop specific usability guidelines for disaster apps.

5 A DISASTER APP PROTOTYPE IN THE NEW ZEALAND CONTEXT

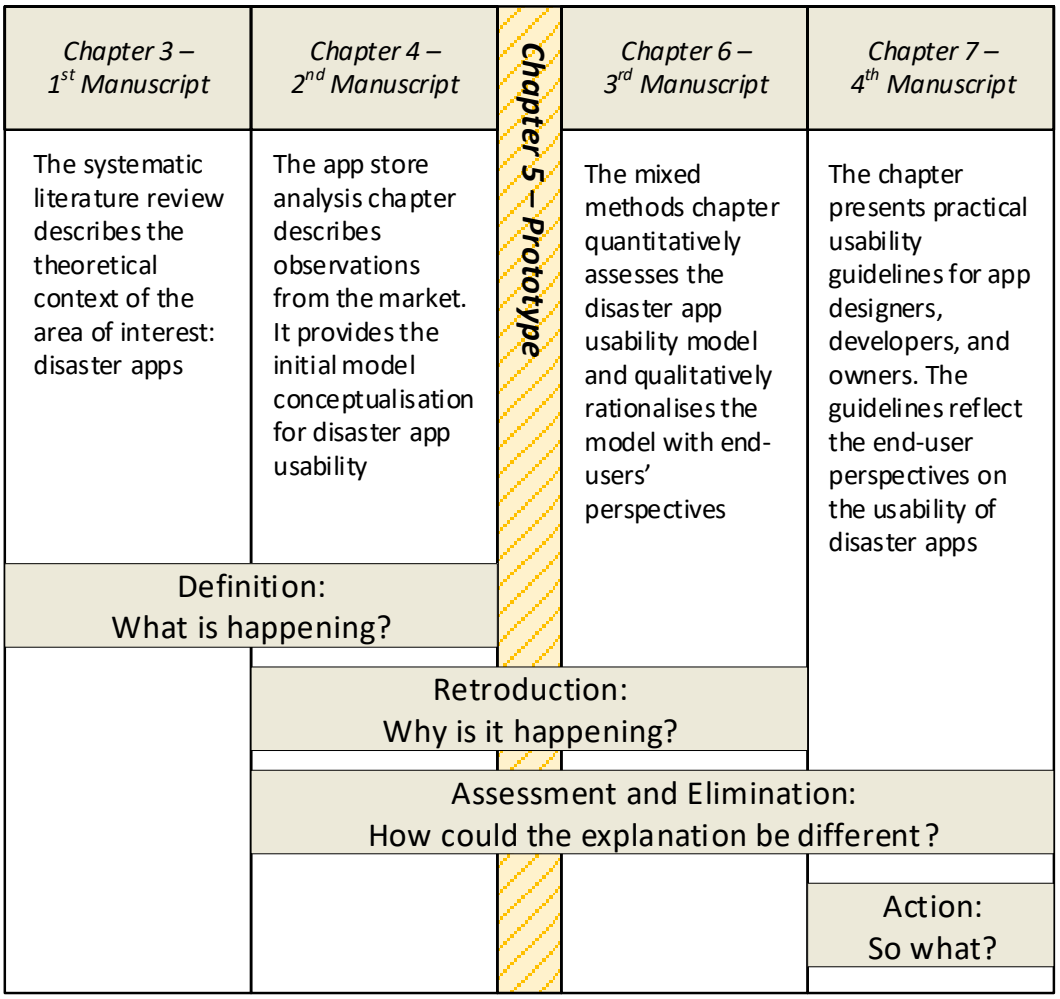

Figure 5-1. Positionality of the prototype chapter to the thesis.

The previous two manuscripts have utilised secondary data to highlight the following:

(1) There is a need for user-centred studies to understand users' needs, motivations, expectations, experiences, and limitations when using disaster apps; and

(2) There are usability considerations particular to the use of disaster apps.

However, to have an in-depth understanding of the users' perspectives of usability requires also a closer interaction with the users. Best practice guidance on risk and crisis communication advises 'knowing your audience'. Developing technological products that convey emergency or crisis information requires an understanding of not only the needs of the audience but also the concerns that influence their reception and use of information, products, and systems (Kain et

al., 2010). The next stages (Chapter 6 and 7) of this doctoral research incorporates results from an inquiry with users using a medium-fidelity prototype[2].

The prototype was used to stimulate conversations with the public on to gather their perspectives of disaster apps and usability. As the doctoral project is situated in New Zealand, the prototype reflects the hazards context and alerting and warning needs of the New Zealand public. The prototype was developed using the Justinmind v8.7.0 (2019) software[3]. This prototype chapter is positioned before the third and fourth manuscripts (See Figure 5-1) to discuss: (1) the context of alerting and warning in New Zealand, (2) the conceptual design for the prototype, and (3) the role of the prototype in the succeeding stages of the research.

5.1 CONTEXT OF ALERTING AND WARNING IN NEW ZEALAND

In New Zealand (NZ), multiple agencies have the mandate to warn the public on actual or suspected threats, risks, hazards, or emergencies (Ministry of Civil Defence and Emergency Management, 2016, 2017). The Ministry of Civil Defence and Emergency Management (MCDEM) operates the National Warning System, which is the primary channel to communicate national level warnings to 16 local Civil Defence and Emergency Management (CDEM) agencies. Subsequently, the CDEM agencies have the responsibility to provide official alerts to their communities for many local hazards.

[2] There are three degrees of fidelities for prototyping. Low-fidelity prototypes are used at the early stages of development and are often implemented using physical forms (for example, paper, whiteboards, and sketches). Medium-fidelity prototypes are refined versions translated on technological platforms using multimedia design tools or interface builders. High-fidelity prototypes are further refined prototypes having functionalities similar to an end-product (Petrie & Schneider, 2007).

[3] The researcher presented and published this app conceptualisation at the 16th International Conference on Information Systems for Crisis Response and Management in Valencia, Spain, May 19–22, 2019. Available at http://idl.iscram.org/

Monitoring agencies, such as GNS Science (geological survey) and the MetService (meteorological agency), also provide public alerting related to their respective hazards (Wright et al., 2014). Moreover, the NZ Police, Fire and Emergency NZ, NZ Transport Agency, Ministry of Health, and Ministry of Primary Industries also provide alerts related to their respective jurisdictions (Ministry of Civil Defence and Emergency Management, 2017).

The NZ Civil Defence also uses a multi-channel approach to ensure that as many people as possible can receive information. There are at least 20 public alerting platforms for these agencies to communicate to the public, including billboards, radio announcements, cell broadcasts, emails, loudspeakers, and websites (Ministry of Civil Defence and Emergency Management, 2018). Multiple technological options exist to deliver alerts to the public through their mobile devices, and these include the use of social media platforms and broadcast massaging (Wright et al., 2014).

5.1.1 Use of social media in public alerting in New Zealand

Many of the NZ public alerting agencies use social media platforms to communicate (Wright et al., 2014). The public can access social media information through websites as well as through respective apps on their mobile devices. However, the use of social media platforms has limitations. Users have to opt in through individually following various accounts, and they have to check different streams and sources to receive updates (Wright et al., 2014). The presence of the agencies on popular social media platforms is also not consistent. For example, not all NZ public alerting agencies have Facebook or Twitter accounts (Wright et al., 2014). A quick scan of 24 alerting authorities on Facebook and Twitter shows that although most have official accounts on both social media platforms, some may have only one or the other, or none at all, as illustrated in Table 5-1.

Table 5-1. NZ public alerting agencies' social media presence as of 2018

		Facebook		Total
		Yes	No	
Twitter	**Yes**	18	2	20
	No	3	1	4
Total		21	3	24

Another limitation of social media platforms is the reliance on third-party social media algorithms for providing updates (Wright et al., 2014). Social media content does not necessarily arrive in chronological order (Biersdorfer, 2016). For example, Facebook prioritises posts from families and friends rather than organisations (Bromwich & Haag, 2018).

With the changes in technology and the new media ecosystem, over-alerting can create issues in how the public responds to alerts (National Academies of Sciences, Engineering, and Medicine, 2018a). During a crisis, users can encounter difficulties in making sense of too much data; information overload can occur when human capacity cannot keep up with the torrent of data arriving (Stratmann & Boll, 2016). Aside from social media and other technological platforms, public alerting authorities can also push high-priority alerts via the Emergency Mobile Alert (EMA) system.

5.1.2 Emergency Mobile Alert (EMA)

New Zealand recently adopted the EMA system in 2017, which allows authorised agencies to release alerts via cell broadcast technology (Ministry of Civil Defence and Emergency Management, 2017). Other countries have similar systems; for example, the Wireless Emergency Alert (WEA) in the United States of America (Bean et al., 2015); and Cell Broadcast Service (CBS) of Taiwan (Chang & Chen, 2018). The emergency alerts, different from text messages, do not cause network congestion as they are distributed through a geo-targeted wireless channel (Bean et al., 2016; Chang & Chen, 2018). Moreover, the alert messages delivered to mobile phones are distinct from standard messages as they are uniquely displayed on devices accompanied by distinct tones and vibrations (Bean et al., 2016).

How an individual receives the message can affect how the individual responds to the threat (National Academies of Sciences, Engineering, and Medicine, 2018b). During a crisis, users can encounter issues. For example, anxiety, fatigue, and other stressors can hamper information processing (Stratmann & Boll, 2016). The typical emergency alert message (see Figure 5-2) is delivered through a pop-up notification mechanism in the user's smartphone (Falcão, Krebs, Kumar, & Erdogmus, 2018). The simple message dialogue may be suitable to convey a single message during an unchanging situation, but multiple messages over a complex scenario may require a different manner of presentation to help the users to understand the situation (Iannucci, Falcao, Erdogmus, Griss, & Kumar, 2016).

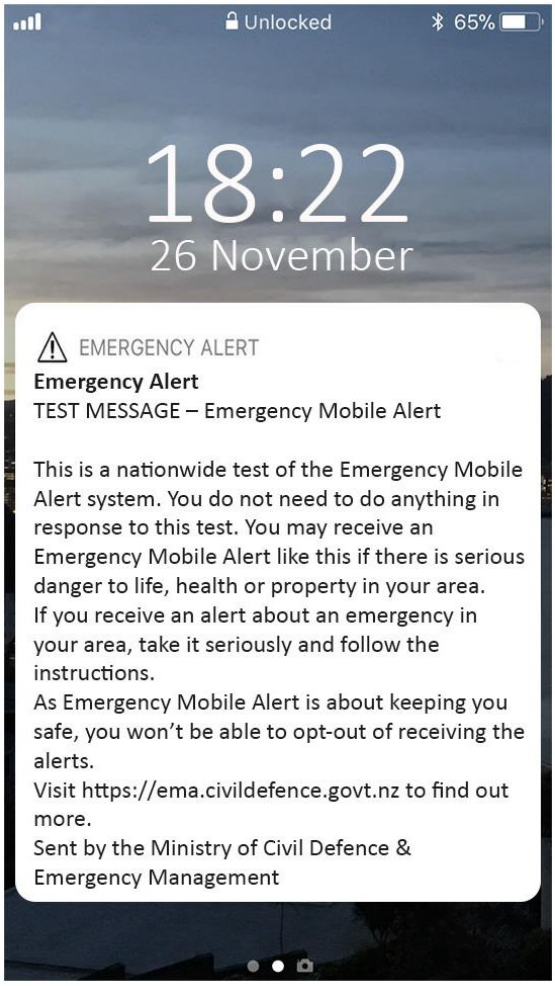

Figure 5-2. Emergency Mobile Alert example.

Another interface issue, as encountered in a test broadcast in New Zealand, is the disappearance of the alert message when users tap on to the notification on their smartphones and the inability to retrieve it a later time (Ministry of Civil Defence and Emergency Management, n.d.). Although not raised in academic literature, smartphone users have raised interface and retrieval issues of emergency alerts. Table 5-2 presents anecdotes from users raising this issue in online forums. Further research is needed to make the interface more intuitive. As technologies change, so do user behaviour and public response; continued research on human engagement with alert messages is thus critical (National Academies of Sciences, Engineering, and Medicine, 2018a).

Table 5-2. Anecdotes on disappearing alert messages.

Anecdotes	Forum
Last night I got an emergency alert. I didn't have my glasses on and as I reached for the phone, I lost the message. How can I find that message?	Apple discussions
I imagine most people push OK in a panic to stop the loud sound, and then are left wondering what it was exactly that was so important.	Android Stack Exchange
Where are emergency alerts (WEA) stored on the iPhone? One popped up and disappeared before I could read it.	Apple discussions

5.2 INITIAL CONCEPTUAL DESIGN

Mobile apps have the potential to be used as a medium for disaster communication to harness curated social media content while integrating official information (Houston et al., 2015; Spielhofer et al., 2019). To maximise the impact of disaster communication, new media and traditional media should be integrated (Klafft & Ziegler, 2014; Lindsay, 2011). Andersen (2016, p. 128) emphasises that "using some form of medium to transmit information is still central," and official information from authorities is still most critical.

The prototype conceptualised for this research project is an aggregating platform that aims to address the issues (as discussed in Section 5.1) relating to the alerting and warning context in

New Zealand. The app will collect, store, and display information that is made public by authorised agencies. These include preparedness information, social media messages, and EMA broadcasts. The app aggregates information from official sources and authorised alerting agencies into one platform, providing means to find critical information segregated from the noise of multiple media sources and other non-hazard-related information.

The initial motivations for the app concept are (1) to lessen information overload by consolidating messages from various official social media sources, and (2) to address the emergency alert interface issues by collating, storing, and displaying emergency alert messages for users. In addition, (3) the app provides preparedness information from reliable sources. The app's main features are partitioned into three screens (see Figure 5-3): the home screen, alert screen, and prepare screen.

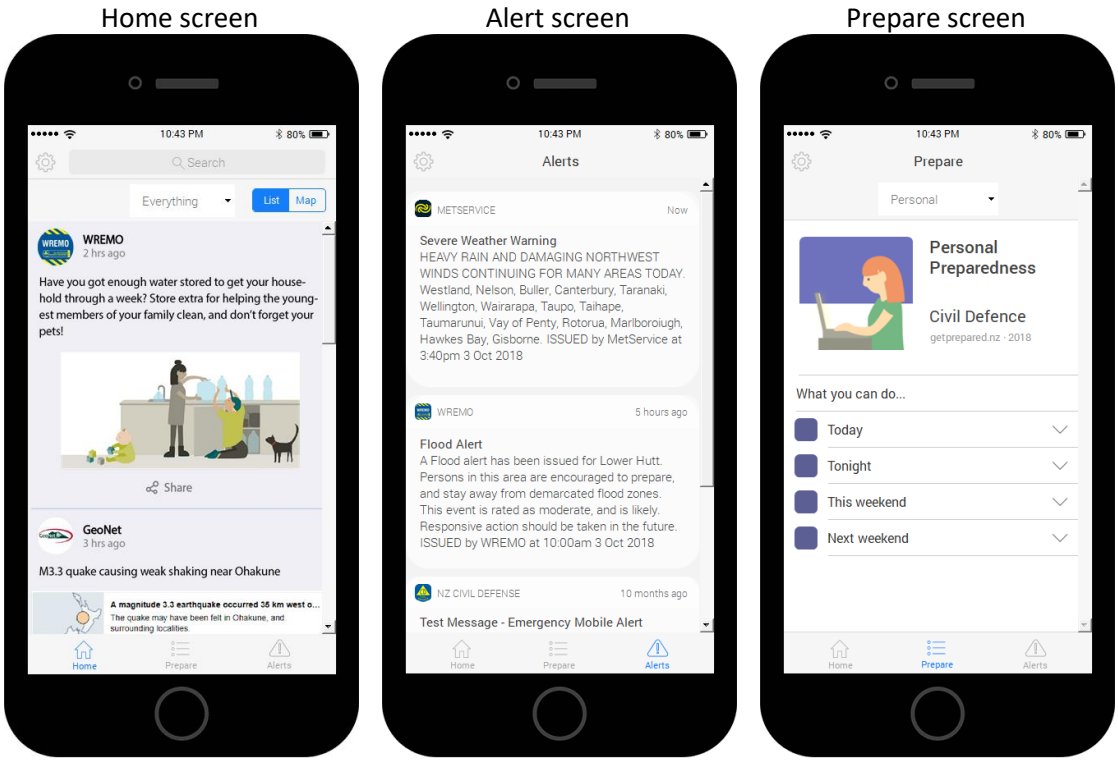

Figure 5-3. Screenshots of the prototype

5.2.1 Home screen

The home screen displays a real-time feed, harvesting content from participating authorities' social media channels. By collating information from official sources, it reduces the noise that may be encountered when using multiple social media apps. In social media sites, posts on a user's feed can contain mundane topics that may become noise when seeking information about a hazard event. Separation of credible information from that which is trivial is needed (Imran et al., 2015).

5.2.2 Alert screen

The way information is processed, stored, and displayed can affect users' decision-making capabilities during critical scenarios (Prasanna, Yang, & King, 2013). Users can make errors when under stress, which may cause them to dismiss alerts before reading the information. The alert screen collates, stores, and displays official emergency alert messages from authorities, allowing users to retrieve the information as needed.

5.2.3 Prepare screen

Most of the apps in crisis informatics literature focus on the response and recovery stages (Tan et al., 2017). However, there is potential in utilising new media tools to encourage preparedness for a crisis (Veil et al., 2011). In addition to delivering up-to-date information from official agencies, the app provides credible preparedness information. The prepare screen is an offline repository of emergency preparedness information that users can access at any time.

With the three components combined, the app is a 'one-stop-shop' that aims to provide preparedness and response information on hazard events to the public living in New Zealand. The primary concept for the app is to aggregate the information available from authorised agencies in New Zealand and deliver it to the public through a simple platform. Appendix E provides the screen documentation for the prototype.

5.3 USE OF THE PROTOTYPE FOR THE NEXT RESEARCH STAGES

To further understand the perspectives of the users, a usability inquiry was conducted using the conceptualised medium-fidelity disaster app prototype with members of the public as participants. Usability inquiry is a method that gains user insights through observing users as they interact with an artefact and through engaging them with questions and discussions (Nielsen, 1994a; Zapata et al., 2015). The goal of an inquiry is not to test the artefact but to draw an in-depth understanding of users and their perceptions (Nielsen, 1994a). The prototype, referred to as *NZ Alerts* to the participants, is used as a tool to engage participants in a conversation about disaster apps and usability.

I used a semi-structured interview format to gather feedback from participants on their perspectives of usability. Semi-structured interviews allowed me to guide the participants through a logical line of questioning while permitting the participants to dictate the pace of the discussion. I conducted two pilot interviews before proceeding with the actual data gathering, and this enabled a refinement of the inquiry process, questions, and interview flow. Appendix F details the interview script for the usability inquiry. I facilitated all eighteen interviews through one-on-one sessions with the participants. The third and fourth manuscripts utilise the data gathered from the usability inquiry. The data analyses, however, are conducted separately according to the objectives for each paper.

- The third manuscript (Chapter 6) uses a mixed methods approach to understand the usability factors and their influence on users' intention to continue using disaster apps. The paper primarily focusses on building a usability–continuance model through quantitatively analysing survey data. The usability inquiry data is used to complement the model qualitatively. It provides insights that explain the intricacies of the quantitative relationships.

- The fourth manuscript (Chapter 7) centres on building a set of usability guidelines for disaster apps. The usability inquiry data is used as part of an iterative design process. The guidelines anchor on themes gathered from academic publications on the usability of disaster apps. The statements inferred from the usability inquiry are further evaluated and refined with app stakeholders to develop a set of user-centred usability guidelines.

6 [3RD MANUSCRIPT] USABILITY FACTORS AFFECTING THE CONTINUANCE INTENTION OF DISASTER APPS: A MIXED METHODS STUDY

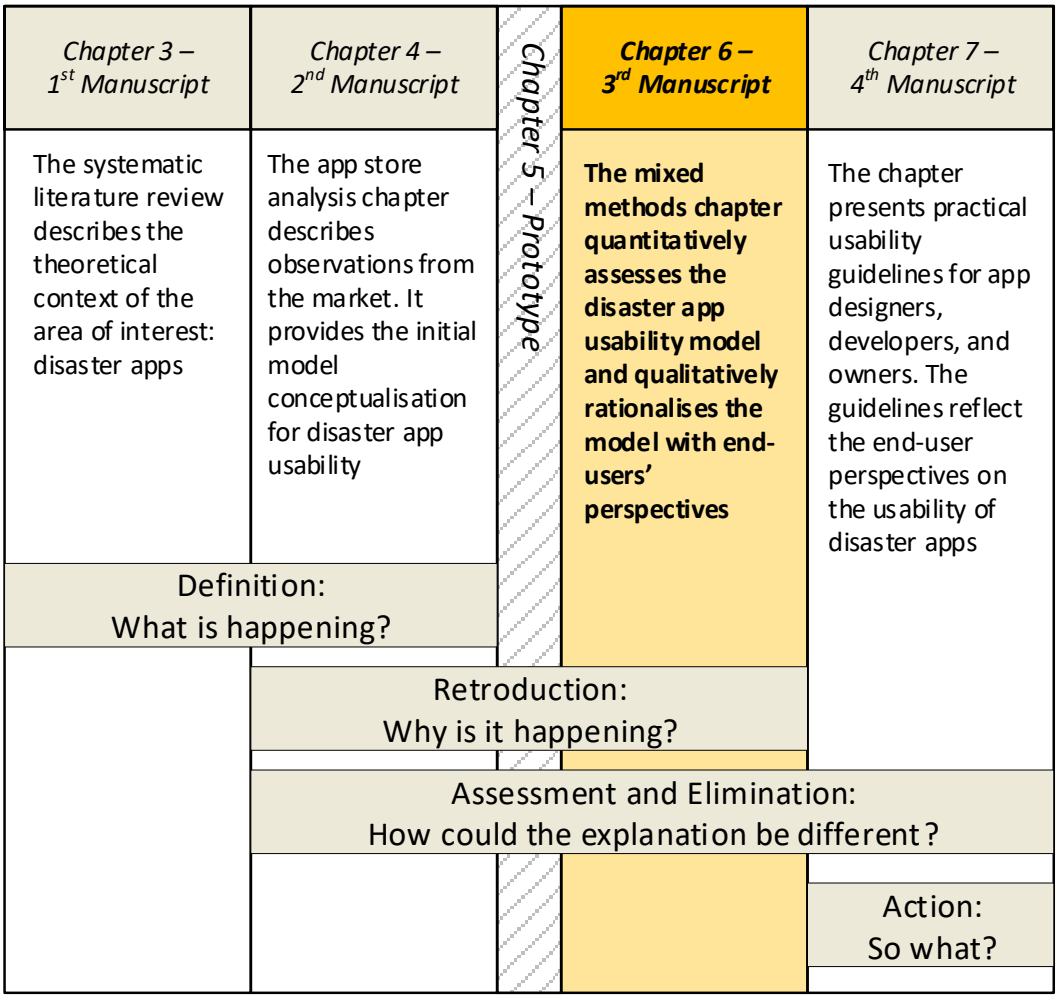

Figure 6-1. Positionality of the 3rd manuscript to the thesis.

ABSTRACT

Mobile apps have the potential to aid disaster response by providing an avenue to distribute relevant and time-critical information to the public. Disaster apps already exist in the app markets. However, it is a challenge to engage users in retaining disaster apps on their smartphones. A mixed methods approach is used in this study to investigate whether usability factors affect users' intention to continue to use an app (referred to here as continuance intention). First, quantitative methods, applying structural equation modelling with survey data

from 271 disaster app users, tested a usability–continuance model. Second, a qualitative usability inquiry, using in-depth interviews with 18 participants, explored the users' insights of the relationships identified from the quantitative modelling. The results showed five usability factors to have significant influence on continuance intention. The key positive influencers are (1) users' perceptions as to whether the app delivers its function (*app utility*); (2) whether it does so dependably (*app dependability*); and (3) whether it presents information that can be easily understood (*user-interface output*). Subsequently, too much focus on (4) *user-interface graphics* and (5) *user-interface input* can discourage continuance intention. The results have practical implications for designers and developers, providing guidance on what factors to focus on to enhance the continuance intention of disaster apps.

MANUSCRIPT PREPARATION AND SUBMISSION DETAILS

I co-designed the data collection instruments with Dr Prasanna, Dr Stock, Dr Hudson-Doyle, and Dr Leonard. After I had prepared the initial draft of the quantitative survey, it was extensively reviewed by Dr Prasanna and Dr Stock. With the supervision of Dr Prasanna, I conducted two rounds of pilot testing, analysed the pilot data, and made modifications to the instrument. I then designed the usability inquiry, and it was refined by Dr Hudson-Doyle. Dr Leonard supported me in the pilot inquiry session and suggested adjustments to the interview flow and questions. I also conducted the collection and analysis of the data with the support of my supervisors, including Professor Johnston, who also guided me in the structuring and editing of the manuscript. I prepared the final manuscript and submitted it to the journal, *Computers in Human Behavior*, in October, 2019. The quantitative component of this mixed methods study was presented as a work-in-progress paper at the 1st Asia Pacific Conference on Information Systems in Crisis Response and Management, November 5–7, 2018, in Wellington, New Zealand.

6.1 INTRODUCTION

Mobile applications (apps) have the potential to improve the public's response to disasters. Public-facing mobile apps used for crises often feature capabilities that aim to enrich users' situation awareness (Tan et al., 2017). Situation awareness is the perception, comprehension, and projection of contextual information within a limited volume of time and space (Endsley, 2000). In this chapter, we define disaster apps as mobile apps that aid the public in retrieving, understanding, and using time- and location-critical information to enhance their decision-making processes during a disaster situation.

Disaster apps are becoming popular among the general public (Bachmann et al., 2015). Crisis management authorities have put effort into developing and promoting official disaster apps. For example, the Red Cross and Red Crescent Societies are releasing disaster apps in different countries (American Red Cross, 2015). Governments are also pouring funding into disaster app development and improvement, and examples include the US's FEMA app (US FEMA, 2016) and Australia's Emergency+ app (Australian Government, 2016). The disaster apps included in this study are one-way communication tools available to the public that provide information about natural hazards, such as severe weather, wildfires, earthquakes, or multi-hazards.

While disaster apps are becoming more readily available, availability in the market does not necessarily lead to continued use by the public. Studies on mobile apps show that one out of four apps is abandoned after the initial download and use (Deloitte, 2012; Localytics, 2017). Furthermore, although hundreds of disaster apps exist in app stores, only a few have a significant user base. Only a small percentage of the population download and use smartphone apps that could help during disasters (Reuter, Kaufhold, Spielhofer, & Hahne, 2017; Spielhofer et al., 2019). Disaster apps are not necessarily designed for everyday use (Reuter, Kaufhold, Spielhofer, et al., 2017); hence, users do not interact with disaster apps as frequently as other types of apps. Engaging users to continue retaining a disaster app installed on their smartphones

then becomes a challenge (Tan et al., 2017). In other words, disaster apps have the problem of *continuance intention*, a term which refers to users' intention to continue using a particular technology after its initial acceptance (Bhattacherjee, 2001).

Users can re-evaluate their earlier decision of accepting a technology and can choose to discontinue use (Thong, Hong, & Tam, 2006). A critical consideration in continuance intention for mobile apps is usability (Li & Lu, 2017; Lim, Bentley, Kanakam, Ishikawa, & Honiden, 2015). Users can continue or discontinue using a particular technology after accumulating perceptions from the initial or ongoing experience. However, existing studies on disaster apps do not particularly focus on usability (Romano et al., 2016; Tan et al., 2017). This is a gap in disaster apps research. The design of safety-critical systems has always emphasised the importance of usability (Kwee-Meier et al., 2017). Furthermore, the usability of systems becomes especially crucial during crises as conditions of extreme time pressure and high stress can cause individuals to experience degradation in information processing and decision-making abilities (Kwee-Meier et al., 2017; Sarna, 2002). This chapter, then, investigates whether usability factors affect continuance intention in the context of mobile disaster apps that are meant for use by the general public. The chapter seeks to answer the question: *How does usability affect continuance intention of disaster apps*?

The chapter is structured as follows. It first provides a brief background on continuance intention before the theory and hypothesis section, which presents the conceptual model and study's hypotheses on the effects of the usability factors to continuance intention. The methodology follows. The quantitative results are presented, then the qualitative findings. The discussion section highlights the implications of the results and offers opportunities for future research.

6.2 CONTINUANCE INTENTION OF MOBILE APPS

Research on continuance intention, particularly on mobile technology, is scarce (Nascimento, Oliveira, & Tam, 2018). For mobile apps, the line between acceptance and continuance is short

and blurry as users can quickly abandon apps after the initial download and use (Kim & Kim, 2014). The impressions made during early usage after download become critical to users' intention to retain or abandon apps (Bang, Lee, & Kim, 2017). A few papers have studied continuance intention for mobile apps, but none, to the authors' knowledge, has addressed disaster apps. Moreover, the existing research on continuance intention for mobile apps has often been based on broader generic information systems (IS) theory (See Table 6-1).

Table 6-1. Past literature on factors affecting continuance intention for mobile apps.

	Prior papers		**Factors influencing continuance**	
	Author (Year)	**Type of apps studied**	**Factors**	**Base theory**
1	Kang (2014)	Social media apps	Performance expectancy Effort expectancy Social influence Facilitating conditions	UTAUT
2	Okumus et al. (2018)	Diet apps		
3	Hew et al. (2015)	Various	Performance expectancy Effort expectancy Social influence Facilitating conditions Hedonic motivation Price value Habit	UTAUT2
4	Chen at al. (2012)	InstaFind	Satisfaction Perceived usefulness Confirmation	ECT
5	Hsiao et al. (2016)	Social media apps		
6	Oghuma et al. (2016)	Instant messaging apps		
7	Lu et al. (2017)	Not indicated	Performance expectancy Effort expectancy Mobility Enjoyment Satisfaction Post-usage attitude	UTAUT UTAUT2 ECT
8	Ozturk et al. (2016)	Hotel booking app	Utilitarian value Hedonic value	
9	Hoehle & Venkatesh (2015)	Social media apps	App design App utility Interface graphics Interface output Interface input Interface structure	
10	Hoehle et al. (2015)	Social media apps		
11	Tarute et al. (2017)	Not indicated	Functionality Design solution Interaction Information quality	

Much of the studies have been on workplace-based theories such as the unified theory of acceptance and use of technology (UTAUT); its extended version (UTAUT2); and the

expectation–confirmation theory (ECT). The weakness to these workplace-based theories is that they do not translate well to mobile technologies as they do not take into account the circumstance of mobility (Lu et al., 2017).

Technology for portable devices may have a different context of use from its stationary counterparts, thus may have various issues that need to be studied and considered (Harrison, Flood, & Duce, 2013; Lee, Moon, Kim, & Yi, 2014). Different studies tried to factor the mobile context of apps into their continuance intention models. Lu, Liu and Wei (2017) include mobility in their proposed model that integrated ECT with UTAUT/2. Other mobile app continuance intention studies (for example, Hoehle & Venkatesh, 2015; Hoehle et al., 2015; Ozturk et al., 2016; Tarute et al., 2017) have veered away from the IS theories and created new models with determinants specially conceptualised for mobile apps.

