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Abstract

There is growing evidence that the number and severity of natural disasters and their cascading events such as power blackouts are increasing. These extreme events threaten human lives, displace hundreds of thousands of people and cause huge financial losses. Therefore, it is important to understand better how socio-economic systems can best respond to these disasters and how they can recover quickly, build back better and become more resilient.

This thesis comprises five separate studies of four different types of disasters. The overall objective is to improve the understanding of how society copes with and makes decisions in crisis and emergency situations, and how disaster affected areas recover, particularly in terms of speed and quality. This is a huge subject and rather than focusing on just one event or a single type of disaster, the objective is to look at different types of disaster events by studying people's risk perception and their (real or expected) disaster behaviour in the context of different phases of the disaster cycle from immediate response to longer-term recovery and resilience building.

The five studies featured in this thesis are: 1. Behaviour during a long-lasting blackout in France and Germany, investigated through role-playing scenario exercises to study how society would cope. The aim is provide information to emergency managers and policy makers about community needs and people's likely behaviour in future blackouts, 2. Analyses of people's preparedness, perception and behaviour during floods in the UK and Germany and their attitude to public authorities, investigated through face-to-face interview surveys with people living and working in the flood prone areas, 3. Analyses of flood evacuation compliance, from both decision-theoretic and game-theoretic perspectives, using the Warning Compliance Model, which incorporates a Bayesian information system that formalizes the statistical effects of a warning forecast based on the harmonious structure of a Hidden Markov Model, 4. Examining recovery after two major comparable floods in UK and Germany in terms of the impacts, levels of preparedness and government response, investigated with face-to-face interview surveys with residents and businesses and online surveys with experts, 5. Tourist destination recovery in the Philippines after earthquake and typhoon, investigated through interviews with tourist managers and stakeholders.

The key areas for future research revolve around identifying in more detail and with greater precision those factors that predispose a society to respond effectively to a disaster, to recover as quickly as possible and to build resilience in order to better confront future disasters.

List of included articles

1. Mahdavian, F.; Platt, S.; Wiens, M.; Klein, M.; Schultmann, F. (2020a): Communication blackouts in power outages: Findings from scenario exercises in Germany and France. In International Journal of Disaster Risk Reduction 46, p. 101628. DOI: 10.1016/j.ijdrr.2020.101628. © 2019 Elsevier. Reprinted with permission

2. Mahdavian, F.; Wiens, M.; Platt, S.; Schultmann, F. (2020b): Risk behaviour and people's attitude towards public authorities – A survey of 2007 UK and 2013 German floods. In International Journal of Disaster Risk Reduction, p. 101685. DOI: 10.1016/j.ijdrr.2020.101685. © 2019 Elsevier. Reprinted with permission

3. Wiens, M.; Mahdavian, F.; Platt, S.; Schultmann, F.(2020): Optimal Evacuation-Decisions Facing the Trade-Off between Early-Warning Precision, Evacuation-Cost and Trust – the Warning Compliance Model (WCM). In Working Paper Series in Production and Energy. DOI: 10.5445/IR/1000125578

4. Platt, S.; Mahdavian, F.; Carpenter, O.; Wiens, M.; Schultmann, F. (2020): Were the floods in the UK 2007 and Germany 2013 game-changers? In Philosophical transactions,Royal Society. Series A, Mathematical, physical, and engineering sciences 378 (2168). DOI: 10.1098/rsta.2019.0372.

5. Khazai, B.; Mahdavian, F.; Platt, S. (2018): Tourism Recovery Scorecard (TOURS) – Benchmarking and monitoring progress on disaster recovery in tourism destinations. In International Journal of Disaster Risk Reduction 27, pp. 75–84. DOI: 10.1016/j.ijdrr.2017.09.039. © 2019 Elsevier. Reprinted with permission

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Part A: Overview

1. Motivation

The number and severity of natural disasters and their cascading effects, such as power blackouts, are increasing and pose an increasing threat to human life and the economy. Therefore, the factors that can make societies more resilient in the face of this increasing risk need to be studied in order to reduce these risks for the future. The goal of this doctoral thesis, which includes five separate studies, is to address different types of disasters and understand how society behaves and makes decisions in crisis and emergency contexts, and how disaster affected areas can recover in terms of speed and quality after the events and which factors can be considered to call an area recovered.

2. Introduction

There is a growing body of scientific evidence pointing to the long-term trend in global warming and climate change, which has led to an increase in the magnitude and frequency of natural hazard events and increasing casualties, displacement and economic loss an understanding of the seriousness of threat of global warming has developed over the last few decades (Flohn 1980; Leggett 1990; Parry et al. 2007; Hoegh-Guldberg et al. 2018). One of the effects of changes in climatological patterns is the increasing frequency and intensity of storms and precipitation events, which lead to increased risk of river and coastal flooding, changing the return period of 100-year flood to 50-years or less (Dankers and Feyen 2008). Many scientific articles show an increase in number of affected people and number of disasters (Alfieri et al. 2016; Bruine de Bruin et al. 2014).

Climate change will influence the nature of the climatic hazards people and ecosystems are exposed to and also contribute to deterioration or improvement of coping and adaptive capacities of those exposed to these changes. The risk of climate change to human systems (e.g., agriculture and water supply) is increased by the loss of ecosystem services that are supported by biodiversity (e.g., water purification, protection from extreme weather events, preservation of soils, recycling of nutrients, and pollination of crops) (Oppenheimer 2015). Consequently, many studies (Blaikie et al. 2014; Verner 2010; Birkmann et al. 2011) focus on the vulnerability of humans and societies, rather than solely on the level of climatic change and respective hazards (Oppenheimer 2015). Major natural disasters pose immense problems for the people, societies and economies affected and for agencies and national governments attempting to rectify the damage, disruption and injury (Platt et al. 2016). This dissertation reports research on two types of disaster, first hypothetical, then real case. For the first type, a hypothetical power blackout in France and Germany is studied where the research focuses on the response phase of the disaster management cycle (DMC). The second type embraces a real pair of flood events in the UK and Germany and the case for recovery from typhoon and earthquake in the Philippines as back-to-back events, where the research covers the response, recovery and mitigation phases of DMC. A brief introduction to each study will be given in the end of this chapter.

With such a complex research topic, that spans a number of hazards, events and regions, and has wide spread ramifications across the politico-socio-economic system, it is prudent to be begin by defining terms. The first part of this chapter, provides the basic definitions and key notions to provide the background of disaster management and disaster policy measures.

3. Definitions and background of disaster management

3.1 Hazard and disaster

Hazards may be defined as "a threat to people and the things they value" such as a natural or man-made hazard (Cutter 2001) which may or may not turn into a disaster. Based on systems theory, disasters occur when a misfit occurs between physical hazards, the built environment, and human culture (Mileti 1999) and the situation goes beyond the abilities of the local population to recover. There are three types of hazards including natural, man-made, and technological (Phillips 2015).

Hazards from the natural environment causing significant losses include convective and tropical storms, coastal and riverine floods, floods, mudslides, earthquakes and volcanoes, which could negatively impact residents, homes, businesses, bridges, ports, and roads (Mileti 1999). In many cases, people, businesses, and infrastructure can resist or rebound well from disaster impacts. However, not all disasters are 'equal opportunity events' for the affected people (Phillips 2015).

Flooding results from various sources and represents one of the most common disaster types worldwide which can be the result of fast melting snow, breaking dams, water drainage systems, thunderstorm and storm. In these situations, people may need to evacuate these areas to survive. Storms cause even more economic losses than floods and displace more people. Cyclonic storms vary in impact and intensity and are typically feared more than tropical storms or depressions (Phillips 2015). However, there are more deaths and greater economic losses worldwide from earthquakes than either storms or floods (EM-DAT 2020).

Disasters occur when a social system's normal functioning has been critically interrupted by the levels of damage and impact (Alexander 1993; Birkmann et al. 2013). They can be technological, financial or natural, while natural disasters include, storms, floods, earthquake, tsunami and volcano (UNDRR 2019; Carter 2008). This thesis addresses three natural hazards: riverine floods, storms and earthquakes and one technological (man-made) hazard, a major electricity blackout.

Disasters are the product of a complex relationship between the physical environment (both the natural and built environment) and society (its behaviour, function, organization and development, including human perception) (Quarantelli 1999). The term is used colloqually by the general public and the media and is used more or less rigorously by scientists, government agencies and insurance companies (al-Madhari and Keller 1996). Carter (2008) defines disaster as a "disruption to normal patterns of life … including destruction of or damage to government systems, buildings, communications, and essential services". The United Nations definition of disaster is a "serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts". Cisin and Clark also define disaster as one or a series of events that disrupt normal activities. Barkun (1974) writes, "we shall take disaster to be a severe, relatively sudden, and frequently unexpected disruption of normal structural arrangements within a social system or subsystem resulting from a force, 'natural' or 'social', 'internal' to a system or 'external' to it, over which the system has no firm 'control' (al-Madhari and Keller 1996)".

Some authors consider that there is no such thing as a 'natural' disaster since damage and loss are caused by human action putting life and property in harm's way (UNDRR 2019). Based on Paragraph 15 of the Sendai Framework, disasters can be small or large, frequent or not, sudden or slow onset and caused by natural, man-made, technological, biological, or even environmental hazard. Therefore, strictly speaking, there is no such thing as a natural disaster, but only natural hazards (UNDRR 2019). Krimgold (1974) addresses the issue of scale and suggests that disasters can be local (which may exceed the capacity of local resources), national (which need help from other nations) or international (al-Madhari and Keller 1996).

It is clear that the same size of event will cause different levels of damage in different parts of the world depending on the level of preparedness of the society, the quality of its planning processes, building construction and infrastructure resilience. Disasters occur when the coping capacities of socio-ecological systems are overwhelmed (ISDR 2004). This can be due to lack of resources and information, the result of institutional failures, and/or as a result of the speed of development and application of appropriate technological innovations (Pelling 2011).

The Federal Emergency Management Agency (1984) defines disaster as an event leading to fatalities, injuries, and property damage that cannot be managed through the regular procedures and resources of government. Its unexpected and sudden development requires immediate, coordinated, and effective response by government and private sector organizations to meet human needs and speed recovery (al-Madhari and Keller 1996). The World Bank (1989) puts an economic slant on its definition of disaster as, "an extraordinary event of limited duration (such as war or civil disturbance) or a natural disaster (such as an earthquake, flood, or hurricane) that seriously dislocates a country's economy". McCaughey BC (1985) emphasises the psychological damage that disaster events cause, defining a disaster as "an event that occurs suddenly, unexpectedly, and uncontrollably, that … often results in adverse psychological consequences for the survivors" (al-Madhari and Keller 1996). The Red Cross (1983) defines disaster in its Disaster Relief Handbook as "a catastrophic situation in which the day-to-day patterns of life are in many instances suddenly disrupted and, as a result, people need protection, food, clothing, shelter, medical and social care, and other necessities of life" (al-Madhari and Keller 1996). Disasters will, to varying degrees, disrupt the physical, environmental, psychological, social and economic functioning of communities. This can have significant health effects (The Australian Institute for Disaster Resilience 2019).

What all these definitions have in common is that *disasters cause a disruption to normal life leading to loss of life and property and the need for relief and recovery and surpass the capacity to manage locally and hence require external assistance*.

Al-Madhari and Keller (1996) define a disaster as an event with ≥10 fatalities, or/and economic loss over ≥1 US$ million, or/and a need to evacuate ≥ 50 people.

The impacts of disasters generally refer to impacts on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to hazardous climate change events and the vulnerability of an exposed society or system. Floods, droughts, and sea level rise are subsets of the impacts of climate change on geophysical systems (Oppenheimer 2015). Oppenheimer (2015) provides a diagram mapping the interaction of hazard, vulnerability and exposure, that results in risk (Figure 1)

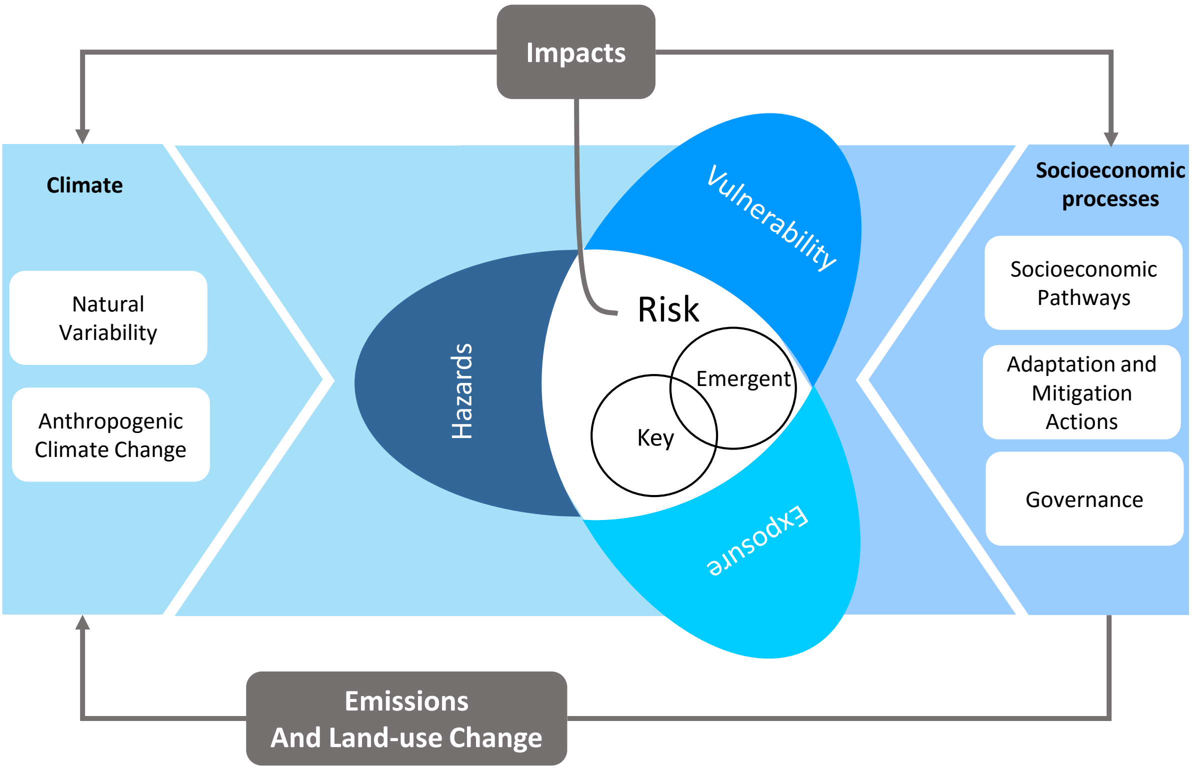

Figure 1 Risk and disaster impacts (Oppenheimer 2015)

3.2 Disaster risk management (DRM) and Disaster risk reduction (DRR)

ISO 31000 defines Disaster Risk Management (DRM) as “coordinated activities to direct and control an organisation with regard to risk” (Risk Management Basic). The United Nation office for Disaster Risk Reduction (UNDRR) describes disaster management as focusing on "the organization and management of resources and responsibilities to address all aspects of emergencies and disasters" (UN-SPIDER). Figure 2 illustrates the risk management process as defined in ISO 31000.

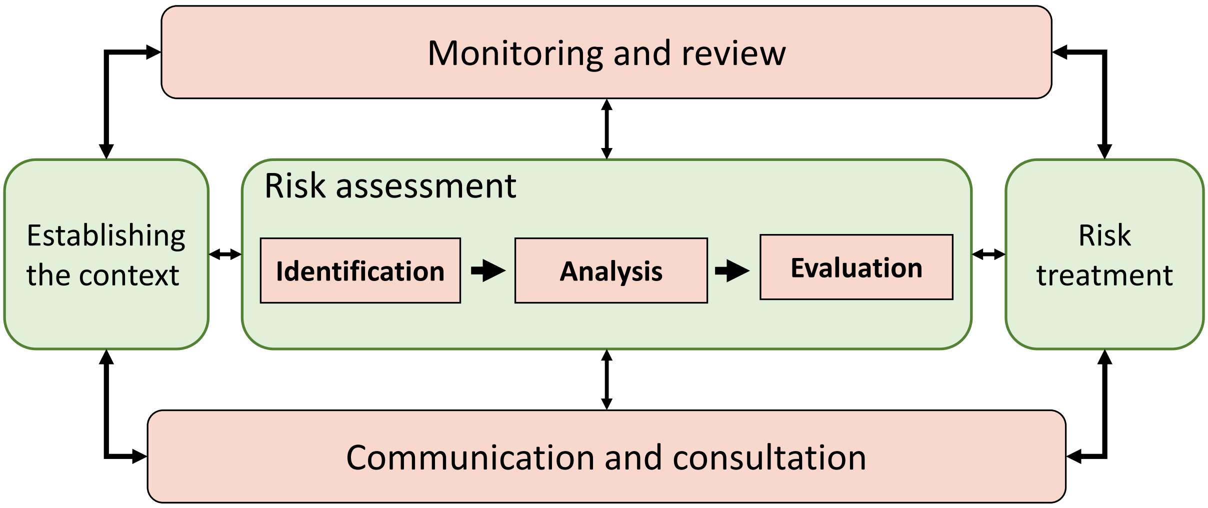

Figure 2 Risk management process (AS/NZC ISO 31000 2009)

DRM is therefore a structured method to decrease and control risks, through risk assessment procedures, developing strategies and taking specific actions which lead to managing uncertainty and potential losses (Reliefweb Glossary of Humanitarian Terms). It focuses on the organization and management of resources and responsibilities to cover all aspects of preparedness, response and initial recovery steps (UN-SPIDER). To be effective, disaster management should not be implemented reactively, but rather needs to be implemented in a comprehensive and continuous way (Carter 2008).

Ideas change over time. Initially, disaster management focused on response and relief efforts following disaster events (ISDR 2004; Lewis et al. 1976; Twigg 2004)

The shift in focus from the hazard to the impact on communities has been a key development in disaster risk management and risk reduction (The Australian Institute for Disaster Resilience 2019). Also known as Emergency Risk Management, DRM is an organized process that supports the wellbeing of communities and the environment (LEMC and LRCC 2015). It focuses on the management of risk rather than the management of hazards (The Australian Institute for Disaster Resilience 2019).

DRM approaches include risk prevention, mitigating negative impacts, insurance, and dealing with the consequences of a particular risk. In some key sectors affected by natural hazards, such as water supply, energy, agriculture and transportation, risk management may form a core element of business activity owing to the potential for high losses (Reliefweb Glossary of Humanitarian Terms; ISDR 2004).

Risk governance is highly related to the decisions and implementation of actions by governments and governmental institutions (Renn 2008; Birkmann et al. 2013). It is related to the concept of meta decision-making, encompassing the trade-offs between opposing strategies that need to be made by the authorities in charge of managing recovery.

On the other hand, Disaster Risk Reduction (DRR) aims at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development (UNDRR 2017). Risk is reduced by analysing and managing the causes of disasters, through reducing social and economic vulnerability to hazards, and improving preparedness for harmful events (Reliefweb Glossary of Humanitarian Terms).

3.3 Disaster management cycle

Regardless of the nature or even the size of the disaster, emergency management covers three main phases: (1) Impact, (2) Response and (3) Prevention (mitigation and preparedness). The response phase can usefully be sub-divided into immediate relief and longer-term recovery.

An understanding of the phases of disaster management goes back 100 years, to 1920 when Samuel Henry Prince (1920) defined the three different phases of societal response to disaster: emergency, transition and rehabilitation. Coetzee and van Niekerk (2012) consider this as the basis of traditional disaster studies. Prince for the first time described the societal response after a disaster into different phases. The first phase of an emergency involved confusion and uncertainty among the disaster affected people. The transition period is when organized groups, such as the army, respond to the impact of a disaster and provide rescue and relief services. The final phase was when the society and economy began to recover and things returned to normal (Coetzee and van Niekerk 2012; Prince 1920).

Various disciplines have been influenced by Prince's ideas, including sociology, geography, psychology, civil defence, public administration and development studies (Quarantelli 1986; Tierney

1998; Coetzee and van Niekerk 2012; Quarantelli 1997). Some of the key thinkers who built on Prince's model and developed the concepts of the disaster management cycle further were Carr (1932), Powell J (1954), Chapman (1962) and Stoddard (1968). Prince's work was extremely influential as can be seen in a subsequent comparative study by Carr (1932). Carr identified four phases: preliminary, dislocation, readjustment and delay. Powell (1954) identified eight distinct stages: predisaster, warning, threat, impact, inventory, rescue, remedy and finally recovery when attempts are made to resume normal operations following a disaster (Table 1). Chapman (1962) developed Powell's ideas and reduced the number of stages to six by eliminating the first and the last stages in table 1.

Table 1 Eight Socio-Temporal Stages of Disaster (Palen et al. 2007)

Stage 0: Pre-disaster State of social system preceding point of impact
Stage 1: Warning Precautionary activity includes consultation with members of own social network
Stage 2: Threat Perception of change of conditions that prompts survival action
Stage 3: Impact Stage of "holding on" where recognition shifts from individual to community affect and involvement
Stage 4: Inventory Individual takes stock, and begins to move into a collective inventory of what happened
Stage 5: Rescue Spontaneous, local, unorganized extrication and first aid; some preventive measures
Stage 6: Remedy Organized and professional relief arrive; medical care, preventive and security measures present
Stage 7: Recovery Individual rehabilitation and readjustment; community restoration of property; organizational preventative measures against recurrence; community evaluation

A study by Stoddard (1968) anticipated later disaster management cycles by identifying three over-arching phases – pre-emergency, emergency and post-emergency phases. He describes warning, threat and evacuation, dislocation and relocation for the pre-emergency phase as key activities. The post-emergency phase includes short and long-term rehabilitation activities (Stoddard 1968; Neal 1997; Coetzee and van Niekerk 2012).

The concepts developed by these authors have an underlying similarity to the work of Prince in that they consider distinct disaster time periods. However, it is important to note that these early stage studies considered the different phases in a linear fashion (Coetzee and van Niekerk 2012). This traditional linear approach started to change during the 1970s, following a dramatic increase in the impact of disaster events causing more deaths and greater economic losses than in previous decades (Wisner et al. 2004; Coetzee and van Niekerk 2012).

The earliest disaster management cycle (DMC) was drawn by Baird et al. (1975) (Figure 3). This DMC includes six different phases: mitigation and prediction, preparedness for relief, warning, relief, rehabilitation and reconstruction.

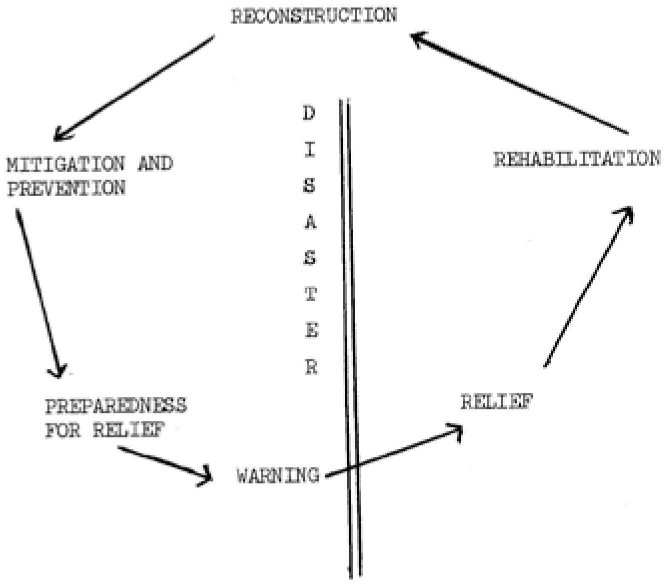

Figure 3 Disaster occurrence with an activity system over time (Baird et al. 1975)

This diagram, which they labelled "*Disaster occurrence with an activity system over time*", mapped the ongoing process of disaster management that requires society, government and businesses to be involved in all phases of disaster to reduce the impacts of disaster and to recover effectively (Ullah and Gungor 2014; Coetzee and van Niekerk 2012). It demonstrated graphically for the first time how short-term rehabilitation and longer-term recovery are linked to mitigation and prevention (Baird et al. 1975).

Figure 4 illustrates the author's approach to the DMC, with the three main phases in the outer ring and overlapping activities in the inner ring.