In these newer continuance intention models, usability was commonly recognised as influencing continuance intention. Poor usability is identified as one of the main reasons for app abandonment (Cheng, Caine, Pratt, & Connelly, 2013). Conversely, good usability perceptions lead to improved continuance intention. Tarute et al.'s (2017) study on consumer mobile app engagement shows that the positive view of usability results in better engagement that subsequently improves continuance intention. Similarly, Ozturk et al.'s (2016) study on a hotel booking app suggests that improving usability will increase the perception of value that subsequently affects continuance intention positively.

A mobile application usability–continuance model was introduced by Hoehle and Venkatesh (2015). It is one of the first models that deconstructs usability into factors and relates them to continuance intention. Most studies on continuance intention look at its determinants at an aggregate level. However, there is value in decomposing determinants into specific attributes so they may provide guidelines towards the design of systems that encourages continuance intention (Islam, Mäntymäki, & Bhattacherjee, 2017). The Hoehle and Venkatesh (2015) model

looks into usability and disaggregates it into six factors as determinants: *app design*, *app utility*, *user-interface (UI) graphics*, *UI input*, *UI output*, and *UI structure*. The study demonstrated that the six factors representing usability affect the continuance intention of mobile apps. The model was conceptualised and validated from data from over 1,200 participants (Hoehle & Venkatesh, 2015), and it was further supported in another study with data from over 1,800 social media app users from four countries (Hoehle et al., 2015).

6.3 Theory and Hypotheses

The conceptual model used for this study adapts the Hoehle and Venkatesh's (2015) usability–continuance model but reconceptualises it for disaster apps. A limitation with Hoehle and Venkatesh's (2015) model is that it has been applied only to social media apps' data. Technology models often "do not consider the particulars of the emergency response domain, or, alternatively, they are so general that the particulars of this domain are lost in the abstraction" (Elmasllari, 2018, p. 1000). We discuss in this section the conceptual model and the hypotheses, contextualising them with insights derived from studies on: critical-context technologies (for example, Bolstad, Costello, & Endsley, 2006; Endsley, 2000), design for emergency management (for example, Kremer, 2018; Lin, 2019), and mobile health (mHealth) technologies (for example, Ettinger et al., 2016).

People's behaviour towards technological systems for emergencies is different compared to those in the general domain (Prasanna & Huggins, 2015). Taking into account the users and their contexts is essential when designing systems for disaster management (Endsley, 2000; Prasanna et al., 2013). The previous disaster app study (Chapter 4) had investigated whether Hoehle and Venkatesh's (2015) factors adequately represent usability for disaster apps. The results show *app dependability* as an additional usability factor necessary for the crisis context. Our adaptation of Hoehle and Venkatesh's model occurs with the addition of *app dependability* as a seventh factor (see Figure 6-2). Our hypothesised conceptual model considers seven factors as

independent variables and continuance intention as the dependent variable, with all factors hypothesised as having significant relationships with continuance intention[4].

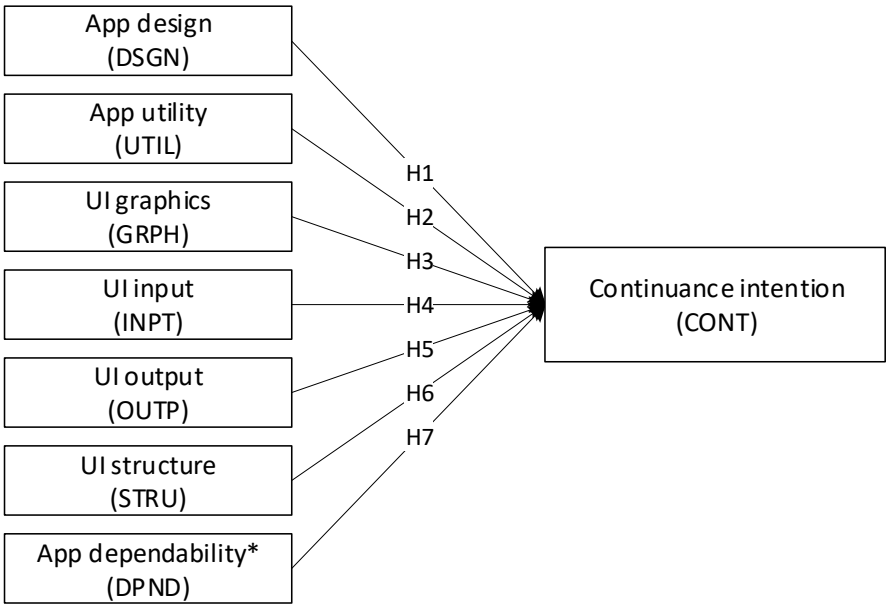

Figure 6-2. Conceptual disaster app usability-continuance model.

App design is the degree to which users perceive the app to be well designed (Hoehle & Venkatesh, 2015). In crisis response literature, design problems cause user frustration that can lead to misuse or non-use of a product (Bolstad et al., 2006). We hypothesise, similarly, that for disaster apps, the users' overall impression of the *app design* will influence continuance intention.

- **H1:** *App design* (DSGN) significantly influences continuance intention (CONT).

App utility is the degree to which the app users perceive that the app delivers its purpose (Hoehle & Venkatesh, 2015). The objective of most disaster apps is to bring essential information at the time of need (Moss, 2015). A study on disaster apps has shown that citizens have a low level of acceptance of disaster apps because they perceive that the apps cannot meet their

[4] Only the higher level items of the usability model from Chapter 4 were quantitatively tested with the dependent variable, continuance intention. Two pilot studies were conducted for the survey. Feedback from the pilot studies indicated the need to shorten the survey to enhance the response rate; hence, the lower level items were dropped.

designed objectives (Bopp et al., 2019). We hypothesise that users' perception of *app utility* will influence their decision to continue or discontinue using disaster apps.

- **H2:** *App utility* (UTIL) significantly influences CONT.

UI graphics is the degree to which users perceive the app's graphics to be adequately designed (Hoehle & Venkatesh, 2015). In designing for emergency management, graphical considerations are vital to providing useful information in disaster conditions (Lin, 2019). In communicating uncertainty, sophisticated designs could lead to misrepresentation, oversimplification, or overloading of information (Doyle, Johnston, Smith, & Paton, 2019). Aesthetics can enhance users' trust in using an app and, subsequently, complicated or burdensome designs can cause users to delete apps (Crane, Garnett, Brown, West, & Michie, 2017). We hypothesise that users' perception of *UI graphics* will influence their continuance intention of disaster apps.

- **H3:** *UI graphics* (GRPH) significantly influences CONT.

UI input is the degree to which users perceive that the app allows for easy input (Hoehle & Venkatesh, 2015). In crisis management technologies, input mechanisms can help or hinder users' interaction with a system (Nurse et al., 2012; Prasanna et al., 2013). It has been shown in studies with responders that users can reject technological systems for various reasons, such as when an interface requires too much explicit attention (Elmasllari, 2018). Similarly, for the public, we hypothesise that their perception of *UI input* will influence their intention to continue or discontinue using a disaster app.

- **H4:** *UI input* (INPT) significantly influences CONT.

UI output is the degree to which users perceive that the app displays information effectively (Hoehle & Venkatesh, 2015). Information from safety-critical systems should be easily understandable. How information is presented by a system affects a person's ability to achieve awareness during dynamic or crisis situations (Endsley, 1995, 2000). Interface output is not

limited to visual display but may also refer to auditory outputs. Studies have shown that for warning apps, annoying output, such as inappropriate sounds, may cause users to delete apps (Felt et al., 2012). We hypothesise that users' impression of their disaster app's *UI output* will influence their intention to continue keeping the app.

- **H5:** *UI output* (OUTP) significantly influences CONT.

UI structure is the degree to which users perceive the app is structured well (Hoehle & Venkatesh, 2015). During a crisis, disaster apps will be of limited use if users need to figure out how to use the tool (Veil et al., 2011). In designing for emergency management, the interface is considered to be the touchpoint where users will decide to continue or stop using a tool (Lin 2019). Interface design decisions—such as layout, navigation, and spatial positioning of elements, among others—must be carefully aligned to ensure users have positive perceptions of an app (Kremer, 2018). We hypothesise that users' perceptions of the *UI structure* of their disaster apps will affect their intention to continue or discontinue use.

- **H6:** *UI structure* (STRU) significantly influences CONT.

App dependability is defined in this study as the degree users perceive that the app can operate dependably from start to end of an app's usage cycle. The use of disaster tools can be distinctive from ordinary and everyday counterparts (Tan et al., 2017). To the best of the authors' knowledge, no specific research has studied special usability considerations for disaster apps. However, research in other fields has shown that users of safety-critical technologies emphasise the importance of perceiving a level of dependability on their tools. A study on Web2.0 in the disaster context saw that a crash in a system could prohibit users from trusting and using the technology (Mills & Chen, 2009). In mHealth literature, the perception of unreliability can cause mistrust of technological tools. To perform their jobs reliably, clinician users of mHealth apps must deem their devices to be dependable (Ettinger et al., 2016). Similarly, disaster app users must be able to perceive that the app will operate dependably during the entire duration of use,

especially in the context of critical situations. For these reasons, *app dependability* is included as the seventh factor hypothesised to have a relationship with continuance intention.

- **H7:** *App dependability* (DPND) significantly influences CONT.

6.4 METHODOLOGY

A sequential explanatory mixed method research approach, based on Creswell and Plano Clark (2011), was chosen for this study. The study first focusses on the quantitative component to test the conceptual model and determine the usability factors affecting continuance intention. It then uses qualitative methods to assist in understanding and explaining the quantitative results. This mixed methods study received peer-reviewed approval under the Massey University code of ethical conduct for research, teaching, and evaluations involving human participants.

6.4.1 Quantitative method

The primary objective of this chapter is to identify the influence of the usability factors on the continuance intention of disaster apps. The study started with quantitatively testing the usability–continuance model using structural equational modelling.

6.4.1.1 Instrument development

We gathered the quantitative data from actual disaster app users using an online survey instrument through Qualtrics Survey (Qualtrics, 2019). The questionnaire, which asked about the perception of the usability of an existing disaster app that participants had, or were using at the time they completed the survey, comprised of (1) demographic and qualifying questions and (2) the items to reflect the conceptual usability–continuance model. A total of 32 items were used to reflect the model constructs. Four items reflected the dependent variable, continuance intention, and each of the seven usability factors also had four reflective items. Each item asked respondents' level of agreement to the statement on a 5-point Likert scale from 1 (strongly agree) to 5 (strongly disagree). We initially used the items developed by Hoehle and Venkatesh

(2015) and added four new items to reflect the *app dependability.* We conducted a pilot study with 30 participants, which resulted in refining and contextualising the items for disaster apps. We then tested this refined instrument with another set of 20 participants, resulting in minor changes in the item wording and questionnaire format. See Appendix G for the questionnaire used for this study.

6.4.1.2 Sampling and data collection

The sampling frame for this research project was developed by identifying popular disaster apps in New Zealand, after which we invited the app owners to promote the survey to their users. Three app owners agreed to take part and supported the survey through inviting their users to participate in the survey using their official social media accounts. As part of an agreement with the app owners, we withhold the app names and any identifiable information for privacy reasons. We also distributed the survey through other social media channels, snowballing through interested online community groups.

Since the survey was distributed online, the respondents were not limited by New Zealand's geographical boundaries. Although the majority of the respondents were from New Zealand (77.1%), the survey also attracted respondents from the United States of America (9.2%), Canada (2.6%), and other countries (11.1%). Five hundred and sixty-two participants submitted responses.

Other app users, outside the major apps targeted for distribution, answered the survey. The initial qualifying question controlled the respondents to ensure they were disaster app users, and respondents had to provide the names of the disaster apps installed on their phones. We cross-validated the apps identified by the users by looking up the app descriptions in the app markets to ensure that they fit the definition of disaster apps in this study. The apps eligible for the study are communication platforms providing the public with information on a specific

natural hazard, or multiple hazards, such as extreme weather events, earthquakes, volcanic hazards, and tsunami. A total of 337 respondents qualified to be disaster app users.

Of these 337, we assessed missing values and outliers, and normality to ensure the quality of the dataset. Sixty-seven were omitted from the data set because of incomplete or disengaged responses, such as all responses being uniform without variations. Only responses that had a 90% completion rate were included. A final set of 271 entries (80.41% of the qualified responses) were retained for further analysis. Some items in the survey were negatively worded, and we reversed the scoring of these items to ensure consistency in the analysis.

6.4.1.3 Data analysis

Analysis of the survey data followed the standard two-stage process of structural equation modelling (Hair, Black, Babin, & Anderson, 2014). A measurement model assessment was first conducted through factor analysis. Confirming a stable measurement model provides statistical support that the survey items used adequately measure the theorised constructs. We then conducted a structural model assessment and evaluated the causal relationships of the usability factors to the dependent variable, continuance intention. We used software programmes SPSS and AMOS for the analysis (IBM, 2017b, 2017a).

6.4.2 Qualitative method

To further understand the perspectives of the users, we employed a usability inquiry using a disaster app prototype (Chapter 5). Usability inquiry is a method that gains user insights through observing the users as they interact with an artefact and through engaging them with questions and discussions (Nielsen, 1994a; Zapata et al., 2015). The goal of an inquiry is not to test the artefact but to draw an in-depth understanding of the users (Nielsen, 1994a), and the artefact is instead used as a discussion prompt. Our inquiry used a medium-fidelity prototype from Tan et al. (2019) to interact with the participants and employed a semi-structured interview to gather feedback from participants.

6.4.2.1 Participant recruitment

We recruited respondents from the survey to participate in the usability inquiry. We sent email invitations to 89 respondents who provided their contact details and indicated their willingness to partake in future studies. Nine people volunteered to contribute to the inquiry. Additional recruitment was conducted through the posting of flyers on two university campuses, and another nine individuals joined the study. In total, the usability inquiry had 18 participants.

6.4.2.2 Data collection and analysis

The line of inquiry was in the form of semi-structured interviews. The participants were asked to freely explore each section of the disaster app prototype. Core questions were used to guide the investigation of the users' views of the app components as well as the app as a whole (see Table 6-2). The questions were designed to encourage interviewees to have an open discussion about their experience with the app and their expectations of usability.

Table 6-2. Interview guide core questions.

1. Core questions for app components (after the user interacts freely with each screen): a. What comments or issues do you have with the look? b. What comments or issues do you have with the controls? c. What comments or issues do you have on the intuitiveness to navigate the screen? d. What comments or issues do you have on how information is presented? e. What comments or issues do you have on the words or icons used? 2. Core questions for the app: a. In a crisis scenario, do you think the design of the app is appropriate? b. What would make you keep or uninstall the app?

The insights from the interview portions were subjected to thematic analysis as similar to Braun and Clarke (2006, 2013a). The initial reading of the data was theoretically driven. We used the conceptual model (Figure 6-2) as the foundation for the analysis, seeking to understand the relationships between the factors and continuance intention. We looked at how the individuals responded to questions 1a–1e and 2a. First, we coded their answers according to the usability factors and then reviewed whether their answers initiated mentions on keeping or uninstalling the app. We then looked at the participants' answers to question 2b: *What would make you keep or uninstall the app?* We inferred whether their responses were associated with the

usability constructs. We compared the two sets and then aggregated the responses by collapsing and combining the ideas as necessary. From there, we built insight summaries of the users' perspectives of the relationships between the factors and continuance intention. We used NVIVO software (QSR International, 2019) to assist in the data analysis.

6.5 QUANTITATIVE RESULTS

Detailed below are the results of the standard two-stage process for structural equation modelling. The measurement model assessment results show a stable model, indicating the items used for modelling represent the theorised constructs. The structural model assessment results indicate which usability factors have causal relationships with the dependent variable, continuance intention.

6.5.1 Measurement model assessment

The survey had 32 items, with four items reflecting each usability factor and the dependent variable, continuance intention. Exploratory factor analysis (EFA) is recommended to first ascertain the number of hypothetical factors (Fabrigar & Wegener, 2012). Given that we were testing a model with an additional theorised factor (*app dependability*) and in the specific context of disaster app use, we deemed it appropriate to conduct an initial EFA. The EFA determined whether each usability factor and the dependent variable are adequately represented and distinct.

Table 6-3 shows the results from the EFA using the maximum likelihood extraction[5] and a Promax rotation method[6]. The resulting pattern matrix retains 22 items out of the 32. The items

[5] Maximum likelihood as a factor extraction method is appropriate if the research purpose is for understanding the latent structure of a set of variables (Treiblmaier & Filzmoser, 2010).

[6] Promax, an oblique rotation, is preferred by many researchers as prior research has shown that oblique rotations are better than orthogonal rotations at producing realistic solutions when factors are actually correlated (Treiblmaier & Filzmoser, 2010).

are represented by the acronyms in the matrix, and Appendix H lists the reflective items and the associated acronyms used for this study. The matrix shows eight distinct groupings of variables with strong correlations. It affirms the theorised number of factors (the seven usability factors and the variable, continuance intention) was adequately determined.

Table 6-3. EFA pattern matrix showing eight distinct factor groupings.

	Factor							
	1	2	3	4	5	6	7	8
α	0.959	0.858	0.777	0.924	0.828	0.898	0.916	0.936
CONT2			0.406					
CONT3			0.880					
CONT4			0.747					
DSGN1		0.983						
DSGN2		0.432						
DSGN3		0.688						
DSGN4		0.799						
UTIL1								0.837
UTIL2								0.880
GRPH1	0.917							
GRPH2	0.913							
GRPH3	0.943							
DPND2						0.834		
DPND3						0.975		
INPT1				0.840				
INPT2				0.994				
OUTP1							0.687	
OUTP2							0.820	
OUTP3							0.953	
STRU1					0.732			
STRU2					0.721			
STRU3					0.816			

The resulting EFA pattern matrix is significant. With the sample size of 271, all factor loadings in the solution are above 0.40. The results meet the suggested factor loading threshold by Hair et al. (2014) for sample sizes greater than 250. The eight-factor model also cumulatively explains 76.92% of variance reported in the EFA. The EFA pattern matrix shows convergent validity; that is that the item measures for each factor belong together, as the average loadings per factor is higher than 0.70. The matrix also indicates no cross-loading between factors, showing that the item measures of each factor are distinguishable from the measures of other factors. Reliability

was attained in this solution as the alphas for all constructs were higher than the recommended threshold of 0.70 (Fornell & Larcker, 1981).

Having extracted an eight-factor structure through the EFA, we then conducted a subsequent confirmatory factor analysis (CFA) in AMOS software. After reviewing the modification indices, we dropped one item, STRU1, to achieve a good model fit (see Table 6-4). The CFA confirmed a factor structure with a model fit that meets the threshold recommendations from Hu and Bentler (1999). Furthermore, all the regression weights had a critical ratio (t-value) of greater than 1.96, indicating all paths to be significant.

Table 6-4. Measurement criteria showing good model fit.

Criteria	Reported Value	Recommended Threshold*
CMIN/df	1.658	<3 and >1 excellent
CFI	0.979	>0.95 excellent
RMSEA	0.049	>0.06 excellent
PCLOSE	0.528	>0.05 excellent
SRMR	0.053	<0.08 excellent
GFI	0.913	
AGFI	0.876	

*From Hu & Bentler (1999)

Reliability, and convergent and discriminant validity were achieved with this model. Table 6-5 shows the construct correlation matrix resulting from the CFA. All factors have composite reliability (CR) of greater than 0.70. This indicates reliability based on Hair et al.'s (2014) suggested threshold. The average variances extracted (AVE) for all constructs were higher than the recommended 0.50 to establish convergent validity (Kline et al., 2012). Discriminant validity was also satisfied for all factors. Discriminant validity can be examined by finding whether the square root of AVE is higher than the absolute value of correlations between factors (Hair et al., 2014).

Table 6-5. Construct correlation matrix for reliability, and convergent and discriminant validity.

	CR	AVE	CONT	DSGN	DPND	UTIL	GRPH	INPT	OUTP	STRU
CONT	**0.815**	**0.602**	**0.776**							
DSGN	**0.876**	**0.645**	0.487	**0.803**						
DPND	**0.903**	**0.824**	0.474	0.674	**0.908**					
UTIL	**0.937**	**0.882**	0.761	0.612	0.517	**0.939**				
GRPH	**0.959**	**0.887**	0.324	0.649	0.542	0.453	**0.942**			
INPT	**0.926**	**0.862**	0.193	0.593	0.522	0.381	0.439	**0.928**		
OUTP	**0.916**	**0.785**	0.468	0.778	0.681	0.537	0.727	0.665	**0.886**	
STRU	**0.890**	**0.801**	0.404	0.716	0.700	0.506	0.593	0.663	0.840	**0.895**

Note: Square root of AVE on diagonal

6.5.2 Structural model assessment

The structural model consists of the seven usability factors as independent variables and the dependent variable, continuance intention. Evaluating the structural equation model shows that the R^2 for continuance intention is at 0.64, indicating that the independent variables show sufficient explanation for the variance of the dependent variable. Figure 6-3 displays the results of the model estimation of the causal model, showing the standard regression weights of the independent variables to continuance intention.

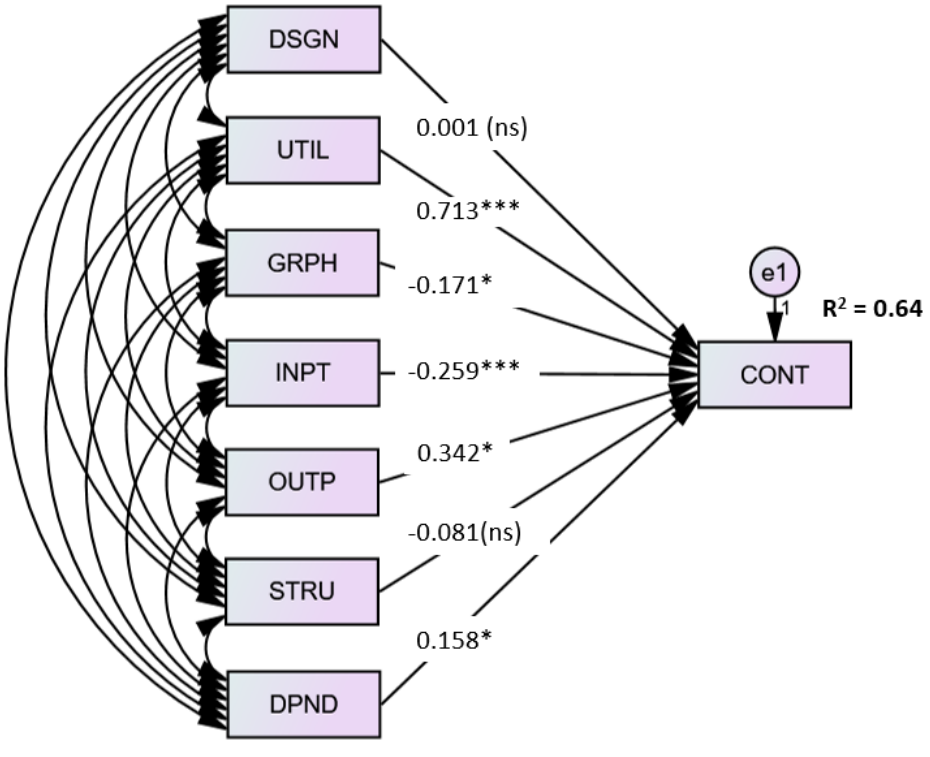

Figure 6-3. Structural model results.

Five out of the seven hypothesised relationships were statistically significant at either 0.05 or 0.001. The hypotheses H2, H5, and H7 show that continuance intention is positively influenced by *app utility*, *UI output,* and *app dependability*. For hypotheses H3 and H4, the results show that both *UI graphics* and *UI input* significantly affect continuance intention negatively. Finally, for hypotheses H1 and H6, *app design* and *UI structure* show no indicated significance in predicting continuance intention.

6.6 QUALITATIVE RESULTS

To further the relationships of the seven factors to continuance intention, this study also engaged with the users to understand their perspectives. A usability inquiry using a prototype was conducted with 18 members of the public. The inquiry participants were all experienced smartphone users. The participants had a median age of 29.5 years and a range between 18 to 60 years old. Twelve of the participants identified as female and the remaining six as male. At the time of the interview, all except one of the participants had iOS-based smartphones. One participant had an Android-based phone but had just owned an iPhone. The inquiry had an overall positive response from the participants. All of them were keen to see the prototype become available in the market. The views of the participants showed further insights into why the usability factors relate to continuance intention. The interviewees conveyed responses that notably considered the context of interacting with a disaster app.

6.6.1 Positive relationships

App utility, *UI output*, and *app dependability* played a significant role in their evaluation of whether to keep or uninstall an app, as follows.

6.6.1.1 App utility

The participants indicated their intention to keep an app if they found value in the app's purpose. "*It makes sense*" was a common phrase from the interviewees. One interviewee

indicated that they would keep the app as "*it will be a trusted primary source for pertinent information*." Another interviewee highlighted that they would keep the app as the existing apps in the market did not provide similar service: "*Currently, I don't have anything similar to this*." Yet another participant found it helpful that the app communicated its purpose explicitly during the initial interaction:

> *It's good at the very beginning we are seeing* [information from the emergency agencies]*, it shows the purpose of this app straightaway. Instead of scrolling and going to other screens to know.* [At first glance] *it shows me the purpose.*

Conversely, the negative perception of utility can influence the users to uninstall the app. A common view from the interviewees was that they might delete an app if they perceive that the app is incapable of delivering its purpose. Content relevance was a recurring theme when discussing utility. The interviewees expressed that when an app's content is inaccurate, false, or irrelevant, they may uninstall the app. One interviewee said: "*If it provides false information all the time, I may delete it.*" Frequency of use was also a recurrent theme when discussing utility. Interviewees also mentioned hating having an application that is not used for a while, leaving them feeling that the app is inactive and thus may not provide needed information when the situation arises: "*I will uninstall an app if I don't use it for too long.*"

6.6.1.2 UI output

The interviewees also highlighted that *UI output* influences users' decision to keep a disaster app. One interviewee emphasised that effective presentation is "*absolutely important and key to the app*". The app cannot get information presentation wrong as "*it gets into the territory of life-safety.*" A common issue that interviewees raised when discussing *UI output* is the effectiveness of the notifications. As one interviewee mentioned, "*I delete apps when it sends a lot of notifications*." The apps' output must "*be efficient and not annoying*", as one interviewee

stated. The more the users perceive the app to be effective in presenting output, the more likely the users will keep the app. However, an ineffective output can lead users to uninstall the app.

6.6.1.3 App dependability

Most of the participants said that they would keep the app until they have negative experiences with it. One interviewee noted that she does not use apps often and appreciated that she did not encounter any issues while interacting with the app: *"No issues* […]*, which is a good thing. Especially if it is a new app, sometimes it can be hard for me*." The participants gave examples of dependability issues when discussing negative experiences that could lead to uninstallation. The interviewees raised concerns that included app errors and unexpected behaviour as, for instance, crashing, lagging, getting stuck, and failure of the app to update. Encountering errors can reduce their overall impression and may lead them to uninstall the app, as stated by one interviewee: "[I'll delete an app] *if it often gets stuck* [and] *cannot run fluently*." Participants also highlighted that they do not see themselves using the disaster app often, so encountering issues during the limited time of interaction could be consequential.

6.6.2 Negative relationships

The quantitative model shows that *UI graphics* and *UI output* both have a negative relationship with continuance intention (see Section 0). The interviews provided insight into why users expect minimal graphics and input for disaster apps.

6.6.2.1 UI graphics

Most of the interviewees found the aesthetics of the app to be plain. However, the colour scheme was deemed to be appropriate to the nature of the app. One interviewee mentioned: "*Quite grey.* [Needs] *colours, but then it's a disaster app. The grey* [gives it a] *serious tone*." Another interviewee mentioned that aesthetics is not of primal importance for a disaster app: "*Overlook aesthetics. Core information is important and that I'm able to find it*." Others found

the simple graphics to be a positive attribute of a disaster app. One participant mentioned: "[The graphics are] *simple and easy. It won't distract when there is an actual disaster.*"

In contrast, a showy looking app might cause them to doubt the app. An interviewee mentioned: "*No to* [noisy] *types of design. I do not want much going on. When something happens, I don't want to go through a lot.*" Another interviewee expressed a similar sentiment: "*Alert apps should not be extravagant. Just easy to use.*" Concerning animation related to graphics, one interviewee highlighted that less is better: "*Minimum animation makes sense. Animation* [might be] *irrelevant in an emergency situation*." For disaster app users, *UI graphic*s is not deemed to be of primary importance to the nature of the app. The qualitative findings align with the results in the quantitative model: fewer graphics is better to encourage continuance intention.

6.6.2.2 UI input

The participants highlighted that for a disaster app, it is appropriate that there are fewer options for input. One interviewee stated that minimal input allows users to intuitively understand the app: "*Not too much is needed to work it out. If* [there is an] *emergency, good to use. Quick to find things out."* Another interviewee reiterated: "*Useful, easy. If you are in a rush. No typing things. It's all there.*" Furthermore, some of the interviewees indicated that if the app provided too many input buttons and mechanisms, it can confuse the users and take valuable time for them to get the information they need. One interviewee recalled an experience she had with a different disaster app where she stopped using the app because it gave her too many input options: "*I just remember that I try to avoid using the app if I can because it's a lot fussy*."

6.6.3 No relationships

Issues related to *UI structure* were not particularly prominent in the interview data. However, the interviews gave some insight into why *app design* may not affect the decision to keep or delete the app.

On *app design*, the participants did not feel that the app had a distinct look or a prominent brand. However, branding was not deemed to be influential to their use of the app. One interviewee mentioned: *"I didn't get the brand.* [It is] *not necessarily important.*" Another participant echoed the outlook that other usability factors are more significant for the context of disaster apps: *"This kind of app should not be about branding.* […] *but more important for people to know* [about an event]."

However, a few of the respondents indicated that the app's design concerning the phone environment, such as memory capacity, could lead to uninstallation. One interviewee stated that if their phones did not have room, the app might be deleted: *"I found it interesting, but depends how much capacity is in my phone. If I don't have much capacity, I will uninstall*." When asked further on this topic, the participants, however, did not know the capacities for their phones nor the average size of the apps: "*No idea* [on the size]*, I want* [the app] *to hang out there but not take too much space."* Some of the participants indicated that they were likely to keep the app when they do not encounter the issue of capacity: "*If it's a small app and it's not a bother, there's no reason to delete the app*." The app size can be an issue, but the interview data shows mixed feedback from the participants. App size may influence the participants' decision to uninstall. However, other factors, such as *app utility,* can come to the forefront of the decision. One participant said: "*Don't really care for space. If it's necessary, I will download it."* Future research should investigate the users' limits and tolerance on the app's usage of phone resources and how that influences uninstallation.

Overall, these qualitative findings provided users' insights as to why the factors relate to continuance intention. They support the relationships found in the quantitative model. More importantly, these results show that the users' reasons for continuance intention attribute specifically to the context of disaster apps. The participants highlighted concerns that may not

apply to general-purpose apps, such as the sensitivity to life safety, as well as the expectation of low frequency of use.

6.7 DISCUSSION

This study pioneers usability–continuance research on disaster apps. It is one of the first to start the discourse for future research on the usability of disaster apps as well as on the users' intentions to use publicly available technologies for disaster management. While much research work has explored the potential functionalities of apps for disasters, the usability of these apps is often overlooked (Tan et al., 2017). Furthermore, most continuance intention studies have looked at usability in an aggregated manner (Islam et al., 2017), and only a few studies on the usability of mobile apps have studied the underlying factors of usability. To the best of our knowledge, no other research has explored disaster apps' usability and its association with continuance intention.