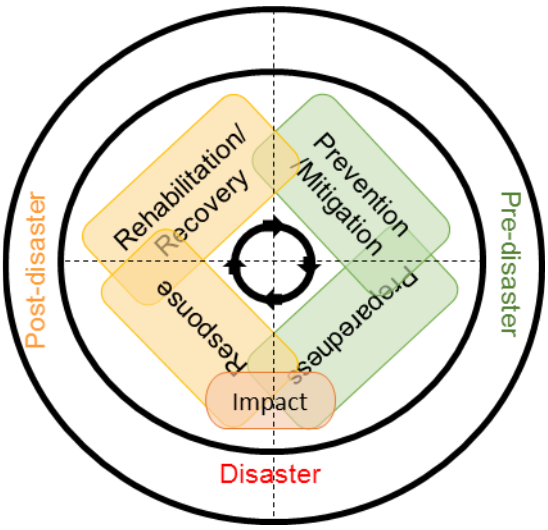

Figure 4 Disaster Management Cycle (as proposed by the author)

3.3.1 Phase 1 – Pre-disaster

Prevention and Mitigation and Preparedness

Prevention includes actions designed to impede the occurrence of a disaster and/or prevent this occurrence from causing harmful effects on people or key installations (Basumi and Abdul Nifa 2017). It is also defined as reducing or eliminating the danger of natural events which threaten people's life and their property, social resources and their environment (Reliefweb Glossary of Humanitarian Terms). Mitigation applies when the prevention effects persist but still can be reduced (Carter 2008). In fact mitigation can include structural and nonstructural measures undertaken to limit the adverse impact of natural hazards, environmental degradation, and technological hazards (Todd and Todd 2011). Preparedness comprises measures that enable governments, organizations, communities, and individuals to respond quickly and effectively (Carter 2008). For this purpose, population and relevant institutions need education and training to facilitate evacuation, rescue, and relief operations (Reliefweb Glossary of Humanitarian Terms).

The pre-disaster phase can reduce the difficulties of disaster response by developing the capacity of disaster management if the activities in this phase have appropriately being conducted. In fact, this phase is considered as the most important phase, and different measures should be taken in the areas of risk assessment, prevention/ mitigation, disaster preparedness, and risk reduction (Brundiers and Eakin 2018; Todd and Todd 2011; Phillips 2015). These measures are proposed in Hyogo Framework for Action 2005-2015 (UN ISDR 2005; Todd and Todd 2011).

3.3.2 Phase 2 – Disaster Impact/Response

Disaster Impact represents the phase during which the disaster strikes and causes deaths, injuries and destruction. It will take a time after the impact of a disaster for a community to realize the severity of the situation and the steps they need to take to deal with the impact (Coetzee and van Niekerk 2012).

Warning is the time when a hazard has been identified but is not yet threatening a particular area (Carter 2008), and in many disasters there is some advance warning. However, this early warning may be announced too late, or be inaccurate (Mahdavian et al. 2015). Early warning by definition is the provision of timely and effective information through an official recognizable institution to people in a hazardous situation to give them time to take action and to reduce their risk (Reliefweb Glossary of Humanitarian Terms).

The primary focus of this phase is rehabilitation. Planning for actions in this phase need to be realistic with quick delivery, and be considered and assessed in terms of their post disaster capacity. In the response phase, it is essential to not only include public stakeholders and the private sector, but also poor and vulnerable groups. The benefits of local participation need to be balanced against the need for fast action. Therefore each particular situation will require its own trade-off (Todd and Todd 2011).

3.3.3 Phase 3 – Post-disaster

The third part of DMC is the post-disaster phase which includes response, rehabilitation and recovery. The period after disasters provides the context for the next disaster and opportunities to improve resilience and introduce sustainability objectives (Halldin et al. 2011; UNDP 2016; Berke and Campanella 2006)

Each of these phases can overlap with the preceding and following phases.

The measures taken immediately are called "response" when the main aim is to reduce fatality and economic losses and to manage the immediate disruptions caused by disaster. The decisions and actions taken during and soon after disaster including immediate relief, rehabilitation, and reconstruction, belong to the response phase (Carter 2008).

Recovery is the process of returning to proper level of functioning communities and the nation after a disaster (Carter 2008). The concept of recovery will be explained in more detail later in this chapter.

The factors that need to be considered in the post disaster phase are creating strong institutions and using local capacity for recovery and reconstruction. Transparency and flexibility to modify targets are important. Adequate and speedy funding, as well as monitoring and evaluating progress are necessary tasks (Todd and Todd 2011).

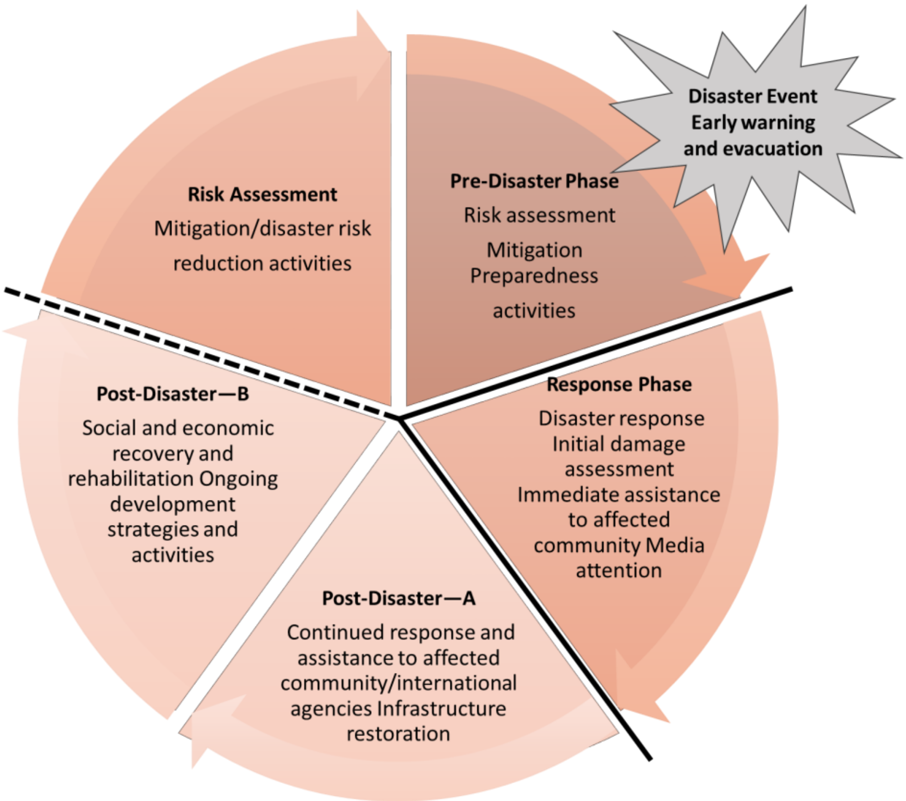

Figure 5 Disaster cycle based on work by Ian Davis Cranfield (Todd and Todd 2011)

The three main phases of the DRM Cycle — pre-disaster, disaster response, and post-disaster – lack clear boundaries and overlap chronologically, as well as in terms of the ongoing activities (Todd and Todd 2011). Todd and Todd 2011 also identified various key lessons from each phase of the DRM Cycle (Figure 5).

3.4 Risk

Risk is a neutral term that describes the potential for deviation from an expected outcome which can be subdivided into threats and opportunities (Risk Management Basic). However, in its everyday meaning and in the context of safety science and risk management risk is associated with negative consequences. Risk is the potential for physical, social, economic, environmental, cultural or institutional adverse consequences or losses, in a particular area and time period (Birkmann et al. 2013, p. 201; United Nations 2004). In its most simplistic form, risk is defined as the product of the severity of a hazard and its vulnerability (UNDRO 1980; Alexander 1997).

Risk = hazard x vulnerability (Manyena 2006)

To reduce risk, the nature of the hazard and the vulnerability of the people and activities exposed to the hazard need to be identified, analyzed and evaluated. Different disciplines, for example seismology or insurance, have conceptualized risk, hazard and vulnerability in different ways. To estimate risk on a multidisciplinary basis, awareness of physical damage and injuries and fatalities, as well as economic losses, and social, organizational, business and institutional damage are necessary (Manyena 2006).

3.5 Resilience, adaptation and coping

Resilience is derived from the Latin word resilio, meaning ‘to jump back’ (Manyena 2006; Klein et al. 2003). Resilience encompasses a society's capacity to bounce back after a disaster, its level of preparedness to confront or deal with a disaster and its ability to recover quickly and successfully (Alexander 2013). Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (The Australian Institute for Disaster Resilience 2019; UNDRR 2017). In simple terms resilience is a measure of a person's or a community's ability to cope with or adapt to hazard stress (Pelling 2003). All of the following definitions describe this aspect of a system coping with extraordinary circumstances.

Paton et al. (2000) emphasizes the psychological aspects of resilience, suggesting that resilience describes an active process of self-righting, learned resourcefulness and growth — the ability to function psychologically at a level far greater than expected given the individual’s capabilities and previous experiences (Manyena 2006; Paton et al. 2000). Research shows that people affected by disaster often demonstrate greater psychological resilience than assumed (Brundiers and Eakin 2018; Bonanno 2004). Research has also shown that the shared experience of disaster can bring the best out of people, increasing solidarity, helpfulness, and facilitating bonding among people, which, in another situation, would not have happened (Brundiers and Eakin 2018). Systems with limited capacities to cope or to recover in the face of adverse consequences lack resilience, while systems that can cope and adapt are described as resilient (Birkmann et al. 2013). Disaster resilience can be viewed as the intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its nonessential attributes and rebuilding itself.

Windle (2011) has a slightly different take on resilience, describing it as a dynamic process encompassing positive adaptation within the context of significant adversity or following threats. The World Health Organisation also views resilience as positive adaptation, including protective behaviour that reduces the impact of risk outcomes (Windle 2011). This way resilience can be seen as the adaptive capacity of a system to evolve and to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope (Adger 2006). Adaptation is a continuous property of society with levels of adaptive capacity changing over time. Such changes can be a result of disaster events but also daily processes of development. Adaptation is distinct from coping. Coping implies conservation and protection of the current system and institutional settings, whereas adaptation implies a longer-term and constantly unfolding process of learning, experimentation and change that modifies vulnerability (Pelling and Dill 2010; Birkmann et al. 2013). Efficient adaptation depends on financial resources, technology transfer and cultural, educational, managerial, institutional, legal and regulatory practices, both domestic and international (Pelling 2011). This implies that it is often easier for advanced societies and wealthier individuals to adapt to risk.

The fundamental social attributes that shape adaptive capacity also influence the potential for local mitigation (Pelling 2011; Betsill and Bulkeley 2003). The distinction made by the UNFCCC between mitigation and adaptation may aid policy formulation but is intellectually problematic. Mitigation can most logically be viewed as a subset of adaptation where adaptation is targeted to support mitigation. Pelling (2011) explains that vulnerability and adaptation interact and influence each other over time, shaped by flows of power, information and assets between actors, yet their relationship depends on the scale and type of the hazard risk and socio-ecological systems.

Understanding resilience is important because it helps to guide post-disaster decision-making (Tierney 1997; Webb et al. 2000; Rose and Liao 2005; Platt and So Senior 2017). Resilience may be quantified in terms of probability of failure, consequences of failure, and time to recovery. It may also be conceptualised as comprising four distinct dimensions: technical, organizational, social and economic (Platt et al. 2015).

3.6 Vulnerability

Vulnerability is a multidimensional concept that helps to identify those characteristics and experiences of communities (and individuals) that enable them to respond to and recover from environmental hazards (Cutter et al. 2003). Vulnerability is defined as the propensity or predisposition to be adversely affected and it encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (United Nations 2016) A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to natural hazards, including climate-related risk (Oppenheimer 2015). Alexander (1993) defines vulnerability as a function of the costs and benefits of inhabiting areas at risk of natural disaster. Disasters often hit the poor and the marginalised more severely. For the marginally employed, disaster can lead to prolonged loss of occupation or income by destroying the means of production or commerce (Alexander 1997).

In a sense, vulnerability is the flipside of resilience and resilience and vulnerability are related concepts in various scientific disciplines (Klein et al. 1998; Manyena 2006). This linkage between resilience and vulnerability is mainly credited to Peter Timmerman in 1981 in a monograph called *Vulnerability, Resilience and the Collapse of Society.* The impetus for his work came from a concern that some of the concepts coming to the fore in the growing subject of climate impact assessment were under-examined. In particular, Timmerman was concerned that the vulnerability of complex modern societies was under-estimated and required building 'buffering capacity' or resilience into our socioeconomic systems.

The vulnerability of socioeconomic systems to hazards includes deficient information, communications and knowledge among social actors, the lack of institutional and community organisation, weaknesses in emergency preparedness, political instability, poor economic health, poor or dangerous building stock, inadequate infrastructure and lack of sensible urban planning. These are all factors that increase vulnerability to a hazard and therefore increase risk (Manyena 2006).

Three main branches of vulnerability research are: exploring the reasons that make community or places vulnerable, measuring social resistance to hazard, and finally the combination of potential exposure and societal resilience in particulate places (Adger 2006).

An elaboration of the principles underlying vulnerability emerged from the physical hazards tradition, which led to a study of the vulnerability of physical assets – building stock and infrastructure (Coburn and Spence 2003; Adger 2006). There is considerable research on physical vulnerability and less on social vulnerability, perhaps because of the difficulties of measurement. Social losses are therefore usually missing in after-disaster cost/loss estimation reports (Cutter et al. 2003). Some of the positive and negative social factors affecting vulnerability are socioeconomic status, gender, race and ethnicity, age, development, employment loss, infrastructure, education, social dependence, special needs populations (Cutter et al. 2003)

As with resilience, there has been a shift in the discourse from vulnerability to adaption (Schipper 2006; Orlove 2009). Adaptation has become as essential component of international climate action (Dovers 2009) and it is described for people to enable them to reduce vulnerability to face climate stress (Orlove 2009; Agrawal 2010; Ribot 2011). The Intergovernmental Panel on Climate Change (IPCC) conceptualises vulnerability as the outcome of susceptibility, exposure and adaptive capacity for any given hazard and describes vulnerability as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (Pelling 2011; IPCC 2008). Nevertheless, the predominant understanding of adaptation is that while it is distinct it is part of the wider concept of vulnerability. In 2001, the IPCC defined adaptation to climate change as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007; Ribot 2011). Vulnerability analysis is the first step in any adaptation or intervention that can help move from affirmative to transformative climate action (Ribot 2011). Adaptation includes both adaptive capacity and adaptive action as subcategories (Pelling 2011). Perceptions and cognitive constructs about risks and adaptation options as well as cultural contexts influence adaptive capacities and thus vulnerability (Oppenheimer 2015).

In terms of adapting to climate change, (Pelling 2011) writes, "individuals and socio-ecological systems have always responded to external pressures. However, climate change brings a particular challenge. There are many uncertainties about speed and impact of climate change in daily life and its visibilities and the challenges for sustainability of socio ecological systems. Pelling (2011) attempts to capture the complex relationship between hazard and risk on the one hand and resilience and development on the other, suggesting that adaptation can provide the "bridge" (Figure 6). Development processes of a society, however, have significant implications for exposure, vulnerability, and risk (Oppenheimer 2015).

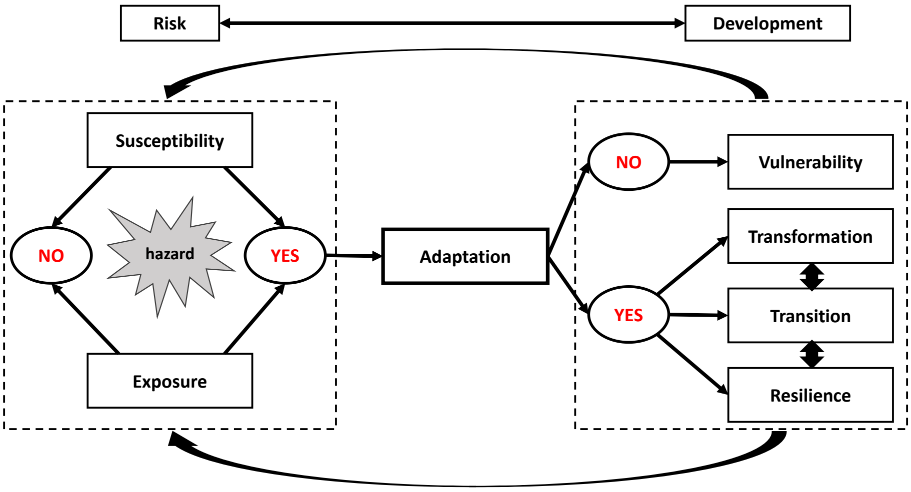

Figure 6 Adaptation as the bridge between risk and development (Pelling 2011)

As resilience can be seen as the adaptive capacity of a system to accommodate to hazards (Adger 2006) adaptive capacity can be conceptualised both as a component of vulnerability and as its inverse, declining as vulnerability increases (Cutter et al. 2008). Knowing the cause of vulnerability can help identify the multiple social, economic and political areas of intervention. In fact, adaptive actions should be based on a deep understanding of vulnerability. Of course, not all causes identified through vulnerability analysis are treatable, and many causes can best be identified by analyzing acts of adjustment that are now being called adaptation. Adaptation makes the link between risk and vulnerability, one focusing on generation of risk and the other on the response to risk (Ribot 2011).

3.7 Recovery

Recovery is defined as “the act or process of returning to a normal state after a period of difficulty” (Merriam-Webster). This begs the question of what is “normal” (Mansfield et al. 2010). Although most people identify recovery with a return to the status before the event, this may not be sensible if a place remains excessively vulnerable to risk and a better strategy may be to improve resilience through change (Platt et al. 2016). Other terms that are used somewhat interchangeably with recovery, but with less precision, include reconstruction, restoration and rehabilitation. Reconstruction implies rebuilding physical infrastructure, restoration implies a return to pre-disaster conditions and rehabilitation seems to suggest an improvement on pre-disaster conditions. None are as broad, all encompassing and precise as the term recovery.

The response and rehabilitation phase are actions for days and weeks after the onset of a disaster, while the recovery phase continues for months and even years after an event, and covers reconstruction and restoration of infrastructures and livelihoods (UN-SPIDER). Although recovery is often viewed as the last stage in the disaster management cycle it may be the longest and most expensive of the various phases (Phillips 2015).

The recovery process is therefore a complex, multidimensional nonlinear process (Chang 2010; Hettige et al. 2018). An emerging perspective claims that disaster recovery has no clear endpoint; moreover, it does not necessarily entail a return to pre-disaster conditions. Some researchers assert that for recovery to be considered successful, post-disaster activities should increase a community’s disaster resilience rather than restore pre-disaster levels of vulnerability (Mileti 1999; Wisner et al. 2004; Chang 2010). It is argued that successful recovery, by individual businesses or entire cities, involves adaptation to changed circumstances (Chang 2010; Alesch et al. 2001; Alesch et al. 2009). For example, a place may regain its pre-disaster population, but the new residents may be entirely different from the old (Chang 2010). Even if the place recovers, the characteristics of the place may change. Rarely do places return to exactly the same pre-disaster conditions, rather they reach a new stable state of 'normality'. Structural change and long-term losses occur in major disasters, often accelerating pre-disaster trends and recovery planning needs to anticipate and plan for a post disaster 'new normal'. The close relation between disaster recovery and the resilience of affected communities are a common aspect of disaster risk reduction programs since the adoption of The Hyogo Framework for Action 2005–2015. The capacity of disaster affected communities to build back better or to recover with little or no external support following a disaster has become a center of attention, which emphasizes the importance of resilience rather than just vulnerability (Manyena 2006).

Recovery involves restoring or improving livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and ‘build back better’, to avoid or reduce future disaster risk (OCHA 2017). Recovery proceeds through formal channels (governmental interventions) and informal mechanisms (individuals and communties), in some cases spontaneously, in indirect ways, or through deliberate action (Brundiers and Eakin 2018). In addition to these change processes, disasters can create the opportunity of a "reset button" to improve building infrastructure and institutions (Agrawal 2011). Disasters can present opportunities for communities and society to critically review established ways of thinking and doing (Oliver-Smith 1996). Disasters can provide leverage and finance for projects and agendas, which may not be a priority in normal times (Lakoff 2010). The window of opportunity is the opportune moment, when the time is right because not only the problems are seen and solutions are found, but also political support is available and constraints do not constrain action (Brundiers and Eakin 2018; Kingdon 1995). The ‘window of opportunity’ is narrow if the improvements of post-disaster is completing, and could last for about 18–36 months after an event (Platt and So Senior 2017). This window of opportunity differs from one country to another, partly due to the country’s political climate (Kingdon 1995).

Building back better is linked to the concept of sustainable development. Crisis and disaster can be seen as “symptoms of underlying persistent system unsustainability” (Patterson et al. 2017). As it was explained earlier, the pre-disaster is the period before disasters, which requires prevention and mitigation measures to lower the risk of upcoming disaster (Halldin et al. 2011). To link disaster risk reduction and sustainable development, Spangle (1986) supports pre-event planning for post-event recovery and planning for sustainability in advance of any disaster event (Brundiers and Eakin 2018; Berke et al. 1993). Although building back better means reducing risk and increasing sustainability, people put value on other aspects of housing, livelihoods and the environment and are willing to live with risk. The corresponding phase in sustainability transition is the predevelopment phase, and to be prepared for this transition, a network of actors are involved, who gather around a sustainability challenge, deliberating pathways of change, while trying to integrate diverse interests, to advance sustainability collectively. This process is called building a “transition arena” (LOORBACH 2010) and mobilising latent system resources which some identified as a “shadow network” (Brundiers and Eakin 2018; Olsson et al. 2006).

Various studies have focused on housing or business recovery; very few studies have used published statistical time series data to examine how societies recover (Chang 2010). Nor has there been research to systematically compare recovery processes between different hazards and different events in different countries. There is no inclusive and well accepted method of measuring recovery and various authors have suggested that all the qualitative and quantitative indicators needed to be used for better understanding of recovery path, outcomes, and procedures (Hettige et al. 2018). Recently, however, the author of this thesis has been involved in a research project at the Centre for Risk Studies at the Judge Business School in the University of Cambridge, funded by AXA Insurance, aimed at measuring the speed and quality of recovery after over 100 natural hazard events (storms, floods, earthquakes and tsunami) and investigating what factors might have been causal. To date, six individual case studies have been published (Carpenter et al. 2019a, 2019b, 2019c, 2019d, 2020a, 2020b) and a report of all 100 cases will published in the future.

Although developed countries economically loose more in disasters, the poorest countries are more vulnerable, particularly in their poor neighborhoods where people suffer higher fatalities and over-proportionately higher economic loss. They also have the greatest difficulty in organizing recovery and therefore take longer to recover (Platt et al. 2015).

In the last few decades the average estimated annual damage to property and economic activity caused by natural disasters increased dramatically from less than US$10bn to US$100bn (Platt et al. 2016). Moreover, there is a growing trend in both hydrological disasters (for example flood) and technological disaster (for example power blackout) as is shown below in figure 7.