The results of the study demonstrate that there are particular usability considerations specific to the use of disaster apps. Furthermore, the usability–continuance model presented in this study can guide developers on what to focus on to enhance the continuance intention of disaster apps. In the disaster apps' context, the study: (1) affirms *app dependability* as a usability factor; (2) highlights *app utility* and *UI output* to be most significant to contributing positively to continuance intention; and (3) shows that *UI graphics* and *UI input* negatively influence continuance intention. Results from both the quantitative and qualitative components of this study demonstrate that disaster apps have specific usability considerations compared to general apps

6.7.1 Affirmation of app dependability

The results have shown that the perception of dependability will affect users' decisions as to whether they will continue to use or abandon a disaster app. The validation of *app dependability*

as a factor implies that, when developing disaster apps, building a perception of dependability should also be prioritised. This finding can challenge the 'release early, release often' approach to app development. Because of the nature of the fast-moving app markets, developers are often compelled to release apps early, and redesign, and update and correct errors as they occur through the apps' lifespan (Teixeira, 2017). However, for disaster apps, this approach may need to be reconsidered as it may prove contrary to enhancing continuance intention. Encountering errors was the most common reason provided by the inquiry participants for uninstallation. Occurrences of errors or crashes may be more critical for disaster apps than other types of information apps. If an app crashes, users can lose confidence and may develop the impression that the app will not be reliable during a disaster situation and, thus, deem the app unusable. Failure to convey a certain level of *app dependability* may cause users to discontinue using disaster apps.

6.7.2 Significance of app utility and UI output

Among all factors, *app utility* has the most significant influence on continuance intention. The more users perceive that the app delivers its intended function, the more likely the users will continue using the app. A user's experience becomes more favourable when a system operates in a mode that is consistent with users' expectations (Prasanna et al., 2013). For the inquiry participants, utility comes with the expectation that the app provides relevant content. The findings align with studies on interfaces for safety-critical contexts, emphasising the need to provide important, complete, and updated information during crises (Kwee-Meier et al., 2017). Relevant content means focussing on delivering information that is temporally proximate to the time of the event, spatially proximate to the location of interest for the user, and purposefully proximate to the indicated objective of the app. The strong relationship of *app utility* to continuance intention implies that app retention can be encouraged by ensuring that the app delivers targeted content that is aligned with its purpose.

UI output is also significant. Apps should not just be able to provide their intended technical purpose but should also deliver information effectively. Information from disaster apps should be easily understandable. The more favourable users view the interface output of the app, the more likely they will continue using the app. Conversely, a poor impression of the app's output may cause users to discontinue the app. As indicated by the participants in the inquiry, for disaster apps, annoying or inappropriate notifications may cause users to delete apps. Effective output involves providing information in the users' language and a standardised format that users can easily interpret (Hoehle & Venkatesh, 2015). In usability studies of situation awareness systems, interface output is recommended to be suitably designed, including such aspects as structured presentation of information and adequate formatting, to account for its users' cognitive load (Kwee-Meier et al., 2017). A well-designed *UI output* will encourage continuance intention.

6.7.3 Negative effects of UI graphics and UI input

UI graphics has a negative relationship with continuance intention. The results are contrary to the 'aesthetic–usability effect' observed in various studies where more attractive graphic artefacts are viewed to have significant positive implications to acceptance and use (Lidwell, Holden, & Butler, 2011; Xu, Peak, & Prybutok, 2015). However, aesthetic impressions vary for different domains. Users' visual preferences differ depending on the categorical context (Papachristos & Avouris, 2013). Results from this study demonstrate that, in the area of disaster apps, too many graphical elements have an adverse effect on continuance intention. Users can abandon apps because of frustration with graphical complexities. Inconsistent use of colours, symbols, and notations are some potential issues related to unwanted complexity (Prasanna et al., 2013). For disaster apps, to promote continuance intention, interface graphics should be used appropriately but sparingly.

UI input also has a negative relationship with continuance intention. The purpose of disaster apps must be considered when designing *UI input*. The majority of disaster apps are information dissemination tools from authorities to citizens, often involving one-way communication that requires minimal input from users (Tan et al., 2017). In the context of the disaster apps in this study, providing avenues for input can discourage continuance intention. Allowing for user input may increase the level of noise and uncertainty of information being presented. Other studies also have raised concerns about input mechanisms for mobile apps as some input methods may inhibit user interaction rather than enhance them (Page, 2013). In a study of wellness apps, it was highlighted that input should be kept to a minimum so as not to overtax the users (Platt, Outlay, Sarkar, & Karnes, 2016). Input complexities, such as too many layers or menus, can lead to difficulties in accessing information when used during time-critical and cognitively demanding situations (Prasanna et al., 2013). To encourage continuance intention, for apps that are meant to communicate critical information during disasters, the focus should be on reducing complexity, which entails providing fewer input mechanisms.

These results challenge disaster app designers and developers to consider the extent of *UI graphics* and *UI input* on their apps. Designers should highlight the features promised to their users but also should downplay qualities that are not deemed essential to users.

6.7.4 Future research

This research work argues that the context of use for disaster apps is different from general app use. As such, we investigated and presented a model as it applies to the domain of disaster apps. This study scoped and only considered one-way communication apps that provide information about natural hazards. Future studies should build on our work and explore whether similar observations can be found for different typologies of disaster management apps. Although most disaster management apps are one-way communication tools, various other types also exist, including tools that foster multi-directional communication (Tan et al., 2017). Our result

highlighting the need to minimise *UI input* may impact the design of such devices. Depending on the purpose of the apps, the contexts of use may differ. Thus, it would be helpful to compare and contrast the results to make inferences about whether the model can be generalisable to other types of disaster management apps.

Furthermore, this study did not explore interaction effects that could influence the relationships within the model[7]. For example, Hoehle et al. (2015) have investigated if cultural values influence the usability and continuance intention of social media apps. In the disaster management literature, Prasanna and Huggins (2015) have explored whether age, gender, and experience have interaction effects on the symbolic adoption of emergency operations' information systems. Future studies should explore the interaction effects of other variables. Finally, the study looked at continuance intention based on the assumption that users continue to use a single smartphone device. The study did not consider the technological lifespan of devices or the use of multiple devices. The average lifespan of smartphones can be as short as 2.5 years (Statista, 2018), so future research on the continuance intention of apps should consider the likelihood that users will re-install the app when they upgrade and transfer to a new smartphone.

6.8 CONCLUSION

This study has investigated usability and continuance intention in the domain of disaster apps. We highlight that for disaster apps, usability factors have distinct relationships with continuance intention that may be different from other apps. Considering the perspectives of the users through an inquiry provided further understanding of these relationships. The key positive influences on users' intention to continue using a disaster app are the users' perceptions of whether the app delivers its function (*app utility*), whether it does so dependably (*app*

[7] For the broader doctoral project, I explored technological self-efficacy as an interaction effect (see Section 6.9 as an addendum). However, due to the limitation of the measurement item used for the variable, this portion was excluded from the manuscript intended for publication in a journal.

dependability), and whether it provides information that can be easily understood by the users (*UI output*). Further, too much focus on *UI graphics* and requiring too much *UI input* interaction can encourage abandonment of the app. The results have practical implications for designers and developers, and the usability–continuance model can provide guidance on what factors to focus on to promote the continuance intention of disaster apps.

6.9 ADDENDUM: EXPLORING AN INTERACTION EFFECT ON THE MODEL

Aside from the hypothesised main effects (H1–7), I also explored whether the users' technological self-efficacy (TSE) may have an interaction effect on the usability factors and continuance intention. TSE is the users' evaluation of their own capability to use technology. Self-efficacy, people's judgement of their own capabilities, affects people's actions in terms of how much effort to take when facing a task or challenge (Bandura, 1993).

One survey question was used as a reflective item to measure the participants' TSE. The question asked the respondents to rate whether they consider themselves to be technically savvy in smartphone use. The respondents answered through a 5-point Likert scale of 1 (definitely yes) to 5 (definitely not). This exploratory investigation hypothesised that individuals with higher TSE may put more value on the influence of each usability factor in their intention to continue using disaster apps. The hypotheses on the interaction effects are stated below:

- H8a: The positive effect of DSGN to CONT will be stronger for users with higher TSE;
- H8b: The positive effect of DPND to CONT will be stronger for users with higher TSE;
- H8c: The positive effect of UTIL to CONT will be stronger for users with higher TSE;
- H8d: The negative effect of GRPH to CONT will be stronger for users with higher TSE;
- H8e: The negative effect of INPT to CONT will be stronger for users with higher TSE;
- H8f: The positive effect of OUTP to CONT will be stronger for users with higher TSE; and
- H8g: The positive effect of STRU to CONT will be stronger for users with higher TSE.

A test for interaction effect, a form of moderation (Hair et al., 2014), was used to determine whether TSE has significant interaction effects with the usability factors and continuance intention. With TSE introduced as a moderator, a good model fit was still attained. Table 6-6 shows the significant interactions.

Table 6-6. Structural model results with interaction effects

	Model with main effects only		Model with interaction effects	
R^2	0.64		0.69	
Main effects				
DSGN	0.001		0.006	
DPND	0.158	*	0.116	
UTIL	0.713	***	0.718	***
GRPH	-0.171	*	-0.196	**
INPT	-0.259	***	-0.294	***
OUTP	0.342	*	0.403	**
STRU	-0.081		-0.067	
Interactions				
TSE			-0.009	
TSE x DSGN			-0.166	
TSE x DPND			0.087	
TSE x UTIL			0.163	**
TSE x GRPH			-0.264	**
TSE x INPT			-0.129	
TSE x OUTP			0.631	***
TSE x STRU			-0.343	**

*p-value<0.05; **p-value<0.01,***p-value<0.001

Although TSE in itself does not have a significant effect on CONT, TSE moderates some, but not all, of the main effects. With TSE introduced to the model, the variance explained (R^2) in CONT increased to 0.69 as opposed to the 0.64 with just the main effects-only model, supporting TSE as a moderator that influences usability factors to continuance intention.

The test for interaction showed that TSE and DPND, TSE and UTIL, and TSE and GRPH have significant interaction effects to continuance intention. The results supported three hypotheses to be statistically significant at the 0.01 or 0.001 level:

- H8c. TSE strengthens the positive relationship between UTIL and CONT;
- H8d. TSE strengthens the negative relationship between GRPH and CONT; and
- H8e. TSE strengthens the positive relationship between OUTP and CONT.

The results do not support the remaining hypotheses (H8a, H8b, H8f, and H8g). The findings show that TSE does not have a significant relationship (p-value > 0.05) between DPND to CONT

(H8b) and INPT to CONT (H8f). Furthermore, H8a and H8g are not supported since, at the outset, DSGN and STRU did not have a significant main effect to CONT in the main model. Figure 6-4 summarises the results on the effects of TSE on the main model.

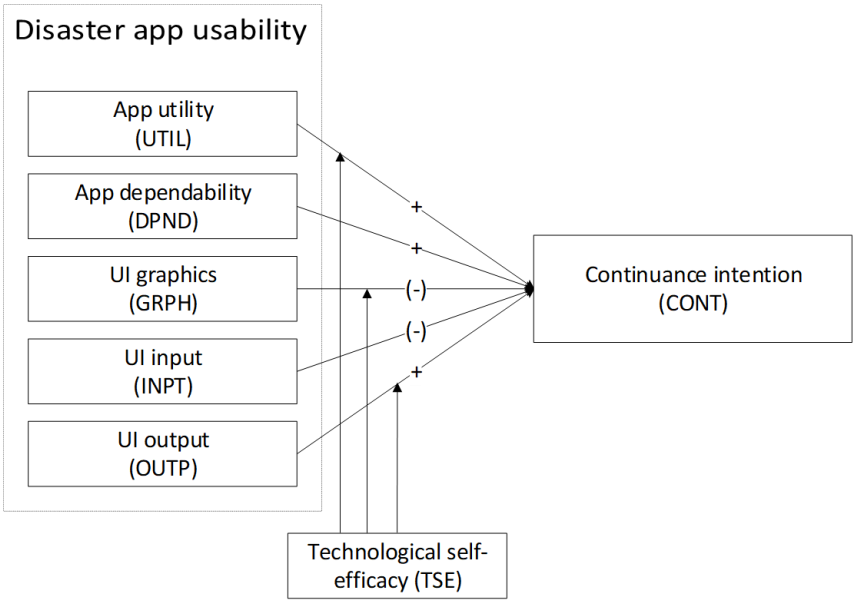

Figure 6-4. Illustration of results including the interaction effect.

The slopes of results are plotted in Figures 6.5, 6.6, and 6.7 to provide an interpretation of the significant interaction effects. The plots show the high and low levels of TSE at one standard deviation above and one standard deviation below the mean; the method is based on Aiken and West (1991) and Dawson (2014). Figure 6-5 confirms the positive effect of UTIL on CONT is stronger in the case of a higher self-reported TSE score when compared to the effect of low TSE. The graph indicates that individuals with higher TSE put more value in app utility of disaster apps in driving their continuance intention than those individuals with lower TSE. Similarly, Figure 6-6 shows that the positive effect of OUTP to CONT is stronger with participants that have higher TSE than the participants that scored themselves lower. Figure 6-7, on the other hand, shows that the negative effect of GRPH on CONT is stronger for those with higher TSE than those with lower TSE. Individuals with higher TSE are less impressed with UI graphics embedded in disaster apps than those with lower TSE. For individuals with high TSE, high *UI graphics* results in lower continuance intention than those with low TSE.

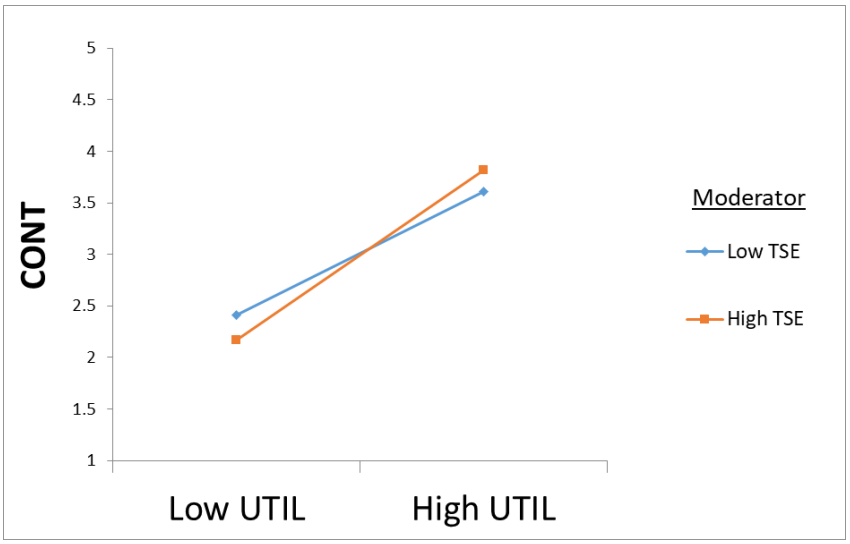

Figure 6-5. Effects of UTIL and TSE on CONT

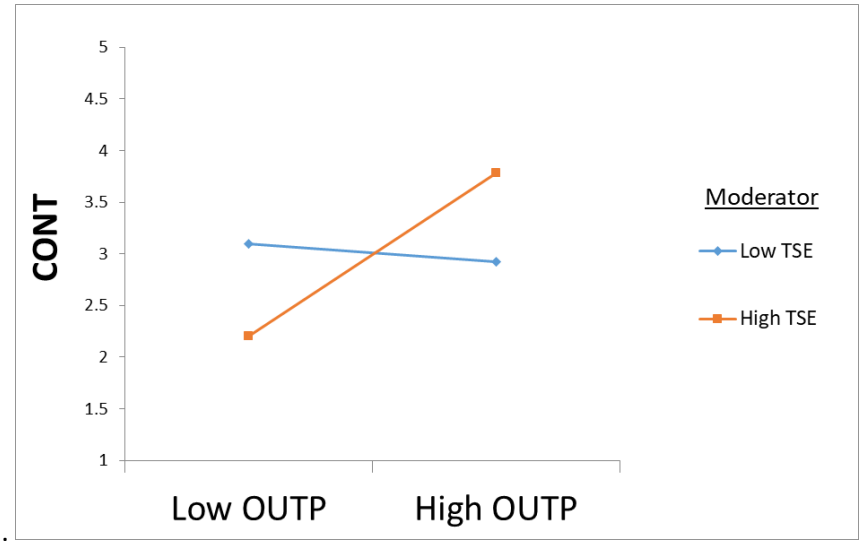

Figure 6-6. Effects of OUTP and TSE on CONT.

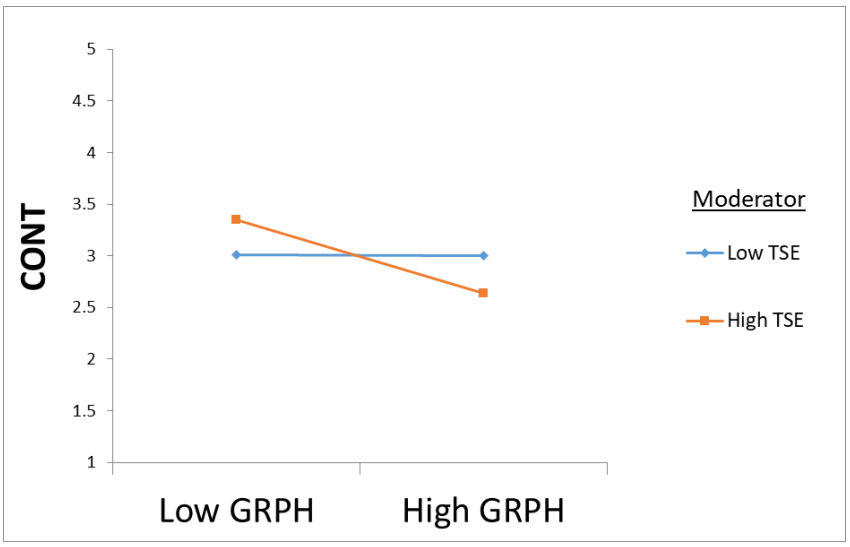

Figure 6-7. Effects of GRPH and TSE on CONT.

6.9.1 Interaction effect of technological self-efficacy

Aside from the main effects, an interaction effect on the model was explored. The more technologically proficient users perceive themselves, the more intense these relationships become. The results imply that as TSE increases (as users gain more self-confidence in technological efficacy), the value users place on *app utility* and *UI output* also increases in influencing continuance intention. On the other hand, higher TSE also indicates a stronger negative influence of graphics on continuance intention. The more users deem themselves as being technologically proficient, their perception of the complexity or simplicity of *UI graphics* will impact their decision to abandon apps. The results imply that the intensity of the effects of the factors may change as users gain more confidence in their use of disaster apps.

Using only one reflective item for TSE is an acknowledged limitation, and a more robust method would be to use several items to reflect TSE. The test for the TSE as an interaction effect was exploratory in nature. Despite using a limited measurement item, this investigation has demonstrated that TSE could influence the relationships in the model. Future studies could strengthen the validity of the results by including more questions in the survey as reflective items to represent TSE. Future studies also should explore the implications of the interaction effect with the design strategies for disaster apps. Other information systems studies also have investigated the influence of cultural values as well as demographic qualities, such as age and gender, as moderators to continuance or adoption models (for example, Hoehle et al., 2015; Prasanna & Huggins, 2015). Direction for the future can also explore how other variables, aside from TSE, could moderate interactions in the main model.

7 [4TH MANUSCRIPT] UNDERSTANDING END-USERS' PERSPECTIVES: TOWARDS DEVELOPING USABILITY GUIDELINES FOR DISASTER APPS

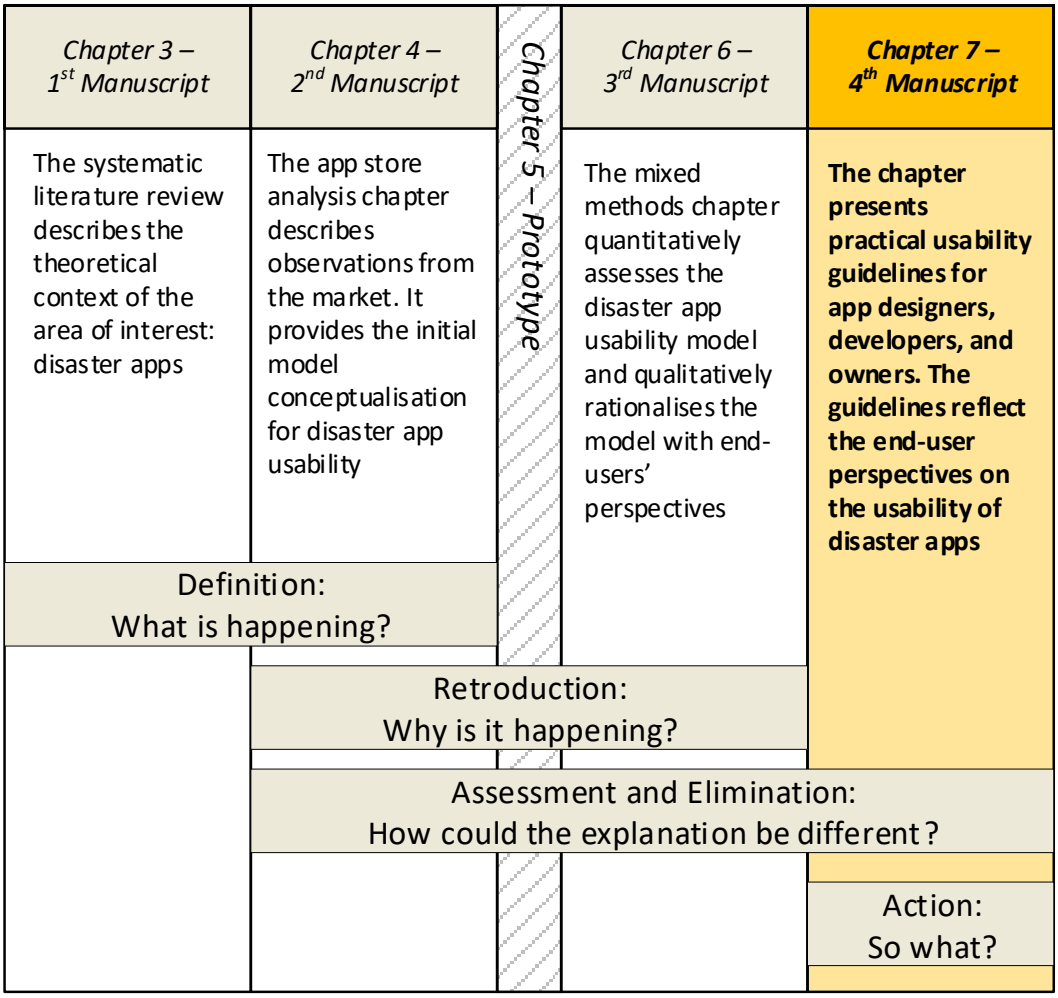

Figure 7-1. Positionality of the 4th manuscript to the thesis.

ABSTRACT

Several mobile applications (apps) targeted for disasters preparedness and response already exist for the public to download and use. A large amount of research has been conducted to investigate the functionalities of these apps in aiding the public during disasters; however, only a few studies have investigated the apps' usability in the context of crises. In acute situations, seemingly minor usability issues can become critical concerns. Disaster app studies have provided usability recommendations, but these often offer isolated insights only to the context of the individual studies. Furthermore, only a few disaster app studies integrate the perspective

of civilians as the targeted end-users. This study aims to understand the disaster users' perspectives and incorporate them in developing usability guidelines. The development of the usability guidelines involves an iterative design process, informed by a literature review, inquiry with 18 end-users, and feedback from 10 app stakeholders and seven domain experts. The inquiry with end-users highlighted their anticipation of having a low frequency of use with disaster apps, which poses particular usability challenges. The proposed usability guidelines consider the concerns raised by the end-users and provide three main recommendations: (1) make critical information salient when the situation arises; (2) account for cognitive load in the interface design, assuming stress and other factors that can occur during crises; and (3) build trust during the limited interaction the user has with the app. The study pioneers the development of usability guidelines for public-facing disaster apps as a way of providing app designers and researchers with a benchmark that reflects the perspectives of the public as end-users.

MANUSCRIPT PREPARATION AND SUBMISSION

I drafted the manuscript and received support from my supervisors on conducting the research. Dr Prasanna provided direction for the overall research design for this study; Dr Leonard gave guidance in the development of the data-gathering instruments for the inquiry, the focus group discussion, and the expert feedback survey; and Dr Stock and Dr Hudson-Doyle provided further refinements of data-gathering instruments. I conducted the data collection (18 inquiry sessions, one focus group discussion with ten stakeholders, and seven feedback sessions with domain experts and analysed the data with input from my supervisors. Professor Johnston and the supervision team guided me in structuring and refining the paper. The manuscript is intended for submission to the journal, *Progress in Disaster Science*.

7.1 INTRODUCTION

Fast-changing developments have increased technological capacities to address information-sharing needs for public protection during disasters (Büscher et al., 2016). The public can receive alerts and warnings about hazard events from multiple sources and through various platforms (Wright et al., 2014). Efforts have been made to address the multiplicity of information by developing built-for-purpose disaster apps that collect, curate, and disseminate emergency information needs (Bachmann et al., 2015; Tan et al., 2017). Disaster apps have functionalities that provide localised information directly to users in affected areas. They are platforms through which critical information can be delivered promptly (Fallou et al., 2019).

Much of the research on new crisis technologies has focussed on capabilities and functionalities and has often left ethical, legal, and social issues (ELSI)—such as usability—unconsidered (Büscher et al., 2016). Usability is about ensuring the product can support users to achieve their goals and addresses the question: *Can the user make the product do what it is intended to do?* (McNamara & Kirakowski, 2007). In the context of disaster apps, usability entails providing the elements to effectively facilitate users in receiving critical information so they can make decisions during crises (Sarshar et al., 2015). Guaranteeing usability is an issue that needs to be addressed as crisis-related technological products with poor usability can compromise the safety of their users (Büscher et al., 2016; Nurse et al., 2012).

Usability guidelines can come in many forms. The level of detail varies and can range from generic principles to detailed recommendations (Mariage, Vanderdonckt, & Pribeanu, 2004). A usability guideline is "any statement ensuring some adequacy of a particular user-interface with respect to a particular context of use where a given user population has to fulfil interactive tasks with a given system" (Shitkova, Holler, Heide, Clever, & Becker, 2015, p. 1604). Fundamentally, most usability guidelines anchor on the International Organization for Standardization's (ISO's)

seven general principles, Nielsen's ten usability heuristics, or Shneiderman's eight golden rules on interactive design (see Table 7-1).

Table 7-1. Fundamental guidelines for usability.

ISO (1998)	Nielsen (1994b)	Schneiderman (1998)
1. Suitability for task 2. Self-descriptiveness 3. Controllability 4. Conformity with user expectations 5. Error tolerance 6. Suitability for individualisation 7. Suitability for learning	1. Visibility of system status 2. Match between system and real world 3. User control and freedom 4. Consistency and standards 5. Error prevention 6. Recognition rather than recall 7. Flexibility and efficiency of use 8. Aesthetic and minimalistic design 9. Help users recognise, diagnose, and recover from errors 10. Help and documentation	1. Consistency 2. Universal usability 3. Informative feedback 4. Dialogue designing yielding at closure 5. Prevention of errors 6. Easy reversal of actions 7. Support of internal locus of control 8. Reduction of short-term memory load

Source: Kwee-Meier et al. (2017).

Although these various principles may be used, usability guidelines often provide further advice that reflects the needs of a particular domain (Mariage et al., 2004; Shitkova et al., 2015). In the various fields that involve the use of safety-critical systems, guidance on interface design goes beyond generic guidelines and provides advice, such as offering updated information, reducing complexity, simplifying graphics, and improving automation (Kwee-Meier et al., 2017). These usability recommendations acknowledge that the lack of usability can lead to the compromised safety of responders (Elmasllari & Reiners, 2017; Kuula et al., 2013; Nurse et al., 2012).

Although usability guidelines for safety-critical technologies do exist, these often take the perspectives of responders as users, and examples include the domains of firefighting, nuclear emergencies, health and emergency, and police (Kwee-Meier et al., 2017). In contrast, only limited research has evaluated disaster technology applications from the perspective of civilians as the targeted users (Spielhofer et al., 2019; Tan et al., 2017).

However, the usability of personal technologies should not be overlooked in disaster communications. Trends show that the public is gaining more agency during crises with the help of technologies, such as social media and apps (Palen, Hiltz, et al., 2007; Stephens, Ford, Barrett,

& Mahometa, 2014). Furthermore, as Liegl, Oliphant, and Büscher (2015) have argued, usability for crisis technologies cannot only be decided by experts but has to be a "product of engagement with the technology by directly or indirectly implicated publics" (p. 1). Despite the growing awareness of the role of the public as end-users, only a few studies have investigated the usability of disaster apps from the public's perspectives (Romano et al., 2016; Tan et al., 2017).

Ahmad et al. (2018) reviewed academically published mobile application usability guidelines and identified 17 domain areas. None of the guidelines was specifically for public-facing crisis, emergency, or disaster apps—therefore, this is a gap in the literature. To the best of the authors' knowledge, no academic research has yet developed appropriate guidance on improving usability for public-facing disaster apps. This chapter seeks to address this gap and asks the question: *What usability guidelines should be considered from the insights of the public as end-users to develop a usable disaster app?* The study aims to build usability guidelines that cater specifically to public-facing disaster apps as a way of providing app designers and researchers with a benchmark that reflects the perspectives of the public as end-users.

7.1.1 Research process and paper outline

This study uses an iterative process driven by a design science approach to develop the guidelines. Design science has been used in information systems research to develop usability guidelines (for example, Shitkova et al., 2015). It is a research method that presents a procedure for creating an artefact (Hevner, March, Park, Ram, & Ram, 2004)—in this case, the usability guidelines for disaster apps. Figure 7-2 illustrates the research process adopted in this study.

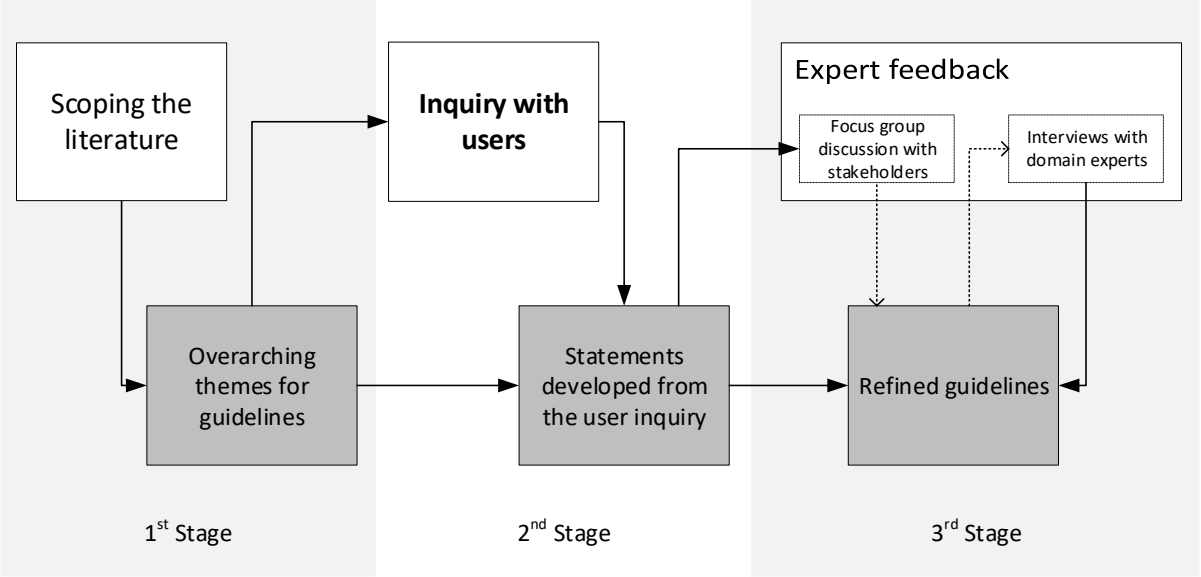

Figure 7-2. Iterative design process to develop the usability guidelines.