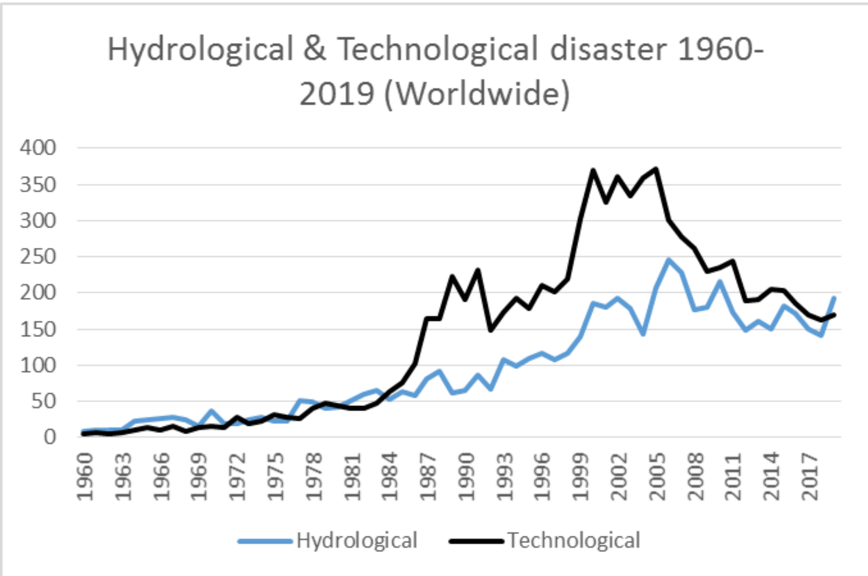

Figure 7 Worldwide disasters 1960-2019. Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium, Created on: February 21, 2020

4. Research structure and content of thesis

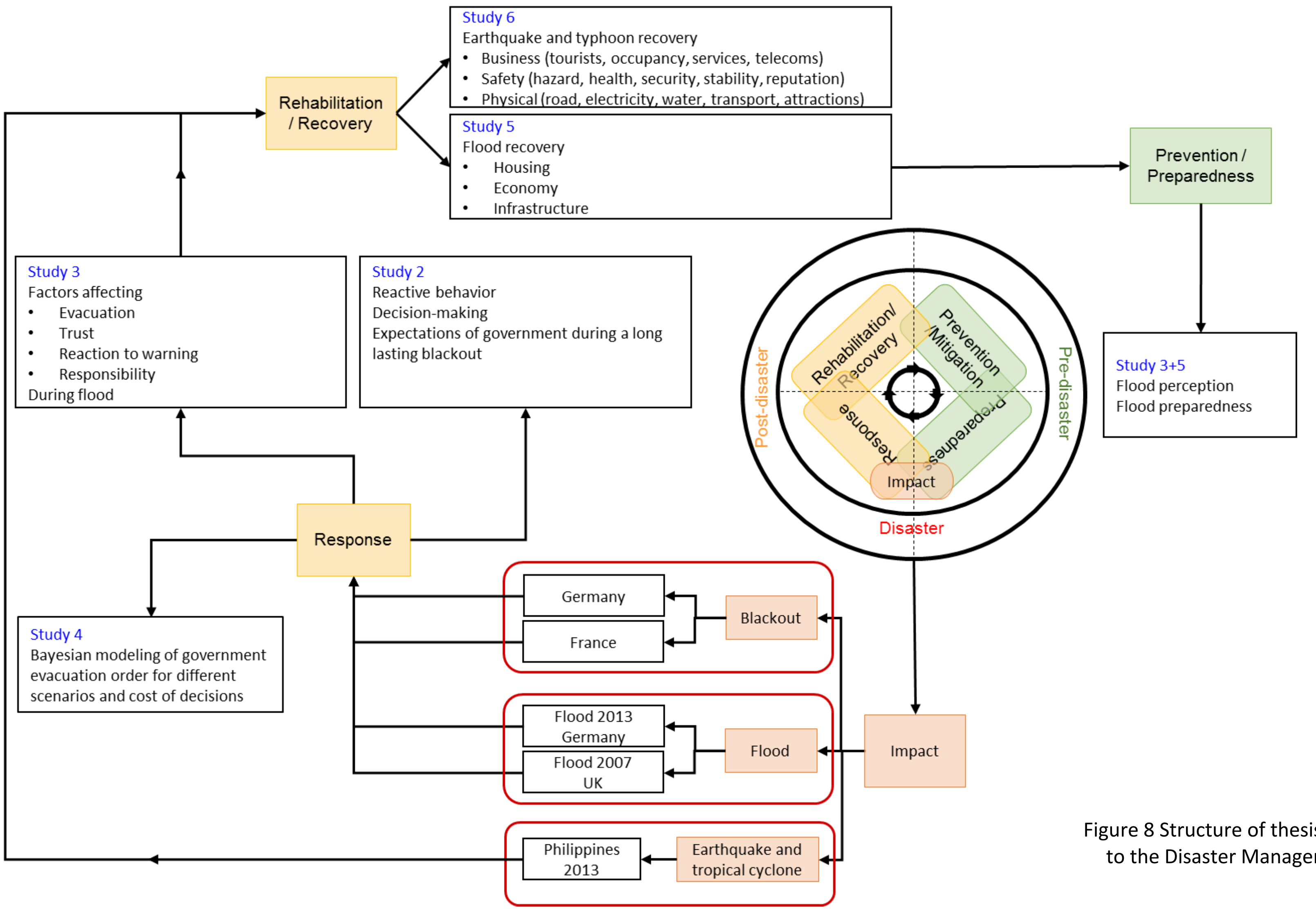

Figure 8 Structure of thesis and relation to the Disaster Management Cycle

Figure 8 shows the relationship between the discussed material and the structure of the thesis. The study numbers in this figure and the following text refer to the five journal papers of this cumulative dissertation published by the author.

This thesis comprises five separate studies of four different types of disasters – power blackout, flood, earthquake and tropical cyclone, and four different phases of the disaster management cycle – from impact through response, recovery and resilience building. The aim is to provide a broad overview of all phases of the disaster cycle for a limited range of different types of disasters to better understand the factors that improve successful outcomes and thus inform policy decisions. Each study is representative for one paper. These five papers are listed in publication section.

Study 1, describes a scenario exercise of a 72-hour hypothetical power outage using role playing with university students in Karlsruhe Institute of Technology in Germany and Paris Dauphine University in France. The scenario is designed to explore how society would cope with a power failure over successive time periods. The aim is to provide information to emergency managers and policy makers about community needs and people's likely behaviour in future blackouts. The study starts with its impact and continues till the post disaster response phase. It identifies which groups of people are most vulnerable, how people make their decisions, how they cope with the problems such as lack of food, water, and information and how resilient they are.

Study 2, 3, and 4 are flood related. Unlike blackouts, which are fairly infrequent in Europe, flooding is becoming increasingly common.

Study 2, describes people's response to floods in Germany 2013 and the UK 2007. The findings are based on interviews with residents and businesses in flood prone areas. The studies explain how people responded in both the short and medium term, and how prepared they consider themselves for the future floods.

Study 3, describes a model designed to analyze the cost of issuing or not issuing an evacuation order in different scenarios under conditions of uncertainty.

Study 4, describes the process of recovery after the Germany 2013 and the UK 2007 floods. Together with interview surveys with residents and businesses the findings are also based on an internet survey with flood experts in Germany and the UK. The study provides information about prevention and mitigation measures taken after the two events and how residents and governments are adapting, and preparing for future floods.

Study 5, describes post-disaster recovery of the tourist sector in the Philippines after back-to-back disasters in Philippine where an earthquake occurred in mid-October and three weeks later a typhoon hit the same area. The research uses three sets of indicators (business, safety and physical) to measure recovery.

A short explanation of each study is provided below.

4.1 Study 1: Communication blackouts in power outages: findings from scenario exercises in Germany and France

Study 1 reports findings from scenario exercises held with University students in France and Germany that were designed to explore reactions to an extended electricity blackout. The demand for electricity has dramatically increased and daily life is now totally dependent on electricity. Although the event of a power blackout is uncommon, particularly in developed and industrialized countries, the increasing severity of natural hazards due to climate change, the complexity of the power grid, technical failures and human errors, the increasing risk of cyber-attacks, and a combination of these factors has increased the chance of power failure globally (Bruch et al. 2011; Klein et al. 2018). Some recent examples of large worldwide blackout, with the number of affected people into the millions, include Ontario and NE US in 2003, Italy 2003, Spain 2004, Brazil 2009, India 2012, Pakistan 2015, Turkey 2015, Argentina, Paraguay and Uruguay 2019 and Venezuela 2019 (Bruch et al. 2011; Wikipedia 2004).

Electricity power is part of modern critical infrastructure and it is necessary to increase the resilience and maintain the stability of systems to avoid blackout. Pescaroli and Alexander describe the vulnerability of critical infrastructure to the cascading effects of disasters (PESCAROLI and Alexander 2015). A disruption of the electricity network would be followed by large cascading events and impact communication and social interaction. Planning and preparing for electricity power outage is one of the important functions of government (Caldwell 2014; Panteli and Mancarella 2015). The way different countries deal with and prepare for extended blackouts varies and coping with crises is easier if people have the capacity to forecast and anticipate disasters such as blackout (Aldrich 2012). Nigeria, Iraq and Pakistan have experienced frequent major blackouts, whereas in Germany only a minority of the population has experienced a power outage longer than a few hours.

Although an infrequent occurrence in developed countries, a blackout in 2019 in Berlin lasted 30 hours and left 30,000 households and 2,000 businesses without electricity (Knight 2019). In 2012 in Munich a blackout affected 450,000 people for 10 minutes to over 3 hours. A blackout in Hanover in 2011 affected 600,000 people (Nicola 2012) and in 2006 a European blackout affected people in Germany and France. Because of the relative infrequency of blackouts in Europe, it is unclear how the crisis would proceed in a real situation, and, in order to be able to manage an extended blackout, it is important for authorities to anticipate the potential reaction and perception of society as well as their expectations in terms of government communication and action.

One of the ideas about reactions to disaster and disruption is that people and organizations try to maintain the continuity of behaviour (Rogers and Nehnevajsa 1984). They also become more united and connected rather than panicking and looting. Nevertheless, a typical human response to disasters is to deny or reinterpret a warning, to downplay or eliminate the possible threat (Dynes 1994; Quarantelli 2001; Drabek 2016). The immediate response to a disaster, according to Rogers and Nehnevajsa (1984), is a self-protecting reaction and peer support, meaning people react firstly by protecting themselves and their loved ones, secondly seeking information and confirmation about the hazard, and finally they 'follow the crowd' and respond as a group.

Hiete et al. (2010) provide an overview of how the legal regulations relevant to power failure crisis management vary with duration. The thresholds are a blackout up to 8 hours, between 8 to 24 hours, and in the worst case, for a blackout over 24 hours. These time periods were adopted in role-playing scenario exercises with university students in Germany and France. The four workshops aimed to investigate emotional reactions, reactive behaviour, personal decision-making and expectations of government during a hypothetical 3-day blackout. Students were asked to imagine a blackout in the city where they live and to play a particular role they were allocated. The scenario game exercise collapsed real time to highlight significant issues and to focus on people's decision-making, responses and imagined actions. The use of scenario planning allows us to explore how professionals and the public might respond to an unclear future, in this case an extended blackout, in advance of what is an infrequent risk.

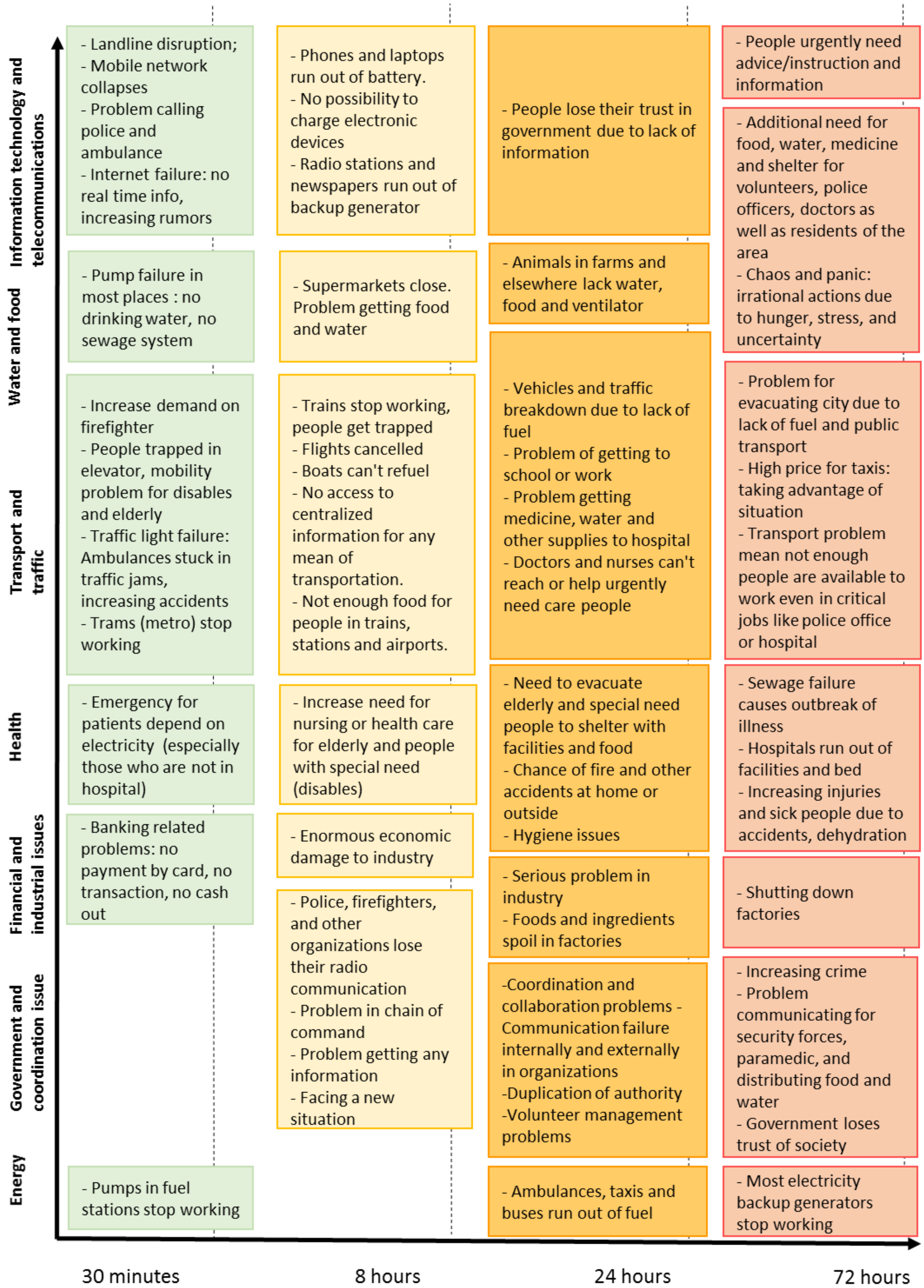

Figure 9 Blackout cascading effects over four time periods (developed by the author of this thesis and Miriam Klein)

The methodology for scenario design, data collection and result analysis are described in detail in the paper "Communication blackouts in power outages: findings from scenario exercises in Germany and

France” in study 2 (Mahdavian et al. 2020a). Figure 9 illustrates some of the potential cascading effects in different time periods after the onset of a blackout.

4.2 Study 2: Risk behaviour and people’s attitude towards public authorities – a survey of 2007 UK and 2013 German floods

Study 2 focuses on flood events in the UK and Germany and explores pre-disaster mitigation and preparedness and post-disaster response.

As mentioned earlier, hydrological disasters, which include avalanche, flash flood, coastal flood, riverine flood and mudslide, are increasing with global warming and climate change and present major problems worldwide which many scientists have been addressing and proposing solutions. One of the key issues is the erosion of flood plains and the increasing risk this poses.

In Europe, North America and Japan, there are few remaining dynamic flood plains and the current situation for European flood plains is critical (Tockner et al. 2008). Some 95% of the original floodplain area has been converted to other uses and over 40 European countries, nearly 90% of alluvial forests have vanished from their potential range (UNEP– WCMC 2004). Among the remaining flood plains in Europe, many of them are far from pristine and have lost most of their natural functions. For example, about 20,000 km^2 of the former 26,000 km^2 of floodplain area along the Danube and its major tributaries are isolated by levees (Nachtnebel 2000; Busnita 1967). However, major flood events have highlighted the vast extent of plains still subject to flooding. Worldwide, 60–99% of the entire riparian corridor has been transformed into cropland and/or is urbanized, the latter particularly so in Europe (Tockner et al. 2008).

To give an indication of the frequency of flooding, a review of major worldwide hydrological events occurring 2018-19 was derived from news items published in online German newspapers.

On 4th February 2019, in Queensland Australia, 20,000 houses were threatened by the flood and 16,000 people were temporarily without electricity (ZON 2019a). On 9th July 2019 in Washington U.S.A, streets, parking garages and subways were flooded by heavy rain (SPON 2019). South Carolina ordered the evacuation of its entire coastline on 2nd September 2019 because of risk of hurricane Dorian (Korge 2019a).

According to the UN Emergency Aid Office (OCHA), in November 2019 more than 908,000 citizens of Sudan in the East African were affected by flood, many people had to evacuate their homes and some got cut off from the outside world (ZON 2019b).

In Asia, on 3rd July 2019 in Japan more than a million citizens were ordered to leave their homes due to the risk of landslide and flood (Optensteinen 2019). On 10th August 2019 "Lekima" storm, classified as a super typhoon, reached China's east coast killing 18 people and more than a million people had to evacuate their homes (Midasch 2019). On 26th of August, Schneider reported that the capital city of Indonesia was sinking due to natural hazards such as coastal flood and earthquake, and the government is planning to move the capital from Jakarta to a newly build city because of rising flood risk due to global warming (Schneider 2019).

In Europe, on 10th August 2019 in Luxembourg a tornado injured several people and up to a hundred houses were destroyed and 180 buildings were damaged in the villages of Pétange and Käerjeng

(Diekmann 2019). Venice declared an emergency due to extreme flooding on the 13th November 2019 and the Mayor of Venice claimed flooding was more frequent due to climate change (Korge 2019b).

There were also a number of floods in the UK and Germany – the respective study region – since 2018. In England, in November 2019, “a woman died and many homes were evacuated as widespread flooding left a trail of devastation across swathes of the Midlands and northern England” (Parveen and Murphy 2019). In UK more than a thousand people had to evacuate their homes, and numerous roads and railways were closed in February 2020 (Duhm 2020).

In Wuppertal in May 2018 numerous streets were flooded, and several trees fell over and the extent of the damage is considerable (Bredow 2018).

Western and southern Germany in June.2018 entire streets became rivers and rivers burst their banks. Several communities were trapped and 300 fire-brigade personnel were on duty all night (Ziegler 2018).

On 20 May 2019 large parts of south-east Germany were expected to experience constant rain for a few days and there was a risk of flooding, exacerbated by melting Alpine snow (Lingenhöhl 2019). On 20th May 2019 Storm Axel caused a flood warning level 3 of 4 in Bavaria during the night and on 21st May, in Helmstedt, Lower Saxony, a hospital had to be evacuated (Langer 2019) and there were reports of “the heaviest rainfall ever recorded on Germany's southern border with Austria“ (Silk 2019).

In February 2020, on Wangerooge island in Germany flood and storm almost completely destroyed a beach (Maxwill 2020). Also in February 2020 in Koblenz (SPON 2020) there were warnings of the rising water levels on the Moselle and Rhine after heavy rain, and the difficulty of building a retaining wall if the river rose over 5 meters (SWR 2020).

These are only some of the examples of flooding around the world, but climate change is a slow onset event, which is causing a rising trend both in terms of frequency and economic losses of flood (EM-DAT; Alfieri et al. 2016). Therefore, it is essential to increase resilience with respect to flood risk and flood impacts. Mitigating the immediate and direct impacts of flooding, such as saving life and reducing property damage, and reducing the long-term impact by increasing resilience is possible by advance planning, educational effort, and preparedness.

In study 2 of this thesis, people's preparedness and the factors that affect people’s responses during a flood are studied. The interviews and survey were conducted among the residents of two places: Catcliffe, near Sheffield in the United Kingdom, which was badly flooded in 2007, and Passau in Bavaria, Germany, which was hit by floods in 2013. Both places have been flooded numerous times. Sheffield was flooded most recently in 2000 and 2007, while Passau, at the confluence of the rivers Inn, Ilz and Danube, was flooded in 2002 and 2013. 106 people were interviewed in total; 74 people from Passau and 32 people from Catcliffe, of whom 45% and 56% in Passau and Catcliffe respectively were directly affected by previous floods.

In total, 17 hypotheses were developed, divided in two parts. Part 1 focusses on perception and flood preparedness, and part 2 analyses the hypothetical evacuation behaviour and the influence of trust in government with respect to risk perception and preparedness (Mahdavian et al. 2020b).

Study 1 and 2 analyzed people’s behaviour, risk perception, preparedness, reaction, decisions, and role of trust in government in different crisis. However, if it comes to the question how people get the instruction about the best time to react and what to do, or how to deal with the situation, a decision-making approach was adapted in study 3.

4.3 Study 3: Optimal Evacuation-Decisions Facing the Trade-Off between Early-Warning Precision, Evacuation-Cost and Trust – the Warning Compliance Model (WCM)

Study 3 explains how decision-making is critical for government, authorities and emergency managers during the uncertainty of natural disasters. The particular focus is on decisions regarding evacuations during flood.

In addition to heavy rains and overflowing the rivers, flooding is also caused by dam failure, urban drainage basins, storm surges, deforestation and melting snow. Different emergency plans are necessary for each flood scenario.

Emergency Managers have the critical task of alerting the public to the threat of natural disasters in order to save their lives (Baumgart et al. 2008). The primary aim of emergency management is to minimise loss of life and economic damage for society (Kolen and van Gelder 2018). Carpender et al explain the importance of consistence and accurate public warning prior to and during the emergency situation (Carpender et al. 2006).Therefore, forecasting flood is an essential part of flood risk management because the scale, scope and timing of a flood is a necessary information the authorities need to estimate the threat of flood and plan emergency response (Kolen and van Gelder 2018) . For example, the European Flood Awareness System (EFAS) is used in addition to national flood forecasts in European countries and provides probabilistic flood forecast information 10 days prior to the flood event for national authorities within Europe (Pappenberger et al. 2015).

The problem is, despite having advanced weather forecasting, there is a chance that authorities receive a false alarm. A false alarm is defined as an event which was forecasted to occur, but did not, due to imperfect forecasts. In an ideal world, the false alarm rate (FAR) would be zero but due to many uncertainties in technology and the dynamics of the flood situation the forecasts are prone to errors (Barnes et al. 2007). After authorities receive the forecast they have to decide whether to order an evacuation or not, and what warning and alarm they should give to the public, taking into consideration the many uncertainties and limitations of the forecast.

Kolen defines evacuation as a process starting with alerting, warning, deciding, preparing, and temporarily leaving an unsafe location with people, animals, and belonging and going to a safer place (Kolen 2013).

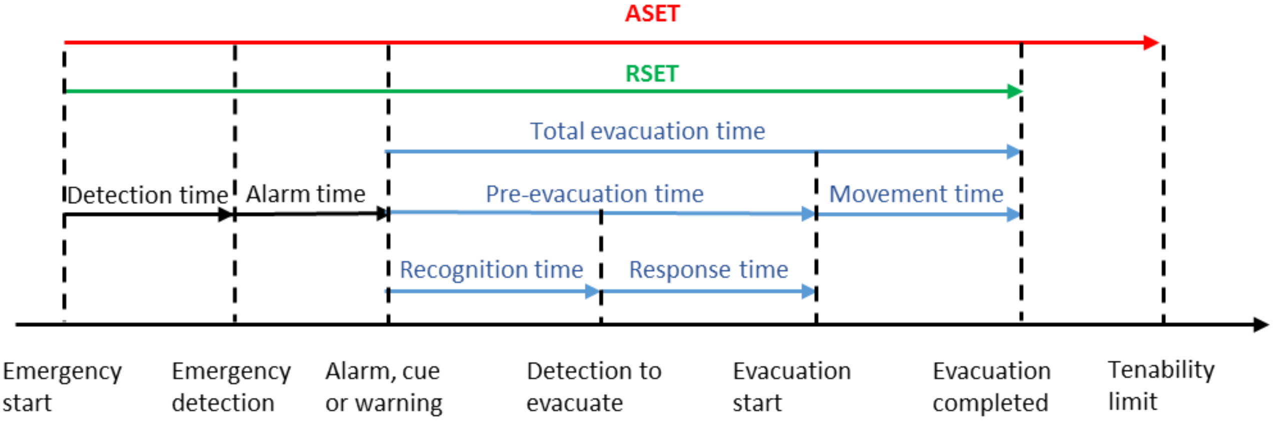

Figure 10 Evacuation timeline representation (Lovreglio 2016)

Evacuation time is considered as the period between the first evacuee or vehicle leaving until the last evacuee gets to safety. The mode of evacuation would depend on the particular circumstances of a flood and on the physical ability of those at risk (Baou et al. 2018). Figure 10 is the timeline for evacuation Lovreglio (2016).

It can be seen that the process of evacuation can be divided into distinct phases, such as the time needed for forecasting or detection, issuing alarm, recognizing and then reacting to an alarm, and finally time needed to evacuate to a safe location. All these steps proceed with many uncertainties. For example, the government, because of time constraints, may need to issue an alarm or evacuation order before they receive a completely accurate and reliable forecast.

A government evacuation order can either be mandatory or recommended, but in both cases, there are risks, some of which can be anticipated, others not. For example in Hurricane Floyd after a mandatory evacuation, people spent 10 times more than usual in traffic jam in the road to get to the safe place (Dow and Cutter 2002). In the mandatory situation, the best scenario or outcome is when everyone at risk gets to a safe place in time, as happened with Hurricane Floyd. However, there might be two further scenarios. The first possibility is that due to heavy traffic jam and a late start for evacuation or a changing severity of disaster, people get trapped by the flood during the evacuation. This happened in Japan tsunami 2011 when government first announced the height of tsunami as three meters, then to six meters and finally to nine meters. By the time people realised the scale of the impending disaster and started to move to a safer location when was already too late (Mahdavian et al. 2012). The second possibility for the government is to issue a wrong evacuation order because they over-estimated the scale of the disaster, told people to evacuate, but nothing serious happened. This false alarm from authorities could lead to a loss of trust and faith among the people (this effect is called "crying wolf" in many articles). However Dow and Cutter (1998) argue that despite receiving a false evacuation alarm people still follow government advice when a subsequent hurricane happens and again the government asks them to evacuate. Although “crying wolf” may not apply in hurricane, it might happen in floods, because floods are more likely to be underestimated in many countries if they have not been severely affected in the past. This might mean that people are more intolerant of repeated false alarms. Earle (2010) and others refer to different types of trust. With respect to the time-line there is trust based on past behaviour and another type of trust which refers to future behaviour, which is called calculative trust. Trust in government would be the second, calculative type of trust and could change in the future if previous behaviour was untrustworthy.