Design science promotes a bottom-up approach that encourages engagement with various stakeholders to develop trusted technological artefacts, such as systems, tools, and guidelines (Hevner et al., 2004). 'Knowing your audience' aligns with the best practice for risk and emergency communication. Developing usable information products for conveying emergency information requires designers to "understand not only the information needs of their audiences but also the problems and concerns that influence audiences' reception and use of information, whether print or electronic" (Kain et al., 2010, p. 306). The guidelines from this study aim to reflect the insights of end-users as gathered from the inquiry process.

The next three sections of this paper (Sections 7.2, 7.3, and 7.4) present the methods and results for each stage of the iterative process for developing the usability guidelines. These sections are as follows:

- The guideline development process starts with a literature review, as the 1st stage, to gain an understanding of what usability recommendations already exist for disaster apps. Section 7.2 details the scoping review process and presents three overarching themes formed from the literature.

- The inquiry with the users, the 2nd stage, provides in-depth insights into the users' perceptions and expectations of usability. The overarching themes from the literature guide the thematic analysis of data gathered from the users. Section 7.3 details the usability inquiry method, discusses the user insights, and presents the initial guideline statements.
- Feedback from experts, the 3rd stage, further improves the statements. Section 7.4 provides the expert feedback process and presents the resulting usability guidelines from the completed iterative design process.

The inclusion of literature and the insights of other stakeholders, aside from end-users, is part of the iterative process to provide a lens of criticality that strengthens the soundness of the usability guidelines. The data collection of each of the second and third stages of this research received peer-reviewed approval under the Massey University code of ethical conduct for research, teaching, and evaluations involving human participants. This chapter concludes with a discussion (Section 7.5) that highlights the significance and implications of the usability guidelines and offers opportunities for future research.

7.2 SCOPING THE LITERATURE

The process of designing the guidelines started with a scoping literature review to summarise the existing academic discourse on the topic and to find overarching themes, following Arksey and O'Malley's (2005) five-step process, as follows:

(1) Defining the problem – the review began with an overarching question from the literature: *What usability guidelines or recommendations exist for disaster apps*?

(2) Identifying relevant studies – the initial literature search started with the Information Systems for Crisis Response and Management (ISCRAM) digital library, an open-source database that hosts proceedings from ISCRAM conferences. ISCRAM is a leading

community in the field of information systems in disaster management that looks into using computer-mediated communication towards improving emergency management (Reuter, Backfried, Kaufhold, & Spahr, 2018). Also, the proceedings have special tracks that focus on human-centred design. Given this, the ISCRAM database provided a purposeful start for scoping the literature. Furthermore, a keyword search for articles was conducted on the EBSCO discovery service on these topics: disaster or crisis, smartphone apps or mobile apps, and usability. Articles were also found in other information systems conferences, such as the European Conference on Information Systems (ECIS) and the Hawaiian International Conference on System Science (HICSS).

(3) Selection of articles – the screening of the articles was conducted in two ways. The first inclusion criteria ensured that the articles have disaster apps as the artefacts of focus and the second that the articles should touch on the topics of usability or interface design.

(4) Charting the data – the articles were investigated for any mentions of usability guidelines or recommendations to improve the interface or interaction with the apps. The recommendations from each article were listed and summarised.

(5) Analysing and collating the results – the listed recommendations were compiled, sorted, combined, and collapsed to form groups of statements similar to each other. Three overarching themes on usability recommendations were formed.

7.2.1 Overarching themes from the literature

The literature on usability and disaster apps is relatively new. Nonetheless, the literature search found 11 academic publications that investigated disaster apps and discussed usability or related aspects. The articles differ in scope and focus (see Table 7-2). However, they share recurring and common themes in their recommendations to improve the usability of disaster apps.

Table 7-2. Disaster apps usability studies and their focus.

	Study	The focus of the study
1	Estuar et al., 2014	Validated the user interface of the eBayanihan app
2	Karl et al., 2015	Highlighted the benefits and challenges of crisis-specific apps
3	Sarshar et al., 2015	Investigated the design challenges of two apps, GDACSMobile and SmartRescue
4	Kotthaus et al., 2016	Analysed app store data to gauge the persuasiveness of mobile warning apps
5	Romano et al., 2016	Evaluated a mobile application for emergency response
6	Reuter et al., 2017	Conducted and analysed user surveys on three apps, KATWARN, NINA, and FEMA
7	Kaufhold et al., 2018	Presented the design and evaluation of 112.Social, a mobile crisis app
8	Kolathayar, 2018	Presented the development of an earthquake preparedness app
9	Kremer, 2018	Showcased calm technology for app interface using a tsunami warning app as an example
10	Fischer et al., 2019	Conducted and analysed a survey on the public on their intention to use warning apps
11	Tan et al., 2019	Conducted statistical analysis of usability factors affecting the continuance intention of disaster apps

The studies provided isolated suggestions for improving usability but, when taken together, formed themes of recommendations for disaster app usability. See Figure 7-3 for an example of how suggestions from various articles map into an overarching theme. A similar process of grouping and mapping was conducted to form two other overarching themes.

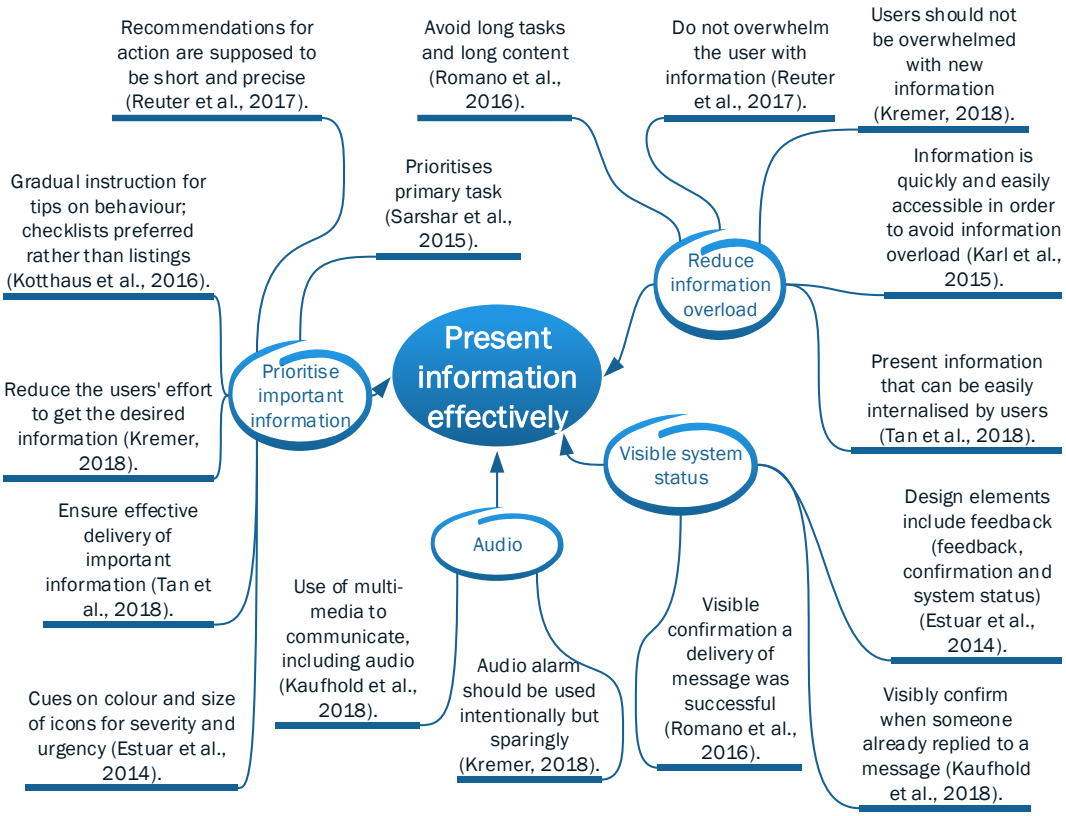

Figure 7-3. Example of grouping recommendations to form a theme.

Table 7-3 summarises the usability recommendations derived from the papers and the three thematic groupings. These three overarching themes were used as the basis for analysing the usability inquiry, the next stage of the iterative process for building the guidelines.

Table 7-3. Summary recommendations and thematic groupings from the literature review articles.

Theme	Recommendations/insights	Estuar et al., 2014	Karl et al., 2015	Sarshar et al., 2015	Kotthaus et al., 2016	Romano et al., 2016	Reuter et al., 2017	Kaufhold et al., 2018	Kolathayar, 2018	Kremer, 2018	Fischer et al., 2019	Tan et al., 2018
1. Present information effectively	Highlight and prioritise important information			•	•		•			•		•
	Reduce information overload		•			•	•			•		•
	Make audio output meaningful and intentional							•		•		
	Make system status visible	•				•		•				
2. Develop a non-complex interface	Communicate calm	•					•			•		
	Reduce complexity and improve intuitiveness	•		•					•			
	Make navigation short and easy		•			•						
	Ensure buttons and controls allow for easy input						•	•				•
	Make visual display meaningful (relatable, consistent, readable)	•				•	•			•		
	Use language that is understandable to the user					•			•			
3. Build trust	Convey credibility/trustworthiness		•		•			•			•	•
	Make interface flexible and adaptable to personal preferences	•		•	•		•					
	Reduce/eliminate errors	•						•		•		•
	Content should be context-aware		•	•			•				•	
	Ensure privacy and security			•			•				•	

• Indicates the recommendation was observed in the article

The recommendations altogether put particular emphases on aspects that are critical to crises contexts. Issues, such as information overload, system complexity in acute scenarios, and trust, are brought to the forefront. The three overarching themes from the literature are as follows:

(1) **Present information effectively** – information overload can occur when there is more information than can be processed by human capacity (Stratmann & Boll, 2016). When

a disaster situation arises, a torrent of data may become available through a disaster app. Disaster apps should be designed in a way that ensures users are not overwhelmed with too much new information (Kremer, 2018; Reuter, Kaufhold, Leopold, et al., 2017). Lengthy content and tasks should be avoided (Romano et al., 2016), and essential information should be made easily accessible (Karl et al., 2015).

(2) **Develop a non-complex interface** – system complexity can slow down the perception, comprehension, and projection of information during crises (Bolstad et al., 2006). For disaster apps to communicate information quickly and effectively, efforts should be made to reduce the complexity of the app (Sarshar et al., 2015). The app should be neat and straightforward (Kolathayar et al., 2018). The interface has to be intuitive so that minimal effort is needed from users if they need to be reacting to events around them (Estuar et al., 2014). Navigation should be short and direct, and, ideally, steps to retrieve critical information should be minimised (Karl et al., 2015; Romano et al., 2016).

(3) **Build trust** – the persuasiveness of an app in encouraging its users to take action is influenced by the users' perception of the credibility of the app (Kotthaus, Ludwig, & Pipek, 2016). Disaster apps are expected to perform with minimal errors (Kremer, 2018). For disaster apps, the perception of dependability—the degree that users perceive the app can operate dependably during the usage lifecycle—affects the users' understanding of an app's usability (Tan et al., 2018). This finding reiterates the need to consider life-safety contexts when designing disaster apps. Trust can be built through communicating quality (Karl et al., 2015), expressing reliability (Kaufhold, Rupp, Reuter, Amelunxen, & Cristaldi, 2018), and conveying user privacy and security (Fischer, Putzke-Hattori, & Fischbach, 2019).

7.3 INQUIRY WITH USERS

After obtaining overarching themes from the literature review, a usability inquiry was utilised to gather information about the target users' preferences and understanding of usability to develop the initial guideline statements. The usability inquiry used a prototype from Tan et al. (2019) as a tool to engage with the participants[8]. A usability inquiry is not about testing the prototype, but, rather, the prototype is used as a prompt to draw insights from the users on their perceptions of usability (Nielsen, 1994a; Zapata et al., 2015).

Insights from the users are gained by observing them as they go through the prototype, talking with them and asking them questions (Nielsen, 1994a; Zapata et al., 2015). The medium-fidelity prototype used in this study has three screens (see Figure 7-4): (1) a home screen that acts as a feed that displays news from emergency management authorities; (2) a prepare screen that contains preparedness information; and (3) an alert screen that collects and displays the official emergency alerts.

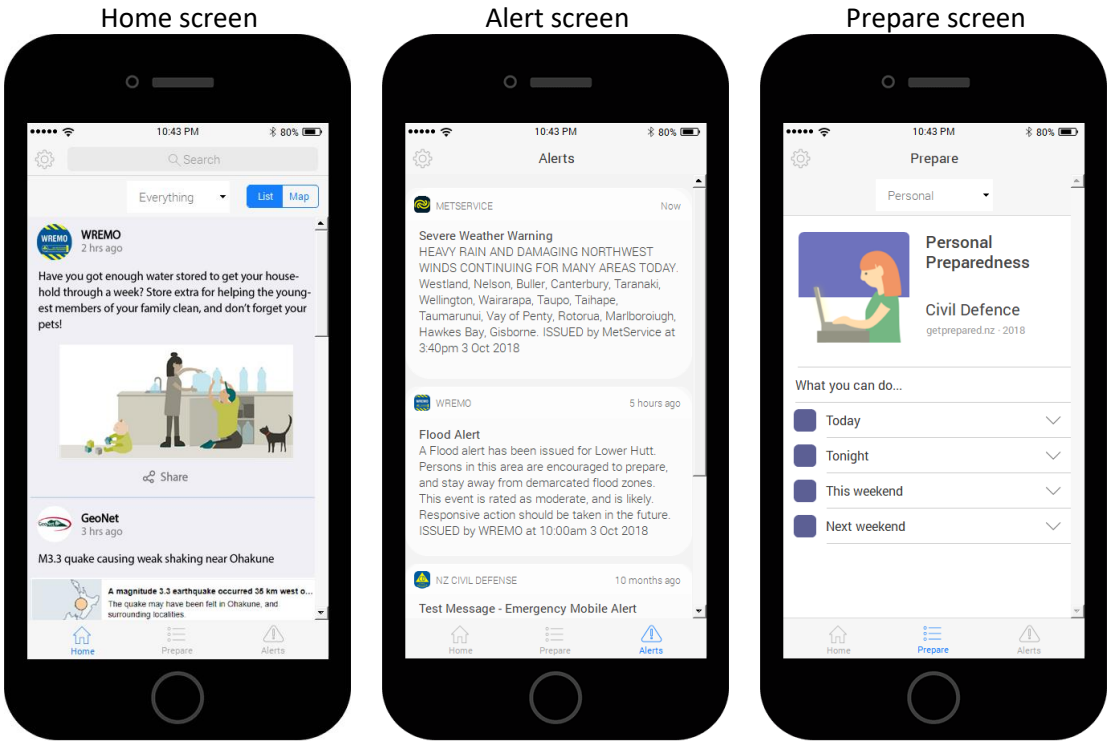

Figure 7-4. Sample screen interfaces on the prototype used for the usability inquiry.

[8] See Chapter 5 and Appendix E for more details on the prototype.

Participants were recruited through an online survey and by posting invitation flyers around two university campuses. All of the 18 participants of the usability inquiry had at least two years ownership of a smartphone. Twelve of the participants were female, and six were male. The participants had a median age of 29.5 years. Seventeen of the participants had smartphones operating on iOS at the time of the data gathering, and one had an Android-based phone but had previously owned an iPhone. All inquiry sessions were held in Wellington, New Zealand.

The inquiry used semi-structured interviews to gather users' perceptions of usability. The process of the inquiry began by asking the participants demographic and introductory questions. Then, the participants independently navigated through and freely explored each of the prototype's three screens. A set of core questions (see Table 7-4) steered the conversations with the interviewees. The questions were designed to encourage interviewees to discuss their experience with the app and their expectations of usability. The inquiry sessions took between 40 to 90 minutes to complete. With the consent of the participants, their interaction with the app and their responses to the questions were recorded. All the interviews were conducted in Wellington, New Zealand.

Table 7-4. Interview core questions for the usability inquiry.

Interview core questions
1. Core questions for app components (after the user interacts freely with each screen): a. What comments or issues do you have with the look? b. What comments or issues do you have with the controls? c. What comments or issues do you have on the intuitiveness to navigate the screen? d. What comments or issues do you have on how information is presented? e. What comments or issues do you have on the words or icons used? 2. Core questions for the app: a. In a crisis scenario, do you think the design of the app is appropriate? b. What would make you keep or uninstall the app?

The interview data were subjected to thematic analysis following Braun and Clarke's (2006) process to form the guidelines. The initial step is familiarisation with the data through the transcription of the interviews. Then, the reading and the interpretation of the data was conducted through the lens of the literature findings. The analysis used the three overarching

themes developed from the literature review (Section 7.2.1) as the initial basis for coding. The investigation noted the interviewees' responses to the questions, observed whether the participants provided any insights on usability considerations or recommendations, evaluated the comments on where they fit in the overarching themes from the literature review, and then assigned a code for that statement. Table 7-5 shows an example of coding an interview excerpt.

Table 7-5. An example of coding a portion of an Interview.

Transcribed interview excerpt	Relevant overarching theme		Usability inquiry initial code (abbreviation)
Seems like Facebook. Which makes me very comfortable. A good thing. I appreciate that it looks like an app I am familiar with. In terms of the way it scrolls… how it says share… it's what I am used to. Those things are important to make it easier for me to use it.	Theme 2: Develop a non-complex interface	→	Leverage on similar interface (LEVE)

Similar to the example in Table 7-5, each comment on usability provided by the participants was analysed, assigned to an overarching theme, compared to any previously identified code, or assigned a new initial code. The codes were then subsequently developed and refined as more comments were interpreted. After coding all the transcripts, the analysis investigated the codes within each relevant overarching theme. The codes were collapsed, combined, and refined into the initial guideline statements. The NVIVO software (QSR International, 2019) was used to assist in the data analysis to develop the initial guideline statements.

7.3.1 Findings from the usability inquiry

The usability inquiry provided users' perceptions of usability for disaster apps. The participants found value in the app concept and design and gave their opinions on what aspects of the app worked for them. The participants provided several suggestions and comments on usability. The narratives from the inquiries that formed the initial guideline statements are discussed further in this section.

7.3.1.1 Frequency of use

One unexpected topic—that of the frequency of use—surfaced and cut across the overarching themes. Although the participants found value in the potential functionalities of a disaster app, they did not expect to use disaster apps frequently. Given the prospect that disaster apps may only be used during crisis events, the participants expressed the importance of getting things right, as two interviewees noted:

> *Since it may be just read once; the information must be easily digestible.* [Interview 9]

> *I would only probably use this app when something is going on.* [The current content] *is probably not going to be long enough for me to see what I want to see. But I assume that if there is more to say about it, the app would say more.* [Interview 5]

This suggests that the participants' expectation of usability is associated with their expectation of how often they will use the disaster app. When asked about the appropriateness of the design for crises (Question 2a, Table 7-4), the majority of the participants emphasised that disaster apps need to allow novice users to navigate with ease. One interviewee said:

> *Especially for someone who doesn't* [use apps often]*, this is easy to understand and straightforward. No issues. Really simple, which is a good thing. Especially when* [I have a new app]*, sometimes it can be hard for me.* [Interview 8]

Since a disaster app is expected to be used irregularly, most users will be new to the app, and they need to learn how to use the interface quickly. Given this low frequency of use, the participants anticipate navigation within a disaster app to be simple and straightforward. One interviewee commented:

> *Don't use complicated design. Make it simple. If people are not used to it, they will find it difficult to use.* [Interview 6]

One participant recognised that the app would not be used unless a disaster strikes, but he will keep the app as a trusted source of information:

> *The app is useful to be in my pocket; not that the app will get the most use. … The app would be a trusted primary source for pertinent information. I may not have it for everyday information but as a trusted source.* [Interview 9]

A disaster app, therefore, needs to establish trust through the users' limited interaction with it. One participant highlighted that, even if the app will not be regularly used, the users need to sense that the app is still alive and being kept up-to-date:

> [I will uninstall] *if the app has not made any update in a long time. Usually, I pay attention to the last time of revision. If it hasn't changed in a long time, it's because it's no good.* [It means] *no one is working on it. A good app should be updated time to time.* [Interview 12]

These insights gathered on the theme of frequency of use have further highlighted the significance of the three overarching themes from the literature: (1) present critical information effectively, (2) develop a non-complex interface, and (3) build trust. The low expected frequency of use leads to anticipation from users that the app will saliently present critical information when the situation arises and that it will have an easy interface configuration to aid the users when they need to use the app. With the disaster app only used occasionally, it is challenging to establish trust during initial and limited interaction with the users. The overarching statements were revised to reflect the low frequency of use context (see Table 7-6).

Table 7-6. Wording revisions for the overarching themes to reflect insights on frequency of use.

Theme	Themes from literature	Revised overarching themes
1	Present information effectively	Make critical information salient
2	Develop a non-complex interface	Consider cognitive load when designing the interface
3	Build trust	Build trust, anticipating the level of interaction

The insights from the usability inquiry relating to these three revised overarching themes are as follows:

7.3.1.2 Make critical information salient

The participants recognised that when a crisis happens, many updates can come in rapid succession. Users would need quick and easy access to information during a disaster. The participants anticipate that they will use the app but would only spend the minimum necessary amount of time and concentration to find the information needed for them to make timely decisions. If the notifications all flood in at the same time with each having content of varying levels of importance, a user might miss a critical message. Multiple messages, if equally displayed with no prioritisation, might confuse the users. One participant stated:

> *During crisis situation, we would be doing a lot of things. If there are a lot of notifications – I might miss lots of information that is coming in.* [Interview 4]

When asked about how the prototype presents information (Question 1d, Table 7-4), the majority of the participants expressed their expectation that the disaster app would immediately pinpoint to the crucial messages. Some of the participants noted that the prototype did not highlight or prioritise any particular information. Stressing this gap, the participants then suggested some ways for the app to make critical information salient. The leading suggestions from the interviews focussed on the role of visual display, such as typography, elements, content length, and display structure, but also provided some insights on audio and sensory prompts. Table 7-7 shows sample quotes from the interviewees.

Table 7-7. Selected suggestions from usability inquiry participants on making information salient.

Participant suggestions	Selected sample quotes
Typographical emphasis	*For tsunami warning use bold or red to stand out more. I would like high-risk alerts to be bold and stand-out.* [Interview 14]
Accentuating interface elements	*Colour will make it easier to find things. For alerts, expecting something red. I want the shape to have more colours in them. Not the same* [colour] *equally. Use red for most important; yellow for not as important; lighter colour for not important. Then, in a glance, you can find which is important.* [Interview 1]
Length of content	*Three to four lines is okay. Too* [much] *content will make people confused. Too short, maybe it will not contain as much information.* [Interview 11]
Top-to-bottom structure	*It would be good* [if the app] *rates notifications from high to low severity. Good to put severity-related information on top.* [Interview 4]
Audio prompts	*Maybe if there is a high-risk alert, it beeps. A little beep. Earthquake nearby or tsunami or something big*. [Interview 14]

- *Typographical emphasis* – participants recommended typographical emphasis to capture users' attention. The most common suggestion was to use bold font weight for critical words or information. Other techniques suggested by the participants included varying the font size and changing the font colour. They also acknowledged the effectiveness of using capitalisation to highlight information. Some participants showed a preference for some techniques over others. For example, one participant indicated his preference for the use of bold lettering rather than the use of capital letters.
- *Accentuating interface elements* – the participants also suggested highlighting critical information through emphasising interface elements in the app via the use of colours. The participants stressed that during crises, easy access is needed, and the app should help them find information quickly. One of the participants identified as colour-blind, and he suggested that the colour palette for highlighting information should consider the range of colours that will be distinguishable for those with colour-blindness[9].

[9] A colour-blind person will have difficulty in distinguishing a specific colour or a combination of colours (Venugopal, 2015).

- *Length of content* – the participants also expected an ideal content length for reading effectiveness during crisis scenarios. In general, they wanted the message to be short and concise but also highlighted that it should not be too short that it leaves out important information that would prompt the user to seek information elsewhere.
- *Top-to-bottom structure* – the participants expected many updates to come from the app during crisis events. The participants emphasised the importance of a top-to-bottom structure where the most critical information is prioritised to be on top. Also, if the message is extremely crucial, the participants suggested pinning the post on top so that even if the users scroll down to read other details, they can still see the pinned message.
- *Audio and sensory stimulus* – the participants also indicated that audio output could be useful to grab attention. However, most participants would only want sound notifications for severe warnings. Incorporating sounds should be carefully considered, and the level of volume should be not too loud. For most of the participants, a small sound accompanied by vibration is sufficient. Continuous or blaring sounds are deemed annoying and unnecessary, and participants also would want to have the option to mute or adjust the sound settings.

Table 7-8 summarises the statements related to making critical information salient. Overall, the suggestions given by the participants show different strategies to make information striking when an acute situation occurs. The participants envisaged disaster apps to be quick in grabbing their attention towards critical information.

Table 7-8. An initial list of statements for the first overarching theme.

Theme	Code	Recommendation
1. Make critical information salient	PRIO	Critical information should be prioritised
	EQUA	Avoid equal display of importance
	VARY	Use varying techniques to make important information salient
	TECH	Consider typographical emphasis, interface elements, content length, top-to-bottom structure, and audio and sensory prompts
	AUDI	Use audio output purposefully

7.3.1.3 Consider cognitive load when designing the interface

The inquiry participants commented on the prototype's looks, controls, and intuitiveness (Questions 1a, 1b, and 1c, Table 7-4). The usability insights gathered from participants' answers to these questions focussed on: (1) the familiarity and simplicity of the interface and (2) the preference for short textual information and suggestions to balance the text with some imagery. Aside from making critical information salient during disaster situations, the participants also wanted the interface to be easy and comfortable on the occasion that they do use the app.

7.3.1.3.1 Familiar and simple interface

A common expectation from the participants was for the app's interface to give them a feeling of ease. Except for one, all participants used social media on their smartphones. They had either Facebook or Twitter installed on their phones. The participants confirmed that they felt more comfortable when they found the interface similar to other apps they have used. One interviewee mentioned:

> *The more similar it is to other* [apps]*, the better. Not really the place to be innovative. Must know how to use it.* [Interview 2]

Simplicity is desired in anticipation that the app will be used in situations that may be stressful:

> *I do like the simplistic version of it … Do not want much going on. When something happens, don't want to go through a lot.* [Interview 13]

> *Minimalistic is good. Alert apps should not be extravagant. Just easy to use.* [Interview 15]

One participant even mentioned his aversion to a different disaster app as it was too busy:

> *Thinking of* [app] *in particular, it has got a lot of options. It has a lot of information. I just remember that I try to avoid using* [app] *if I can because it's a lot fussy.* [Interview 3]

Moreover, the participants noticed that the prototype's intentional design to reduce the need for input as the prototype did not have too many buttons:

> *Useful, easy. If you are in a rush. No typing things. It's all there. Too many options and buttons get confusing and time-consuming.* [Interview 8]

On the portions that allowed for input, the participants offered recommendations to make input even easier for the user. For example, on the search bar, some participants proposed that the app could use autocomplete suggestions when the user types in a query.

7.3.1.3.2 Balancing text and imagery

When asked about the words and icons used in the app (Question 1e, Table 7-4), the participants provided their opinions about their desired proportion of text and images included in the app. Most preferred to see less textual information and suggested the use of images to help users digest information. Participants noted that images attract people's attention. The non-textual cues, however, should be meaningful. The participants wanted the images to have added value in facilitating the delivery of content. Table 7-9 shows some selected examples and quotes where imagery can help users digest content.

Table 7-9. Selected quotes from inquiry participants on using visuals to support textual information.

Examples	Sample quotes from the interviews
Logos to familiarise with alerting organisations	*I like the logos for each. Really helpful when scrolling to look for something.* [Interview 15]
	I don't like scrolling by the name. I would prefer the logo of the organisation rather than [just] *the name.* [Interview 1]
Maps to communicate tsunami hazards	*If there was an alert tsunami for the city centre, would something come up? Like an alert. Would it be accessible to see for people? For example, for people to see 'oh, I am in a safe place'. … Or you don't know the tsunami lines. It would be good* [to show] *a little blue dot* [of] *where you are. Then you could have a message that would say 'look an earthquake happened, this is the potential line for tsunami, get yourself above this line'.* [Interview 3]
Multi-media to make preparedness interesting	*For preparedness, use fun videos and pictures. For example, what is a tsunami? How to get prepared when those happen? Bulletins on what to do in the scenario.* [Interview 12]

Making use of icons rather than just using text headlines can improve user navigation. The participants found the logos displayed along with the agencies' names aided them in seeking information from the app. Participants also mentioned how a map would be more helpful over textual alerts, especially if a tsunami hazard is involved. The participants perceive that during a tsunami event, the use of maps would improve communication of affected areas, evacuation directions, closed roads, and congestion, thus also facilitating improved situational awareness. Aside from alerting, participants noted that the app could present preparedness details through the use of creative multi-media, such as infographics and videos, to make it more engaging.

The participants provided suggestions that revolve around simplifying the interface and using imagery to allow easier absorption of information, taking into account that users will be interacting with the app on a limited basis and such occasions may be in stressful environments. These statements emphasise the need to consider the cognitive load of the users. Table 7-10 summarises the initially developed statements under this theme.

Table 7-10. An initial list of statements for the second overarching theme.

Theme	Code	Statement
2. Consider cognitive load when designing the interface	LEVE	Leverage on interfaces that are familiar to users
	NEAT	Keep the design neat and simple
	INPT	Reduce the need for user input
	VSUA	Use meaningful visualisation to enhance the content (e.g. image, logos, maps)
	RTIO	Rationalise the use of text and images
	TEXT	Limit textual information

7.3.1.4 Build trust, anticipating the level of interaction

When asked what would make the participants keep or uninstall the app (Question 2b, Table 7-4), the participants indicated that trust was an important factor. The participants acknowledged the challenge of establishing trust when the interaction with an app is infrequent. The participants discussed insightful comments on how trust can be built or lost as the users interact with the app.