Study 3 of this dissertation deals with the decision-theoretical perspective on the flood evacuation problem and examines the aspect of flood-evacuation compliance in more detail. The following simplified decision situation is considered. In a potentially flood-prone city, two risk groups can be distinguished: a smaller group, e.g. one that lives very close to the coast and is therefore exposed to a high risk (group A) and a second larger group (group B) that lives in the hinterland and would only be affected by an extreme flood. The warning compliance model comprises a probabilistic and a decision-theoretical or game-theoretical part. For the first, the random events are modeled using a Hidden Markov chain depicting both the escalation and de-escalation phase of a hypothetical severe flood event. At the same time, the performance of the early warning system (information system) can be taken into account in the model by determining the Likelihood Matrix accordingly. The warnings emanating from the early warning system are observable for both the affected population and the local government.

However, with respect to the impact of a possible severe flood, there is an information asymmetry between government and population, i.e. we assume that the government is better informed than the population about the actual impact of an approaching flood. The decision-theoretical or game-theoretical part covers the interaction between the local government and the two groups. The local government can send a (non-binding) evacuation request to each of the two groups and they then have to decide whether to follow it. The population will only believe the government's announced threat if it has a high level of trust in the government's competence. This trust variable is a decisive factor for the population's compliance. In addition to the information system, the decision also includes damage costs, which include both the danger to life and limb and the complications that an evacuation entails. The government can also weight the extent to which it takes into account the evacuation difficulties of the population and the economic consequences. The setting, which formally corresponds to a Stackelberg game between government and population, can then be solved for all conditions and the respective influence or scope of compliance can be calculated for each constellation in generic form.

4.4 Study 4: Were the floods in the UK 2007 and Germany 2013 game-changers?

Disaster response and disaster preparedness phases of the disaster cycle were covered in Studies 1, 2, and 3. The next two studies are studies about recovery and mitigation.

As it was defined earlier, recovery is returning to a normal or acceptable state after a disaster, specifically, when 90% of displaced people, disrupted businesses, and affected working population have returned to home or work (Platt et al. 2020). In many cases the aftermath of the disaster presents an opportunity to create a more resilient environment by applying new resources and adopting better solutions to mitigate the risk for future events, a process that has come to be known as 'building back better'.

The two case studies in study 4 refer to the same study region as in study 3 – the 2007 flood in Catcliffe UK, and 2013 flood in Passau Germany. This research reported on surveys of residents and businesses in each place as well as on surveys of national flood experts in both countries. Despite some differences in the characteristic of the two areas, the flood events were comparable in terms of their impacts, levels of preparedness and government response. In study 5, the cases are compared in terms of patterns of recovery. The number of residents' interviewees in Catcliffe was 32 and in Passau 74. They were asked the following three main questions.

1. How many months after a flood they thought they got back to almost normal (if ever).

2. Whether they felt that their home was safer and better prepared to cope with another flood, less prepared or about the same?

3. Has the local area been made safer and more resilient, or is the state of the area about the same or even worse?

The survey of flood experts in each country asked more questions and was therefore more detailed. A total of 150 experts in UK and 110 experts in Germany were contacted and 27 in UK and 21 in Germany responded to the survey (a response rate of 18% and 19% respectively).

The main questions to experts was directed to establishing the impact of flood, speed and quality of recovery in different sectors of housing, economy, employment, population, infrastructure, and non-domestic buildings[1]. The expert survey also investigated the roles of the state and the insurance sector.

[1] Non-domestic = buildings such as hospital, schools and local government, and excluding houses, industry and commerce

Experts were asked what went well and what went badly during the flood emergency and recovery in both countries. Finally, the study discusses the key reforms, initiatives and improvements in flood resilience and management in each country. Table 2 compares the different aspects of these two floods and flood impacts in Germany and UK.

Table 2 Comparison of floods in UK and Germany

	Catcliffe, Sheffield/Rotherham	**Dreiflüsse-Eck (Altstadt), Passau**
Character	low density commuter village	high density, historic city centre
Location	2.5 miles from Rotherham and 4 miles from Sheffield city centre	historic centre of Passau at confluence of Danube, Inn and Ilz
Date flood	25-Jun-07	03-Jun-13
Population 2011	2,108	2,990
Population year of flood	1,971	2,981
Population 18-64	64%	66%
Area	30 ha	37 ha
Flooded area	16 ha	26 ha
Flooded area %	52%	70%
Properties total/flooded	372/195	800/560
Evacuation	Forcible evacuation due to fears dam failure	Water supply failure meant 60 inmates of Passau prison had to be transferred
Comparison of the impact of flooding in UK and Germany		
Extent	6 out of 9 Regions	8 out of 16 States
Fatalities	13	14
People Displaced	38,000	80,000
GDP, PPP (event year)	USD 2.2 tn	USD 3.6 tn
Economic Loss	USD 3.3 – 4.9 bn	USD 6.7 – 9.1 bn
Insurance Loss	USD 2.6 bn	USD 1.8 bn
Average cost per house	USD 32,000	USD 56,000
Insurance Households	75%	32%
Government Aid	USD 180 mn	USD 8.9 bn
Flood risk homes 2018	5.5 mn	3 mn

(Environment Agency 2007; Thieken et al. 2006; Bertelsmann Stiftung 2017; British Geological Survey; DLR 2013; Bayerisches Landesamt für Statistik 2019; Bubeck and Thieken 2018; BMF 2013)

4.5 Study 5: Tourism Recovery Scorecard (TOURS) – Benchmarking and monitoring progress on disaster recovery in tourism destinations

This last study describes recovery from a pair of natural disasters in the central Visayas region of the Philippines. The Philippines is listed among the top five countries in the world in terms of the annual number in natural disaster events, as well as being in the third most at risk country in terms of natural disaster (Guha-Sapir et al. 2014; UNU-EHS)

The aim of this study is to measure the recovery of three tourism destinations affected by two back-to-back disasters: a magnitude 7.2 earthquake (Bohol earthquake) and a super typhoon (Haiyan) on 15 October 2013 and 8 November 2013, respectively. The Bohol earthquake left 222 people dead, 8 missing, 976 injured and more than 73,000 damaged buildings, while three weeks later typhoon Haiyan left 6,300 dead and 550,000 destroyed homes according to official reports by the National Disaster Risk Reduction and Management Council (NDRRMC 2013a, 2013b).

This study reports a set of indicators which aim to measure recovery of the three destinations and their readiness to welcome tourists again (Khazai et al. 2018). The Central Visayas region experienced huge economic impact after these two disasters and hundreds of tourists were stranded for days after the storms, according to the World Bank survey (GFDRR 2014). The storm was in the headlines of international news for a week and frightened away tourists from this region, causing massive cancellation in the tourism sector (Sidel 2014).

Damage to business, including the tourist industry, after disasters occurs globally. Australia after the Katherine flood in 1998, countries around the Indian Ocean after the 2004 tsunami, and Japan after the Great East Japan Earthquake in 2011, all suffered economic damages that escalated with negative media coverage. Recovery to restore normal services took longer than it might had without this negative reports (Faulkner and Vikulov 2001; Sönmez et al. 1999; Faulkner 2001). In fact, after a disaster, media reports have a potential devastating impact on tourist destinations and pose severe challenges to marketing of the area and neighboring destinations (Beirman 2016; Weir 2005). Yet, reliable, up-to-date information about the reinstatement of tourist attractions, transport, accommodation, facilities and safety can greatly reassure tourists and speed of return to normal operation. This research developed a framework with a set of indicators to measure recovery in a way that is useful for communication with prospective tourists. This framework was applied to three tourist destinations in the Philippines and was used to benchmark the key impacts of the disaster and monitor the progress of recovery. The framework is called the “Tourism Recovery Scorecard” (TOURS), and it is designed to be used by tourism stakeholders, including tour operators, government and public sector and visitors to tourism destinations. In the TOURS framework, there are three main dimensions: safety, physical recovery, and business recovery, corresponding with how the concept of resilience is divided into psychological, physical, economic dimensions and with the three dimensions of sustainability: social, environmental and economic. Each of the three dimensions mentioned earlier were measured by five to six different indicators (Table 3).

The stakeholder survey was conducted by a research team from Karlsruhe Institute of Technology (including the author) in August 2016. The respondents were selected from people in the tourism industry who had personal experience of the disaster event and had witnessed the recovery process in their industry and the whole area.

Table 3 Indicators used in the survey in the Philippines

Safety	**To what extent:**
Reputation	was the destination reported as safe on: TV, Radio, Print Media; Social Media; Word of Mouth
Hazard	did you feel safe in relation to secondary or natural hazards triggered by the main event?
Health	was health and spread of disease controlled?
Security	was the destination safe in terms of crime/ terrorism?
Stability	was the destination politically stable?
Overview	did the destination feel safe for tourists?
Physical Recovery	**To what extent:**
Roads	was debris cleared where tourists go?
Electricity	was electricity restored?
Water	was drinking water restored?
Attractions	have attractions been restored?
Transport	have transport systems been restored for: Flights; Ferries; Public Transport; Private Car?
Housing	have people been rehoused?
Overview	does the destination look recovered?
Business Recovery	**To what extent:**
Foreign	has foreign tourism recovered?
Local	has local tourism recovered?
Occupancy	have hotel bookings recovered?
Services	have restaurants, shopping, tourism agencies/services; ATM recovered
Telecomes	have mobile phone networks recovered has the tourism economy recovered?
Overview	has the tourism economy recovered?

A total of 40 people from the tourism sector were surveyed in three disaster affected areas: Cebu, Bohol, and Bantayan. Respondents included experts in Philippines governmental organizations, tour operators, hoteliers and resort sector operators. They were asked to answer the same set of questions for two different time periods: Right after the disaster and at New Year. New Year in the Philippines was 2.5 months after the event. New Year was selected to help the respondents fix the time in their memory as New Year was the first tourist season after the event and was a transition period between short- and medium-term recovery. Two different types of scaling were used – binary, in which respondents could indicate either the place was recovered or not, and a 10-point Likert scale, where respondents could be more precise about the scale of recovery (table 4).

Table 4 Key informants interviewed

	Rating Scale	Binary Scale
Cebu	12	3
Bohol	6	11
Bantayan	2	6
Total	20	20

4.6 Methodology overview of all mentioned studies and their relevancy

Table 5 The relevancy and methods overview of included papers in dissertation

	Paper 1 Blackout Response	Paper 2 Flood Response	Paper 3 Evacuation Cost	Paper 4 Flood Recovery	Paper 5 Recovery Monitoring
Scenario planning	✓				
Face to face survey/study	✓	✓		✓	✓
Online survey		✓		✓	
Focused group		✓		✓	✓
Stakeholders and experts				✓	✓
Disaster response	✓	✓	✓		
Disaster recovery				✓	✓
Disaster prevention and mitigation	✓	✓	✓	✓	
Disaster preparedness	✓	✓			
Recommendation for the policy makers	✓	✓	✓	✓	✓
Quantitative analyses	✓	✓	✓	✓	✓
Qualitative content analyses	✓			✓	
Theoritical analyses			✓		

5. Summary and conclusion

This chapter comprises first a summary conclusion of each study, and then a brief discussion of the implications with respect to the disaster cycle will be given.

Study one: Scenario planning blackout

Scenario planning and role-playing have been used in various scientific disciplines to investigate possible outcomes of hypothetical situations. This study is unique in the way it used a role-playing scenario to study people's potential behaviour during an imagined blackout in Germany and France, and to compare possible emergency reactions in these two countries. The study also aimed to inform policymaking and to raise the awareness amongst policy makers regarding societal needs, thoughts and expectations in such an event. Moreover, using scenario game in this study also played an important role in understanding how people's emotions might change over the time and how these changes might influence their strategies and reactions during blackout. To the best knowledge of the authors, similar studies have not been done before.

Blackouts are rare events, particularly in highly industrialized countries such as Germany and France; therefore, this infrequency of occurrence poses problems and limitations for research. To understand what would be the primary needs that authorities and emergency managers are expected to provide for society a hypothetical 3-day blackout scenario was designed using both inductive and incremental approaches to answer three main research questions:

1. What are the potential cascading effects of a 3-day blackout and the implications for different types of people?
2. How might people react and feel during a long-lasting power blackout?
3. What would be the level of societal resilience, preparedness and potential response to a possible crisis of a 3-day blackout?

The role-playing scenario, which was conducted among the university students in Germany and France, provided important insights into these research questions. This study demonstrated clearly how quickly and unexpected the chain of cascading effects develops during a blackout, and how unprepared societies are to face this disaster.

Qualitative and quantitative analysis of the data illustrated the results which policy makers need to consider for future events and they are how people's emotions and reactions change drastically during the 72 hours of power outage, from calm and safe, to desperation and frustration. Furthermore, in both study areas, participants had a great deal of hope and trust in the authorities in the first 24 hours, but after not getting any information about the electricity outage nor any advice about how to cope or what to do, their trust dropped dramatically and they start to coordinate things on their own way. In the open discussion participants argued that even if the reason for blackout had been a cyber-attack, although they would have been scared, they would have preferred to know.

In the blackout scenarios, coping strategies and adaptive behaviour of people were clearly identified. For example, people organized their community to support the elderly, children and disabled, meanwhile searching for food, water and information. As might be expected, negative emotions and concerns increased in all groups of participants over the 72 hours, and after the first day, moves to evacuate began (figure 11).

Uncertainty about what is happening and how long it will continue caused most concern and lack of communication aggravated anxiety and caused considerable distress. Table 6 shows the expectations of participants from the authorities.

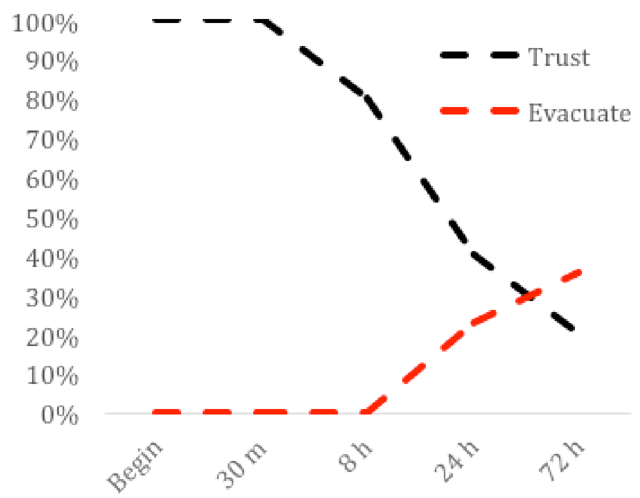

Figure 11 The relationship between trust and evacuation

Table 6 Expectations from authorities over time

30 Mins	8 Hours	24 Hours	72 Hours
- **Information** expected - The problem fixed soon - Short blackout - **Confirm with people** that public service is still functioning - Traffic police manage the traffic	- **Information** expected from police, Red Cross, government, city hall (Find the way to inform people considering people have no access to internet and TV) - Water distribution - Nursing care for elderly - **Advice** from government about how to behave and what to do if it continued - Provide water	- **Information** and guidance - Government provide food and water and other initial needs - Shelter provision for people in need - Help from other regions or other countries - Evacuation - Government visit old people at home - Employers to not expect their employees to go to work - Security force (police, army) provide security - Local government officials in the area - Local and central government implement emergency measures - University provides information - Community organizations step in - Foreign authorities support foreigners - Provide portable toilets - Calm down people	- All points from previous time period plus: - Government plans organized evacuation - Firefighters provide humanitarian support

The findings from this study suggest people are neither familiar or prepared for this type of crisis, and authorities need contingency plans not only to keep critical services supplied with power, but also how to communicate and advise citizens in a major extended power outage. Government late or uncoordinated reactions would increase frustration and self-planning, which could escalate the disastrous situation out of hand.

Study two: Flood response in Germany and the UK

There are many studies about people's risk behaviour during disasters in different countries, but what particularly make this research rare are firstly, comparing the risk behaviour, flood awareness and flood preparedness of two different countries together, and secondly comparing the attitudes towards public authorities in case studies of the German flood 2013, and the UK flood 2007. This research was designed to investigate two broad research questions.

1. Firstly, what is the level of risk perception and flood preparedness in the two selected areas in Germany and the UK, and what influences them?
2. Secondly, attitudes toward government and reaction to government advice during the flood?

To address these research questions, a survey with forty-four questions was designed, over 130 statistical tests using SPSS software were conducted, and seventeen key hypotheses were analysed. The survey data were collected during the field study in the flood-affected area in the UK and Germany, among the people who personally experienced the flood and those who would potentially be affected in a future flood.

For respondents without flood experience, the most frequent constellation is the combination of low perception and low preparedness (40%). It can be concluded that lack of perception of flood risk causes a lack of preparedness. A further 32% perceive themselves to be at medium or high risk but are still unprepared (table 7). People's flood risk preparedness could be improved by technical guidance and financial support.

Table 7 Constellations of perception and preparedness

	No flood experience (N=53)			Flood experience (N=50)		
	Perception			**Perception**		
	Low 1, 2	Med 3	High 4, 5	Low 1, 2	Med 3	High 4, 5
Preparedness						
Low 1,2	40%	15%	17%	19%	2%	20%
Med. 3	9%	9%	2%	5%	8%	14%
High 4,5	2%	4%	2%	10%	8%	14%

Table 8 shows the hypotheses developed and tested for both countries of the UK and Germany. The results also showed that risk perception and preparedness is higher among older people. In both study areas, trust in government was fairly low. However, during the emergency, people stated that if the government asked them to evacuate immediately, about 70% in Catcliffe and 80% of respondents in Passau would take immediate action to evacuate. Furthermore, despite the high trust in family and low trust in government, if the government asked them to evacuate and their family said it was unnecessary, nearly 70% of respondents in Passau and Catcliffe would follow the government advice. The decision to evacuate is significantly higher amongst women than men. Reaction analyses of flood experienced people during the emergency showed 78% of them acted self-protectively in Catcliffe compared to 42% in Germany, which could be due to the lower trust in government in the Catcliffe area of the UK compared to Passau in Germany. Flood experienced people in both areas were dissatisfied with early warning and the poor response of emergency managers in the first phase.

Table 8 Hypotheses generated from literature review (HC: hypothesis confirmed, HR: hypothesis rejected)

	Hypotheses	**Test results**
PART 1 Perception and flood preparedness		
H1a	Perception of flood risk is higher amongst people with experience of flooding	HC
H1b	People with flood experience see themselves better prepared for floods	HC
H2	Perception of flood risk is higher in Passau-Germany than Catcliffe-UK because the flood was more recent.	HC
H3	People with higher risk perception see themselves better prepared for flood	HC
H4a	Perception of flood risk is higher among older people than among younger people	HR
H4b	Older people see themselves better prepared for flood than younger	HC
H5a	Perception of flood risk is higher among women than among men	HR
H5b	Women see themselves better prepared for flood than men	HR
H6a	Perception of flood risk is higher among people with high risk aversion than among people with low risk aversion	HR
H6b	Risk averse people see themselves better prepared for flood	HR
PART 2 Attitude toward government and reaction to government advice		
H7	Flood experienced people see themselves more responsible for preparedness	HR
H8	People who see citizen more responsible for preparedness should also see themselves better prepared	HR
H9	Respondents in UK see citizens instead of government more responsible for flood preparedness compared to Germany	HR
H10	Trust in government is higher among German respondents compared to UK respondents	HC
H11	People who see citizen more responsible for preparedness are less likely to follow government evacuation order	HR
H12	People with low trust in government are less likely to follow government order to evacuate	HC
H13	People with low trust in government chose to listen to family rather the government	HR
H14	Older people are more likely to evacuate immediately than younger ones	HR
H15	Women are more likely to evacuate immediately than men	HC
H16	Risk averse people are more likely to evacuate immediately	HR
H17	Age does not influence trust in government	HC

Table 8 shows the hypotheses developed and tested for both countries of the UK and Germany. The results also showed that risk perception and preparedness is higher among older people. In both study areas, trust in government was fairly low. However, during the emergency, people stated that if the government asked them to evacuate immediately, about 70% in Catcliffe and 80% of respondents in Passau would take immediate action to evacuate. Furthermore, despite the high trust in family and low trust in government, if the government asked them to evacuate and their family said it was unnecessary, nearly 70% of respondents in Passau and Catcliffe would follow the government advice. The decision to evacuate is significantly higher amongst women than men. Reaction analyses of flood experienced people during the emergency showed 78% of them acted self-protectively in Catcliffe compared to 42% in Germany, which could be due to the lower trust in government in the Catcliffe area of the UK compared to Passau in Germany. Flood experienced people in both areas were dissatisfied with early warning and the poor response of emergency managers in the first phase.

Study three: Calculating Optimal Evacuation-Decisions cost

The most important outcomes and insights of this study are as follows:

- Scope for compliance: The model identifies the scope for compliance, i.e. the parameter constellations where the communication between government and people really matters. Compliance is necessary when the interests of the population and the state diverge, but it is effective if the trust-level of the population exceeds a minimum level.

- Zone of Compliance: In the model, people are willing to follow a request if the probability-point (which reflects the discrete probability distribution of the expected flood events) lies within an area where people trust the impact which is announced by the government. This area is called "zone of compliance". For high trust-levels, this zone of compliance can be wide indicating a high willingness of the citizens to follow the government's orders over a high range of parameters. However, for low trust-levels this zone can be very narrow; in this case the citizens ignore the state's announcements and make the evacuation decision on their own.

- Communicative responsibility of the government: If the interests of citizens and authority are aligned and trust is sufficiently high (compliance without conflict of interest), the authority has influence on the citizens decisions and must take this responsibility into consideration. In particular, affirmative communication is necessary to avoid misunderstandings.

- Applying empirical data to the escalation-phase we see that the population in region A would already evacuate on its own but that the state would also order this evacuation, which hints at responsibility of affirmative orders.

- Applying empirical data to a (hypothetical) announced Black Swan flood we find that the inhabitants of region B would not react to an S2 warning and that the authority would not order evacuation either. However, the authority's decision is sensitive to its preference parameters: Only if the state gives the highest priority to saving lives it would order evacuation. Nevertheless, this order would lack compliance due to the very low probability.

- The insights of the model show that it is a necessary next step to combine the decision-theoretic framework with elements of risk perception.

Study Four: Flood Recovery in Germany and the UK

Monitoring recovery after major floods is an important topic that various researchers from around the world have investigated. What makes this study different and innovative is the comparison of highly comparable floods in the UK and Germany that involved a survey of both residents and experts in each country.

The results of experts and residents' survey analyses in Germany and the UK for recovery of these areas can be summarised as follows:

- The flood impact on different sectors as well as speed and quality of the recovery were similar in both countries (in Germany few months faster)

- In Germany more than 60% of recovery funding came from federal aid, whereas in the UK more than 90% came from household insurance

- The economy of both countries took between one to one and a half year to recover.

- In both Germany and the UK residents believe that most homes and businesses in the flooded areas were no, more resilient after they recovered. However, in the UK neighbourhood areas are thought to be safer than they were prior to the flood due improved flood defences and better systems of early warning. There was no similar improvement in area wide safety in Germany.

- This finding from the survey of local people in the affected areas contrast with the view of experts in each country. In Germany, experts believe that all sectors improved after the flood in 2013, whereas experts in the UK believe infrastructure was the only sector that showed significant improvement after the 2007 flood.

Figure 12 shows how after each flood, experts believe that different aspects of society and the economy changed compared to the pre-flood state.

Figure 12 Experts' assessments about change in socio-economic sectors

In addition to the detailed questions about flood damage and recovery in different sectors, experts highlighted things that went well or badly during and after the flood (table 9). Positive notes were referring to the forecast and warning in comparison to the previous floods, better coordination and collaboration among agencies and emergency management services, more resilient communities and faster recovery in comparison to the past, and also initiation of flood resilience improvements. On the other hand, highlighting things that went bad explains the scale of the disasters in both countries were overwhelming. The states and task forces were not well resourced and prepared, and coordination had difficulties. Meanwhile inadequacy of flood defences and vulnerability of critical infrastructure were clearly seen. In both Germany and the UK, some flood affected people suffered psychologically for long term after the events.