The most recurrent theme when talking about trust was the perception of credibility achieved through content. Most of the participants acknowledged that trust develops when an app provides quality and relevant content. When communicating a hazard, the participants would initially look for three pieces of information: time, location, and severity of the event. The participants would then seek the source of information. It is, therefore, good practice to communicate essential information succinctly and to display the origin of the content. The participants build trust in the app and its material when they trust the information source:

> *Good. It's clear what the alert is. Information on when it is issued and who by. You'll know if it's relevant or not.* [Interview 3]

Also, because of the criticality of the potential information from a disaster app, the participants found it comforting that the content is curated and not just a random social media post:

> *I feel like I can trust it because it shows the source for each alert and each information. I don't have to worry about fake news. Since it's not on social media platform, I don't have to worry about rumours.* [Interview 17]

However, not everyone is conversant in the disaster management environment and jargon. Some of the participants did not recognise the terms and the alerting organisations presented in the prototype. As a measure to address this issue, some of the participants suggested that the app should provide means for the users to know more about the alerting environment and the organisations involved:

> *But the organisations. I wouldn't know* [what they are]*. I have only been here for four months. The organisations are foreign. Give a quick overview of what those organisations are and what they do.* [Interview 12]

The participants also felt the content to be more relevant if it were contextualised or personalised as, for example, providing actionable items rather than just giving general warnings:

> *If there's a chance of a strong wind tonight, … what you can do? Sometimes we get informed about putting our outside furniture inside our homes. These sort of things would be very useful. Instead of just the static* [warning] *text.* [Interview 4]

Participants indicated the leading cause for users to uninstall a disaster app would be if they view the app to be unreliable. Inaccurate content will lead participants to distrust a disaster app. Aside from the relevancy of content, the participants also mentioned other instances that would lead them to lose trust and uninstall the app. Table 7-11 lists examples of reasons for uninstallation mentioned by the participants.

Table 7-11. Selected quotes from inquiry participants on their reasons for uninstalling a disaster app.

Reasons	Sample quotes
Inaccuracy	*If information is not accurate. I will not trust it. I will search for other apps.* [Interview 11]
Errors	*If it was lagging. If it makes my phone slow down.* [Interview 14]
Inactivity	*If it is not up to date. It should not have information just from a day ago or two days ago.* [Interview 4]
Privacy	*If it uses personal information beyond geo-location, I would want to know why.* [Interview 9]

Encountering errors would contribute to a negative perception of the app. Minor inconveniences, such as the app getting stuck or responding slow, can also reduce trust in the app. Faults on notifications, such as receiving too many of the same alert, will cause the user to uninstall the app.

Furthermore, users do not want to feel that a disaster app is static and unengaging. Ensuring visible system status would aid in portraying a sense of engagement with the users. For example, a status prompt of when the app was last updated or if the app information is updated could be shown. A participant provided an example, as illustrated in Figure 7-5.

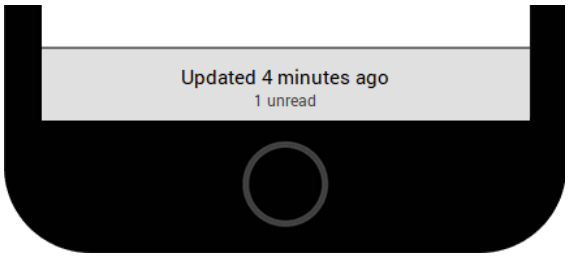

Figure 7-5. Example of updated system status.

Finally, although not a common topic, the issue of privacy was raised. Participants indicated that privacy could be a concern as users may uninstall apps if they felt that their privacy disregarded. They noted their willingness to give personal information, such as geo-location, in exchange for localised information but expected the apps to be transparent about the data they use.

These statements developed relating to trust are summarised in Table 7-12. These findings show that relevant and relatable content evokes trust. Suggestions from participants to improve the perception of relevancy included providing essential details succinctly. This includes providing the source of information and contextualising and personalising information when possible. Participants also indicated that disaster apps should also minimise errors, engage by providing visible system status, and communicate respect for users' privacy.

Table 7-12. An initial list of statements for the third overarching theme.

Theme	Code	Statement
3. Build trust, anticipating limited interaction	RELV	Provide relevant content
	SIGN	Show information significant to time, location, and severity
	SRCE	Display the source of information
	PERS	Personalise or localise the content to the user
	ERRO	Minimise errors and loading time
	VISI	Provide visible system status to evoke that the app is alive and updated
	PRVY	Show regard to users' privacy

Through the inquiry, the users provided several suggestions and comments on usability. Table 7-13 presents the initial guideline statements developed and their alignment with the literature recommendations.

Table 7-13. Initial guidelines statements after the usability inquiry and their alignment with the literature recommendations.

The first iteration of the guidelines			
Revised overarching themes	**Code**	**Initial statement guidelines developed from the usability inquiry**	**Recommendations/insights from literature**
1. Make critical information salient	PRIO	Critical information should be prioritised	Highlight and prioritise important information
	EQUA	Avoid equal display of importance	Reduce information overload
	VARY	Use varying techniques to make important information salient	
	TECH	Consider typographical emphasis, interface elements, content length, top-to-bottom structure, and audio and sensory prompts	
	AUDI	Use audio output purposefully	Make audio output meaningful and intentional
2. Consider cognitive load when designing the interface	LEVE	Leverage on interfaces that are familiar to users	Communicate calm
	NEAT	Keep the design neat and simple	Reduce complexity and improve intuitiveness
	INPT	Reduce the need for user input	Make navigation short and easy
			Ensure buttons and controls allow for easy input
	VSUA	Use meaningful visualisation to enhance the content (for example, image, logos, maps)	Make visual display meaningful (relatable, consistent, readable)
	RTIO	Rationalise the use of text and images	Use language that is understandable to the user
	TEXT	Limit textual information	
3. Build trust, anticipating the level of interaction	RELV	Provide relevant content	Convey credibility/trustworthiness
	SIGN	Show information significant to time, location, and severity	
	SRCE	Display the source of information	
	PERS	Personalise or localise the content to the user	Make interface flexible and adaptable to personal preferences
			Content should be context-aware
	ERRO	Minimise errors and loading time	Reduce/eliminate errors
	PRVY	Show regard to users' privacy	Ensure privacy and security
	*VISI	*Provide visible system status to evoke that the app is alive and updated	*Make system status visible

*VISI was initially under Theme 1, but it was regrouped to Theme 3 as insights from the users show that simple cues, such as system status, help build trust with the app.

7.4 EXPERT FEEDBACK

After developing the initial guideline statements from the user inquiries, these were presented iteratively to two sets of experts to gather feedback for improving the guidelines: (1) a focus group discussion with ten stakeholders of an existing app and (2) a set of seven individual evaluations with domain experts. The guidelines are targeted to provide design considerations for app owners, developers, managers, and researchers (that is, the stakeholders) when building and improving disaster apps. The stakeholders are included as part of the design to evaluate the guidelines, contributing improvements so the guidelines can become more relevant in appropriating change in research and practice.

The design science approach promotes multiple strategies and methods for evaluating artefacts like guidelines (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). This study uses an *ex-ante* naturalistic evaluation strategy. An *ex-ante* evaluation is ideal for formative assessments of initial designs for further improvement, and this means appraisal can happen even prior to the full development of an artefact (Johannesson & Perjons, 2014). Naturalistic evaluation, involving real users, fits this study as is recommended for socio-technical artefacts as it allows multiple stakeholders to be engaged in providing different perspectives and interests (Johannesson & Perjons, 2014). *Ex-ante* naturalistic evaluations allow for methods such as focus group discussion and interviews.

- **Focus group discussion with stakeholders** – the first iteration for improving the guidelines was with a group stakeholders of an established disaster app in New Zealand. The disaster app was chosen as the app's product team hosts quarterly meetings open to various stakeholders, including the government, researchers, and the public. With consent from the product team, a focus group discussion was conducted with its stakeholders during one of their meetings. The group included members of the app team as well as external parties that have a strategic interest in the success of the app. In total, 10 participants engaged in the

focus group. During the discussion, other apps and their respective stakeholders were identified, snowballing for a sample of domain experts to contact for the next iteration of feedback.

- **Feedback from domain experts** – seven experts agreed to participate in one-to-one interviews for the next feedback iteration. The domain experts included in the study have expertise in technology use for disaster communications, with involvements in the development, management, or implementation of apps related to disasters. The unstructured interviews lasted between 30 to 60 minutes. After each meeting, these domain experts completed a survey to evaluate the guidelines. The questionnaire included scaled items for each of the initial guideline statements in Table 7-13. The survey asked the participants to provide a score between 1 to 6 for each statement, with 1 being 'extremely irrelevant' and 6 being 'extremely relevant'. The survey also included open-ended questions to allow further articulation as necessary. See Appendix I for the questionnaire.

The feedback from both the stakeholders and domain experts allowed for further refinement of the guidelines. Sections 7.4.1 and 7.4.2 present the insights gained from the feedback iterations and the resulting guidelines, respectively.

7.4.1 Experts' feedback on the initial guideline statements

The focus group discussion participants suggested changes in the phrasing for some of the guidelines. For example, the statement '*minimise errors and loading time*' was changed to '*minimise impact of errors and reduce loading time.*' Table 7-14 shows the revised statements.

Aside from suggesting minor changes to the phrasing, the group discussed the applications and implications of the guidelines. The product team reflected on their app and described to their stakeholders how they have applied strategies that would align the app to these guidelines. The stakeholders noted during the discussion that these strategies are often developed through learned experience over time. As such, they pointed out the value of the guidelines: new app

developers can look into guidelines to consider the usability context of disaster apps at the outset. The focus group participants also indicated that the proposed guidelines are appropriate starting points to steer conversations toward the context of disaster apps that may not be captured succinctly in general UI guidelines.

Table 7-14. Guideline statements after the focus group discussion.

Theme	Code	Statement
Set 1: Make critical information salient	PRIO	Critical information should be prioritised
	EQUA	Avoid maintaining an identical level of priority when displaying different alerts
	VARY (TECH)	Use varying techniques to make important information prominent (e.g. typographical emphasis, colour contrast)
	AUDI	Use audio output purposefully
Set 2: Consider cognitive load when designing the interface	LEVE	Utilise existing interfaces that are familiar to users
	NEAT	Keep the design neat and simple
	INPT	Reduce the need for user input
	RTIO	Rationalise the use of text and images
	TEXT	Limit textual information
	VSUA	Use meaningful visualisation to enhance the content (e.g. image, logos, maps)
Set 3: Build trust, anticipating limited interaction	RELV	Provide relevant content
	SIGN	Show information significant to time, location, and severity
	SRCE	Display the source of information
	PERS	Personalise or localise the content to the user
	ERRO	Minimise the impact of errors and reduce loading time
	VISI	Provide visible system status to evoke that the app is alive and updated
	PRVY	Show regard to users' privacy (e.g. privacy statement)

*Highlighted are the revised statements after the focus group discussion

The feedback from domain experts shows that, overall, the seven experts also found the overarching themes and statements to be appropriate for use in a set of disaster app usability guidelines. Figure 7-6 presents the average scores the domain experts gave on each of the statements (highest possible score is 6). All of the statements received average ratings of higher than 4. The lowest scoring statement was on the guideline referring to audio output, and it was further revised according to the suggestions of the experts to include not only auditory but also other sensory outputs.

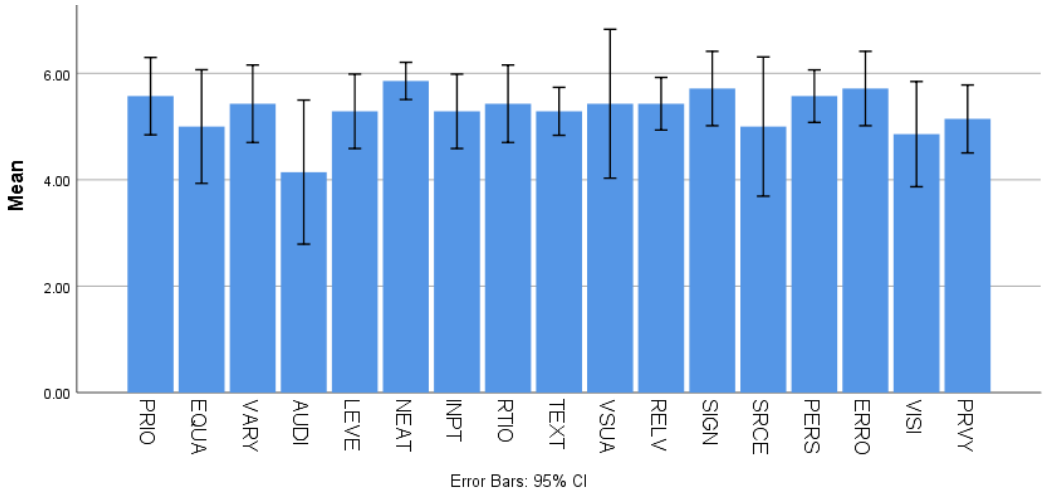

Figure 7-6. Average scores provided by the domain experts on the initial guideline statements.

Aside from commenting on the wordings, the experts recommended developing the guidelines into an evaluation tool. Suggestions included re-purposing the statements to be part of a usability questionnaire or evaluation matrix where an app can be scored and benchmarked. One of the expert participants suggested:

> *I would first … conduct an actual UI/UX test with users, then apply a transformation of those results into* [an] *evaluation matrix* [based on the guidelines]. *… An evaluation matrix would be valuable and applicable as a diagnostic tool.*

The feedback from the experts also noted that the guidelines are limited to the context of general users and does not consider those with disabilities, such as those with hearing or visual impairments. They suggested future developments of the guidelines, or evaluation tools thereof, should provide accessibility considerations for those with disabilities. However, developing such an evaluation tool is beyond the scope of this study, and it is identified as an important future research direction.

7.4.2 Guidelines for the usability of disaster apps

A disaster app should perform in a way that matches the user's expectation of the app's purpose. The guidelines presented below (see Table 7-15) are the final output of the iterative design process. They incorporate the themes from the literature, the insights from the users, and the

feedback from the experts. Disaster app design and development must account for the possible low frequency of use with the possibility of intense use during an acute period of crisis. The developed guidelines provide considerations for such a context: (1) ensuring that critical information is made salient when the situation arises; (2) accounting for cognitive load in the interface design, assuming for stress and other factors that can develop during crises; and (3) building trust during the anticipated limited interaction the user has with the app.

Table 7-15. Resulting guideline statements after the iterative design process.

Make critical information salient: • Critical information should be prioritised • Avoid maintaining an identical level of priority when displaying different alerts • Use varying techniques to make important information prominent (e.g. typographical emphasis, colour contrast) • Non-visual output (e.g. audio or vibrations) should fit purposefully to the context of the information

Consider cognitive load when designing the interface:
• Utilise existing interfaces that are familiar to users
• Keep the design neat and simple
• Minimise the need for user input
• Rationalise the use of text and images
  ○ Limit textual information
  ○ Use meaningful visualisation to enhance the content (e.g. image, logos, maps)

Build trust, anticipating the level of interaction with users:
• Provide relevant content
  ○ Show information significant to time, location, and severity
  ○ Display the source of information
  ○ Personalise or localise the content to the user
• Minimise the impact of errors and reduce loading time
• Provide visible system status to evoke that the app is alive and updated
• Show regard to users' privacy (e.g. privacy statement)

7.5 Discussion

A range of disaster apps exists to provide information to citizens when crises occur (Bopp et al., 2019; Fallou et al., 2019). With the increasing availability of smartphones for the public, multiple studies have investigated the functional possibilities for apps to aid the public during disasters. However, there is a limited understanding of, or guidance for, their usability (Tan et al., 2017). To the best of our knowledge, no other research has outlined guidelines for the usability of

disaster apps. From the iterative design process, we have shown a set of guidelines with three overarching themes that reflect the end-users' insights, including their expectation for a low frequency of use. The statements produced from this study focus on particular issues that are critical for disaster apps that are not fully captured in generic fundamental usability guidelines like that of ISO, Nielsen, and Schneiderman. Table 7-16 maps how the statements align with the fundamental usability guidelines.

Table 7-16. Comparing the resulting disaster app usability guidelines to fundamental usability guidelines

Theme	Guideline statements	ISO (1998)	Nielsen (1994b)	Schneiderman (1998)
1. Make critical information salient	Critical information should be prioritised			
	Avoid maintaining an identical level of priority when displaying different alerts			
	Use varying techniques to make important information prominent (e.g. typographical emphasis, colour contrast)			
	Non-visual output (e.g. audio or vibrations) should fit purposefully to the context of the information			
2. Consider cognitive load when designing the interface	Utilise existing interfaces that are familiar to users	○	●	○
	Keep the design neat and simple	○	●	○
	Minimise the need for user input	○	●	○
	Rationalise the use of text and images		○	○
	Limit textual information			
	Use meaningful visualisation to enhance the content (e.g. image, logos, maps)			
3. Build trust, anticipating the level of interaction with users	Provide relevant content	○		
	Show information significant to time, location, and severity			
	Display the source of information			
	Personalise or localise the content to the user	●		
	Minimise the impact of errors and reduce loading time	●	●	●
	Provide visible system status to evoke that the app is alive and updated		●	●
	Show regard to users' privacy (e.g. privacy statement)			

Legend:

● Similar statement exists in the fundamental usability guidelines

○ Comparable, as inferred, to those in the fundamental usability guidelines

The fundamental usability guidelines offer some guidance on considering cognitive load and building trust. However, they do not capture the importance of saliency of critical information. Moreover, the statements in the resulting guidelines from this study provide particularities to disaster apps. For example, to provide relevant content in the disaster app context means to 'show information significant to time, location, and severity'. Statements like these will not be captured in generic usability guidelines. This section further discusses the resulting guidelines in the context of disaster apps as they align with the concepts of (1) salience, (2) cognitive load, and (3) trust. The discussion then highlights (4) the implications and directions for future research. Finally, the (5) limitations and (6) conclusion are provided.

7.5.1 Salience

The first group of statements in the guidelines encourages apps to employ techniques to ensure the saliency of critical information. Risk communication research acknowledges that salience should be considered when designing products and systems for communicating emergency information: "Low salience in design means that readers may fail to recognize the relative importance of pieces of information or the value of the overall message" (Kain et al., 2010, p. 321). It is essential to highlight that salience is not just about presenting the most relevant or important information; salience should be considered in the context of constraint within periodic interaction between the user and the media or technology (Vultee, Ali, Stover, & Vultee, 2014). For disaster apps to be useful for members of the public in a crisis, in the limited window of expected interaction, the apps must be able to prioritise information effectively, allowing the users to retrieve information quickly to make timely decisions. The persuasiveness of a piece of data during a crisis depends on how it is presented and organised as placement and hierarchy aid users in deciding which information is critical (Kain et al., 2010; Stratmann & Boll, 2016). The guidelines presented in this chapter put particular focus on saliency, advising designers to prioritise critical information through avoiding identical displays on the level of significance of messages and consider using various techniques to highlight information.

7.5.2 Cognitive load

The second set of statements encourages design that does not adversely impact users' cognitive load. Cognitive load—the working memory demands for problem-solving, reasoning, or thinking—affects users' performance in completing tasks or decision-making (Schmutz, Heinz, Métrailler, & Opwis, 2009). Mobile apps are particularly sensitive to users' cognitive load because of the limited screen size, and they are usually used in multi-task settings because mobile apps can be used at any time in varying contexts (Harrison et al., 2013). Research on cognitive load from different disciplines found that the quality of users' decisions correlates positively with the amount of information but only up to a certain point, and anything further beyond the critical point would reduce the performance of the user (Chewning & Harrell, 1990; Eppler & Mengis, 2004). Research in information systems also has identified countermeasures to information overload. Overload can be reduced through the format of delivery, such as encouraging the simplified design of products, using the aid of visualisation, and organising and rationalising the use of text (Eppler & Mengis, 2004).

Technological systems used in high-stress environments, such as in disasters, must be able to support the users considering their cognitive load, allowing them to make critical decisions and perform tasks effectively (Bolstad et al., 2006). The guidelines presented in this study encourage interface design that does not overload the users. The statements cover: utilising existing interfaces that are familiar to users, keeping the design neat and simple, reducing input requirements from users, and rationalising the use of text and imagery. Systems that demand their users to remember large amounts of detail often lead to users making decision errors (Prasanna et al., 2013). Disaster app users, expressed through the insights from the participants in this study, prefer a familiar and straightforward app that makes them feel at ease. Using simple and familiar interfaces, as suggested by the guidelines, reduces the demand on users' working memory to re-learn the interface of the app.

7.5.3 Trust

The third set of statements encourages disaster app designers to consider usability and its role in building trust. Users will stop utilising an app when they mistrust it (Damián-Reyes, Favela, & Contreras-Castillo, 2011). Trust is an important driver for the public's perception and uptake of technologies related to hazards or disasters (Appleby-Arnold et al., 2019; Siegrist & Cvetkovich, 2000). Studies on technologies for alerting, such as the Wireless Emergency Alerting service, have shown the importance of maximising and maintaining trust among stakeholders to ensure the effectiveness of disaster communications (National Academies of Sciences, Engineering, and Medicine, 2018b).

Similarly, as observed in this study, disaster apps must obtain and sustain trust from their users. Spence et al. (2015) have highlighted that a medium for disaster communications becomes more trusted as a user increases the rate of use of that medium. The challenge, however, for disaster apps is to build trust anticipating the level of interaction. Results in this study have shown that users do not expect to use disaster apps frequently. An app, therefore, must evoke trust at every possible opportunity during the limited interaction. The guidelines from this study encourage apps to build trust at the forefront through providing relevant content, minimising the impact of errors, ensuring visible system status, and showing regard for privacy.

7.5.4 Implications and directions for future research

The resulting guidelines from this study can generate further conversations about the design of disaster apps. Past research by Reuter et al. (2017) on social media and app use during crises also had a similar finding on the low frequency of use of disaster technologies—the public only expect to engage with the crisis technologies when an event is occurring or about to happen. The expected low frequency of engagement implies that there is limited interaction between the user and the app until an actual situation and need arise for its use. The user's decision to keep or uninstall an app can, therefore, come from a quick judgement made on the usability of

an app during an occasion of limited interaction, such as the first use after download (Kim & Kim, 2014). The guidelines as a whole encourage discourse on usability to focus on salience, cognitive load, and trust, and looking into these three would aid in improving users' outlook towards disaster apps.

Similarly, our past study (Chapter 4) demonstrates that users' perceptions of usability factors influence their intention to continue or discontinue using disaster apps. The role of usability as it relates to users' intention to keep the disaster app further highlights the value of the guidelines presented in this paper—the statements' direct advice based on usability as perceived by the end-users. Adherence to the guidelines has practical implications where users' impressions of the apps' usability will lead them to keep them rather than uninstalling disaster apps.

This chapter has highlighted that guaranteeing usability of disaster apps is an issue that needs to be addressed. It has developed usability guidelines to set as a benchmark for future studies, taking into consideration the users' perspectives and their anticipation of a low frequency of use. The experts' feedback in this study also acknowledged the value of the guidelines, and developers looking to establish new disaster apps can look into these contextualised usability recommendations at the outset. The experts also suggested that future research can look into developing evaluation tools from these guidelines.

Future studies can also explore other theoretical concepts that can be drawn from the fields of information systems and psychology to find means to optimise the limited interaction to motivate the use of disaster apps. Some theories to explore are applications of Bhattacherjee's (2001) expectation–confirmation theory (ECT) and Herzberg's (1959) motivation–hygiene theory. ECT may be relevant in understanding the acceptance–discontinuance behaviour where users uninstall disaster apps after initial download and use. ECT points out that users can choose to reverse their decision to use an artefact even after initial acceptance. Discontinued use can occur if there is a discrepancy between usability expectation and the experience of the product

(Islam et al., 2017). Herzberg's motivation–hygiene theory, on the other hand, may help differentiate usability factors that act as motivators versus hygiene factors—namely, factors that need to be maintained to avoid dissatisfaction and uninstallation (Cockton, 2013; Tuch & Hornbæk, 2015). Further investigation is needed on such theories in the context of the usability and the anticipated low frequency of use of disaster apps.

7.5.5 Limitations

We acknowledge that the study has limitations. Social desirability bias could have occurred during the usability inquiries and the expert feedback. Social desirability bias in usability studies can happen when participants want to impress the moderator and tend to criticise themselves rather than the artefact (Natesan, Walker, & Clark, 2016). It was made clear at the beginning of each inquiry, focus group, and expert interview that the session was not about judging the participants' capabilities but rather to understand their perceptions on disaster apps and their usability and insights on improving the guidelines. We attempted to reduce social desirability bias as suggested by Natesan, Walker and Clark (2016) through maintaining a professional relationship (not being overly friendly) during data gathering and encouraging the participants to provide both positive and negative feedback. Providing criticism was also framed positively as a means to enhance the research.

Another limitation to our study is that the artefact used for the inquiry was a medium-fidelity prototype. Although the purpose of the study is not about testing the prototype, its quality and context may have influenced the responses of the interviewees. Furthermore, the prototype used in this study is an aggregator of multi-source information and supports one-directional communication with the users acting mainly as recipients of the information. As such, the guidelines resulting from this study will be more relevant for one-way communication disaster apps rather than for multi-directional communication tools, such as crowdsourcing disaster apps. Nevertheless, the guidelines presented are still significant as they highlight the usability

concerns relating to salience, cognitive load, and trust. This limitation could motivate further research in developing usability guidelines as applied to different levels of sophistication of disaster apps.

7.5.6 Conclusion

This chapter answered the research question: *What usability guidelines should be considered from the insights of the public as end-users to develop a usable disaster app?* Usability guidelines were developed, reflecting the end-users' perspective through an iterative design process anchored on data collected from the usability inquiry but also involving insights from the literature and feedback from experts. Through the process, results have shown that users do not expect to use disaster apps frequently. The proposed set of guidelines aimed to address this context adequately. The statements provide three overarching themes for guidance: (1) disaster apps need to communicate critical information effectively in anticipation that users will have minimal or no experience with the app; (2) similarly, disaster apps have to ensure the interface design considers the users' cognitive load, foreseeing that users may only use the app in a stressful scenario; and (3) disaster apps have to find means to leverage their usability to gain and maintain trust, given the expected limited interaction with the users. The set of guidelines provides practical usability considerations for designers and developers of disaster apps. This study provided insights that could help designers in acknowledging usability concerns as they relate to salience, cognitive load, and trust. These bring attention to designers as well as researchers on the issue of responsible design, ensuring the usability of public-facing disaster apps.

8 DISCUSSION AND CONCLUSION

This chapter brings the previous components together to provide a holistic discussion and conclusion for the thesis. The first section returns to the research questions and provides an overview of how the thesis has addressed the questions. The second section discusses the research implications, the third section reflects on the impacts of conducting the research, and the fourth section covers the limitations and suggests areas for future research. The final section concludes the thesis.

8.1 RESEARCH OVERVIEW

Only a few studies have looked into the usability of public-facing apps that are built specifically to communicate information during disaster situations. This doctoral research project set out to answer the first research question: *How does usability influence citizens' perception of disaster apps?* The thesis has shown that usability, although understudied, affects users' intentions to continue or discontinue using disaster apps. Through the sequential mixed methods approach, the studies have determined five usability factors to affect continuance intention of disaster apps: a*pp dependability*, *app utility,* and *UI output* affect continuance intention positively, while *UI graphics* and *UI input* affect continuance intention negatively. Through the research process, the studies have also shown that there are special usability considerations for disaster apps that differ from generic apps.

The systematic review (Chapter 3) scoped the literature on disaster apps and determined the extent to which usability was studied. A study of user reviews from the markets (Chapter 4) further highlighted particular considerations for disaster apps. An in-depth inquiry with actual participants provided further insights into the context of disaster app use (Chapters 6 and 7). Two prominent contexts of use differentiate disaster apps:

(1) Low frequency of use – users do not expect to use disaster apps often and perceive disasters to be low likelihood events; and
(2) Acute scenario of use – users recognise that the disaster apps are most useful when there are disaster events. However, if the apps are used during a disaster situation, users may find themselves in a stressful environment where their information-processing capabilities may be impaired.

These particular contexts provide implications for the usability of disaster apps. *App dependability*, as introduced in Chapter 4 (2nd Manuscript), becomes an important usability factor that affects users' impressions due to life-safety concerns associated with disaster apps. To contextualise a distinct usability model for disaster apps, the quantitative testing conducted in Chapter 6 (3rd Manuscript) showed specific usability factors affecting users' intention to continue using disaster apps. Reflecting on life-safety in acute situations with the factors *app dependability*, *app utility*, and *UI output*, a disaster app should be designed in a manner that allows users to perceive that the app is capable of dependably delivering its purpose in an easily understandable output during a disaster situation. The context of low frequency of use relates to the characteristics of *UI graphics* and *UI output*—disaster apps should be designed in a way that users perceive that the app can be easily used without much complexity. As emphasised in Chapter 6, graphics should be kept to a minimum and the need for input reduced.

The results of the studies provide particular guidance for the design and development of disaster apps, addressing the second research question on guiding the enhancement of usability for end-users: *What guidance can end-user insights provide for the design of usable disaster apps?* Chapter 7 (4th Manuscript) presented a set of guidelines that answers the second question. From the findings of the usability inquiry, guidelines giving particular focus to end-users' concerns were developed. The guidelines, evaluated with app stakeholders, offer three main

recommendations to enhance the usability of disaster apps: (1) to make important information salient, (2) to consider cognitive load when designing apps, and (3) to build trust.

The four manuscripts have answered the research questions and addressed the research objectives. Table 8-1 summarises highlights from each manuscript and shows their alignment to the questions and objectives.

Table 8-1. Alignment of manuscripts to the research questions and objectives of the thesis.

Research questions	Research objectives	Manuscript and highlights
RQ1. How does usability influence citizens' perception of disaster apps?	RO1. To understand the state of research on mobile apps for public use in crisis management	1st Manuscript • The paper showed the types of apps that are used by the public during disasters, the interactions apps can foster, and the stages of the disaster cycle apps can be used in • More importantly, the manuscript emphasised the existing research gap on the usability of disaster apps
	RO2. To capture current perspectives on the usability of existing disaster apps from users	2nd Manuscript • The paper highlighted particular considerations for disaster apps. *App dependability* was introduced. The paper underlined that the perception of *app dependability* affects users' impression of usability due to the associated life-safety aspect of disaster apps • Other themes also surfaced from the analysis. These include users' opinions of content relevance, the existence of advertisements, resource usage, audio-interface, and in-app browsing • The paper also defined the constructs that will be tested in the next manuscript
	RO3. To establish which usability factors are important to citizens in their use of disaster apps	3rd Manuscript • The paper highlighted the importance of continuance intention for disaster apps • The paper presented a usability-continuance model, showing five usability factors affecting the continuance intention of disaster apps • *App dependability*, *app utility,* and *UI output* affect continuance intention positively, while *UI graphics* and *UI input* affect continuance intention negatively • The paper also showed that users raise distinct concerns, such as life safety and low frequency of use
RQ2. What guidance can end-user insights provide for the design of usable disaster apps?	RO4. To develop a set of usability guidelines from the insights of the end-users	4th Manuscript • A set of guidelines was presented, taking into consideration the issues raised by the users • The guidelines provide points to consider for developers and designers that address concerns raised by the users • The guidelines offered three main recommendations: (1) to make important information salient; (2) to consider cognitive load when designing apps; and (3) to build trust

8.2 IMPLICATIONS

Mobile apps are at the frontier for innovation in improving public preparedness and strengthening the link between citizens and authorities during disaster response (Gómez et al., 2013; Willems, 2012). The general public has access to many freely available disaster apps in the markets. There is also a growing research field interested in improving the technical capabilities of disaster apps. However, few studies explore the topic of usability. In this regard, this doctoral project provides three major contributions to the study of usability and disaster apps:

(1) It reiterates the importance of investigating usability of technological products for disasters. The research points out that studies on usability should not be limited to responders as the main end-users, but investigations should also be conducted on products that are meant for use by the public, such as disaster apps.
(2) The research also showcases the utilisation of user-centric data, emphasising the value of the end-users' perspectives in understanding usability.
(3) Furthermore, the doctoral project investigated usability with special attention to the context of disaster apps. It has produced a theoretical usability-continuance model to advance disaster app research and usability guidelines to encourage responsible design in practice.

These implications are discussed further in the next sections.

8.2.1 Usability and disaster app research

Research on technologies has often focussed on how a product performs functionally and operationally, often neglecting the ethical, legal, and social issues, including the usability of the products (Büscher et al., 2016; Park, Harada, & Igarashi, 2006). Similarly, in the research on disaster apps, usability is not prioritised. As evidenced in Chapter 3, most of the studies on mobile apps in crisis informatics literature emphasised improving functionalities, and only a few discuss the usability of apps. Usability, however, should not be treated as a separate addendum

to the research and development process of technologies (Göransson, Gulliksen, & Boivie, 2003). This doctoral project contributes to the body of knowledge for usability research as it has provided focussed outputs emphasising the usability of disaster apps, such as the conceptual framework for disaster app usability (Chapter 4), the usability-continuance model for disaster apps (Chapter 6), and the usability guidelines for disaster apps (Chapter 7).

The results from the manuscripts in this thesis run parallel with the discourse on usability for safety-critical systems. Information systems supporting emergencies operate in a different context than business-as-usual systems as they are used in dynamic environments and may be relatively unused until a crisis happens (Prasanna & Huggins, 2015). Likewise, as shown in Chapter 7, users anticipate using disaster apps irregularly and infrequently. Disaster app users can encounter issues similar to those highlighted in other safety-critical systems. This section elaborates some of the related issues raised on usability in the wider literature that complements and aligns with the findings from this research:

- A person's **working memory** is a limited resource. Users may commit errors when they need to remember large amounts of information (Prasanna et al., 2013). Supportive systems should be designed in a way that they do not rely heavily on users' memory (Stratmann & Boll, 2016). One of the guidelines presented in Chapter 7 highlights the need to leverage existing recognisable interfaces. Disaster apps may be used infrequently. The anticipated limited interaction should be taken into account, and designers should not rely on users' recall while operating the app. Utilising interfaces that are familiar to users can help address this issue.
- **System complexity** can slow down the perception, comprehension, and projection of information (Bolstad et al., 2006). This is especially so on interfaces that are infrequently used by users, and have too much information or too many options or menus that contribute to the complexity and hamper the effective use of a system's interface (Prasanna et al.,

2013). Complementarily, findings from the usability inquiry (Chapters 6 and 7) also expressed users' preference for a simple app with minimal graphics and a reduced need for input.

- **Inappropriate mental models** can also occur when users misunderstand information because the system operates in a mode that is inconsistent with their expectation (Prasanna et al., 2013). Multiple disaster apps are available in the market where the apps have different target user roles as well as diverse purposes (Gómez et al., 2013; Ridler-Ueno, 2013). Considering the context where the app is not expected to be used on a day-to-day basis, it is especially important that a disaster app communicates its purpose and delivers content that matches the user's expectation. As highlighted in the app store analysis study in Chapter 4, users expect disaster apps to deliver content that is proximate to purpose, time, and location.
- **Information overload** can occur when there is more information than can be processed by human capacity (Stratmann & Boll, 2016). Moreover, overload can also overburden a user's sensory capacity (Prasanna et al., 2013). Systems must consider the gap between the volume of data produced and the users' capabilities to process the needed information to make critical decisions (Endsley, 2000). When a disaster situation arises, a torrent of information regarding the hazard may become available to the user. Disaster apps must consider techniques that would help users to process and prioritise the information effectively. Guidelines presented in Chapter 7 offer such considerations to reduce cognitive load.
- **Attention tunnelling** occurs when users fixate on a specific component and become blinded to other surrounding elements (Bolstad et al., 2006). In the mobile app context, users are assumed to have the ability to perform multiple tasks, like walking, while using the app. However, an app with poor usability may require too much cognitive load from the user and impede them from performing the primary task at hand (Harrison et al., 2013). A disaster app must be designed in a way that it does not adversely impact users from making critical

decisions. Chapters 6 and 7 have highlighted that considerations should be given to simplify the use of disaster apps through minimising the need for input and rationalising the use of graphics.

- **Anxiety, fatigue, and other stressors** can adversely affect how users intake information; stressors can also strain attention and burden working memory (Stratmann & Boll, 2016). Systems used in high-stress environments, such as in disasters, must be able to support the efficient intake of information (Bolstad et al., 2006). This supports the findings in Chapter 4, where *app dependability* was identified as a unique factor affecting users' perception of the usability of disaster apps. Because of the life-safety concerns, users need to perceive that a disaster app can dependably deliver information when the situation arises.
- **Misplaced salience** is the tendency for users to prioritise information that is not actually important, and this can occur when critical information is not given sufficient prominence (Prasanna et al., 2013). Presentation affects how compelling or salient data is perceived to be (Stratmann & Boll, 2016). Disaster app users put importance on the content relevance and expect the app to focus on the most pertinent and appropriate information. Guidelines in Chapter 7 offer usability considerations that can make information more salient.

Carver and Turoff (2007) have emphasised the need for a user-centred approach when designing systems for emergency management. Issues that are encountered by responders in their systems may also be similar to issues faced by the public during their use of disaster apps. Studies on usability for technological tools in disasters should not be limited to products for responders but should also be conducted with products meant for the general public. Considering the rapidly changing dynamics of the app markets, user-centred research is needed (Bachmann et al., 2015). As highlighted in Chapter 3, there is a need for focussed research on engaging with the end-users to understand their interests in the usability and use of disaster apps. The manuscripts presented in this thesis contribute to the academic discourse by providing focussed attention on usability and disaster apps.

8.2.2 Usability and the perspectives of the end-users

Technological systems for communicating hazard information to the public should not neglect end-user needs during the conception and implementation of systems (Le Guenan et al., 2016). Despite the existence of multiple apps in the markets and the many proof-of-concept studies of these apps (Estuar et al., 2014; Sarshar et al., 2015), there is a lack of traction for these apps with end-users (Bopp et al., 2019; Spielhofer et al., 2019). The effectiveness of disaster tools relies not only on the functionalities of the apps but also on understanding users' behaviours and perspectives.

As disaster apps proliferate, these tools should be designed so they are perceived as usable by the end-users. Development of technological products must support the users with the particularities of their situations, and this requires a deep understanding of the users that only the users themselves can provide (Göransson et al., 2003). This thesis has shown different user-centric methods, such as app store analysis, usability inquiry, and surveys, in taking steps to understand the users. As shown in the manuscripts, the user-centric data derived from these methods have provided valuable insights into the usability of disaster apps.

- The **analysis of user reviews from the app stores** (in Chapter 4) provided inferences regarding the usability of disaster apps even before conducting primary data collection. Deviating from traditional usability evaluation methods, the app store analysis provided means to capture user perceptions on usability by examining large volumes of user-generated content. Though informal in structure, the reviews hold heterogeneous content that can provide useful information (Martin et al., 2016; Palomba et al., 2015). User reviews from app stores are not mere summaries or recommendations but contain actual self-reports on end-user experiences (Hedegaard & Simonsen, 2013). The analysis of user reviews (n=1,405) helped highlight the experience of the users of existing disaster apps. The analysis of unstructured user-generated content offered an

identification of aspects that are important to users that might otherwise be uncaptured through solicited means (Gebauer et al., 2008). For this study, it allowed for the conceptualisation of *app dependability* as a usability factor important to disaster app users. The emergence of the factor and other usability concerns have highlighted that life-safety is an essential consideration to users of disaster apps.

- The **usability inquiry** conducted with the prototype helped to obtain information from the users of their perceptions of disaster app usability. Usability inquiry is not about testing an artefact. It allows evaluators to deviate from rigid testing procedures and to focus on the users (Carter, 2007). Engagement with the users through the inquiry process provides an avenue to learn more about the users' likes, dislikes, needs, and understanding of a system (Folmer & Bosch, 2004). For this research project, conducting few (n=18) but intimate one-to-one sessions with the participants provided an opportunity to not only receive feedback on the prototype but also to understand the rationale behind the comments. The in-depth insights from the participants transcend beyond specific points of improvement for the prototype—they provide a broader understanding of the usability expectations users have for disaster apps. The participants' insights strengthened the quantitative usability-continuance model (Chapter 6), and they substantiated the disaster app usability guidelines (Chapter 7).
- The use of **survey questionnaires** is one of the most frequently used and recognised methods to understand the usability of technological products (Folmer & Bosch, 2004; Preece, 1993). A well-administered survey provides data that offers a good approximation of perceived usability (Hertzum, 2010). The use of questionnaires (in Chapter 6) allowed for the quantification of the sample's (n=271) subjective perceptions to be generalisable to the larger population of disaster app users. For this research project, the use of an online survey method resulted in a quantitatively sound usability-continuance model that specifically reflects the perceptions of disaster app users. The

model allows us to make contextualise the relationships of the usability factors and continuance intention for disaster apps that may not be reflected in generic IS models.

Establishing good usability for effective systems lies in focussing on the users. In the domain of disaster management, technological solutions need to match the users' needs and expectations (Fischer & Klompmaker, 2012). This research project has shown that the unstructured and structured data from the users is invaluable. User-centric data was used in this thesis for the conceptualisation and affirmation of usability factors for disaster apps, the contextualisation of a model, and the development of a set of guidelines that reflects the perspectives of users.

8.2.3 Contextualised usability model and guidelines

If technological models and concepts used in disaster management are too general, they are often lost in abstraction (Elmasllari, 2018). The domain of disaster management needs to adapt the concepts it uses to the particularities of the field. This research has produced two outputs that are contextualised for disaster apps that contribute to the body of knowledge for usability:

(1) A contextualised model that deconstructs usability into factors that are utilisable; and

(2) A set of usability guidelines that reflect the perspectives of end-users.

8.2.3.1 Contextualised usability-continuance model

This research has presented a usability model that deconstructs usability into factors that can be interpreted towards improving disaster apps. The model presented in Chapter 6 avoids some of the pitfalls of existing usability models in information systems literature. Several existing usability models do not provide antecedents that are insightful for improving technological artefacts. Some models look into usability in such a narrow micro-perspective approach that they can only offer piecemeal interpretations that improve individual apps under scrutiny and do not provide a cohesive approach to enhance usability (Hoehle & Venkatesh, 2015).

On the other hand, some models conceptualise usability in a broad aggregate manner that interpretation of its components can be confounding (Hoehle & Venkatesh, 2015; Islam et al., 2017). The model presented in Chapter 6 moved away from using standard measurements to interpret usability and, instead, investigated usability in a manner that deconstructs it into factors that are utilisable in improving design decisions. The quantitative model has shown that *app utility, app dependability, UI output, UI graphics, and UI input* are prominent usability factors that affect users' intention to continue and discontinue using the apps.

The model presented in Chapter 6 adapts Hoehle and Venkatesh's (2015) model into a disaster app context. The contextualised model shows that the relationships of the factors to continuance intention are different from that of generic apps. For example, *UI graphics* is shown to have a negative relationship with continuance intention. The results provide an inference that disaster app users can negatively perceive an app to have too many visual elements. Further inquiry revealed that a *fussy* app could leave an impression that the interface will be too confusing and complicated for use in acute scenarios, such as in a crisis.

The research has argued that the contexts of use of disaster apps is different from their generic counterparts and, thus, needs theories and concepts that account for the particularities of disaster apps. This research has provided a model that is adapted for disaster apps and that integrates the perspectives of users. The existence of a specialised model also enables the development of guidelines that supplement development insights for disaster app designers.

8.2.3.2 Contextualised guidelines

Industry guidelines already exist from popular mobile platforms, such as iOS and Android, to help developers create apps with a user-friendly standard interface (Apple Inc., n.d.-a; Google, n.d.-c). However, the dynamic disaster management environment imposes particular demands that may not be covered by generic guidelines. The design of disaster apps should consider the contexts of the low frequency and acute scenarios of use. When these rare occurrences happen,

the users must find good usability with the app to encourage continuance intention. These issues are addressed in the guidelines discussed in Chapter 7. The guidelines emphasise the need to: (1) make information salient, (2) consider cognitive load when designing disaster apps, and (3) build trust so as to anticipate limited interaction.

A few illustrations are given below as examples of design considerations that could be questioned or shaped from the guidelines. The screenshots are taken from the Red Cross Hazard App (New Zealand Red Cross, n.d.), the GeoNet App (GNS Science, n.d.), and the MetService App (MetService, n.d.).

- **Making information salient** – in a situation where there may be multiple pieces of hazard information streaming in simultaneously, important information should be made visibly salient. Visualisation techniques should help guide users to critical information as equal displays of importance will not help the user prioritise information. For example, in Figure 8-1, the screen shows three alerts expressed in the same format. The users are not directed to prioritise any particular one.

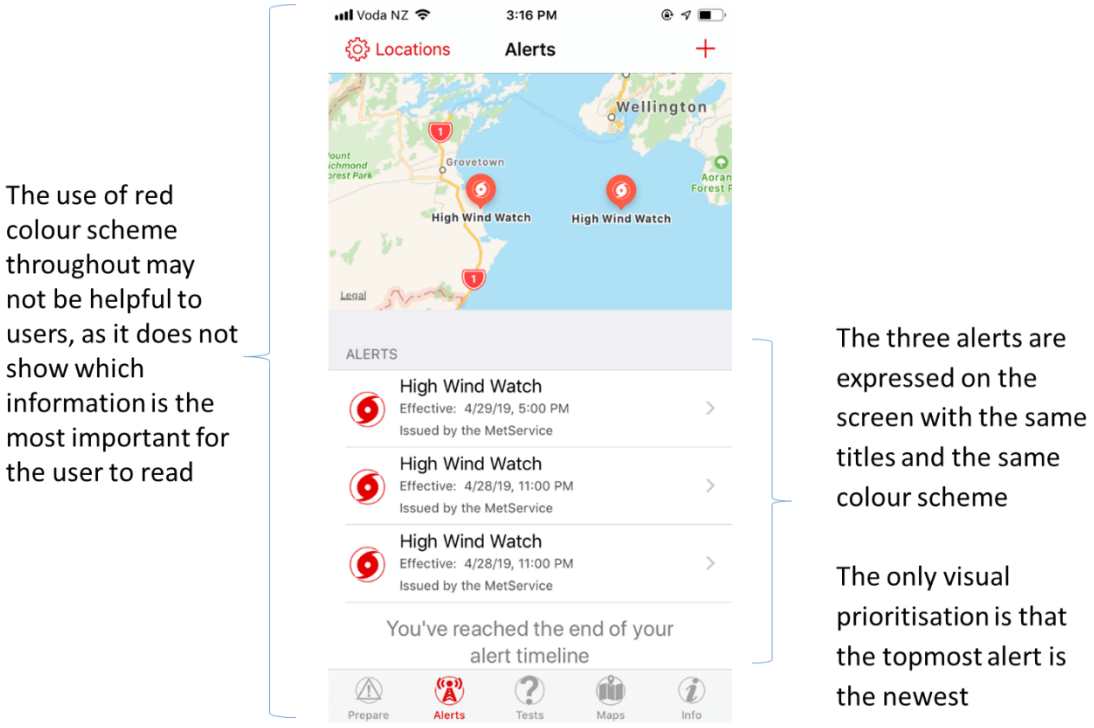

Figure 8-1. Illustration on equal display.

In contrast, in Figure 8-2, the most critical information is placed on the top of the screen. The colour contrast of red and white against the blue background also draws user focus to the top portion of the screen. These strategies help users to see that there is severe weather information.

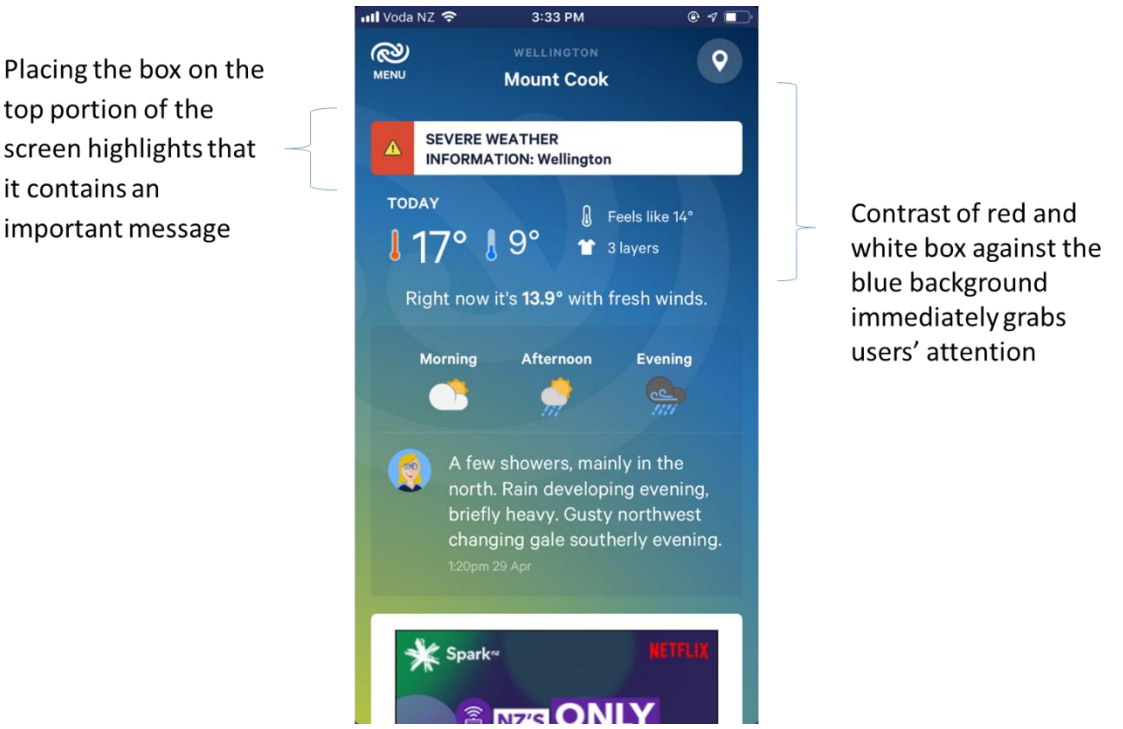

Figure 8-2. Illustration on making information salient.

- **Reducing cognitive load** – colours and symbols can be useful for making important details striking, but overuse of graphical emphasis may also add to the cognitive load of the user. As illustrated in Figure 8-3, despite the use of colours and symbols, the elements can become too overwhelming. The user might find it challenging to decipher which information to prioritise. Too much unprioritised information can create a negative experience for users. The guidelines in Chapter 7 have highlighted the need to keep the design neat and simple and to use meaningful visualisation to enhance interpretation of the content.

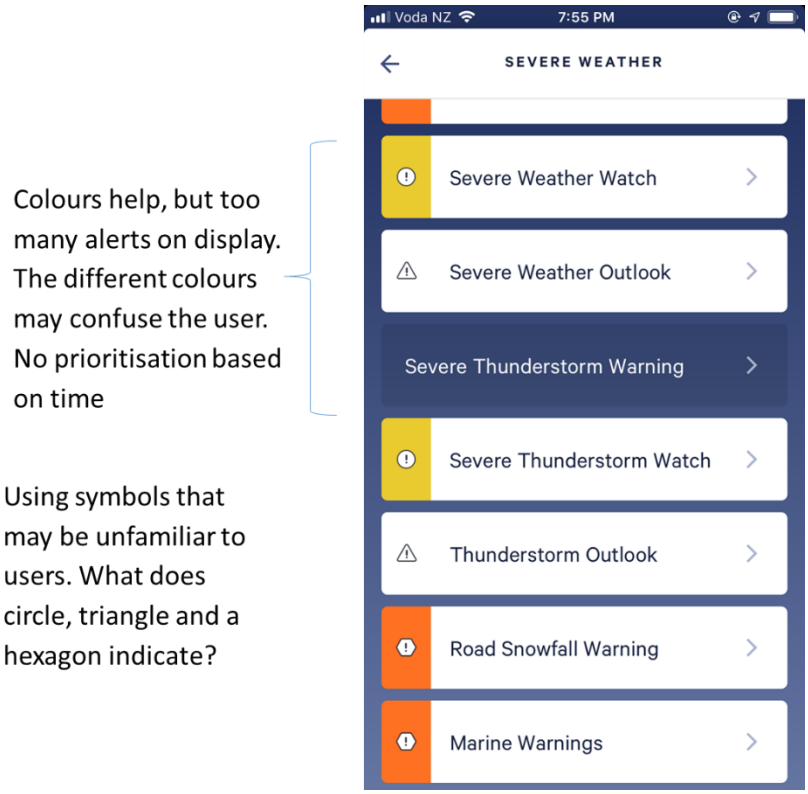

Figure 8-3. Illustration on cognitive load concern.

- **Building trust, anticipating limited interaction** – displaying relevant information can help users build a positive perception of an app even with limited interaction. Understanding users can guide design decisions. In Chapter 4, disaster app users recognise relevance to take shape in three forms: (1) purpose proximity, (2) spatial proximity, and (3) temporal proximity. Such insights provide nuances that disaster app information should be prioritised according to the apps' perceived relevance by the users. When the app fulfils its primary purpose but is still saturated by too much information, then time and location proximity should be considered. An earthquake app shows (see Figure 8-4) an excellent example of fulfilling the purpose of the app while displaying relevant content that is easily digestible.

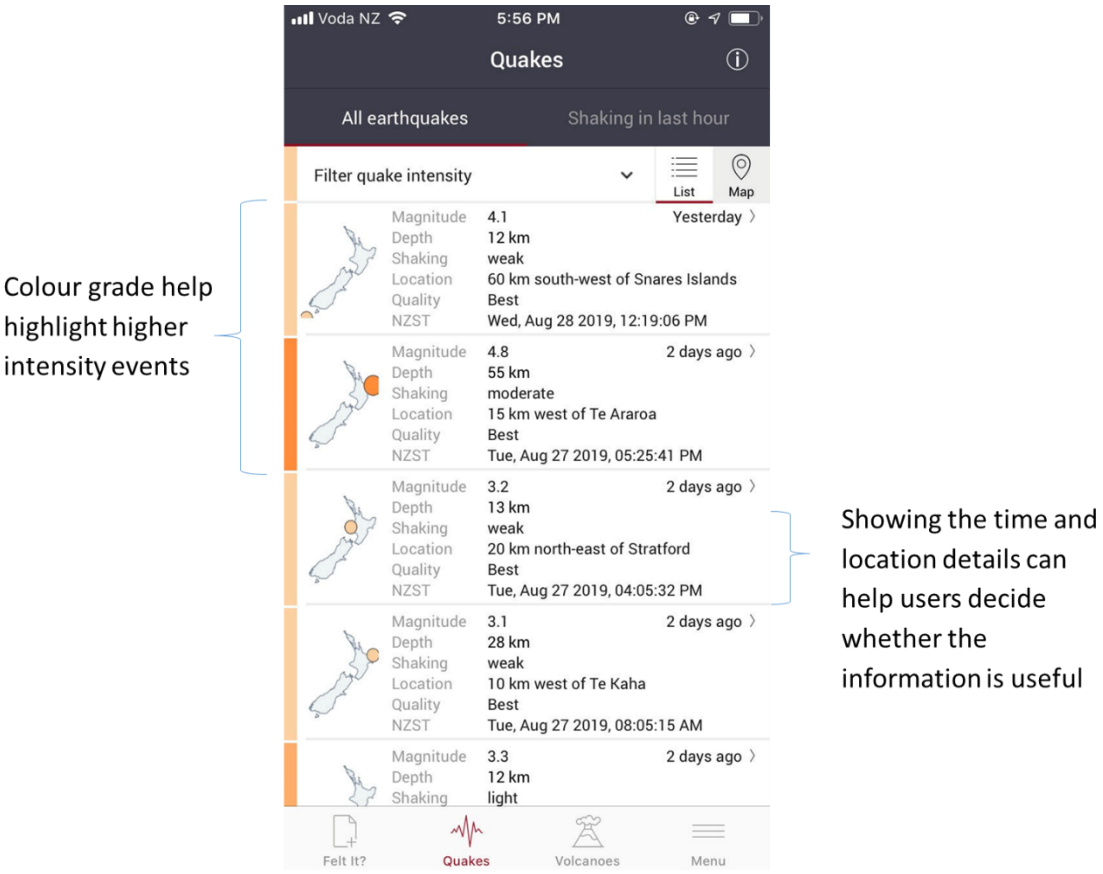

Figure 8-4. Illustration on content relevance.

The illustrations presented above have highlighted disaster-app-related issues and show the application of some of the key findings from the previous chapters. The guidelines in this research are not assumed to replace existing industry best practices but, rather, supplement guidance so designers and developers can consider the particularities of disaster apps.

While much research explores the potential functionalities of apps for disasters, the usability of these apps is often overlooked. This research contributes to the body of knowledge on usability and disaster apps through the various highlights from four manuscripts. Taken together, the thesis also provides implications for a broader body of usability research. It has argued for usability research on technologies for the public, it has demonstrated the value of using user-centric data, and it has contextualised a model and a set of guidelines specific for disaster apps.

8.3 IMPACTS OF THE RESEARCH

I have presented parts of the research in a range of formats and engaged with various audiences. The manuscripts in this thesis have been published or submitted to international journals, and I have presented and published parts of the research in international conferences for information systems in crisis response and management. I have also delivered award-winning short-format presentations on my research through the QuakeCoRe [10] Lightning Talks and the Massey University Three-Minute-Thesis competition.

The systematic literature review manuscript (Chapter 3), published in 2017, provided a summary of the state-of-the-research for disaster apps. It organised the literature in a clear format that has paved the discussion for disaster apps, critical context technologies, and usability. As of writing, the manuscript has been cited at least 14 times in peer reviewed studies. These include papers on earthquake apps (for example, Buitrago, Rodriguez, Obando, & Fernandez, 2019; Kolathayar et al., 2018), in social media in crisis-context papers (for example, Li, Yang, Zhang, & Zhang, 2019; Park, Kim, & Choi, 2018), and in usability studies (for example, Setiawan et al., 2019). Furthermore, it has been used to argue for the need to conduct further research of citizens' perceptions on apps during disasters (Appleby-Arnold et al., 2019).

The other three papers have been submitted or are being prepared for publication and, when published, will contribute to the working knowledge on disaster app usability. For example, only a few studies on the usability of mobile apps have studied the underlying factors of usability (Hoehle et al., 2015). The second manuscript (Chapter 4) conceptualised new usability themes that reflect the insights from disaster app reviews, and the third manuscript (Chapter 6) furthers the discourse on disaster app usability and its factors by showing the relationship of the factors to continuance intention. To the best of my knowledge, no other academic publication has

[10] QuakeCoRE (2019), the New Zealand Centre for Earthquake Resilience, is a Centre of Research Excellence (CoRE) aiming to improve earthquake resilience of communities through research.

studied the continuance intention of disaster apps. Finally, although many research publications have provided specific guidelines for different app genres (Ahmad et al., 2018), no deliberate usability guidelines have been written for disaster apps. The fourth manuscript (Chapter 7) sought to address this by developing a set of guidelines that would enhance the usability of disaster apps for end-users.

Aside from theoretical contributions, this research work has practical implications. I have participated in the New Zealand Red Cross Hazards App working group and the New Zealand Common Alerting Protocol working group. The two groups involve different stakeholders, such as the Red Cross, Civil Defence Groups, and government Ministries, working to standardise a common language and platform for public alerting in New Zealand. Involvement in these groups has allowed me to have a grounded understanding of the technological advancements in warnings and alerting in New Zealand. At the same time, the research has allowed me to share knowledge on the public's perceptions of apps and alerts. Having developed the knowledge of usability and end-user perspectives of disaster apps through this doctoral project, I have also storyboarded an instructional video for the New Zealand Red Cross Hazards App. The success of this video was recognised by the Red Cross and Red Crescent Societies' Global Disaster Preparedness Center (GDPC). The video was added to the GDPC's Universal App Program Toolkit (The American Red Cross, 2017).

This doctoral work has also caught interest in this research through the publishing of stories in a magazine and mainstream media (Morton, 2018; Shadwell, 2019). I have also engaged with the broader community through presentations at the Wellington City Library and Massey University. These publications and engagements with various stakeholders are early indications of the significant impacts of this doctoral research.

8.4 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Several limitations of this doctoral project need to be acknowledged. The disaster apps focussed on in the study are one-way communication tools. This research project has acknowledged that the socio-mobile environment is challenging the one-way disaster communication paradigm (Andersen, 2016; Tan et al., 2017). With the existence of social media and mobile apps, the public can engage in different types of interactions. However, due to practical constraints, I defined the scope of the research to one-way communication tools. Future research could study the usability of other types of disaster apps, especially those that allow interaction between different stakeholders.

The applicability of the model must take note of the contexts of use of different types of disaster apps. For example, the expectation for minimum *UI input* is anticipated for apps that are meant to disseminate warnings and alerts. However, if an app is intended to foster multiple interactions, the users may demand differently for *UI input*. Another research trajectory, as highlighted in Chapter 3, is to look at popular and every-day-use apps and how these can be augmented for use during disasters. For example, Facebook is launching local alerts that would allow emergency responders to notify users through their Facebook apps (Samenow, 2019). Future research could also look at the usability of these added functionalities in general apps.

The usability-continuance model presented in this study was based on a relatively new model from Hoehle and Venkatesh (2015). Older workplace-based theories on usability and continuance intention have limits for the disaster apps as they do not take mobility into account. However, it may be worthwhile to explore the context of usability and continuance intention to existing psychology and information system theories that did not originate from stationary workplace-based settings. As highlighted in Chapter 7, the theory of planned behaviour and Herzberg's (1959) motivational factors are areas to explore in future studies.

Only the higher-level items of the usability model were quantitatively tested with the dependent variable, continuance intention. It was not possible to quantitatively investigate all the factors of the model from the app store analysis manuscript. The whole model had 25 factors in the lower order level, seven factors in the higher order level, and one dependent variable. In total, if at least four reflective items represent each element in the model, the survey instrument would have contained 132 items. The two pilot studies, conducted before the survey was launched, found the questionnaire with 132 items to be too lengthy. The survey had to be cut short to enhance the participants' response rate. I decided to drop the lower level elements and only to test the higher level constructs towards the continuance intention variable. Future research could investigate the lower order constructs and how these contribute to the model.

The prototype and the subsequent inquiry has its limitations. Due to the researchers' capabilities, only a medium-fidelity prototype on an iOS platform was developed for the usability inquiry. Future research could move the design and development of the app forward into a fully functioning app. However, further usability studies will be needed since the results of the inquiry conducted in this project only captured users' perceptions and not the actual usability. Future research that will develop the app forward will benefit from conducting traditional usability evaluation methods that would provide observable and quantifiable metrics. I also acknowledge the possible partiality of conducting the inquiry myself with the participants. Due to social desirability bias, participants in usability studies may refrain from providing criticism for fear of offending the researcher (Natesan et al., 2016). Although steps were taken to minimise the bias, future research could avoid this bias by employing other usability evaluation methods, such as the think-a-loud method, to triangulate the results further (McDonald, Zhao, & Edwards, 2013).