Table 9 Experts idea about what went well and bad after flood

Germany (21 Experts)	UK (27 Experts)
THINGS THAT WENT WELL	
– Forecast and warning much better than in 2002 – Cooperation among authorities, and authorities with rescue team – Long term volunteers support – Coordination between volunteers and the city – Better preparedness than 2002 – Awareness and preparation have increased a lot since 2002 – 2013 flood damage was 1/3 of 2002 due to better preparation – Tipping point in disaster preparedness and prevention in regard to flooding and storm surge	– Warning and evacuation better than in 1953 – Swift response of Fire service and Environment Agency – Improved management of communications, better collaboration, better reporting from media – Coordination private and public /charity sector – Local authority wardens worked to build community resilience – Community support and response via social media – Insurance company's initial response rapid – Home insurance helped no end – Floods set in motion a number of important improvements to warning and informing capabilities and more resilient infrastructure
THINGS THAT WENT BADLY	
– Task forces unprepared for scale of flood – State aid for uninsured injured parties undermines incentive for personal provision – Wrong warning of flood height and flood characteristic surprised residents at night – Some coordination problem in the field due to differences in mentality – Better communication is needed with public, disaster financing and insurance – Getting flood help is too bureaucratic during disaster – Dike defence is not always successful – Slow dyke constructions along the Danube – Long term psychological effects	– State not resourced to deal with severity of flooding across multiple river basins – Local authority almost invisible – Lack of infrastructure preparedness to floods and importance of recovery as an issue to be considered – Co-ordination and preparation poor, few had signed up to flood warnings, few understood division of responsibilities – Water infrastructure inadequate and response of the water company was defensive – Delay to visit and repair all flooded properties, meant people were displaced for a long time – Blocked drains caused flooding – Government grants poorly administered and few people benefitted from available money – Lack of understanding of resilient construction – Inappropriate responses to the recovery and repair of traditionally constructed buildings – Long term psychological issues

A recent report of over 100 natural disasters by the Centre for Risks Studies, Cambridge for AXA Insurance cited the 2013 German Floods as a "stand-out" event in terms of the speed of recovery. (Carpenter et al 2020) Despite displacing over 80,000 people and causing economic losses of $13 Bn the German economy experienced negligible impact and the flood affected regions recovered to near normal life within 12 months. In general, whereas earthquakes and tsunami are immensely destructive of property, infrastructure and capital, floods disrupt productivity through business interruption and loss of economic output.

In general, several factors lead to the faster recovery after disasters such as floods, including notably adequate and speedy funding, better preparedness, better disaster risk management decision making, and places with higher insurance penetration. In contrast the frequency of disasters seems to have little effect on the speed and quality of recovery. Extensive community participation slows recovery but has an effect on improving the quality of recovery in terms of increased levels of safety and improvements in amenity and the local economy. (Carpenter et al 2020)

Study Five: Tourist destinations recovery in Philippines

Many disaster-affected places suffer economically after a disaster due to the slow recovery of the tourism sector. Despite the physical recovery of the area, the reputation of affected places can be badly affected due to inaccurate or outdated media coverage, which causes tourists to cancel their bookings and change their destination. How the tourism destination prepares for and adjusts to disaster situations has not received a great deal of attention in tourism management research so far.

Reporting the level of readiness of the destination to welcome tourists back after a major natural disaster is an extremely pressing topic, yet it is hardly discussed in academic literatures. This study developed a new approach using scorecards to monitoring and measuring recovery of tourist destinations in the Philippines that were hit by twin severe natural disasters. The approach aimed to provide objective evidence that the authorities and tourism providers could be used to report the progress of recovery and encourage tourists to return, and could also be applied after other types of disaster, including the current global pandemic.

The methodological framework in this study was designed to be used as a crisis communication standard in order to monitor and measure the recovery progress in tourist destinations. It was devised by conducting a survey with 40 carefully chosen expert stakeholders from the Philippines tourism sector.

The comparison of three case study areas in the Philippines was carried out for two snapshots: right after the event and at New Year, 2-3 months after the events. Figure 13 shows the overall comparison of three dimensions of safety, business and physical recovery (each of the corners of the triangles represents one of the three dimensions), and figure 14 breaks these dimensions into the detailed components.

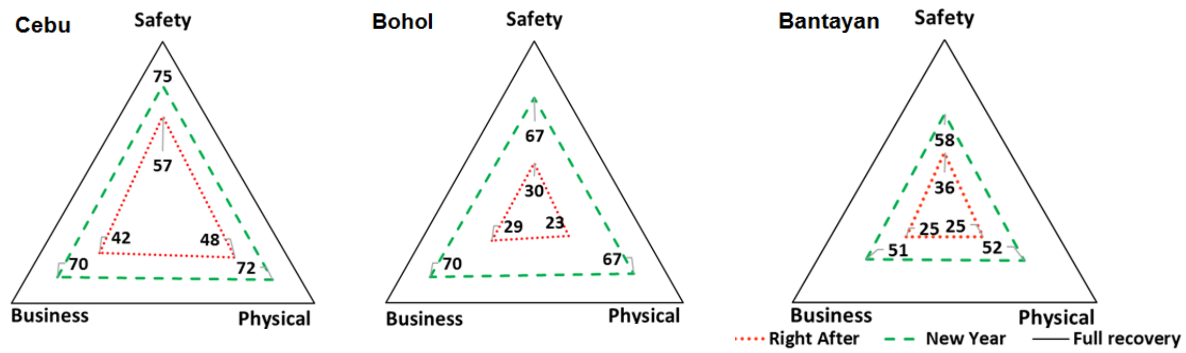

Figure 13 Comparison of recovery Right After disaster with New Year

The city of Cebu had the least damage compared to the other two cities. At New Year, Bohol was almost as recovered as Cebu, while Bantayan was less recovered and less ready to welcome tourists. In figure 14 it can be seen that in all places electricity recovered fastest.

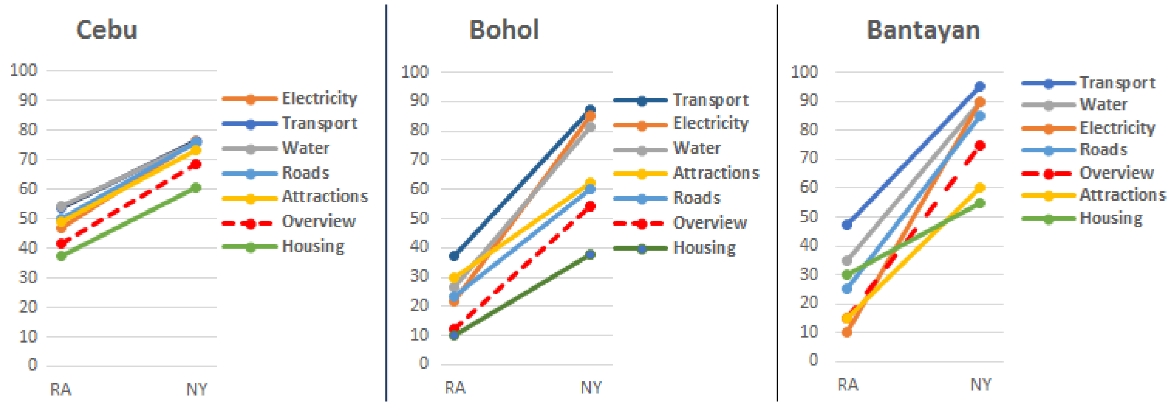

Figure 14 Comparison of speed of recovery after disaster for physical recovery sub-indicators in three cities

By comparing the three heavily affected cities in the Philippines, it can be argued that the severity of the damage is one of the reasons influencing the speed of recovery. Other factors such as the size of the settlement are also influential since larger cities recovered faster, which could be due to the higher mobilisation of expertise and resources.

This approach could be operationalised by the tourism authority selecting a small panel of key informants, who regularly and systematically report recovery metrics. Reports of real recovery, rather than ill-informed negative media reports would help tourism and the economy get back to normal faster.

Overall conclusion

The implications and conclusions from the five discussed studies are summarised according to disaster cycle phases.

Pre-disaster:

The number and severity of natural disasters is growing and it is hard to predict how severely and destructively the next disaster will strike any corner of the world. This is largely driven by the increase in climate related hazards, notably floods and storms. In the past 40 years over 80% of natural hazard events were weather related and the global occurrence of floods is three times higher in the last decade than in the 80s. (EM-DAT and CRED). Cascading effects, including technical failures, such as blackouts, can happen any time due to natural hazards, power grid failure, human error or cyber-attack. In most cases, neither society nor the relevant authorities are adequately prepared.

One of the stand-out conclusions from the recent AXA report on over 100 cases of natural disaster is that better prepared countries with better DRM recover much faster than ill-prepared counties with little or poor disaster risk management. (Carpenter et al 2020) To improve preparedness and facilitate crisis management, the interaction of communities and government is required in advance of disaster. Using scenario planning is one way to increase awareness and preparedness of communities. In addition, the field studies in flood affected areas suggested that regular drills in schools, public lectures by experts, newspaper or magazine article, and educational program on TV or Radio are also important ways of raising awareness and provoking preventive and mitigating behaviour.

Role playing scenario exercise not only increase societal awareness of unexperienced disasters, but also help decision makers better understand people's likely emotional response and subsequent actions and how these could change over the time, especially if they do not receive clear information and instruction from the authorities.

Few people in disaster prone areas take personal responsibility to limit the damage from future event. For example, in Germany and the UK, where flood risk is increasing due to climate change, it is becoming more difficult to get property in flood prone areas, and in Germany the states are planning to withdraw disaster recovery aid. Therefore, progress is needed to turn awareness into effective action.

Post-disaster:

The two key factors in improving both the speed and quality of disaster recovery are the adequacy and speed of funding and the quality of DRM decision-making. (Carpenter et al 2020). This broad conclusion from this study of over 100 disasters is exemplified in the UK and German flood case studies reported in this thesis. The national economies of both the UK and Germany were barely affected by the severe floods, and the flood affected areas recovered within 1 year to 18 months. This largely due to adequate funds being provided in a timely manner, largely by insurance in the UK and from Federal funds in Germany. In both countries, immediate response flood risk management post disaster was good, in terms of decision making and effective action to reduce future risk.

In the UK and Germany houses have been and are still being built in river basins. Meanwhile, in many large catchments risk reduction measures have proved to be ineffective. Yet, despite awareness and familiarity with the flood history of the location, households living in flood prone areas are not installing mitigation measures and living and working without flood insurance.

It is important to stress that in the UK, respondents believe that flood preparedness is both the responsibility of both themselves and the authorities, whereas in Germany, flood preparedness is seen solely as the responsibility of government. Policy makers in both countries should be aware of this fact and need to take this level of expectation into account in flood preparedness measures such as communications, educational material, flood mitigation measures, budgeting and programming.

In general, trust in government is not high. Nevertheless, during all types of emergency, government advice and instruction is normally trusted and followed. However, if government reacts too slowly, if advice is delayed and do guidance is not provided in time, societal trust falls dramatically and people start to take control and plan the situation for themselves. In some circumstances this could worsen the disaster and increase chaos.

In all the studied disasters, people who had direct experience of a past event had a higher level of risk perception and preparedness compared to those who had no previous experience. This applies both to natural and technological disasters. Yet the frequently of disaster occurrence is not proven to influence the speed of post disaster recovery. (Carpenter et al 2020)

6. Methodological inferences and lessons

The research for the foregoing case studies suggest that to better understand how fast and sufficient an area recovers from a disaster, one of the most reliable and low-cost monitoring solution is interviewing key informants. They represent diverse, well-informed, reliable and representative groups of stakeholders who increase the validity and credibility of the results. A survey based on a relatively small group of stakeholders is timely, cost-efficient as provides reliable and valid results. Furthermore, residents and tourists can follow the real information resulting from a knowledgeable group, rather than negative media coverage.

It is clear that a survey needs to be well designed, to be clear and understandable to respondents and to allow straightforward analysis and interpretation of the results. A survey needs to be validated and piloted thoroughly prior to data collection. If the survey is going to be conducted in different languages, cross language translations with native speakers of both countries is highly recommended.

In all the studied countries, when respondents were asked questions about scale, speed and quality of recovery, or the level of damage after the disaster, discrepancies were observed. However, these discrepancies may result from different interpretations of the question and reliability can be improved through clear question phrasing and additional explanation as it was done in study.

Conducting a survey a few months or years after a disaster need care and attention to achieve accurate and reliable answers. Anchoring the question to a particular time, such as an important holiday, helps jog the respondents' memory to think back better. Moreover, when experts are being interviewed, it is important for them to be able to give more detailed assessments. Oversimplifying the choices in the survey increases the tendency to get pessimistic answers. Finally, if someone is being interviewed in person, respondents welcomed asking the questions in more detailed way because it helps them to focus on a specific issue. Finally, to encourage the participant to answer fully, it is highly recommended to design a survey that takes no longer than ten to fifteen minutes and to state this clearly at the outset.

For more results and discussion about each study, please refer to part B of this dissertation or the author's publications, which are provided in the list of publication chapter.

7. List of author's publications

7.1 Journal papers

1. Mahdavian, F.; Platt, S.; Wiens, M.; Klein, M.; Schultmann, F. (2020a): Communication blackouts in power outages: Findings from scenario exercises in Germany and France. In International Journal of Disaster Risk Reduction 46, p. 101628. DOI: 10.1016/j.ijdrr.2020.101628.

2. Mahdavian, F.; Wiens, M.; Platt, S.; Schultmann, F. (2020b): Risk behaviour and people's attitude towards public authorities – A survey of 2007 UK and 2013 German floods. In International Journal of Disaster Risk Reduction, p. 101685. DOI: 10.1016/j.ijdrr.2020.101685.

3. Platt, S.; Mahdavian, F.; Carpenter, O.; Wiens, M.; Schultmann, F. (2020): Were the floods in the UK 2007 and Germany 2013 game-changers? In Philosophical transactions,Royal Society. Series A, Mathematical, physical, and engineering sciences 378 (2168). DOI: 10.1098/rsta.2019.0372.

4. Wiens, M.; Mahdavian, F.; Platt, S.; Schultmann, F.(2020): Optimal Evacuation-Decisions Facing the Trade-Off between Early-Warning Precision, Evacuation-Cost and Trust – the Warning Compliance Model (WCM). In Working Paper Series in Production and Energy. DOI: 10.5445/IR/1000125578

5. Khazai, B.; Mahdavian, F.; Platt, S. (2018): Tourism Recovery Scorecard (TOURS) – Benchmarking and monitoring progress on disaster recovery in tourism destinations. In International Journal of Disaster Risk Reduction 27, pp. 75–84. DOI: 10.1016/j.ijdrr.2017.09.039.

6. Fekete, Alexander; Aslam, Atif Bilal; Brito Madruga de, Mariana; Dominguez, Iris; Fernando, Nishara; Illing, Christian J.; K C, Apil; Mahdavian, Farnaz; et al. (2020): Increasing flood risk awareness and warning readiness by participation – but who understands what under 'participation'?. International Journal of Disaster Risk Reduction (Accepted on 24.02.2021)

7.2 Conference papers

1. Klein, M.; Mahdavian, F.; Wiens, M.; Schultmann, F. (Eds.) (2018a): A Multi-Agent System to Improve the Resilience of Critical Infrastructure in Cross-Border Disasters. IFoU: Reframing Urban Resilience Implementation: Aligning Sustainability and Resilience, 10-12 December. Karlsruhe Institute of Technology. Barcelona, Spain.

2. Klein, M.; Rigaud, E.; Wiens, M.; Adrot, A.; Fiedrich, F.; Kanaan, N.; Lotter, A.; Mahdavian, F. et al. (Eds.) (2018b): A Multi-Agent System for Studying Cross-Border Disaster Resilience. 15th ISCRAM Conference. NY, USA.

3. Mahdavian, F.; Platt, S.; Koyama, M.; Kiyono, J. (Eds.) (2015): Factors affecting survival in tsunami evacuation. 7th International Conference on Seismology and Earthquake Engineering. Tehran, Iran, 18-21 May.

4. Mahdavian, F.; Koyama, M.; Platt, S.; Kiyono, J.(Eds.) (2014): Behaviour Patterns In Major Disasters. Second European conference on earthquake engineering and seismology. Istanbul, Turkey, 25-29 Aug.

7.3 International reports and guideline

1. Carpenter, O.; Platt, S.; Mahdavian, F. (2020a): Disaster Recovery Case Studies Bangladesh Floods 2004. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School; AXA XL.
2. Carpenter, O.; Platt, S.; Mahdavian, F. (2020b): Disaster Recovery Case Studies India-Pakistan Floods 2014. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School; AXA XL.
3. Carpenter, O., Platt, S., Evan, T., Mahdavian, F., Coburn, A. (2020c): Optimising Disaster Recovery: The Role of Insurance Capital in Improving Economic Resilience. Cambridge Centre for Risk Studies at the University of Cambridge Judge
4. Carpenter, O.; Platt, S.; Mahdavian, F. (2019a): Disaster Recovery Case Studies - German Floods 2013. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School.
5. Carpenter, O.; Platt, S.; Mahdavian, F. (2019b): Disaster Recovery Case Studies - UK Floods 2007. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School.
6. Carpenter, O.; Platt, S.; Mahdavian, F. (2019c): Disaster Recovery Case Studies Philippines Typhoon Haiyan. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School; AXA XL.
7. Carpenter, O.; Platt, S.; Mahdavian, F. (2019d): Disaster Recovery Case Studies Vietnam Storm Damrey 2017. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School; AXA XL.
8. Khazai, B.; Girard, T.; Edbauer, L.; Schäfer, A. M.; Daniell, J. E.; Mahdavian, F. et al. (2016): Hotel Resilient Standards: Guidelines and Standards on Disaster Risk Management for Hotels and Resorts. Within the framework of Global Initiative on Disaster Risk Management (GIDRM).

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Part B: Included Articles

Article 1: Communication blackouts in power outages: Findings from scenario exercises in Germany and France

Abstract

Although infrequent, power outages can cause major disruption and incur huge costs. The increasing demand for electricity, more extreme weather events and the possibility of cyber-attack are increasing the risk of blackouts. This paper reports using scenario planning and role-playing exercises with German and French university students to investigate people's possible reactions and their expectations of government during a hypothetical 3-day blackout. The scenario is designed to explore how society would cope with a power failure over successive time periods. The aim is provide information to emergency managers and policy makers about community needs and people's likely behaviour in future blackouts.

1. Introduction

The chance of a long lasting power blackout is low especially in the highly industrialized societies like Europe, but in today's strongly interconnected world even a small disruption in a power network can escalate to a large disruption and systemic failure of critical infrastructure [1]. In the US and Europe the likelihood of large-area failures seems to be greater than might be expected on the basis of extrapolation from small failures [2]. The risk of power blackout is increasing due to technical failure; natural events, cyber-attacks, human failure during maintenance work or a combination of factors [3,4]. Power outages in Italy in 2003, southwest Europe in 2006 and Turkey in 2015 are the examples of blackouts in Europe that caused serious disruptions, despite lasting less than 24 h [5]. Operational reliability of the power system is closely linked to the security of telecommunication networks, including its ability to withstand cyber-attacks [6]. Improving operational reliability is currently a major concern of governments of many countries, including Germany and France. Although infrequent, extensive power outages can cause major disruption and incur huge costs. European power networks extend across country borders and cross border blackouts pose particular problems for inter-agency communication and cooperation. The aim of this research is to explore the potential risks and impacts of a major blackout and to make recommendations for any changes to current policies and procedures.

A role-play scenario planning with university students is used to explore societal resilience to a hypothetical 72 h power failure in Germany and France. The objective was to examine how people's behaviour, emotions and reactions change over the 3 days and to see to what extent they are likely to cooperate with family, friends and neighbors and fend for themselves and how their faith and trust in the authorities and agencies fluctuates.

1.1. Human response to emergencies

There has been extensive research into people's reactions in crisis situations going back to Prince's [7] study of a ship collision in 1917. Drabek and Evans [8] summarised the major contributions of American sociologists to an understanding of human responses to disaster. The first issue relates to labelling panic, looting and other anti-social behaviour as myths [9–15]. Quarantelli [16] suggested that people as a whole do not panic and rather than reacting in an anti-social manner, people typically become more cohesive and unified during situations of collective stress. Tierney [17] writes that the incidence of panic behaviour is vanishingly rare in crisis situations and despite fear and the entirely reasonable desire to flee, people in severe danger try to make rational decisions and work collectively. In an analysis of the World Trade Centre disaster 2001 extreme behavioural action, including panic, was noted in less than 1% of cases [18]. [19] suggest that anti-social behaviours during disaster scenarios, is, at best, over-exaggerated and that human behaviour in disaster scenarios can only frequently be described as "pro-social". In contrast to panic behaviour, the typical human response to disaster warnings is disbelief, denial, and reinterpretation to reduce or eliminate the threat potential [20].

On the other hand, there are examples of looting and crime in a small minority of disasters such as New York blackout 1977 [21,22], Hurricane Katrina [23]. Despite widespread fears of looting during the Kista blackout in a suburb of Stockholm, Sweden there was slightly more criminal activity than usual [24].

The second issue of relevance is that of emergent behaviour – emergent groups of people working together in pursuit of collective goals relevant to the disaster but whose organization has yet to become institutionalized. Emergent phenomena have been a prevalent feature in disasters [25] and may on occasion lead to conflict with formal emergency management [26]. This is one aspect of the extensive literature on social resilience and adaptive behaviour. Hutter et al. [27]; introducing a special edition on resilience, conclude that there are a multiplicity of perspectives on resilience and the lack of a clear definition poses a challenge to operationalising its use in disaster management. This is perhaps not surprising since resilience is a multi-dimensional concept encompassing social, economic, physical, technological and natural dimensions [28]. In social science, resilience is considered as a complex web of social connections and capacities that enable a community to cope with hazards [29,30]. Obrist [31] says resilience is a dynamic process, not as a static state, and social resilience enables people not only to cope with adverse conditions but also to create options and responds proactively to adversity. Keck and Sakdapolrak [32] also suggest that resilience goes beyond coping and encompasses adaptive and transformation processes.

Rogers and Nehnevajsa [33] report on behaviour and attitudes under crisis conditions and suggest that people respond to crises in remarkably similar ways. The disruption created by disasters creates stress, yet individuals and organizations seek to maintain the continuity of behaviour. The first response to impending danger reflects a strong commitment to protecting themselves, their loved ones and even others with whom they may become associated. The second type of response is information seeking. As people become alerted to the potential for danger they tend to seek information about the hazard, from their own senses and to get confirmation from others, particularly family and friends. Finally, there is a propensity to respond in groups, particularly families, by consolidating resources. These three basic behaviour patterns were observed in the scenario workshops reported in this paper.

1.2. Power outages

Electricity is an enabling technology for a host of quotidian activities [34], so its disruption affects normal daily life and has a cascading effect on other infrastructure, for example water supply [35]. Electric power systems are part of the critical infrastructure of modern societies, therefore is essential to boost their resilience [36]. Electricity infrastructure is necessary to sustain human and economic wellbeing [37]. Many countries have, therefore, introduced mandatory requirements for operators to maintain high reliability and stability of supply, for example, The U.S. Department of Energy, Federal Energy Regulatory Commission (FERC) [38] is working with power system operators to ensure reliability of the U.S. power system. In Germany, the transition from fossil fuels to renewables is pushing the industry towards greater flexibility and resilience through various innovations in market design and pricing mechanisms [39]. In France, RTE, the electricity transmission operator, introduced emergency response arrangements in the wake of the storms in December 1999. It is tackling current reliability challenges by leveraging power generation flexibility, stronger cooperation between transmission system operators and coordination centers and adherence to European grid codes [6]. However, power systems are highly nonlinear and it is challenging and uneconomical to make power systems totally resilient [40].

Drawing on examples from around the world, Wood et al. [41] argue that a crucial factor in people ability to cope with adversity is social capital: the extent to which social networks are able to support collective action, and promote psychological wellbeing. One of the earliest detailed accounts of people's reactions comes from the blackout across the eastern seaboard of the United States on 9 November 1965, affecting 25 million people. Six days after the breakdown, the National Opinion Research Centre (NORC) interviewed over a thousand people about how their reactions to the blackout. They found that most people were not in the least alarmed, there was no panic and the majority of people reported that strangers were unusually helpful and friendly to each other. Above all, they found that the blackout affected rhythms of communication and social interaction. For example, the New York Telephone Company reported most calls were to relatives and instead of turning for information to City Hall or formal organizations, people turned to neighbors and to local leaders in the neighborhood [42].