Finally, none of the methods in this study purposefully tested the context of the acute scenario of use. The research has highlighted that in critical situations, the users can be subjected to stress and, consequently, have reduced cognitive load. Future studies could explore the context

of a high-pressure environment through well-detailed usability testing. Some ideas to consider would be laboratory testing or field testing. A laboratory test could involve simulating stress by subjecting the participants in some physical stimulus, like exercise, as they set to complete tasks through the app. Field testing can be conducted by recruiting willing individuals to download the app and then subject the participants to respond to notifications when randomly prompted. However, usability testing that induces stress must carefully evaluate ethical considerations.

8.5 CONCLUSION

Two research gaps were identified at the outset of this thesis. First, the existing studies on usability and continuance intention do not take into account the particular context disaster apps are used in, and, second, most of the studies on disaster technologies consider responders as the target users and not the general public.

This doctoral project addressed the first research gap by providing theoretical contributions focussing on the usability and continuance intention of disaster apps. The state-of-the-research in this field was described in the systematic literature review (Chapter 3). Then, the concept of *app dependability* was introduced, highlighting the importance of considering the context of life-safety when designing for disaster apps (Chapter 4). Furthermore, the research has presented a usability-continuance model that highlighted the usability factors that affect continuance intention (Chapter 6). The model, set in the particular context of one-way communication disaster apps, showed that maximising *app dependability*, *app utility*, and *UI output*, and minimising *UI graphics* and *UI input* would promote continuance intention.

This academic study addressed the second research gap by prioritising the end-users' perspectives in understanding the topics of usability and continuance intention. The thesis used user-centric data from 1,405 user reviews from 58 existing disaster apps, 271 responses from the usability survey, and 18 interviews from the usability inquiry. After obtaining a thorough

understanding of the users' perspectives, this doctoral project finally presented a set of guidelines that could enhance the usability of disaster apps for end-users (Chapter 7).

The manuscripts presented in this thesis have limitations but also highlight areas for future research. The publications and the researchers' engagements with various stakeholders show early indications of the significance of the doctoral research to contribute to academia as well as to broader practice. The discourse from the four manuscripts and the overall doctoral project will move the academic discussion forward on the topics of usability and disasters apps.

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APPENDIX A. HUMAN ETHICS NOTIFICATIONS

1. Low risk notification for usability survey distribution

Human Ethics Notification - 4000017983
1 message

humanethics@massey.ac.nz <humanethics@massey.ac.nz> Tue, Jun 20, 2017 at 6:19 AM
To: A.Lindsay@massey.ac.nz, Marion.Tan.1@uni.massey.ac.nz, R.Prasanna@massey.ac.nz, J.H.Liu@massey.ac.nz
Cc: M.E.Thomas@massey.ac.nz

HoU Review Group
Prof James Liu

Ethics Notification Number: 4000017983
Title: Usability of Disaster Apps Survey

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

If situations subsequently occur which cause you to reconsider your ethical analysis, please log on to http://rims.massey.ac.nz and register the changes in order that they be assessed as safe to proceed.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director (Research Ethics), email humanethics@massey.ac.nz. "

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Dr Brian Finch
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

Appendix A

2. Low risk notification for usability inquiry evaluation

Human Ethics Notification - 4000019856

1 message

humanethics@massey.ac.nz <humanethics@massey.ac.nz> Wed, Jul 25, 2018 at 9:34 PM
To: Marion.Tan.1@uni.massey.ac.nz, R.Prasanna@massey.ac.nz, R.A.Flett@massey.ac.nz
Cc: humanethics@massey.ac.nz

HoU Review Group
A/Pro Ross Flett

Ethics Notification Number: 4000019856
Title: Usability Evaluation on a Disaster App Prototype

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz. "

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

3. Low risk notification for usability guidelines evaluation with stakeholders

Human Ethics Notification - 4000021393

1 message

humanethics@massey.ac.nz <humanethics@massey.ac.nz> Tue, Jul 9, 2019 at 3:42 PM
To: Marion.Tan.1@uni.massey.ac.nz, R.Prasanna@massey.ac.nz, R.A.Flett@massey.ac.nz
Cc: humanethics@massey.ac.nz

HoU Review Group
A/Pro Ross Flett

Ethics Notification Number: 4000021393
Title: Stakeholder Feedback on Usability Guidelines

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz. "

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

4. Low risk notification for usability guideline evaluation follow-up

Human Ethics Notification - 4000021595
1 message

humanethics@massey.ac.nz <humanethics@massey.ac.nz> Mon, Aug 26, 2019 at 3:43 PM
To: Marion.Tan.1@uni.massey.ac.nz, R.Prasanna@massey.ac.nz, R.A.Flett@massey.ac.nz
Cc: humanethics@massey.ac.nz

HoU Review Group
A/Pro Ross Flett

Ethics Notification Number: 4000021595
Title: Usability for Disaster Apps: Follow-up Feedback from Stakeholders on Usability Guidelines

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz. "

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

APPENDIX B. SUMMARY OF ARTICLES REVIEWED FOR THE SYSTEMATIC LITERATURE REVIEW

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
1	Adam (2012)	Social media alert and response to threats to citizens (SMART-C)	One	SMART-C	Presentation of the SMART-C system
2	Adam et al. (2012)	Spatial computing and social media in the context of disaster management	One	SMART-C	Discussion of spatial computing and social media from the perspective of the SMART-C system
3	Ai et al. (2015)	A dynamic decision support system based on geographical information and mobile social networks: A model for tsunami risk mitigation in Padang, Indonesia	One	DDSS	Presentation of a system for early tsunami warning
4	Auferbauer et al. (2015)	Moving towards crowd tasking for disaster mitigation	Multiple	American Red Cross Apps PulsePoint RE-ACTA	Presentation of RE-ACTA app; includes discussion of similar apps
5	Besaleva & Weaver (2014)	CrowdHelp: m-Health application for emergency response improvement through crowdsourced and sensor-detected information	Multiple	American Red Cross Apps CrowdHelp GeoCommons Help Call iTriage Ushahidi	Presentation of CrowdHelp; includes review of other applications
6	Besaleva & Weaver (2013)	Applications of social networks and crowdsourcing for disaster management improvement	Multiple	CrowdHelp Ushahidi	Presentation of CrowdHelp; includes review of other applications
7	Boulos et al. (2011)	Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples.	None		Review of different domains on mobile applications

Appendix B

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
8	Brussee & Pouwelse (2015)	Survey of robust and resilient social media tools on Android	None		Review of robust social media tools on Android
9	Camarero et al. (2009)	Disasters 2.0 application of Web 2.0 technologies in emergency situations	One	Disasters 2.0	Presentation of a social portal (architecture) that integrates and shares user generated information
10	Cooper et al. (2015)	Twitter as a potential disaster risk reduction tool.	None		Review of Twitter and other tools for crisis management
11	Crowe (2011)	The social media manifesto: a comprehensive review of the impact of social media on emergency management.	None		Explanation of social media use and discussion of mobile phone movement
12	Estuar et al. (2014)	Validating UI through UX in the context of a mobile-web crowdsourcing disaster management application	One	eBayanihan	Usability study of a mobile app
13	Frommberger & Schmid (2013)	Crowdsourced bi-directional disaster reporting and alerting on smartphones in Lao PDR	One	Mobile4D	Presentation of Mobile4D
14	Gibson et al. (2014)	Combining big social media data and FCA for crisis response	Multiple	American Red Cross Apps ATHENA-App CrowdHelp Ushahidi	Presentation of ATHENA app; includes discussion of various apps
15	Gómez et al. (2013)	A review on mobile applications for citizen emergency management	Multiple	*Generic discussion of multiple apps*	Review of mobile applications for citizen emergency management
16	Goolsby (2010)	Social media as crisis platform	None		Review of social media and other platforms for crisis mapping

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
17	Handmer et al. (2014)	Updating warning systems for climate hazards: Can navigation satellites help?	One	QZSS Mobile	Discussion on how satellite navigation helps warning systems; app for interpreting and displaying info
18	Havlik et al. (2013)	Robust and trusted crowd-sourcing and crowd-tasking in the future internet	One	MDAF	Evaluation of volunteer networks supported by smartphones
19	Hodapp et al. (2013)	Damage tracker: A cloud and mobile system for collecting damage information after natural disasters	One	Damage Tracker	Presentation of the Damage Tracker system and mobile app
20	Imran et al. (2015)	A processing social media messages in mass emergency: A survey	None		Review of crowdsourcing
21	Karnatak et al. (2012)	Spatial mashup technology and real time data integration in geo-web application using open source GIS – a case study for disaster management	None		Presentation of a geo-spatial integrated architecture for mobile disaster management
22	Link et al. (2013)	Twitter integration and content moderation in GDACSmobile	One	GDACSMobile	Presentation of the GDACS and GDACSMobile system
23	Liu et al. (2011)	Going beyond citizen data collection with Mapster: A mobile+cloud real-time citizen science experiment	One	Mapster	Presentation of Mapster
24	Ludwig et al. (2015)	Crowdmonitor: Mobile crowd sensing for assessing physical and digital activities of citizens during emergencies	Multiple	CROSS CrowdHelp CrowdMonitor DIADEM Mobile4D Ushahidi	Presentation of CrowdMonitor system and app; includes discussion of various crowd sensing apps
25	Ludwig et al. (2015)	CrowdMonitor: Monitoring physical and digital activities of citizens during emergencies	Multiple	CROSS CrowdHelp CrowdMonitor DIADEM Mobile4D Ushahidi	Presentation of CrowdMonitor system and app; includes discussion of various crowd sensing apps

Appendix B

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
26	Markenson et al. (2014)	American Red Cross Digital Operations Center (DigiDOC): An essential emergency management tool for the digital age	None		Discussion of the concept of a digital operations centre; with a mobile apps component
27	Meissen & Fuchs-Kittowski (2014)	Crowdsourcing in early warning systems	One	Unnamed prototype	Presentation of a prototype and discussion of the role of crowdsourcing in early warning systems
28	Meissen & Fuchs-Kittowski (2014)	Towards a reference architecture of crowdsourcing integration in early warning systems	One	Unnamed prototype	Presentation of prototype; an integrated architecture for crowdsourcing in early warning systems
29	Mocanu et al. (2012)	Ubiquitous multi-agent environmental hazard management	One	JADE	Presentation of a model that integrates the robustness of JADE and the Android OS
30	Moreira et al. (2015)	An experimental evaluation of a crowdsourcing-based approach for flood risk management	None		Presentation of a modest evaluation system for verifying Volunteered Geographic Information
31	Murthy et al. (2014)	Capacity building for collecting primary data through crowdsourcing - An example of disaster affected Uttarakhand State (India)	One	MANU	Presentation of a damage assessment app – MANU
32	Poblet et al. (2014)	IT enabled crowds: Leveraging the geomobile revolution for disaster management	Multiple	CrisisTracker Imageclicker OpenStreetMap mobile Sahana TaskMeUp Tweetclicker Ushahidi	Review of approaches and tools to crowdsourcing
33	Poblet et al. (2014)	Crowdsourcing tools for disaster management: A review of platforms and methods	None		Review of platforms and methods

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
34	Reuter et al. (2015)	SOMAP: Network independent social-offline-map-mashup	Multiple	Disaster Alert Earthquake Alert! ELERTS Hurricane Hound MobileMap Outbreaks near me Real Time Warning SOMAP ubAlert	Presentation of SOMAP; includes discussion of other mobile apps
35	Reuter et al. (2015)	XHELP: Design of a cross-platform social-media application to support volunteer moderators in disasters	Multiple	Hands2Help Ushahidi XHELP	Review of social media use and proposes a platform
36	Reuter et al. (2015)	Social-QAS: Tailorable quality assessment service for social media content	None		Presentation on how tailorable QAS can assist the use of citizen-generated information
37	Romano et al. (2016)	Designing mobile applications for emergency response: Citizens acting as human sensors	Multiple	ELERTS Emergency Alert FEMA HelpBridge Motorola Alert My112 SafetyGPS SignAlert	Review of apps and presents the usability test of an app
38	Schimak et al. (2015)	Crowdsourcing in crisis and disaster management – challenges and considerations	One	RE-ACTA	Presentation of RE-ACTA; includes discussion of the relevance of crowdsourcing
39	Schulz et al. (2012)	Crisis information management in the Web 3.0 age	Multiple	Incident reporter Report classifier	Discussion of linked open data, crowdsourcing and presents applications that utilise them for emergency management

Appendix B

	Author (Year)	Title	# of apps discussed	Name of mobile apps discussed	Objective of the paper
40	Shams et al. (2015)	On integrating social and sensor networks for emergency management	None		Review of existing management systems; introduces an architecture proposal
41	Shih et al. (2013)	Democratizing mobile app development for disaster management	Multiple	Donate-N-Request WeReport	Presentation of architecture and discussion of prototypes
42	Slavkovikj et al. (2014)	Review of wildfire detection using social media	One	Firemash	Presentation of a platform for wildfire detection; reviews current systems for using social media for fire detection
43	Soden et al. (2014)	Resilience-building and the crisis informatics agenda: Lessons learned from open cities Kathmandu	One	OpenStreetMap Mobile	Presentation of a case study using OpenStreetMap in Nepal
44	Stollberg & De Groeve (2012)	The use of social media within the Global Disaster Alert and Coordination System (GDACS)	One	GDACSMobile	Presentation GDACSMobile and discussion of Twitter search
45	Szczytowski (2014)	Geo-fencing based disaster management services	None		Presentation of architecture, use case, and trial
46	Weaver et al. (2012)	Applications and trust issues when crowdsourcing a crisis	One	Unnamed prototype	Presentation of a system
47	Willems (2012)	Sustainable futures for learning in a climate of change: Mobile apps, social media, and crisis informatics during emergencies and disasters	None		Discussion on m-learning, apps, crisis informatics and mobile social media
48	Yang et al. (2014)	Disaster mitigation by crowdsourcing hazard documentation	One	Hazard documenter	Presentation of a case on app use for hazard documentation
49	Zheng et al. (2011)	Applying data mining techniques to address disaster information management challenges on mobile devices	One	ADSB	Presentation of a native mobile system; argues for native mobile apps vs. mobile browsers

APPENDIX C. LIST OF APPS INCLUDED IN THE SYSTEMATIC LITERATURE REVIEW

	App Name	Primary Interaction	Primary Purpose Classification
1	ADSB	Many-to-one	Collating reports
2	American Red Cross Apps	One-to-many	Alerting and information
3	ATHENA-App	Many-to-one-to-many	Collating reports
4	CrisisTracker	Many-to-one	Collating reports
5	CROSS	One-to-many-to-one	Crowdsourcing
6	CrowdHelp	Many-to-one	Collating reports
7	CrowdMonitor	One-to-many-to-one	Crowdsourcing
8	Damage Tracker	Many-to-one	Crowdsourcing
9	DDSS	One-to-many	Alerting and information
10	DIADEM	Many-to-one	Crowdsourcing
11	Disaster Alert	One-to-many	Alerting and information
12	Disasters 2.0	Many-to-many	Collaborating platform
13	Donate-N-Request	Many-to-one-to-many	Collaborating platform
14	Earthquake Alert!	One-to-many	Alerting and information
15	eBayanihan	Many-to-many	Collaborating platform
16	ELERTS	One to one	Notifying
17	Emergency Alert	One-to-many	Notifying
18	FEMA	One-to-many	Alerting and information
19	Fire Mash	One-to-many	Alerting and information
20	GDACSMobile	Many-to-one-to-many	Collating reports
21	GeoCommons	Many-to-many	Collaborating platform
22	Hands2Help	Many-to-one-to-many	Collaborating platform
23	Hazard documenter	Many-to-one	Crowdsourcing
24	Help Call	One-to-many	Notifying
25	HelpBridge	One-to-many	Notifying
26	Hurricane Hound	One-to-many	Alerting and information
27	Imageclicker	One-to-many-to-one	Crowdsourcing
28	Incident reporter	Many-to-one	Collating reports
29	iTriage	One-to-many	Alerting and information
30	JADE	One-to-many-to-one	Crowdsourcing
31	MANU	Many-to-one	Crowdsourcing
32	Mapster	Many-to-one-to-many	Crowdsourcing
33	MDAF	Many-to-one-to-many	Crowdsourcing
34	Mobile4D	One-to-many-to-one	Crowdsourcing
35	MobileMap	Many-to-many	Collaborating platform
36	Motorola Alert	One-to-many	Notifying
37	My112	One to one	Notifying
38	OpenStreetMap mobile	Many-to-many	Collaborating platform
39	Outbreaks near me	One-to-many	Alerting and information

	App Name	Primary Interaction	Primary Purpose Classification
40	Prototype - Meissen & Fuchs-Kittowski	Many-to-one	Crowdsourcing
41	Prototype - Weaver et al	Many-to-one	Collating reports
42	PulsePoint	One-to-many	Alerting and information
43	QZSS Mobile	One-to-many	Alerting and information
44	RE-ACTA	One-to-many-to-one	Crowdsourcing
45	Real Time Warning	One-to-many	Alerting and information
46	Report classifier	Many-to-one	Collating reports
47	SafetyGPS	Many-to-many	Collaborating platform
48	Sahana	Many-to-many	Collaborating platform
49	SignAlert	Many-to-many	Collaborating platform
50	SMART-C	Many-to-many	Collaborating platform
51	SOMAP	Many-to-many	Collaborating platform
52	TaskMeUp	One-to-many-to-one	Crowdsourcing
53	Tweetclicker	One-to-many-to-one	Crowdsourcing
54	ubAlert	One-to-many	Alerting and information
55	Ushahidi	Many-to-many	Collaborating platform
56	WeReport	Many-to-one	Crowdsourcing
57	XHELP	Many-to-one-to-many	Collating reports

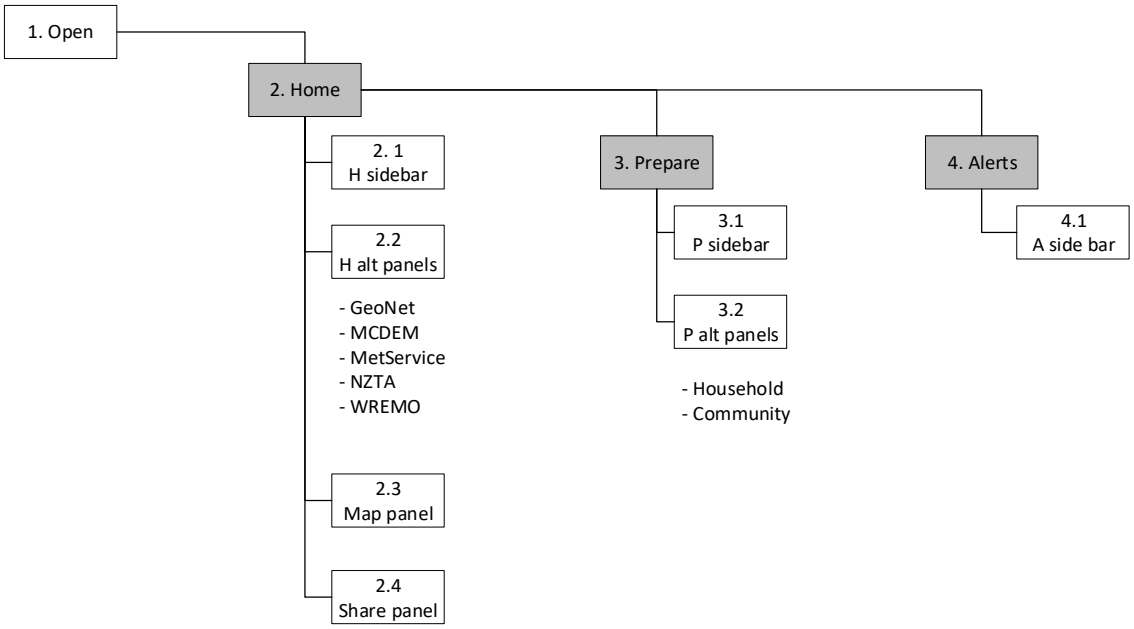
Appendix D. Frequency of observed codes per app

	Apps																																																									
Codes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	Total
Content relevance	14	14	20	14	23	7	8	25	8	10	6	15	15	7	12	21	10	10	19	23	15	17	19	17	10	16	24	14	22	20	37	11	21	18	12	14	5	14	7	7	6	12	24	12	14	17	22	4	15	18	23	6	12	12	21	28	18	32	897
De-emphasis on user settings	1	1	2	1	9	3	3	3		6	4	3	3	2	1	2	2		9	4	10	1	6			1	1	6	7	12	4			1	2	1		1			1	6	9		2	2	2		1	1	1	1	3	2	9	11	3	1	167
Instant start	2	1				5	1			3		1	3	6	4			4	1	1			1	11	3	1	4			5			2	1	2	1		1		6	20		1			1	3	3	1	1	1		13	5		2		4	125
Error-free operation	1	3	1	1		3	3	2		3	2	1	1	1	4	1		1	1	1	2	2	11	11		1	3	1	1	2	1	2	1	3	3		1	2	1	6	1			4		3	3	1			3	1	7	2	1	1		1	112
Logical path		1		2	4		3	1	1	3	2	2	1			2		1			2	1	2	7	4		6	4	4	1	1	1	3	1	2	4	2	2		1	2	2	2	1	1		2			2			1	2	6	2		1	95
Data preservation				1		6				1							1	1	2	10		1	3	3	26		1	2		6	1									4						1		1			1	2		6	1	4	1	1	87
Phome resource usage		2		1	1	1							1	2	1			5		1			4			1				1	2	3	1			1		2		3	1			2		1			1	1	2	7	2	4		1	7		62
Collaboration			1				1	1		1										2	2					1	4		1			2			1									2			3		5						3	4	1		35
Control obviousness		1			1		1	1	1		1		1				1		8	1	2			1	3			2	2	1	4			1		1		3	1	2		1	2			1	1		1	1	1		1		1	6	2		58
Aesthetic graphics				2	1			2		3										2	2		1	2		1		4	5	1	1	1							1			1	1	2							1		1	1	1	1			38
Concise language	1											10	2	1		2					1	1		1				1	2		5			1			1					1				1	1	1		2		1			1				37
Effort minimisation					1	1		3			1						1				2			2	2		1		1	3	1					1				2	1						1	1	1	1		1		1					29
Fingertip-size controls		1	4	2			1	1			1						2		2				1							3				3				1								2	2					1				3	1	1	32
Minimal advertisements	2	1		3	1										3	2	1	2	1								2															1		1	1				1	1		4							27
Search										1	2				2	2											3		1					3		1						2												1					18
Minimal external links																											2	1						1				1		1		1								5	1				1	2		1	17
User-centric terminology								1				1								2	1		1	2				1			2	1		1														1		1									15
Top-to-bottom structure										3					1						2			3			1													1				1							1							2	15
Fingertip-size controls							1	1							1		1						2	2								3	1											1						1									14
Orientation				1		1		2															1								1									1				1									1		1				10
Clean exit															1							1			1																3																		6
Standardised UI element							1								1							1											1						1					1															6
Branding																																										1		1															2
Realism																																																											0
Subtle animation																																																											0

New theme | One or more observation

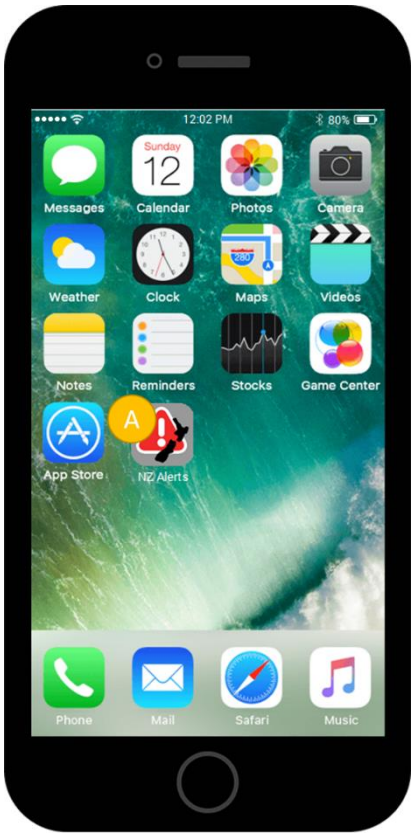
APPENDIX E. SCREEN DOCUMENTATION OF PROTOTYPE

Site map:



Screens:

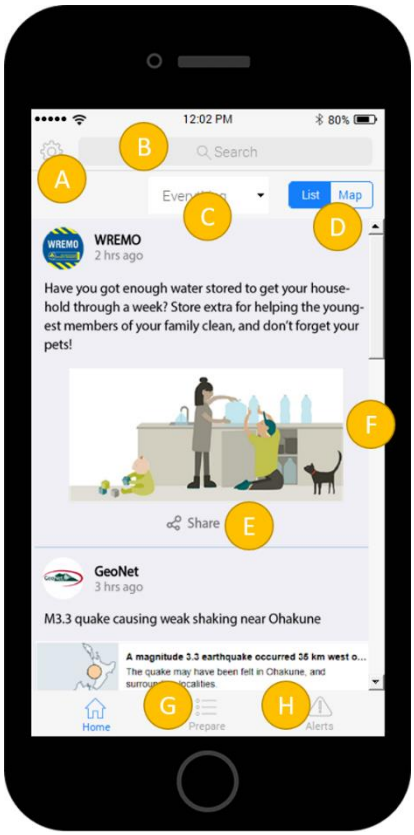
1. Open



Interactions

		Section
A	On Click: goes to <section> with effect: pop →	2 Home

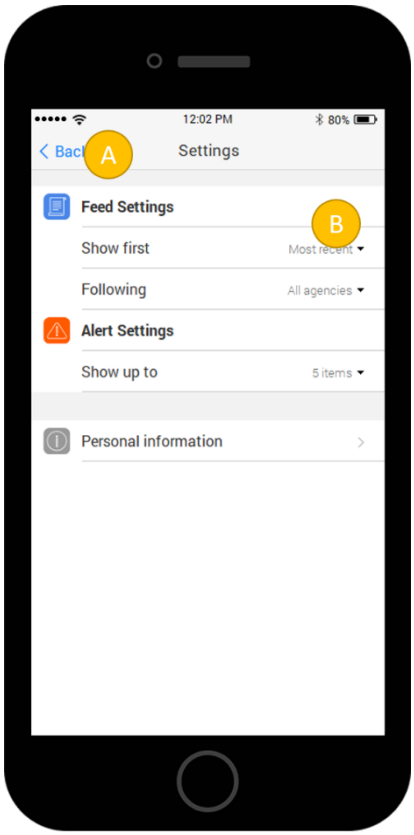
2. Home



Interactions

		Section
A	On Click: goes to <section> with effect: slide right →	2.1 H sidebar
B	On Click: pops up keyboard	
C	On Click: pops up selection: All, GeoNet, MCDEM, MetService, NZTA, WREMO On selection: shows <section> panel →	2.2 H alternate panels
D	On click: goes to <section> →	2.3 map panel
E	On click: goes to share panel →	2.4 share panel
F	On scroll: Scrolls through the page	
G	On Click: goes to <section> →	3 Prepare
H	On Click: goes to <section> →	4 Alerts

2.1. H sidebar

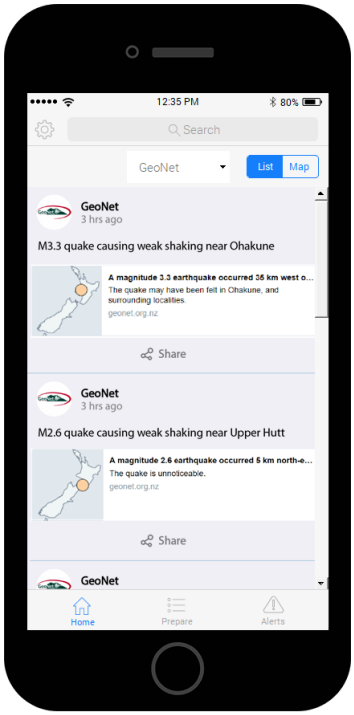


Interactions

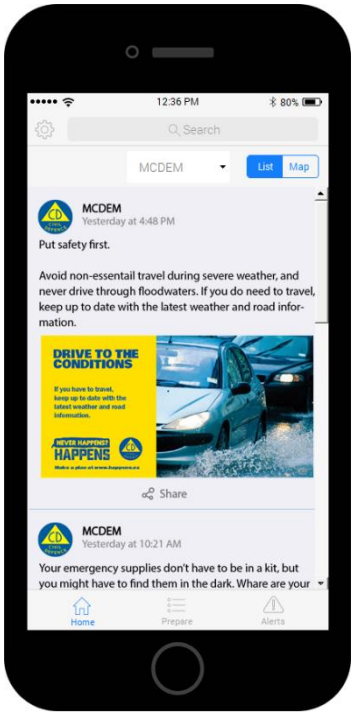
		Section
A	On Click: goes to <section> with effect: slide left →	2 Home
B	On Click: pops up selection: most recent, by proximity	

2.2. H alternate panels

GeoNet

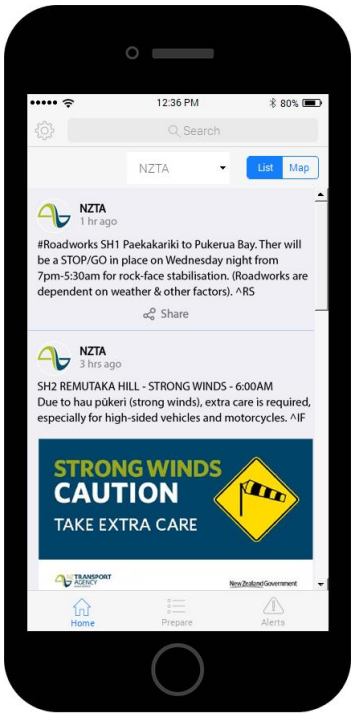


MCDEM

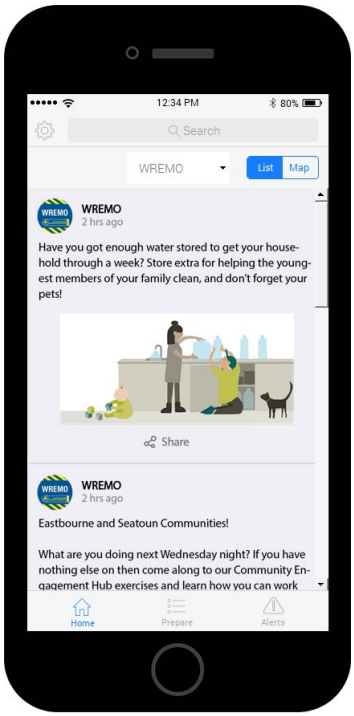


MetService

NZTA

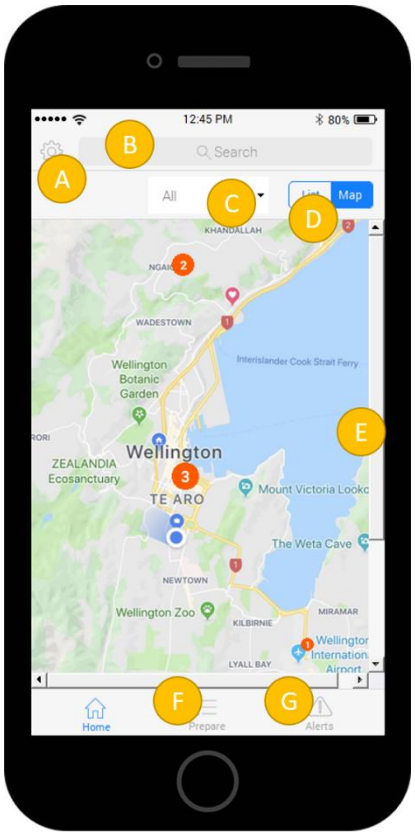


WREMO



Interactions of the alternate panels are similar to ‘2 Home’ screen

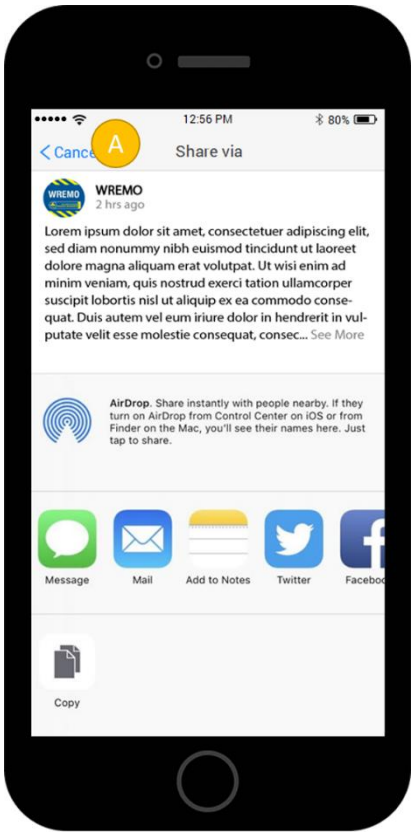
2.3. Map panel



Interactions

		Section
A	On Click: goes to <section> with effect: slide right →	2.1 H Sidebar
B	On Click: pops up keyboard	
C	On Click: pops up selection: All, Severe, Extreme, Moderate, Minor	
D	On click: goes to <section> →	2 Home
E	On scroll: Scrolls through the page	
F	On Click: goes to <section> →	3 Prepare
G	On Click: goes to <section> →	4 Alerts