On August 14, 2003 a massive power outage caused blackouts throughout most of Ontario, along with parts of the US. This power failure was the largest in North American history, spanning 24,086 square kilometres and costing the Canadian economy $1–2 billion [43]. Brenda Murphy [44] conducted a survey of 1200 Ontario residents six months after the outage to discover how they had managed to deal with the emergency. She found that families relied on networks of family, friends, neighbors and community associations to help them get through a crisis. 89% of respondents stated that their neighbors would provide assistance and 37% said they provided assistance during the blackout.

Although rare, Europe has experienced major power failures and maintaining stability of power supply is especially challenging during natural catastrophes [45]. In France and Germany storms and floods are the natural hazards cause the biggest problems. On September 23, 2003, nearly four million customers lost power in eastern Denmark and southern Sweden following a cascading outage that struck Scandinavia [46]. Days later, a cascading outage between Italy and the rest of central Europe left most of Italy in darkness on September 28 [47]. In France and Germany, there have been 10 serious examples of storms causing temporary power outages in the past 10 years (Table 1).

Electricity outages can be both an effect and a cause of cascading effects [58]. For example, the 2013 Germany floods caused widespread disruptions in power supply, which in turn affected water treatment plants and public transport amongst other services and activities [59]. In February 2014 several storms again affected UK and 80,000 homes were left without power for several days. The impacts of power outages on households, the description of the challenges faced and the strategies adopted by them are described by Ghanem et al. [60]. The capacity of households to deal with power outages depends not only on the household itself, but also on the social resilience of the whole community. Cascading effects are common in disaster events and a chain of interaction can amplify the impact on society where the initial power failure can lead to fires, an increase in accidents and fatalities, stresses to the health sector, water shortages and hygiene issues, disruption of refrigeration and food shortages, environmental contamination, carbon monoxide poisoning from disruption of underground ventilation, traffic disruption, disruption to temperature control, people becoming trapped, increased crime, stress on police and emergency services, business continuity and logistics failure and last, but not least communications system and telecoms failure [61].

Table 1 Power outages in France and Germany following storm events

Storm	**Date**	**Impacts of power outage**	**Reference**
Lothar and Martin	Dec 1999	Extensive damage to the French and German national power grids	[48]
Dagmar	Dec 2004	Northern France, including Paris, affected leaving thousands of homes without power.	[49]
Renate	Oct 2006	SW coast of France battered leaving many homes without power for many hours	[50]
Klaus	Jan 2009	Over a million homes in southwest France lost power.	[51]
Katia	Sep 2011	Hurricane caused widespread power outages throughout Europe, including in France and Germany	[52]
Joachin	Dec 2011	Power outages in France and Germany	[53]
Niklas	Mar 2015	Power outages in Germany	[54]
Fabien	Dec 2019	Wind and storms cut power supply to 220,000 homes in southwestern France	[55]
Ciara	Feb 2020	Power cut to 130,000 homes in northern France	[56]
Sabine	Feb 2020	60,000 homes were left without electricity in Bavaria	[57]

The 2011 Tohoku earthquake, in particular to the Fukushima Daiichi nuclear disaster, was a wake-up call to the risk of “cascading disasters” [62]. A paper by Pescaroli and Alexander [63] addresses the vulnerability of critical infrastructure to cascading effects of disasters. They suggest a shift attention from risk scenarios based on hazard to vulnerability scenarios based on potential cascading effects in which they identify nodes that are capable of generating secondary events. Early warning, the behaviour of operators, communication failures and bureaucratic conflicts are, they suggest, the areas in which further research could improve understanding of how cascading disasters propagate in critical infrastructure, and how their progress can be arrested. This approach to systemic risk is being actively pursued by the Centre for Risk Studies in Cambridge University [64].

1.3. Scenario planning

Four scenario role-playing exercise workshops were held with university students in Germany and France. These involved getting the students to dynamically ‘play’ through an imagined future. The game collapsed real time to highlight significant issues and to focus on people’s decision-making, emotional responses and imagined actions [65]. The scenario exercises were designed with input from 5 international experts with experience of using scenario planning in risk management, social science, economics and urban management. The design also drew on an extensive literature review, summarised as follows.

Various authors have suggested the use of scenario planning as a way of exploring the critical role of decision-making and spontaneous behaviour in the stressful time of an emergency like a blackout [66–68]. Moats et al. [69] describe how, after major disasters, people have to make high consequence decisions with incomplete or inaccurate information under time pressure and suggest scenario planning as a way to prepare. Alexander [70] described how scenarios are used in emergency management training and how outcomes are used as the basis of crisis planning. Bradfield et al. [71] say public policy makers are increasingly using scenarios to involve agencies and stakeholders in policy decisions.

In the disaster management field, the scenario approach has been applied in 'ShakeOut' drills to raise public awareness [72,73] and various authors describe how they are used in emergency management [67,71,74–78]. In Germany, scenario planning was used to explore the impact of a blackout on health care [79]. An article by Envision Tomorrow [80] suggested scenarios could be of two basic types – 'normative', which describe a preferred outcome, and 'exploratory', which describe unknown futures. The scenario could be timed for pre, during or post-disaster. The blackout scenario in this research was an exploratory scenario timed for during the event.

In summary, in terms of a conceptual framework to guide the research, this brief literature review points to the following issues. How do people imagine events might cascade after a major blackout and produce a chain of consequences? How do people's feelings change over the 72-h scenario? Are their signs of emergent groupings, coping strategies and adaptive behaviour? How might communication failure impact on individual and communities?

2. Methodology

The aims of the scenario were:

1. To explore the potential cascading effects of a 3-day blackout and the implications for different types of people

2. To learn how people might behave, react and feel in a blackout

3. To gauge societal resilience to a relatively long power outage, and in the process to learn about preparedness and response to a possible crisis of a 3-day blackout in Europe

The 54 participants at the workshops were university masters students who had no advanced knowledge of the nature or content of the scenario. Between 10 and 16 students attended each of the four workshops: two in Karlsruhe, Germany and two in Paris, France. To encourage more lively discussions the participants were divided into tables of 4 students playing the 4 roles: an elderly 80 year-old person in a wheelchair, a parent with 2 children, a single university student and a 12 year-old child, which to cover a range of age differences, different responsibilities, different concerns, different health conditions, and different flexibilities. The roles were assigned, as much as possible, according to the students' background and experience. They were asked if they had experience of living with elderly or disabled people or if they had looked after younger siblings or were married or lived with a partner and the roles were assigned accordingly. The remaining students were asked to play themselves as university students. A mentor was assigned to each group to provide support during the scenario. In order to reduce the possibility of bias, the mentors were instructed that their task was to motivate and encourage the participants to think for themselves and to imagine how they would feel and react in their assigned role, but not to lead the group or provide suggestions or ideas. The mentors kept a note of the participants' emotional reactions, their discussion and imagined actions during each time period.

The workshop lasted about 3 h and was divided into 4 half hour time periods representing different intervals during the blackout: the first 30 min; the next 8 h; 24 h and 3 days. There was a short break between second and third interval. With the addition of the first 30 min, these time periods were similar to those used in the scenarios in the Crisis Management Handbook about power outages in Baden-Württemberg by the Ministry of the Interior, Digitisation and Migration and Federal Office of Civil Protection and Disaster Assistance in Germany [81].

The participants were told that they were living in either Paris or Karlsruhe and "it is a warm day in the middle of summer in the middle of the week. It is 12:30 lunchtime and the electricity goes off". They were told the reason of the blackout was unknown, that it was unclear when the electricity would come back or how widely the problem extended. Cascading impacts, largely drawn from the Crisis Management Handbook mentioned earlier [81], were pinned on the board: no traffic lights, no subway or tram, no telephone landline, no payment by bank cards, no ATM cash, no fuel at petrol stations and, in most cases, no tap water or toilet flush. In groups they brainstormed what would happen and began to create a picture of their feelings and reactions, the decisions they would make, and their expectations of the authorities and local community. The participants were required to make notes about their feelings and behaviour on their individual worksheets. In time period 2 new cascading events were pinned up: shops and supermarkets closed, no mobile network, no Internet, flight cancellations and no trains between cities. After a break, time periods 3–4 continued. No information about the cause or extent of the blackout was given at any time, just a reassurance from the authorities that they were doing their best to fix the problem as soon as possible.

All the participants, without exception, too their roles seriously and were able to imagine the expanding crisis through group discussion. During each time period mentors completed forms documenting their perceptions of the participants understanding and their expectations of help from the authorities, family, friends and neighbors. The roleplaying scenario was followed by an open discussion to share the main lessons and key factors.

3. Results

The data from the 4 workshops included individual students' note, mentors' note and semantic questions for each time period, plus feedback from the end of workshop discussions. The worksheets were analysed for their semantic content and provide the main data source for this results section. Both qualitative and quantitative content analyses were used to code the data [82,83]. A detailed content analysis was made of the words and phrases used by the participants to describe their feelings and reactions, their expectations of and opinions about the emergency services and government, authorities and their imagined behaviour and interaction with others.

3.1. Emotional response

As explained in the methodology section, the participants recorded their feelings, thoughts, reactions and expectations on individual worksheets. This allows us to trace changes in their emotions and behaviour over the four time periods. At the start of the game all the participants were happy and laughing, and many of them did not take the blackout seriously. However, by the start of the second 8 h period no one was laughing, but they still did not expect scenario to continue much longer. By the third period, after 24 h of blackout, the students were heavily into their roles and were frustrated and beginning to get scared. The way they argued and discussed within their group changed completely from the first time period. By the fourth period, after 72 h of blackout, they were very anxious and afraid.

The mentors' notes show that in the first 30-min period most participants (71%) expected the electricity to come back on any second and the remainder (29%) estimated a maximum outage of 2 h. Even after 8 h, over 75% were still hopeful that the power would be back within an hour. By the fourth period (72 h of blackout) the majority of participants had given up any hope that electricity could come back at all and were prepared for the worst. There were some differences between the workshops in France and Germany. Less than 10% of French participants imagined that the electricity could come back, while in Germany 33% still had hope at 72 h.

Table 2 shows the emotionally charged words that the students used to describe their feelings in each time period grouped by role. These words were identified through content analysis of the students' and mentors' notes by noting any instance any word that might describe an emotion was used and were not pre-defined in any way. Interestingly, there was little difference in emotional self-descriptions between French and German participants. The most appropriate or differentiating single word to describe the emotion of each group, has been highlighted in bold. A number of things are striking about this table.

- For all participants there is an escalation of emotional response over the 72 h, from calm puzzlement to worry or fear

- The third period (24 h of blackout) shows the largest range of emotions in terms of the number of words used

- Participants in the child's role used less words to describe their emotions than participants in other roles

- As one might expect, students playing parents with young children showed greater control and emotional endurance than participants in other roles; the elderly quickly went from calm acceptance, when they imagine the blackout to be of short duration, to fear and feelings of being overwhelmed due to the health implications of the outage.

Table 2 Emotional reaction (most repeated words with emotional content in 4 workshops)

	30 Mins	8 Hours	24 Hours	72 Hours
Child	Happy, **Calm**	**Bored,** Puzzled, Worried	Afraid, **Scared,** Worried	**Afraid,** Scared, Worried
Students	**Puzzled**	**Annoyed,** Worried	Scared, Worried, Anxious, Impatient, **Angry,** Overwhelmed	Afraid, **Scared,** Angry
Parents	Puzzled, **Worried**	Annoyed, Worried, Anxious, **In control**	Scared, Worried, Anxious, Hopeless, In control, **Brave**	Worried, Stressed, In danger, **Strong**
Elderly	**Calm**	Worried, Anxious, Weak, **In danger**	Afraid, Scared, Worried, **Overwhelmed,** Stressed, Hopeful	Scared, In danger, **Weak,** Afraid

The emotional pattern recorded by the participants accords with the behaviour observed by mentors. The participants' self-descriptions started to appear distressed and confused after a blackout duration of 24 h. In the subsequent period, some gave up waiting for help from the authorities and began to think for themselves, organize with others or take responsibility and initiate action. Others who were unable to fend for themselves – children, elderly and disabled – settled into a state of fear.

To explore emotional response in greater depth, for the workshops in Paris, a modified form of semantic differential was developed comprising 20 pairs of words in French and English. Table 3 shows the English version of this list.

Table 3 Semantic differential words

Calm	Afraid	Brave	Distrustful	Strong
Panicked	Pleased	Unprepared	Relaxed	Out of control
Scared	Cool	Puzzled	Prepared	Energized
Bored	Patient	Weak	Peaceful	In danger
Sure	Anxious	Composed	Annoyed	Unafraid
Trustful	angry	Able	Unhappy	Unexpected
Expected	Impatient	Happy	Aggressive	Incontrol
Shocked	Passive	Overwhelmed	Worried	Safe

These were based on words used by the participants at the German workshops and represented increasing intensity of emotions from happy/unhappy to able/overwhelmed. They were presented in random order and participants were asked to select all the words that described how they were feeling in each time period.

The first thing to note is that in the first half an hour the number of negative and positive words was roughly equal. Over time the number of negative words used then steadily increased from time period to time period (Fig. 1).

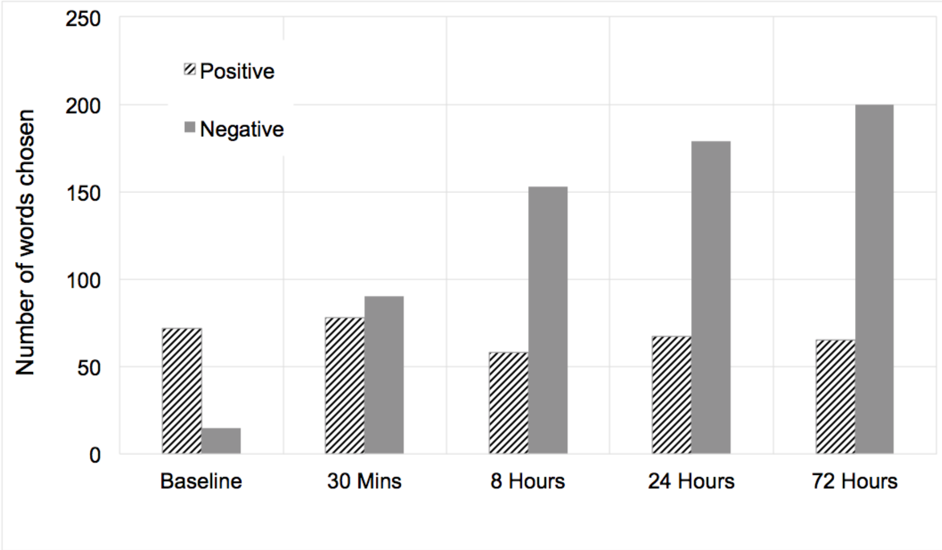

Figure 1 Number of positive and negative words used over time

Plotting some of the most used words Fig. 2 shows how positive emotions remain fairly stable and declining only a little over time, for example by students reporting that they were feeling less calm and safe. Conversely, the number of negative words, reflecting negative emotions, for example feeling scared or overwhelmed, dramatically increase over time.

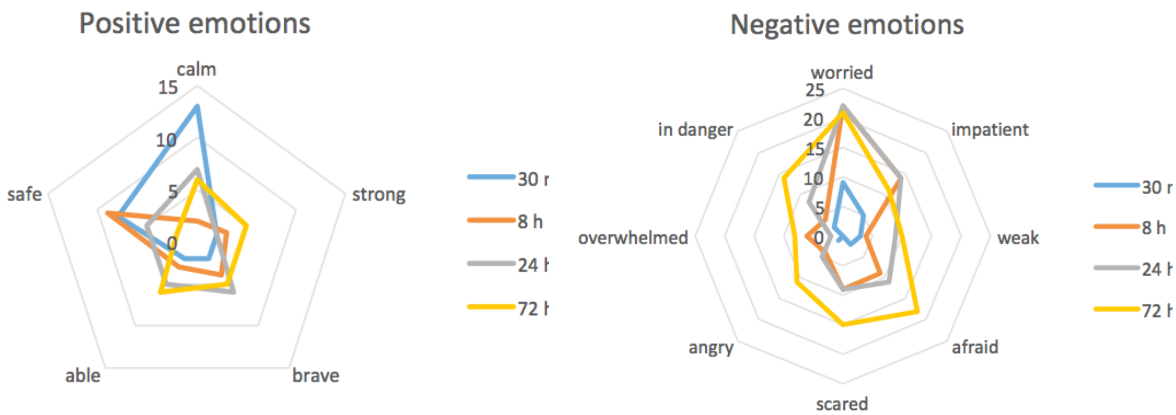

Figure 2 Positive and negative words used over time (N=31 participants)

There were some noticeable differences between the different groups (Fig. 3). Over half the students playing elderly people imagined that they would be scared after 24 h compared to less than a quarter of those playing parents and children and only 13% playing students. In contrast at 24 h the most energized group to take action, for example in searching for information or trying to get food and water, were again the students' group: 88% of them felt energized to do something to remedy the situation. By 72 h, however, their enthusiasm had slumped a little. The energy levels of those playing parents steadily increased over the 72 h as they began to take charge of the situation and initiate action.

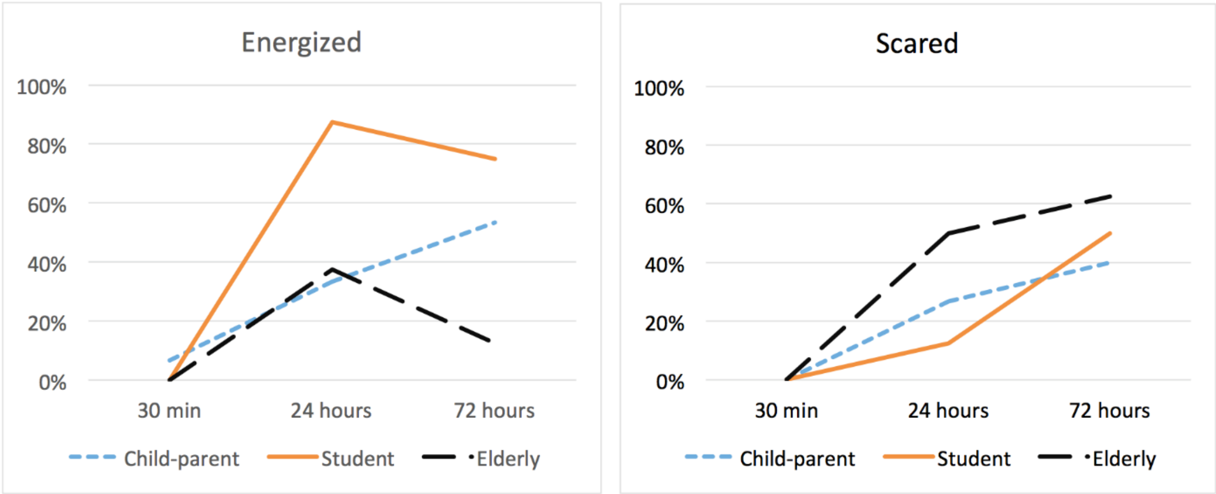

Figure 3 Differences in emotion between groups

3.2. Behaviour

As one might expect, there are certain patterns of behaviour that are common to all four groups of participants and others that are specific. In the first 30-min period everyone wanted to get information about the cause and possible duration of the blackout. At 8-h over 80% of participants were still seeking information, the students in elderly roles were trying to contact people for help and those playing parents were beginning to anticipate a longer outage and to think about getting food and water. At 24-h those playing students were trying to find out how far the blackout extended to see if it made sense to evacuate. Those playing elderly were hoping to relocate to family or hospital. At 72-h people were getting increasingly concerned about security on the streets and some even appeared despairing. Interestingly, some stated their readiness to break into supermarkets to try to find food and water.

One of the most serious actions an individual or family experiencing a blackout could take would be to evacuate and leave their home and flee the area. As one would expect an expressed intention to evacuate increased dramatically over the four time periods to two-thirds of participants in Germany after 72 h and about one-third of participants in France (Fig. 4).

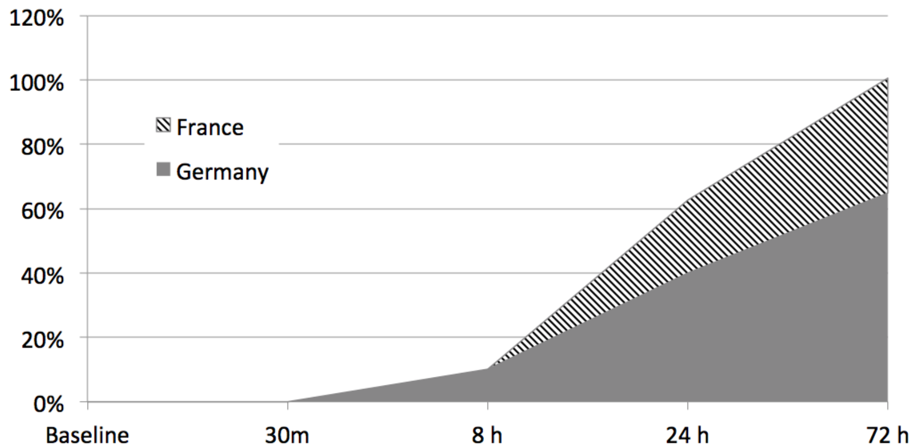

Figure 4 Proportion of participants expressing an intention to evacuate

This difference between the participants in the two countries is arresting. It is possible that, unintentionally, the workshop leader had behaved differently in the German workshops and given a harsher impression of the lack of help from the authorities. However, a detailed analysis of the worksheets did not support this idea. The principal driver for evacuation would seem to be the lack of information, advice and support from the authorities and the need to find reliable supplies of drinking water and food. The city of Karlsruhe, where the German workshops were held, is of course much smaller than Paris where the French workshops were run. It is also nearer to an international border. There are differences in evacuation behaviour between groups of people (Table 4). In both, Germany and France, a large proportion of "parents" and "students" begin to evacuate after 24 h. In Germany a very high proportion (80%) of "elderly" evacuate for health reasons when their family come from other cities in Germany by car to rescue them. In both France and Germany 72 h seems to be a critical time limit for the elderly beyond when they can no longer cope without medicine and health care and support. However, in all workshops, as the final decision to leave the region was made at a late stage and participants anticipated difficulties due to lack of fuel and traffic chaos.

Table 4 Intention to evacuate

FRANCE	8 h	24 h	72 h	All
Child	0%	14%	0%	14%
Student	0%	38%	25%	63%
Parent	0%	38%	0%	38%
Elderly	0%	0%	25%	25%
Total	0%	23%	13%	35%

GERMANY	8 h	24 h	72 h	All
Child	0%	25%	25%	50%
Student	17%	33%	17%	67%
Parent	0%	40%	20%	60%
Elderly	20%	20%	40%	80%
Total	10%	30%	25%	65%

3.3. People's expectations and trust in the authorities

Inaction by the authorities results in a loss of trust. Information plays a crucial role in an emergency and a failure in communication seems to be the most important reason for people losing trust in government. Everyone, no matter what age, gender, physical condition, or financial ability, needs to know what is happening in a crisis. A lack of information, which is very likely as reports of other major blackouts show, is a major problem for victims and dramatically increases uncertainty and anxiety. Uncertainty is an aversive state that people are motivated to reduce and is intensified by a lack of information [84]. The authorities often withheld information from the public in an effort to avoid panic [19]. Rather than helping the situation, communication failure can cause significant problems. Withholding information may delegitimize the government's authority and communication failure is thought to be responsible for people ignoring evacuation orders and other directives [85]. Communication is dramatically improved with social media and instant messaging through smart phones. Nevertheless, communication may be difficult or impossible during extended blackouts [86].

In this scenario, the participants were told that authorities were doing their best to find the cause of the blackout and fix the problem but are unable to say how long it will last. In open discussions, participants said that even though they would have been scared if they had been told it was a cyber-attack, they would have preferred to know rather than not. After 24 h, over half the participants started to react in an angry way ("still no information – that can't be true!") and began to take things more and more into their own hands.

Apart from information about the cause of the event and about a probable duration, the participants expected advice from the authorities. The workshop participants initially trusted the authorities during the first two time periods, but with no guidance and information this trust dramatically dropped in the third time period. Fig. 5 illustrates the decline in trust compared to the express intention to evacuate. As a rule, people only evacuate when told to by the authorities, although the last 50 years there seems evidence that people's trust in government is declining and people place as much faith in advice from friends and family, often through social media connections as they do in government [87–91]. The findings shown in Fig. 5 may be an artifact of the scenario, in that the participants had no information about the blackout and no advice from the authorities, or they may point to a decline in trust.

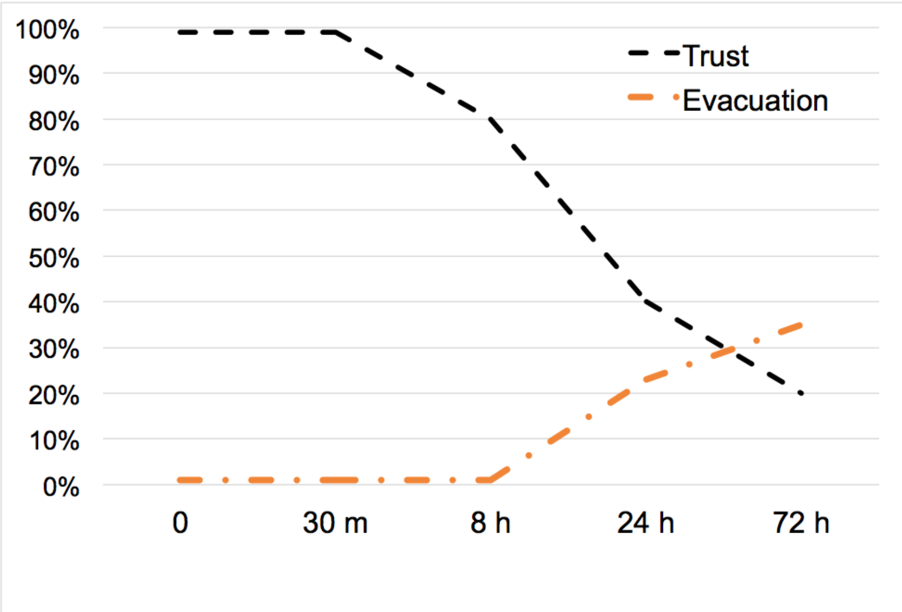

Figure 5 Evolution of trust in authorities and propensity to evacuate

The anticipated need for water increased strongly after 8 h and for food after 24 h for both, German and French participants. Both initially expected food and water to be provided by the authorities or by voluntary organizations. For the elderly, being cared for and being moved to a shelter after 24 h of blackout was considered the responsibility of the authorities. Content qualitative analysis of the mentors' notes showed similar expectations of government. As becomes clear from Table 5, the participants expected the authorities to provide information and increasing levels of assistance as the blackout continued. Since neither information nor support was forthcoming, participant's puzzlement turned to frustration, anger and finally fearful acceptance or action, first to selforganize and second to prepare for evacuation.

Table 5 Participants' expectations of the 'authorities' at different time periods

30 Mins	8 Hours	24 Hours	72 Hours
- Information expected - The problem fixed soon - Short blackout - Confirm with people that public service is still functioning - Traffic police manage the traffic	- Information expected from police, Red Cross, government, city hall (Find the way to inform people considering people have no access to internet and TV) - Water distribution - Nursing care for elderly - Advice from government about how to behave and what to do if it continued - Provide water	- Information and guidance - Government provide food and water and other initial needs - Shelter provision for people in need - Help from other regions or other countries - Evacuation - Government visit old people at home - Employers to not expect their employees to go to work - Security force (police, army) provide security - Local government officials in the area - Local and central government implement emergency measures - University provides information - Community organizations step in - Foreign authorities support foreigners - Provide portable toilets - Calm down people	- All points from previous time period plus: - Government plans organized evacuation - Firefighters provide humanitarian support

3.4. Volunteering and community cooperation

In both countries the level of volunteering and cooperation increased with each time period (Table 5). Volunteerism refers to the activities of people who work outside of formal emergency and disaster management arrangements to help others who are at risk or are affected by emergencies and disasters [92]. In Germany, however, volunteers are highly organized through the Bundesanstalt Technisches Hilfswerk [93] and there are over a million volunteer fire fighters and many relief organizations and local NGOs. In France, volunteering, although almost as important in terms of people involved as a percentage of the workforce, is less professionally organized and more ad hoc than in Germany [94, 95].

The most active group in the game, in terms of volunteering, were those playing the role of students. This phenomenon is similarly evident for other disasters in university cities and a common feature of altruistic behaviour in disaster situations [96]. For example, during the 2013 flood in Germany, Passau was one of the most badly affected cities with 13 m of flood followed by 4 days of blackout in some parts of city. The first author of this paper interviewed 30 flood victims about the situation after flood and all respondents emphasized the positive role of university students in helping and supporting the flood victims for a full week. Interestingly, in the blackout scenario exercise, the same pattern emerged. Participants playing students mentioned they would help others, including strangers, from 8 h until the end of the blackout.

Participants playing the role of parents imagined helping and cooperating only with people they knew i.e. friends and neighbors. In general, neighbors were considered to be the primary and most reliable source of information and support. Some old people suggested community cooperation would happen naturally, and that people would come together spontaneously with community leaders to plan and organize, for example to share food and support each other. Especially noteworthy is the spontaneous self-organization of family members and neighbors, which seem to build an autarkic “small-tie-society” on their own.

4. Discussion

In Europe, a blackout of 72 h is a very rare event. This makes studying and understanding an unprecedented crisis a challenge. Nevertheless, authorities and governments need to be prepared for such an event since the possibility of a blackout due to a cyber-attack, human error, or natural disaster is increasing and will eventually have huge negative effects on society. Authorities need to have an idea about people’s potential reactions, their perceptions of the situation and their expectations of the authorities.

The participants in the workshops were a ‘convenience’ sample and none of the participants had experienced a long lasting blackout. The reported findings are the outcome of role-playing an imaginary situation by groups of young adults, mainly University Masters students, rather than the actual emotions and reactions of children, families and elderly people in a real blackout. Subjecting a real community to an actual 72 blackout to see what might happen would clearly have been unrealistic. This raises important questions of validity and reliability. The key questions are how valid and credible is the imagined communication blackout and how valid and reliable are the findings and specifically, what confidence can we have that the imagined behaviour approximates reality?

In relation to the first question, an extended outage would impose severe strains on government and society as a whole [97,98]. Given our reliance on electricity to power our communications networks it is not unreasonable to assume that national and local government might have difficulty in informing citizens a few hours into the outage [99]. Government business would also be paralysed to an extent. It is possible to imagine a situation in which the authorities did not want to reveal the cause of the blackout for security reasons [100]. In this context scenario planning is a useful technique to anticipate events, which are mainly driven by people’s behaviour and beliefs. Using scenario planning in the way described in this paper is one of the ways one can begin to study, albeit hypothetically, people’s reactions and behaviour in order gauge societal resilience in such a disaster. Scenarios are descriptions of possible events that may occur in the future [101] and are a tool for exploring how new emerging risks could result in loss [102]. Gordon [103] in his review of futures research suggests that mark of excellence in a scenario is its internal self-consistency.

In relation to the second question, all the students were adults; at least half of them were Masters students, some with families, and the rest were third-year undergraduates. They adopted a very mature and engaged attitude to their roles and their imagined reactions and opinions are relevant and useful. One of most interesting aspects of the scenario was seeing students totally immersed in their hypothetical roles and imaginary situation. All the students took the game and their roles seriously and none dropped out. Each developed their own individual story, which together provide a fairly coherent picture of how a community hit by a major blackout might react. Albeit fictitious, the evolution of emotions, perceptions and motivations together with the provided explanations were highly plausible. Nevertheless, the scenario gave rise to important insights both in terms of material welfare and, more importantly, individual mental wellbeing and societal preparedness. Previous research suggests that even when people are aware of a natural or technological threat, this awareness does not necessarily translate into action [104].

Role-playing is a common technique used in studies of behaviour in which researchers assign research participants to particular roles and instruct those participants to act as if a set of conditions were true [105]. The technique capitalizes on people's ability to engage in creative play, to implement certain rules of thought, feeling, and behaviour under certain assumed conditions. That students might be effective at playing arbitrarily assigned roles is bolstered by Goffman's [106] ideas about all social behaviour being a form of dramatic performance. There is a considerable body of literature about using students as research subjects [107,108]. Two reasons are given for concern about using students: validity and generalisability and ethical issues relating to unfair coercion of students as subjects. Convenience was the underlying reason for using students as research subjects in this scenario exercises but the authors do not believe that there were any significant ethical issues as their presence was entirely voluntary and the research did not harm the people taking part nor intrude on their privacy nor threaten their beliefs [109]. Hanel and Vione [110] address the question of how far students can be representative of the general population. Using datasets of psychological variables the authors found that across 59 countries students are as heterogeneous as the general population and that their attitudes are as varied. Peterson and Merunka [111] could find no convincing empirical evidence of the negative consequences of using students for research or of the benefits, other than cost and convenience. Besides psychology, experimental economic research is one of the disciplines that predominantly use students as test subjects. The representativeness of student participants is also a regular point of criticism here, especially in contexts in which job-specific decisions are involved (e.g. farmers, investors). Again, comparisons show surprisingly little difference between student participants and professional representatives [112,113]. However, it would be interesting to repeat the exercise with carefully constituted focus groups of citizens and also possibly to extend the approach to places that experience frequent blackouts where people have evolved strategies to deal with the inconvenience.

Although the participants had the maximum of freedom to make their decisions it is interesting that the pattern of behaviour followed a rather stable sequence. During the first 8 h waiting for information is the predominant reaction and most participants do not immediately interrupt their daily routine. These 8 h can be seen as a temporal buffer, which provides authorities the chance to fix the problem without drastic effects on an urban working day. However, if authorities cannot fix the problem and do not communicate with the population then people start taking matters into their own hands. In particular, the assumed lack of public communication was crucial. Although the situation was fictitious and the participants perceived the game as an entertaining role play most participants were genuinely upset to the government's failure to communicate. They expected information about the root cause of the problem and about the probable duration of the blackout. The predominant reaction of the participants, in particular of those in the role of parents who need to make the decision for the family, was understandable. They got together with neighbors and started to self-organize the provision of the necessities such as food, water, security, and medical support for the elderly and calming distraction for the children. At this point of time, they clearly stated that it was no longer a question of complying with the law and as soon as you believe you are left to yourself, you no longer feel obliged to obey the law. This finding has important implications for the communication policies of the public authorities in such a situation [114]. Although disaster victims may be very concerned and frightened and panic flight behaviour can occur, it is quite rare and people usually behave rationally in weighing alternative course of action [115]. This behaviour was noted in the students, who at a rather late stage, began to objectively and dispassionately discuss their options and only began to self-evacuate as a last resort. This behaviour was restricted to the students playing the role single young adults and only in organized groups. They were quite realistic about the difficulties they would face if many people make this decision at the same time in a situation where they could no longer rely upon critical infrastructure.

It is interesting to speculate in what sense the psychological impact of an extended blackout might be different to that of other disasters, such as storm and flood? And would Europeans who had never previously experienced an extended blackout react differently to people living in countries like Pakistan, Bangladesh, Iraq and Nigeria where blackouts are a common occurrence. Coping with crises is easier when you have the capacity to anticipate and cope with the resulting stress of an emergency such as a major power outage [116]. A study of electricity outages in Finland suggests two contrasting behavioural responses: on the one hand, the uncertainty imposed by a blackout can render people helpless while on the other uncertainty can be seen as a part of everyday life [117]. However, the study did not distinguish between different lengths of outage or whether information about its cause and duration was available or not.

The findings of what mature university students imagined would happen revealed that over the 4 time periods the students' emotional reactions went from frustration, frustration that their smart phones ran out of power or they couldn't get a signal, to worry about family, to anger with the authorities and finally to genuine life-threatening fear. This escalating emotional response was not only a product of inconvenience but also, and perhaps to a greater extent, due to the uncertainty and lack of information. What caused participants the most distress was uncertainty about how long the outage would last and a lack of information about the cause of the outage, how extensive it was and what was being done to fix it. Not knowing why the blackout was happening or how long it would last was the worst aspect of the experience for most of the workshop participants. This is quite different to other types of natural and man-made disasters, such as earthquakes, which happen suddenly and leave a devastating effect, or bush fires where the cause is known and understood. They can also see what firefighters are doing to help. This is not to suggest of course that the severity of these disasters is comparable in terms of loss and damage, but the aspects of uncertainty and lack of information are important considerations in European blackouts.

One way of assessing the reliability of these findings is by comparing them with the evidence reported in the literature. As reported earlier, after the New York blackout in 1965 people were initially annoyed and angry but later strangers were unusually helpful and friendly to each other [42]. And after the Ontario blackout in 2003 Murphy [44] reported that families had a variety of familial and social networks in their local area to call on for support. This is very similar to the behaviour imagined by students in the scenario exercises. The impacts of the Ontario blackout reported by Anderson et al. [46] are also very similar to the cascading events generated by the scenario exercises. In the role play game various students said they would break into supermarkets to steal water and food. Although looting is rare in disasters it did occur during the New York blackout in 1977 [21]. A telephone survey of 2,000 German households [118] by Behrens GmbH Market Research in 2012 reported that 10% of respondents had experienced a long-lasting power failure. They found that in general people were largely unprepared for a major blackout; more than half the respondents has no information about power failures or felt a need to take precautionary measures. Perhaps, unsurprisingly, the more rural the respondents home area, the more self-sufficient they were in terms of food and water. The workshops reported here were conducted with people living in highly urbanized Karlsruhe and Paris and the availability drinking water and food were seen as serious immediate issues. The survey also found that there was no statistical effect on the level of preparation of age, household size, income, education or occupation. However, having a family member with health or disability issues did mean families had taken precautions to maintain life support systems and medical supplies.

5. Conclusion

Blackouts can cause major disruption and incur huge costs but their rarity poses particular problems for research. The study reported here used students as research subjects in France and Germany to role-play the scenario of a 3-day blackout.

To return to the conceptual framework and the questions posed earlier. The students exhibited a clear understanding of how events might cascade after a major blackout and produce a chain of consequences, for example they imagined increased traffic jams and accidents as the result of traffic light failure, which expected would escalate if people could not contact the police because of mobile network or battery failure, they also imagined that hospitals might be overwhelmed because of an increase in accidents, such as setting fire to their home at night by dropping a candle or cooking on an open fire. How do people's feelings change over the 72-h scenario? Are their signs of emergent groupings, coping strategies and adaptive behaviour? How might communication failure impact on individual and communities?

The findings show that people's emotions and perceptions change significantly over the 3 days from initial calm and an expectation that the blackout would be of short duration, through anger and frustration to desperation and genuine fear. A good proportion of the participants had, by the third period at 24 h duration, given up waiting for help from the authorities and were being to organize and look for solutions in terms of volunteering, cooperating with others, finding food and water and contemplating or initiating evacuation. Our findings suggest that people would move from frustration that their smart phones lost power or signal, through anger that the authorities were doing nothing to genuine anxiety and, in some cases, a fear for safety and life-support.

A study of water supply in Kathmandu, Nepal after the 2015 Gorkha earthquake showed that the chronic stressors, such as supply-demand disparity, could improve the adaptive capacity of both agencies and the public to deal with disruptions in infrastructure [119]. In the blackout scenarios there were clear signs of emergent groups, coping strategies and adaptive behaviour, for example, people organizing into groups to take care of elderly, disabled and children, while other groups searched for food and information.

The results suggest that the main cause of the escalation in emotional response was not so much the inconvenience caused by the energy blackout, but the much more serious effects of the communication blackout. Not knowing what was happening or how long it would last caused the main distress. This suggests that the authorities need contingency plans not only to keep critical services supplied with power, but also how to communicate with citizens in a major extended power outage. To assist in preparing for infrequent crises such as major blackouts many observers have advocated that communities and governments engage in pre-disaster planning and preparation [120] and the more issues can be thought through in advance, including by means of scenarios, the greater will be the quality of crisis decision-making and management [121].

Although there are validity issues in using students as research subjects in role-play scenarios the findings from this research are plausible and have an inherent consistency and are indicative of how people would react in a real event that can inform policy. In particular authorities need to anticipate the anxiety occasioned by the information vacuum that would necessarily result from a major blackout. Two main messages are that people want to know what's happening, even if the news is bad, and secondly they want direction from the authorities.

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Article 2: Risk behaviour and people's attitude towards public authorities – A survey of 2007 UK and 2013 German floods

Abstract

This paper reports on people's preparedness, perception and behaviour of flood risk as well as their trust and attitude towards public authorities in the flood context. Two areas were studied: Catcliffe, situated near Sheffield in the United Kingdom, which was severely flooded in 2007, and Passau in Bavaria, Germany, which was hit by an extreme flood in 2013. We conducted a survey in both study areas and collected data on risk perception, people's perceptions of their own preparedness, their use of information, trust in the authorities and evacuation behaviour. We found that although there were few significant differences between the two case studies, risk perception and risk preparedness was significantly higher in Catcliffe than in Passau and during the flood emergency people in Catcliffe see themselves acting more self-protectively (78%) than in Passau (42%). In both places, people who had direct experience of floods had a higher level of risk perception and preparedness compared to those with no previous experience. In both Catcliffe and Passau, trust in government was fairly low. Nevertheless, when people were asked the hypothetical question how they would react to a public evacuation order, almost 70% in Catcliffe and 80% of respondents in Passau would take immediate action to evacuate. Interestingly, the answer was similar when we asked the conflicting question whether the respondents would follow a public evacuation order although their family recommended not doing so.

1. Introduction

In terms of frequency and amount of damage, floods and flood disasters are currently among the greatest global risks. As a result of climate change, the number of flood catastrophes is increasing. Over the last 20 years, more than 120,000 people lost their lives in severe floods worldwide and also the economic damage nearly reached US-$ 600 bn. over the same period showing an upward trend [1,2]. As a consequence, national and international efforts to improve flood precautions and to react quickly in the event of a catastrophe have been stepped up considerably in the last 10–15 years in research, insurance and practical civil protection. In this context, improved flood protection of private households is seen as among the most important factors of flood resilience. People's preparation for flood as well as people's reaction to an impending flood disaster are thus essential factors to reducing flood risks. However, to positively influence the risk behaviour of the population in their own interest, e.g. through risk communication or concrete suggestions of protective measures, a thorough understanding of the complex link between risk perception on the one hand and risk prevention on the other hand is necessary. Among other mediating variables, the trust of the population in the state authorities is a determining factor.

This empirical study reports risk attitudes, trust in government as well as the actual and hypothetical reactions of people in two communities affected by floods (river flooding), following events in the United Kingdom in 2007 and in Germany in 2013. The respondents live in two communities that were severely flooded: Catcliffe, a suburb of 2100 people (2011), between Sheffield and Rotherham in South Yorkshire, and the city of Passau, a town of 50,000 people (2011) near the Austrian border in Bavaria. Both places have been flooded numerous times in the past. Prior to 2007, Catcliffe was flooded in 1973, 1991, 1998, whilst Passau had suffered nine major floods prior to 2013 since records began in the 16th Century. Most recently, Catcliffe, where homes are very close to the River Rother, was flooded in 2000 and 2007, whilst Passau, at the confluence of the rivers Inn, Ilz and Danube, was flooded in 2002 and 2013. The two events were comparable in terms of impacts, levels of preparedness and government response and show similar patterns of recovery [3]. In both places, face-to-face surveys were conducted with local residents most of which were experienced with flooding. All the respondents were living and/or working in flood prone areas and, no matter if they had been personally flooded or not, were aware of flood risk.

The focus of the study is twofold: The first part focusses on flood risk perception and its impact on flood preparedness. In this part we want to find out whether the usually established connection between flood risk perception and flood risk precaution is also confirmed in our case study regions. For of flood precautions we choose a formulation that avoids the problem of a confounding effect from already adopted mitigation measures [4]. The second part looks at the respondents' attitude towards government agencies and its effect on preparation and evacuation behaviour. Public recommendations may refer to long-term, preparatory measures (e.g. construction of flood protection walls) or to very short-term, reactive measures, such as a call for immediate evacuation. Government advice directed at the population will only fall on fertile grounds if there is a sufficiently high level of acceptance among the population. Such advice are more likely to be ignored if citizens either don't trust the state authorities or if they generally have a more critical attitude towards the state or public institutions, and hence show an expressed preference for independence and self-determination. Since we are using the case studies to examine trust and risk prevention in two different countries, a country-comparison of the effects of "trust in government" is also instructive.

The remainder of the paper is organized as follows: In section 2 we provide an overview on the state of the art and establish our research hypotheses. Section 3 provides a more detailed description of the two case study regions, of the respective flood events in terms of people affected and economic damage and of the applied data collection procedure. Section 4 presents the results of the study, which are discussed in section 5.

2. Theoretical background: state of the art and research questions

2.1. Risk perception and flood preparedness

Research on risk perception began in the 1940s, with White [5] seminal contribution about how people's past experience influences their behaviour under threat of flooding. Risk perception can be defined as a "perception of the likelihood and consequence of a future adverse event" [6] and is seen as an essential precursor of mitigation behaviour [7]. Perceptions of risk are a key component in vulnerability assessments, for example in the hazards-of-place model [8,9].

Preparedness is defined as the knowledge, capabilities and actions of governments, organisations, community groups, and individuals to effectively anticipate, respond to, and recover from, the impacts of hazard events [10]. Grothmann and Reusswig [11] suggested that preparedness and preventative actions by residents could reduce flood damage by 80%.

The most influential theoretical foundations, which establish a link between risk perception and risk mitigation were the psychometric paradigm and the Protection Motivation Theory (PMT). According to the psychometric paradigm advanced by Slovic [12] risk perception is a subjective judgment based on several qualitative characteristics including severity of the threat, controllability and personal impact. Similarly, PMT constitutes the theoretical basis for the relationship between risk perception and risk mitigation. Originally developed to understand how people cope with fear and threats, PMT views behaviour as motivated by perception of the severity of the threat, the probability of its occurrence, the effectiveness of an action, and the person's ability to implement this action [13]. Building upon this theoretical foundation, most of the in-depth, systematic research into the relationship between perception and preparedness has taken place over the last 20 years [14–17]. The general findings show that attitudes to risk and the degree of preparedness vary with topographical and geographical location and that each disastrous flood is different in timing and scale.

2.1.1. Flood risk perception

In the literature, there is consensus that flood risk perception is principally influenced by people's experiences and demographic factors, followed by the risk attitudes of civil society and the actions of public institutions [18]. Lechowska [19] suggests that flood risk perception is determined by interrelations between awareness, worry and preparedness and that empirical studies unambiguously indicate that knowledge and personal experience are important factors.

In our study, we therefore assume a strong link between prior flood experience, socio-demographic variables and risk perception (Fig. 1). In our first hypothesis (H1a), we assume that people with experience of flooding show a lower flood risk perception [4,11,20–22]. By the lower-letter "a" we indicate the effect of a variable on flood risk perception and by a lower-letter "b" we indicate the effect on flood risk preparation. For the item "Prior flood experience" we asked the question "Do you have personal experience with the following hazards?" and for risk perception we asked the question "What level of risk do you feel you are in from the following hazards?". For both questions, respondents had to rate their answer using a five-point likert scale.

There is also evidence from various studies that risk perception amongst people who have experienced a flood declines over time. It has been estimated that flood awareness diminishes significantly with a distance of at least 7 years after a flood event [4]; International Commission for the Protection of the Rhine [23]. In Catcliffe, the survey was conducted nearly 12 years after the flood event and in Passau 6 years after the flood. Although we can't control for all aspects in which the two cases differ (except the similarity of the events in terms of scope and damage), we expect a higher risk perception in Passau because it was a more recent event (H2), and expected higher risk perception to increase the preparedness level (H3) which is explained in more detailed later.

Regarding sociodemographic variables and individual parameters we asked for age, gender and elicitated risk preference by the established risk-question "In general, are you a person who takes risk or do you try to avoid risks?". We assumed that older people (H4a), women (H5a) and people with higher risk aversion (H6a) should state a higher risk perception [19,24].

2.1.2. Flood risk preparation

Risk perception in the sense of being aware of risk is a necessary but by no means sufficient condition for people to actively prepare against risk. Other "activating factors" come into play as stated by PMT [4,18]. Similarly, Grothmann and Reusswig [11] built on this idea, arguing that decisions to take precautions, for example installing water barriers, are influenced by appraisals of the threat level, ability to cope, personal experience and administrative measures and that these perceptions interact in various ways. In other words, those activating factors don't apply homogeneously to all people in the same manner. To answer the question of why some people take precautionary action while others do not Grothmann and Reusswig [11] set up a regression model based on PMT that related private flood precautions to previous flood experience, risk of future floods, reliability of public flood protection, the efficacy and costs of self-protective behaviour and the perceived ability to take action. The validity of the model was tested by a telephone survey of residents in flood prone homes in Cologne. Results confirm the explanatory power of the model and the authors conclude that to motivate residents in flood-prone areas to take action it is essential to communicate the effectiveness and cost of private precautionary measures. Since people who haven't previously been affected by a flood show the least self-protection, they should be targeted by risk communication. Bradford et al. [25] also identify those who have not personally experienced floods as being in most need of information and suggest that since many people with no direct flood experience live in areas at risk, consideration must be given to how to raise their perception of risk in the absence of experiential learning.