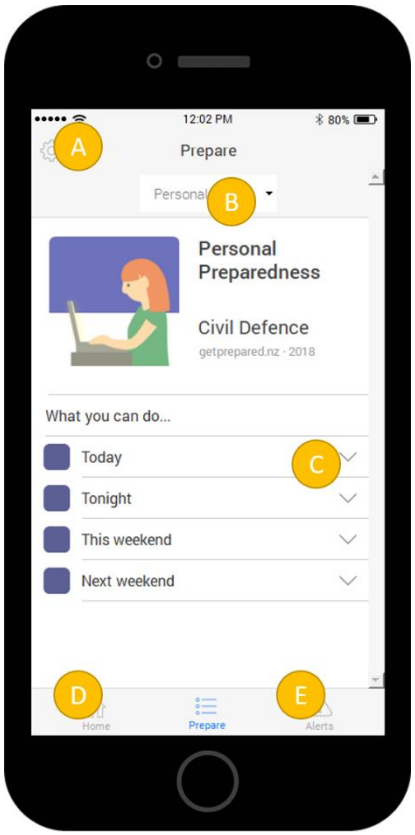
2.4. Share panel



Interactions

		Section
A	On Click: goes to <section> with effect: slide left →	2 Home

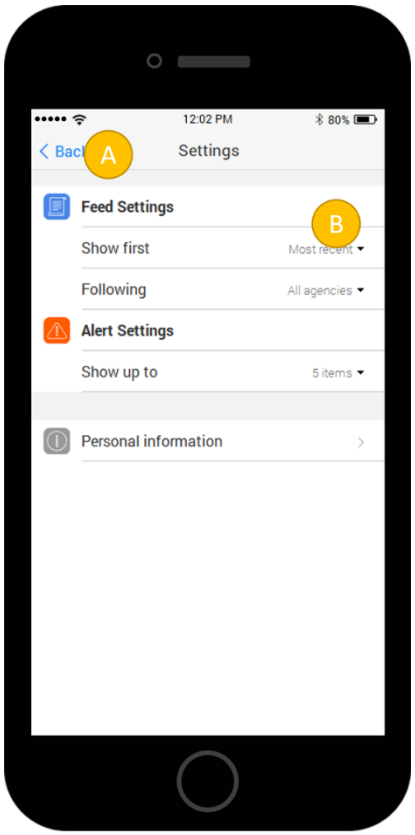
3. Prepare



Interactions

		Section
A	On Click: goes to <section> with effect: slide right →	3.1 P sidebar
B	On Click: pops up selection: Preparedness, Household, Community On selection: shows <section> panel →	3.2 P alternate panels
C	On scroll: Scrolls through the page	
D	On Click: goes to <section> →	2 Home
E	On Click: goes to <section> →	3 Alerts

3.1. P Sidebar

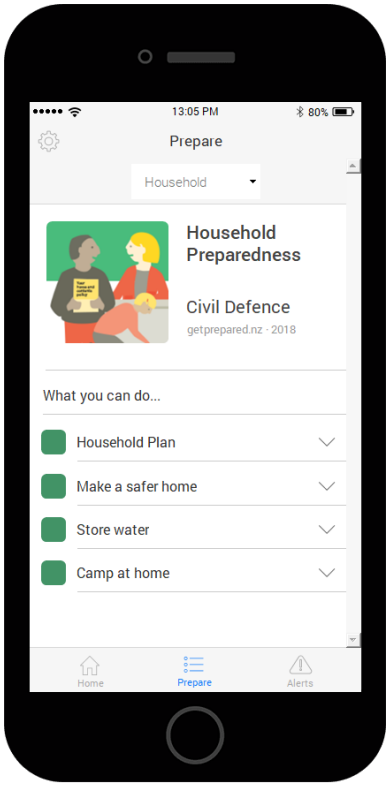


Interactions

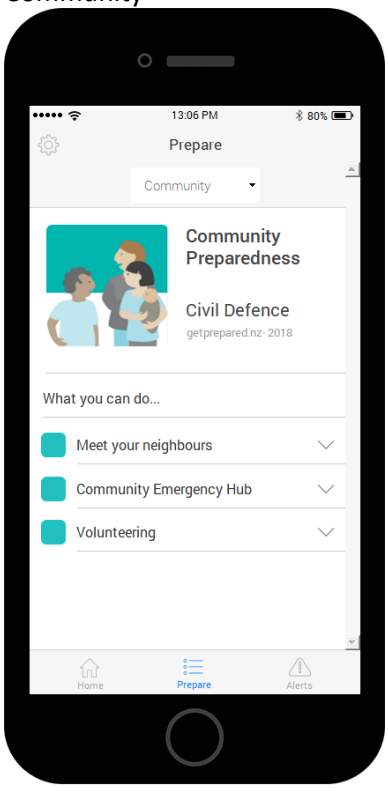
		Section
A	On Click: goes to <section> with effect: slide left →	3 Prepare
B	On Click: pops up selection: most recent, by proximity	

3.2. P alternate panels

Household

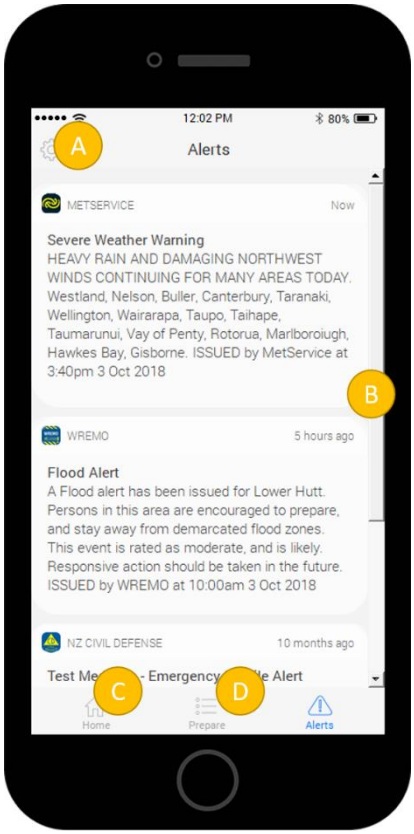


Community



Interactions of the alternate panels are similar to '3 Prepare' screen

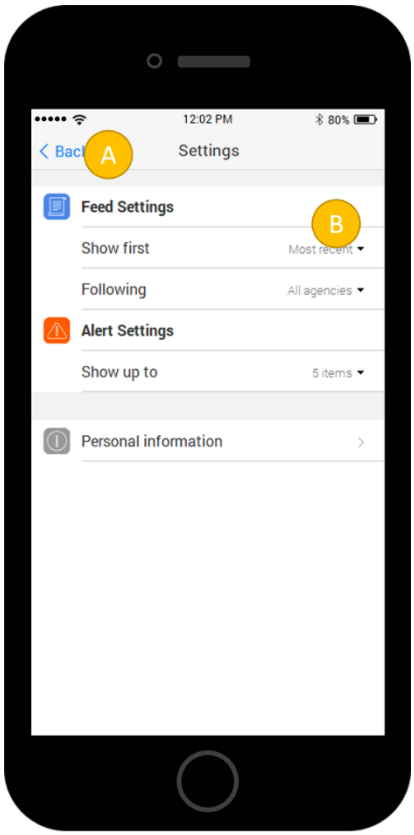
4. Alerts



Interactions

		Section
A	On Click: goes to <section> with effect: slide right →	4.1 A sidebar
B	On scroll: Scrolls through the page	
C	On Click: goes to <section> →	2 Home
D	On Click: goes to <section>→	3 Prepare

4.1. A sidebar



Interactions

		Section
A	On Click: goes to <section> with effect: slide left →	4 Alerts
B	On Click: pops up selection: most recent, by proximity	

APPENDIX F. INTERVIEW GUIDE FOR USABILITY INQUIRY

Information sheet

Introduction
My name is Marion Tan, a PhD student at the Joint Centre for Disaster Research – Massey University. I invite you to participate in a research study entitled 'User Testing – NZ Alerts Prototype'. I have been developing a proof-of-concept disaster app called 'NZ Alerts'. The app targets to provide preparedness and response information on hazard events to the public living in New Zealand. The app aggregates information from official sources and authorised alerting agencies into one platform.

What is the purpose of the study?
The objective for the evaluation is to understand the thinking of a new user to the app. The evaluation will cover the users' overall perception on the app concept itself (app design, app dependability, and app utility) and interface design (graphics, input, output, and structure).

Recruited participants will ideally be an iPhone user, aged 19 years old or above, and of any ethnicity. We are recruiting 30 participants at this stage of the study.

What will participation involve?
Participation will involve individual face-to-face video-recorded interviews with the researcher which can take approximately one hour.

Your name and identity will be held in confidence. The video recording will not have any identifying features as the camera will focus on the participants' hands and device screen only.

User evaluation questions will be used to navigate through each section of the app, focusing on the usability of the app. These will require either a spoken response or a physical response.

All participants will be asked to sign a written consent form to confirm their agreement to take part in the user testing and for their interview to be video recorded prior to the start of the interview.

Once the user testing is completed, participants will receive a $25 thank-you voucher as an appreciation of their time and effort in taking part in the user testing. Participants will be given the opportunity to indicate if they would like to receive a summary of the results at the end of the project.

What are your rights as a participant?
You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study by not answering the questions;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

Where will the research take place?
Interviews will ideally be held in an office or meeting room in Massey University, Wellington Campus. Each interview will last from 40 minutes to 1 hour. The date/time for each interview will be agreed between the participant and the researcher at a convenient time.

Data Management
The data will be used for gather user feedback on the usability of the app and will be securely stored for a period of five years after which time the files will be destroyed. The video files and notes will be stored separately from the consent forms.

Who may I contact for further information?
If you would like more information about the research please contact Marion Tan or her primary supervisor Dr Raj Prasanna

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Massey University
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Phone: 04 801 5799 ext. 62169
Email: R.Prasanna@massey.ac.nz

Thank you for your interest in this research study.
This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director - Ethics, telephone 06 356 9099 ext. 86015, email humanethics@massey.ac.nz

Interview script: Preliminary questions

1. Age:
2. Gender:
3. Job:
4. Personal Income:
5. Where do you live?
6. What is your current smartphone?
    a. [If not iPhone] Have you ever used an iPhone?
7. When did you start using a smartphone? (year)
8. Do you have any of the following apps?
    a. Hazards App – Red Cross
    b. GeoNet App
    c. MetService App
9. Do you have other apps that tell you information about natural hazards?
10. Do you have Facebook or Twitter?
11. Do you follow any of these pages?
    a. WREMO
    b. MCDEM
    c. NZTA

12. Do you follow any other pages that would inform you about any preparedness or response information for disaster events?
13. Do you consider yourself technologically savvy?
14. How comfortable are you in using mobile apps?

Interview script: tasks and guide questions

Imagine that you have just downloaded an app that has just been promoted by local emergency management agency. This is your first try to look at the app after completing a registration process and setting up your account.

Task 1: Enter the app

Guide questions before proceeding to Task 2

1. What are the three things that you notice first?
2. Without clicking on anything, tell us what you would do first?
3. Tell us three words that describe the look of the app.
4. What do you think is the purpose of this app?
5. Did you expect anything else upon entering the app?

Task 2: Explore 'home' page

Guide questions after participant explores the page

1. What type of contents do you expect from this page?
2. Do you like the look of the page? (aesthetics)
    a. What comments or issues do you have?
3. Do you like the controls so far?
    a. What comments or issues do you have?
4. How intuitive is it for you to navigate around the screen?
    a. What comments or issues do you have?
5. Do you like how the information is presented?
    a. What comments or issues do you have?
6. Do you like the words and icons used?
    a. What comments or issues do you have?
7. Is there anything that you expected that did not appear on this page?

Task 3: Explore 'prepare' page

Guide questions after participant explores the page

1. What type of contents do you expect from this page?
2. Do you like the look of the page? (aesthetics)
    a. What comments or issues do you have?
3. Do you like the controls so far?
    a. What comments or issues do you have?
4. How intuitive is it for you to navigate around the screen?
    a. What comments or issues do you have?
5. Do you like how the information is presented?
    a. What comments or issues do you have?
6. Do you like the words and icons used?
    a. What comments or issues do you have?
7. Is there anything that you expected that did not appear on this page?

Task 4: Explore 'alerts' page

Guide questions after participant explores the page

1. What type of contents do you expect from this page?
2. Do you like the look of the page? (aesthetics)
    a. What comments or issues do you have?
3. Do you like the controls so far?
    a. What comments or issues do you have?
4. How intuitive is it for you to navigate around the screen?
    a. What comments or issues do you have?
5. Do you like how the information is presented?
    a. What comments or issues do you have?
6. Do you like the words and icons used?
    a. What comments or issues do you have?
7. Is there anything that you expected that did not appear on this page?

Task 5: Quit the app

Guide questions after participant exits the app

1. Do you like the product branding?
2. After first use, do you think you will keep this app?
3. What will make you uninstall the app?
4. In a crisis scenario, do you think the design of the app is appropriate?
5. Given the chance, how would you improve the app?
    a. What would you change?
    b. What would you add?
    c. What would your remove?
6. Any final comments?

APPENDIX G. QUESTIONNAIRE FOR USABILITY SURVEY

Information Sheet

Usability of Disaster Apps

Dear Participant,

I invite you to participate in my study entitled “Usability of Disaster Apps”. Below are details which may help you decide whether to take part in this survey.

About the Researcher
My name is Marion Tan, a PhD candidate at the Joint Centre for Disaster Research at Massey University, New Zealand. I am conducting this survey as part of my doctoral project under the supervision panel of Dr Raj Prasanna (main supervisor, Massey University), Dr Kristin Stock (co-supervisor, Massey University), Dr Emma Hudson-Doyle (Massey University), Dr Graham Leonard (GNS Science), and Prof David Johnston (Massey University/GNS Science).

About the Project
The study looks at the usability of disaster apps. For the purpose of this survey, a "disaster app" is defined as a smartphone app that provides targeted information regarding a recent, upcoming, or ongoing hazard event.

Through this survey, I aim to understand users’ perceptions of usability when using disaster apps. I expect to use the results of this survey to produce a framework that will help designers and developers in building ‘disaster apps’ with better usability.

Participant Selection
As a member of the public who has access to ‘disaster apps’ from the app markets, you are invited to be part of the study. This study focusses on your perception of usability as experienced by your use of disaster apps. To participate, you need to be at least 18 years of age.

Participating in the Study
Taking part will involve completing an online questionnaire which will take to 15 to 20 minutes of your time.

Your Rights as a Participant

You are under no obligation to accept this invitation. Completion of the questionnaire implies consent. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study by not answering the questions;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- reassurance that any personal identifiable information will be kept confidential and will only be accessed by the researcher and her supervisors;
- be given access to a summary of the project findings when it is concluded.

Appendix G

Data Management
Your responses will be used only for this study. Only the researcher and the main supervisor will have access to your survey responses. Your responses will be combined with all other participants' data for analysis. A coding system is designed to make sure that there are no duplications of responses, but you will not be identified by your responses. Questionnaires will be properly disposed of after encoding. Results of the study may also be used in academic publication, but your anonymity will be maintained.

For Questions or Comments
Should you have any concerns, issues or questions, please contact me at +64 497 93799 or email me at M.L.Tan@massey.ac.nz.

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director, Research Ethics, telephone 06 356 9099 x 86015, email humanethics@massey.ac.nz.

Sincerely,

Marion Tan

I have read and understood the information sheet for this study and consent to the collection of my responses. *(Please choose "Yes" if you wish to proceed.)*

- ○ Yes
- ○ No

Preliminary questions

Q1: Age: _____

Q2: Gender

- ○ Male
- ○ Female
- ○ Gender diverse
- ○ Prefer not to disclose

Q3: In which country do you currently reside? (dropdown menu) _____

Q4: What is your smartphone's platform?

- ○ Android
- ○ iOS
- ○ Windows
- ○ Others (Please specify) _____
- ○ Don't know/ not sure

Q5: Do you consider yourself technology savvy?

- ○ Definitely yes
- ○ Probably yes
- ○ Might or might not
- ○ Probably not
- ○ Definitely not

Q6: For the purpose of this survey, a "disaster app" is defined as a smartphone app that provides targeted information regarding a recent, upcoming, or ongoing hazard event.

Please select or list all disaster apps you have currently installed on your phone.

**Depending on which country the respondent selected, display the list of apps*

** If the respondent does not choose an app, go to an ending page*

**3 slots allocated for 'others'*

NZ	PH	US	AU	Others
• Disaster Alert • Earthquake Alert! • GeoNet • Hazards – Red Cross • Ping4Alerts • MetService • QuakeFeed • Tsunami Alert • ubAlert	• AGOS eBayanihan • Batingaw • Disaster Alert • Earthquake Alert! • eBayanihan • Hazards App by PRC • QuakeFeed • PH Weather and Earthquakes • ubAlert	• Disaster Alert • Earthquake Alert! • Earthquake by American Red Cross • FEMA • Hurricane by American Red Cross • QuakeFeed • Tornado by American Red Cross • ubAlert • Wildfire by American RedCross	• Disaster Alert • Emergency+ • Emergency AUS • Fires Near Me Australia • Fries Near Me NSW • Tsunami Alert • ubAlert •	• Disaster Alert • Earthquake Alert! • QuakeFeed • Tsunami Alert • ubAlert

Carry forward from selected choices

Q7: The succeeding sections will be based on your experience with a single app.

Please select or confirm the app you want to evaluate.

- ○ Choice selected from previous question
- ○ Choice selected from previous question
- ○ Choice selected from previous question

**Selected choice will be piped in to the succeeding 4 sections.*

Part 1 of 3 – General satisfaction [7 Questions]

Rate the following statements according to your experience with [the app – piped in].

I am **happy** with….

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
1	the overall design of the app.	○	○	○	○	○
2	the graphics of the app.	○	○	○	○	○
3	the layout of the app.	○	○	○	○	○
4	how the app takes in my preferences or input.	○	○	○	○	○
5	how the app presents information.	○	○	○	○	○
6	how the app operates from start to finish.	○	○	○	○	○

7. I intend to continue using the app

○ Strongly agree

○ Somewhat agree

○ Neither agree nor disagree

○ Somewhat disagree

○ Strongly disagree

Part 2 of 3 – Usability factors [26 Questions]

App design

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
1	The app's overall design meets my expectations.	◯	◯	◯	◯	◯
2	I think the app needs to significantly change its overall design.	◯	◯	◯	◯	◯
3	Generally speaking, the app is well designed.	◯	◯	◯	◯	◯

App dependability

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
4	I am satisfied with the way the app operates from start to finish.	◯	◯	◯	◯	◯
5	The app works smoothly from start-up to exit.	◯	◯	◯	◯	◯
6	I can depend on the app to work from start to finish.	◯	◯	◯	◯	◯

Interface graphics

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
7	In general, the app is visually appealing.	◯	◯	◯	◯	◯
8	I like the graphics displayed on the screen of the app.	◯	◯	◯	◯	◯
9	Overall, the app uses pleasing visuals.	◯	◯	◯	◯	◯

Interface input

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
10	The app allows me to enter my preferences or information easily.	○	○	○	○	○
11	I am satisfied with how the app allows me to enter information.	○	○	○	○	○
12	I find it difficult to instruct the app to do what I want it to do.	○	○	○	○	○

Interface output

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
13	The content of the app is presented in a style that suits me.	○	○	○	○	○
14	I find it easy to read the information in the app.	○	○	○	○	○
15	I like how the app presents information.	○	○	○	○	○

Interface structure

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Some-what agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
16	I find it hard to find my way around the app.	○	○	○	○	○
17	The layout of the app makes it easy for me to locate the content I need.	○	○	○	○	○
18	I think the app has an organised structure.	○	○	○	○	○

App utility

Rate the following statements according to your experience with [the app – piped in].

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
19	The app is of value to me.	◯	◯	◯	◯	◯
20	I think the app is useful.	◯	◯	◯	◯	◯
21	The app serves its purpose well.	◯	◯	◯	◯	◯
22	To me, the app performs as intended.	◯	◯	◯	◯	◯

Rate the following statements according to your intent on your **continued usage** of the app.

		Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
23	I would stop using the app if I find an alternative.	◯	◯	◯	◯	◯
24	I want to discontinue using the app.	◯	◯	◯	◯	◯
25	I am have considered uninstalling the app.	◯	◯	◯	◯	◯

Part 3 of 3 – Final Page

Thank you for your responses!

Do you have other thoughts or comments?

Please feel free to use the space below to share your experiences with using disaster apps.

_____

_____

_____

_____

_____

Would you like to receive a copy of the results of the survey? Y/N

Would you like to participate in a follow-up research to this study? Y/N

If you answered yes, please leave your email below.

_____

APPENDIX H. LIST OF REFLECTIVE ITEMS USED IN THE SURVEY

Construct	Item ID	Statement
App Design	DSGN1	The app's overall design meets my expectations.
	DSGN2	I think the app needs to significantly change its overall design.
	DSGN3	Generally speaking, the app is well designed.
	DSGN4	I am happy with the overall design of the app.
App Utility	UTIL1	The app is of value to me.
	UTIL2	I think the app is useful.
	UTIL3	The app serves its purpose well.
	UTIL4	To me, the app performs as intended.
App Dependability	DPND1	I am satisfied with the way the app operates from start to finish.
	DPND2	The app works smoothly from start-up to exit.
	DPND3	I can depend on the app to work from start to finish.
	DPND4	I am happy with how the app operates from start to finish.
User-interface Graphics	GRPH1	In general, the app is visually appealing.
	GRPH2	I like the graphics displayed on the screen of the app.
	GRPH3	Overall, the app uses pleasing visuals.
	GRPH4	I am happy with the graphics of the app.
User-interface Structure	STRU1	I find it hard to find my way around the app.
	STRU2	The layout of the app makes it easy for me to locate the content I need.
	STRU3	I think the app has an organised structure.
	STRU4	I am happy with the layout of the app.
User-interface Input	INPT1	The app allows me to enter my preferences or information easily.
	INPT2	I am satisfied with how the app allows me to enter information.
	INPT3	To find it difficult to instruct to app to do what I want it to do.
	INPT4	I am happy with how the app takes in my preferences or input.
User-interface Output	OUTP1	The content of the app is presented in a format that suits me.
	OUTP2	I find it easy to read the information in the app.
	OUTP3	I like how the app presents information.
	OUTP4	I am happy with how the app presents information.
Continuance intention	CONT1	I intend to continue using the app.
	CONT2	I would stop using the app if I find an alternative.
	CONT3	I want to discontinue using the app.
	CONT4	I have considered uninstalling the app.

APPENDIX I. EXPERT FEEDBACK SURVEY FOR USABILITY GUIDELINES

Information Sheet

Several mobile applications (apps) targeted for disasters preparedness and response already exist for the public to download and use. Multiple research has been conducted to investigate the functionalities of these apps in aiding the public during disasters. However, limited studies have investigated the apps' usability in the context of crises. In acute situations, seemingly minor usability issues can become critical concerns. The usability guidelines presented here is an attempt to consolidate various considerations and recommendations for disaster apps.

What will participation in this assessment involve?
You will be given a list of guidelines to read (see next page). Consider your role as a stakeholder in the disaster preparedness/response app team and provide feedback through a discussion with the researcher. A short survey will be handed out after the discussion for you to complete.

What are your rights as a participant?
Evaluators will be asked to sign the consent below to confirm they agree to take part in the providing feedback on the guidelines. Your name and identity will be held in confidence.

You are under no obligation to accept this invitation. If you decide to participate in this evaluation, you have the right to:

- decline to answer any particular question;
- withdraw from the study by not answering the questions;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

Data Management
Only the researcher and her supervision panel will have direct access to the data. The evaluation you provide will be securely stored for a period of five years. After this, the files will be destroyed.

Contact Information
If you would like more information about the research please contact Marion Tan (M.L.Tan@massey.ac.nz) or her primary supervisor Dr Raj Prasanna (R.Prasanna@massey.ac.nz)

Thank you for your interest in this research study.
This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director - Ethics, telephone 06 356 9099 ext. 86015, email humanethics@massey.ac.nz

Appendix I

Consent

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time. By affixing my signature and the date below I have provided consent to participate in this evaluation.

Signature:		Date:	

Questionnaire

The statements shown below are from the usability guidelines the researcher has developed specifically for apps that communicate information surrounding hazards. The statements are grouped into three overarching themes.

Consider your role as a stakeholder in your disaster/hazards app team. Imagine that you will engage in a project to conduct improvements on the usability of your app. Please assess the level of relevance of the statements with regards to improving the usability of your app.

Set 1: Make critical information salient

Code	Statement	Extremely irrelevant	Moderately irrelevant	Slightly irrelevant	Slightly relevant	Moderately relevant	Extremely relevant
PRIO	Critical information should be prioritised	◯	◯	◯	◯	◯	◯
EQUA	Avoid maintaining identical level of priority when displaying different alerts	◯	◯	◯	◯	◯	◯
VARY (& TECH)	Use varying techniques to make important information prominent (e.g. typographical emphasis, colour contrast)	◯	◯	◯	◯	◯	◯
AUDI	Use audio output purposefully	◯	◯	◯	◯	◯	◯

Set 2: Consider cognitive load when designing the interface

Code	Statement	Extremely irrelevant	Moderately irrelevant	Slightly irrelevant	Slightly relevant	Moderately relevant	Extremely relevant
LEVE	Utilise existing interfaces that are familiar to users	○	○	○	○	○	○
NEAT	Keep the design neat and simple	○	○	○	○	○	○
INPT	Reduce the need for user	○	○	○	○	○	○
RTIO	Rationalise the use of text and image	○	○	○	○	○	○
TEXT	Limit textual information	○	○	○	○	○	○
VSUA	Use meaningful visualisation to enhance the content (e.g. image, logos, maps)	○	○	○	○	○	○

Set 3: Build trust, anticipating limited interaction

Code	Statement	Extremely irrelevant	Moderately irrelevant	Slightly irrelevant	Slightly relevant	Moderately relevant	Extremely relevant
RELV	Provide relevant content	○	○	○	○	○	○
SIGN	Show information significant to time, location, and severity	○	○	○	○	○	○
SRCE	Display the source of information	○	○	○	○	○	○
PERS	Personalise or localise the content to the user	○	○	○	○	○	○
ERRO	Minimise impact of errors and reduce loading time	○	○	○	○	○	○
VISI	Provide visible system status to evoke that the app is alive and updated	○	○	○	○	○	○
PRVY	Show regard to users' privacy (e.g. privacy statement)	○	○	○	○	○	○

Appendix I

Which statements are the least helpful when you are modifying your app to improve its usability? Why?

_____

_____

_____

_____

Which statements are the most helpful when you are modifying your app to improve its usability? Why?

_____

_____

_____

_____

What suggestions do you have to improve the guidelines?

_____

_____

_____

_____

If the above guidelines were converted to an evaluation matrix that will provide you with an accumulative usability score, will you consider using it as a tool to evaluate the usability of your app?

_____

What app are you involved with?

_____

What is your role in your app team?

_____

Please leave your email if you want to receive a copy of the results of the study.

_____

APPENDIX J. STATEMENTS OF CONTRIBUTION

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Marion Lara Tan
Name/title of Primary Supervisor:	Dr Raj Prasanna
Name of Research Output and full reference:	
Mobile applications in crisis informatics literature: A systematic review	
In which Chapter is the Manuscript /Published work:	Chapter 3
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	80%
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on feedback from supervisors.	
For manuscripts intended for publication please indicate target journal:	
International Journal for Disaster Risk Reduction	
Candidate's Signature:	Marion Lara Tan
Date:	25 Nov 2019
Primary Supervisor's Signature:	R Prasanna
Date:	25 Nov 2019

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

GRS Version 4– January 2019

Appendix J

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

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DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Marion Lara Tan
Name/title of Primary Supervisor:	Dr Raj Prasanna
Name of Research Output and full reference:	
Usability of disaster apps: A conceptual framework from a qualitative thematic analysis of user reviews	
In which Chapter is the Manuscript /Published work:	Chapter 4
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	80%
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on feedback from supervisors.	
For manuscripts intended for publication please indicate target journal:	
International Journal of Disaster Risk Science	
Candidate's Signature:	Marion Lara Tan
Date:	25 Nov 2019
Primary Supervisor's Signature:	
Date:	25 NOV 2019

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

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DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Marion Lara Tan
Name/title of Primary Supervisor:	Dr Raj Prasanna
Name of Research Output and full reference:	
Usability factors affecting the continuance intention of disaster apps: A mixed-methods study	
In which Chapter is the Manuscript /Published work:	Chapter 6
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	80%
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on feedback from supervisors.	
For manuscripts intended for publication please indicate target journal:	
Computers in Human Behavior	
Candidate's Signature:	Marion Lara Tan
Date:	25 Nov 2019
Primary Supervisor's Signature:	R J Prasanna
Date:	25 NOV 2019

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

GRS Version 4– January 2019

Appendix J

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Marion Lara Tan
Name/title of Primary Supervisor:	Dr Raj Prasanna
Name of Research Output and full reference:	
Understanding end-users' perspectives: towards developing usability guidelines for disaster apps	
In which Chapter is the Manuscript /Published work:	Chapter 7
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	80%
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on feedback from supervisors.	
For manuscripts intended for publication please indicate target journal:	
Progress in Disaster Science	
Candidate's Signature:	Marion Lara Tan
Date:	25 Nov 2019
Primary Supervisor's Signature:	R J Prasanna
Date:	25 NOV 2019

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

GRS Version 4– January 2019