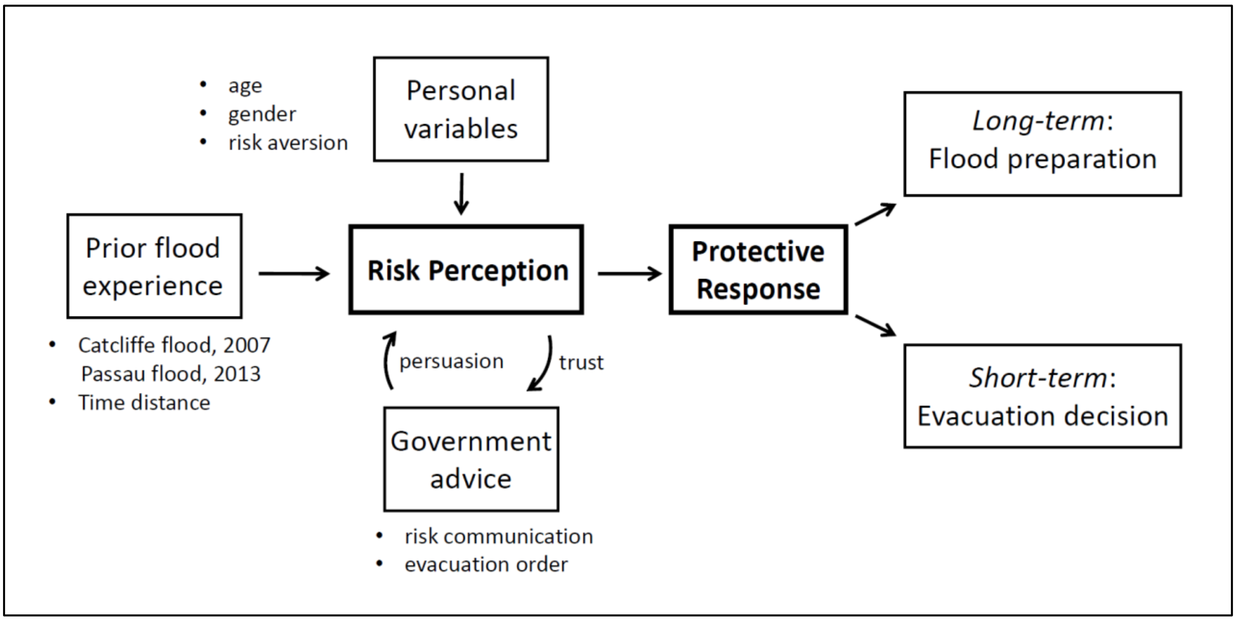


Figure 1 Influence factors and effect chain for people's response on flood risk

Several studies have, however, found only a weak correlation between personal flood experience and performance of precautionary measures [11,26–28]. Other studies even found no significant relationship [29]. Reporting on the results of sociological research in four communities exposed to flood risk in the Eastern Italian Alps, Scolobig et al. [30] found no statistically significant relationship between risk awareness and preparedness. Kienzler et al. [31] conducted interviews with German households that had suffered property damage from floods in 2005, 2006, 2010 or 2011 and found that previous flood experience did not necessarily result in precautionary measures. Overall flood-proofing and retrofitting measures were carried out by less than 15% of respondents and no constant improvement of private precaution could be identified over the course of the four events. Empirical studies from around the world suggest a number of factors may be important in influencing adaptive behaviour. In Lechowska [19]; "worry" is seen as necessary to move from awareness to action. The argument runs that individuals can be aware of flood risk but unless they are afraid, they will not take any action to mitigate the risk. Consequently, a higher level of worry is likely to result in a higher level of preparedness [15]. In contrast, Bradford et al. [25] found that worry does not play a major role in the relationship between awareness and preparedness. A study in Nagoya, Japan, found that preparedness for floods is determined by a complex relationship of socioeconomic factors including home ownership, fear of flooding and the amount of damage from previous floods rather than the individual's previous experience [32]. Based on findings from a survey of risk perception in Germany with nearly 2000 respondents, Gerhold et al. [33] identified 4 kinds of response: self-confident all-rounders (31%), unsure non-prepared (27%), unconcerned optimists (24%) and risk-oriented independents (18%). Women and minority groups generally perceive themselves to be at greater risk than men and majority groups [34]. Religious belief, and fatalism especially, has been found to weaken preparedness [35–37]. It is not that women and minorities always act differently from men, but rather that they do in particular situations and what makes perceptions of hazard subject to race and gender effects are differences in financial resources, home ownership, car ownership etc [38]. In summary, implementation costs and effectiveness are the most important activating factors for reactive measures, but there are also many psychological effects at work. With regard to the latter, the findings are less clear.

In our study, we did not ask the participants to name the measures they had implemented or which they plan to implement, but how well they felt prepared in the face of a flood: "How well are you and your family prepared for the following hazards?" (on a five-point likert scale, ranging from "not prepared at all" to "very well prepared"). We did not ask people what precautionary measures they had taken and relied on them using their own judgement to assess how well prepared they were.

It follows from this that altogether four constellations of risk perception and risk preparation can be distinguished. In the first, both, perceived risk and perceived preparation, are low: People don't perceive the risk as salient, which justifies low levels of preparation. In the second, the state of the perceived risk and perceived preparedness is high: People perceive the risk as a potential threat and are optimally adapted accordingly due to a good preparation. Note, that psychological factors, such as cognitive dissonance [39,40] can also cause such a response: If people perceive a threat but have to admit that they are not well prepared this can evoke a negative feeling of guilt because one did not live up to one's own responsibility. If people perceive a high risk but they feel that there is not much what they can do about it on their own, the third constellation of high perception combined with low preparedness is also plausible. If the number of respondents in this category is high, public authorities not only bear (even) more responsibility for protection of the public, they also have the largest opportunity to improve the preparedness of the population through risk communication and recommending precautionary measures. Fourthly, low risk perception but good preparation corresponds to the seemingly paradoxical case of a negative correlation between risk perception and risk mitigation as described by Bubeck et al. [4]. This effect occurs when the measures (implied by the question) relate to the past and have already been taken and are effective, which in turn endogenously reduces the perceived risk "now". Note that this effect should not be observed in our study because we ask for the perception of risk and preparedness at one point in time.

Since a positive correlation between perception and preparation was found in several studies, we also assume a positive correlation between the two variables (H3). However, we also expect a significant proportion of the first constellation and interpret a high proportion of "high perception – low preparation" as a window of opportunity and a responsibility for public authorities to communicate and act. In addition, we have a second look at sociodemographic variables, risk preference and risk experience and compare the link to preparation with the results from the perception-analysis (lower-case "b"-Hypotheses: H1b, H4b, H5b, andH6b).

2.2. Attitude towards government and reaction to government advice

As government and public authorities, such as first-response agencies, have a pivotal role in crisis management, the public's attitude towards these institutions has an enormous influence on the effectiveness of state crisis management. The more positive the public's attitude towards government decision-makers, the effectiveness of their communication with the citizens will increase with respect to crisis preparation and reaction in at least two ways:

- Higher effectiveness of government advice for flood risk communication and recommendation of preparedness-measures (risk and crisis preparation)
- Higher effectiveness of government evacuation order (risk and crisis reaction)

Two major factors influencing this "attitude" are perceived responsibility and trust. Trust in government is especially important in crisis situations such as floods and in the aftermath of major disasters. Lack of trust may hamper emergency response and recovery causing harm and damaging government's capacity to act [41]. A lack of trust also makes risk communication more difficult. In an extensive survey of 11 'at flood risk' locations in the four European countries Finland, Ireland, Italy and Scotland, O'Sullivan et al. [42] found low levels of understanding of flood risk and low levels of self-assessed preparedness amongst the general public. Hence trust is critical to the effectiveness of any policy for risk communication and public engagement [43]. Trust in government is influenced by demographic factors, such as age, education, and occupation but the most influential factor for trust in government is general satisfaction with democracy [44]. Across Europe, trust in political institutions has dropped since 2009 and, in general, citizens that have benefited less from European integration show lower levels of trust in the government [45].

The factor "perceived responsibility" refers to the values citizens hold in terms of their attitude towards individualism versus state interventionism [46]. The central question here is whether an individual believes that the state is responsible for certain tasks or not. To a certain extent, this determines the relevance of "trust in government". If an individual is convinced that a particular task does not belong or should not belong to the domain of responsibility of the state, trust is of less importance. However, both variables can be positively correlated if a low trust level is the reason for taking more self-responsibility.

In our study we ask about trust in government, in family and in fellow citizens ("How much do you trust the following people or groups in the country you are living?") and where respondents see responsibility for crisis management ("What are your views about flood preparation – People should take more responsibility for themselves or government should take more responsibility?"). While both questions are taken from the classic World Values Survey (WVS)-catalogue, the responsibility question has been slightly adapted to the context of crisis management. We assume that people who see the responsibility rather in the realm of the citizens (own responsibility) than in the realm of government (government responsibility) should see themselves as better prepared for flood (H8). With H7 we suggest that respondents with flood experience think individuals are responsible for flood protection rather than government.

Since the two case studies refer to different countries, it is interesting to compare the answers to the question of responsibility (H9) as well as the levels of trust in government (H10). In the UK, an economically liberal country where state influence has traditionally been viewed critically [47], responsibility should be that of the citizen. For example, in the 5th wave of the World Values Survey, sampled between 2005 and 2009, people were asked whether government or the people should take more responsibility for their lives. The resulting self-reliance-index was higher in UK (5.93) than in Germany (4.5). The lower level of government regulation in the UK than in Germany is also likely to have an impact in this area. We expect therefore that more respondents would opt for self-reliance rather than government responsibility in the UK than in Germany. An indication of this is that compensation for flood damage was paid by private insurance companies in the Catcliffe region, whereas state financial support was paid in Passau. However, there are also reasons that speak against the hypothesis of a lower level of trust in government by Catcliffe citizens (although not necessarily for a higher level of trust than in Passau). A critical attitude towards regulation might not transfer to crisis management because market regulation is different from state emergency aid. Second, even if the British government does not provide financial compensation for flood damage (or at least much less than in Germany), it is noticeably involved in risk communication. For example, in the UK, there have been regular round table dialogues between experts and members of the public on how flood risk agencies could communicate more effectively with the general public [48].

Apart from the overall attitude of people towards the government we were interested in how this attitude affects people's willingness to evacuate in the case of a hypothetic flood. And we wanted to know how trust in government and friends and relatives would influence (hypothetical) evacuation behaviour during a disaster (H11–H13). Community engagement and sense of belonging has been found to positively affect behaviour and people adjust their behaviour when they see others in their community, especially informal community leaders, adopting mitigation strategies [49]. Ties to family and friends should therefore play an influential role with respect to the evacuation decision. Strengthening local preparedness is viewed as an essential element in effective response to flood risk and social networks have been identified as contributing significantly to resilience by fostering individual and community capacity to deal with emergency situations [50]. Recent research on flood risk perception highlighted the importance of understanding and trust in the efficacy of individual protective actions and collective intervention measures [18].

Finally look at the effect of demographic (age, gender) and risk aversion variables on hypothetical evacuation behaviour (H14–H16). Altogether, 17 hypotheses were derived from the literature review reported in the preceding section. In the first part, hypotheses 1 to 6 focus on flood risk perception and perceived flood preparedness, and in part 2 hypotheses 7 to 17 focus on people's attitude towards government and their reaction to government advice, in particular to an hypothetical evacuation order (Table 1).

Table 1 Hypotheses generated from literature review

Hypothesis	Reference
PART 1 Perception and flood preparedness	
H1a Perception of flood risk is higher amongst people with experience of flooding	Barnett & Breakwell [20]; Kellens et al. [21]; Grothmann & Reusswig [11]; Terpstra [22]; Bubeck et al. [4]; Fuchs et al. [51]
H1b People with flood experience see themselves better prepared for floods	White [5]; Kuhlicke [52]; Thieken et al. [53]; Kreibich et al. [28]; Birkholz et al. [18]; Kienzler et al. [31]; Kreibich et al.[54]; Lechowska [19]
H2 Perception of flood risk is higher in Passau-Germany than Catcliffe-UK because the flood was more recent.	Bhattacharya-Mis & Lamond [55]
H3 People with higher risk perception see themselves better prepared for flood	Brown & Damery [17]; Pitt [16]; Raaijmakers [15]; Botzen et al. [14]; Bubeck [4]; Bradford [25]
H4a Perception of flood risk is higher among older people than among younger people	Lechowska [19]; Maidl & Buchecker [24]
H4b Older people see themselves better prepared for flood than younger	Lechowska [19]; Dzialek et al. [56]; Maidl & Buchecker [24]; Gerhold et al. [33]
H5a Perception of flood risk is higher among women than among men	Bustillos Ardaya et al. [7]; Lechowska [19]; Maidl and Buchecker [24]
H5b Women see themselves better prepared for flood than men	Bustillos Ardaya et al. [7]; Lechowska [19]; Maidl and Buchecker [24]
H6a Perception of flood risk is higher among people with high risk aversion than among people with low risk aversion	Haer et al. [57] ; Botzen & van den Bergh [58]
H6b Risk averse people see themselves better prepared for flood	Maidl & Buchecker [24]
PART 2 Attitude toward government and reaction to government advice	
H7 Flood experienced people see themselves more responsible for preparedness	Slovic et al. [59] ; Bubeck [4]; Mileti & Fitzpatrick [49]
H8 People who see citizen more responsible for preparedness should also see themselves better prepared	Based on authors best knowledge this hypothesis is not mentioned in published articles
H9 Respondents in UK see citizens instead of government more responsible for flood preparedness compared to Germany respondents	Based on authors best knowledge this hypothesis is not mentioned in published articles
H10 Trust in government is higher among German respondents compared to UK respondents	Based on authors best knowledge this hypothesis is not mentioned in published articles
H11 People who see citizen more responsible for preparedness are less likely to follow government evacuation order	Based on authors best knowledge this hypothesis is not mentioned in published articles
H12 People with low trust in government are less likely to follow government order to evacuate	Gerhold et al. [33]; OECD [41]
H13 People with low trust in government chose to listen to family rather the government	West and Orr, [38]; Levac et al. [50]
H14 Older people are more likely to evacuate immediately than younger ones	Bateman & Edwards [60]; Resnick [61]; Dash & Gladwin [62]
H15 Women are more likely to evacuate immediately than men	Bateman & Edwards [60]; Whitehead et al. [63]; Karanci & Aksit [34]
H16 Risk averse people are more likely to evacuate immediately	Based on authors best knowledge this hypothesis is not mentioned in published articles
H17 Age does not influence trust in government	Zhao & Hu [64]; Christensen & Lægreid [44]

3. Floods in UK 2007 and Germany 2013

Fig. 2 shows the extent of flooding in both countries during the referent events, and Tables 2 and 3 show how the two floods were similar in relative extent and impact. In terms of the economic loss and the number of people displaced the German floods were approximately twice as severe [66,69]. Private insurers compensated the majority of victims in the UK, whereas in Germany where insurance penetration was lower, government aid was much higher.

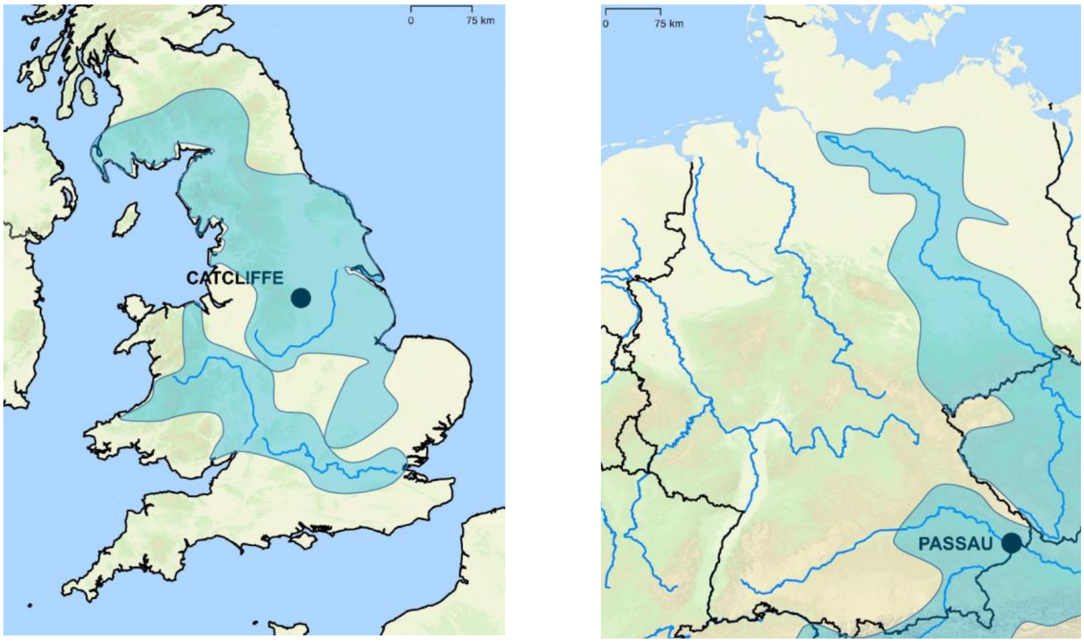


Figure 2 Flooded areas UK 2007 and Germany 2013

3.1. UK floods 2007

In summer 2007, much of the UK was hit by destructive storms and average rainfall around the country reached more than doubled [71,72]. Apart from the economic cost, which was USD 3.3–4.9 billion [67], 13 people died and hundreds had to be rescued in different cities and around 48,500 homes were flooded.

Catcliffe, our UK study area, is a village suburb northeast of Sheffield. During the night of 25 June, the River Rother overtopped its banks, flooding around 100 homes in the lower parts of Catcliffe (about 10% of homes in Catcliffe). Flood depths were so high that bungalows were almost completely submerged by the flood-water [73], and after cracks appeared in the dam at Ulley reservoir more than 700 residents had to be evacuated [74]. In Sheffield the River Don burst its banks, flooding properties, including many commercial and industrial units [73]. The drainage systems could not cope, in part because of inadequate maintenance, and because flood defences were overtopped by the extreme river heights [75]. In Hull and East Riding 1 in 5 homes were flooded [72] and electricity and water supplies were affected for more than a fortnight [68]. In Yorkshire, power outages affected the supply to 130, 000 people, including residents in Catcliffe. A survey of 2265 people in South Yorkshire showed a significantly high number of mental health issues among individuals who reported flood water in the home [76]. The evidence clearly shows that the UK was insufficiently prepared in terms awareness and preparedness [16]. This degree of flood risk persists and it is estimated that 5.5 million homes are in flood prone areas in the UK [77].

3.2. German floods 2013

In Germany, in May 2013, rainfall reached to three times the monthly average and most major catchments experienced flooding. Furthermore, in 16 federal states disaster alerts were declared between May and June [70]. The floods resulted in 14 fatalities, 600,000 people affected, 80,630 evacuated in 8 states, and an economic loss of USD 6.7–9.1 billion. Passau, where this study was conducted, is located at the confluence of the three rivers, Danube, Inn and Ilz, experienced large scale inundations [78,79]. Germany had recent previous experience of major flooding. Floods in 2002 caused 20 fatalities [80]. Although structural defences improved after this flood and most places faced less damage in 2013, in some areas, including Passau, the risk reduction measures and flood defences proved either ineffective or the flooding was more severe than in 2002 [3]. Three million people in Germany live in areas that are considered flood prone, life threatening and with high potential for economic damage [69,70,81]. The location, frequency and intensity of storms has shown considerable variability across Europe over the past century, however, most studies agree that the risk of severe storms will increase for northern and central Europe over this century in response to forecast global climate change [82,83].

3.3. Comparison

Table 2 compares the UK 2007 and German 2013 floods and shows that the scale of the floods was comparable, with the German floods perhaps twice as severe in terms of people displaced and economic loss. In terms of response, the main difference was that Government aid in Germany was considerably higher than in the UK.

Table 2 Comparison of the impact of flooding in UK and Germany [3]

	UK 2007	**Germany 2013**
Extent	6 out of 9 Regions	8 out of 16 States
Fatalities	13	14
People Displaced	38,000	80,000
GDP, PPP (event year)	USD 2.2 tn	USD 3.6 tn
Economic Loss	USD 3.3 – 4.9 bn	USD 6.7 9.1 bn
Insurance Loss	USD 2.6 bn	USD 1.8 bn
Average cost per house	USD 32,000	USD 56,000
Insurance Households	75%	32%
Government Aid	USD 180 mn	USD 8.9 bn
Flood risk homes 2018	5.5 mn	3 mn

4. Case study area and methodology

The survey was conducted in Catcliffe, UK and Passau, Germany. As mentioned earlier, both places were severely flooded and almost half of the interviewees had suffered flooding of their homes or businesses and two-thirds of all respondents lived within 1 km of the flooded river. To have a higher chance of interviewing flood affected people or people who are aware of the risk, the residential area of the flood zone was selected (Fig. 3).

Figure 3 Study areas in Catcliffe (left) and Dreiflüsse-Eck, Three Rivers Corner, Passau (right)- Google earth

Although Catcliffe is a low-density commuter village and Dreiflüsse-Eck in Passau is in the historic centre of Passau, both areas are of similar size 30–37 ha. They also have a similar population size, 2100 and 2990 and similar age profiles. In Catcliffe, 52% of properties were flooded and in Dreiflüsse-Eck approximately 70% were flooded (Table 3) [3].

Table 3 Comparison of floods in Catcliffe and Passau [84–87].

	Catcliffe, Sheffield/Rotherham	**Dreiflüsse-Eck (Altstadt), Passau**
Character	low density commuter village	high density, historic city centre
Location	2.5 miles from Rotherham and 4 miles from Sheffield city centre	historic centre of Passau at confluence of Danube, Inn and Ilz
Date flood	25-Jun-07	03-Jun-13
Population 2011	2,108	2,990
Population year of flood	1,971	2,981
Population 18-64	64%	66%
Area	30 ha	37 ha
Flooded area	16 ha	26 ha
Flooded area %	52%	70%
Properties total/flooded	372/195	800/560
Evacuation	Forcible evacuation due to fear of dam failure	Water supply failure meant 60 inmates of Passau prison had to be transferred

The survey design focused on the factors other researchers have identified as influencing flood resilience and included questions about the respondents perception and understanding of risk, trust in different addressees and in different sources of information, level of preparation, their detailed reactions during the flood event and personal details that may have affected their ability to cope (Table 4). Two native German speakers independently translated the questionnaire into German.

Regarding the flood risk aspects, the questionnaire was independently validated by three experts of flood risk management from the Institute for Risk & Disaster Reduction at UCL, Risk Centre at Judge Business School in Cambridge and a consultant from United Nations Disaster Assessment and Coordination (UNDAC). With respect to the methodological approach and survey design, the authors consulted the GESIS – Leibnitz-Institute for the Social Sciences in Mannheim. The surveys were piloted in September 2018 with students and experts and considerable effort was devoted to honing the questionnaire to ensure that it would be meaningful and understandable to interviewees.

Table 4 Survey factors

Dependent variables	**Independent variables**
Risk perception (5 point scale)	Country (Germany, UK)
Flood preparedness (5 point scale)	Gender (male, female)
Immediate evacuation (Binary)	Flood experience (Binary)
General trust (5 point scale)	Responsibility (Binary)
Trust in government, family, neighbors (5 point scale)	Social activities (Categories)
Attitude to risk (5 point scale)	Knowledge of hazard maps and warning apps (Binary)
Reactions during event	Age (Categories)
Flood preparedness	Employment (Categories)
Attitude during flood emergency (5 point scale)	Source of information (Categories)

Maps of flooded areas were used to target households and businesses for interview and appointments were made to interview people working in local organisations affected by the flooding, including the library, church, cafes, supermarkets, bars, garages, and a cinema. Over 90% of the surveys were conducted face-to-face and the remaining interviews were conducted on the telephone. 32 people were surveyed in the UK and 74 in Germany (Table 5). The interviews in Catcliffe were conducted over four days in early November 2018 and in Passau over five days in February 2019. In both countries native language speakers who were familiar with the flood risk management supported the interviewer, a non-native speaker, to make sure there were no misunderstandings.

Table 5 Respondents in Dreiflüsse-Eck (Three Rivers Corner) and Catcliffe

<table>
<tr><th>Case study area</th><th>Sample size</th><th>Previous experience of flood</th><th colspan="2">Gender</th><th colspan="2">Age</th></tr>
<tr><td rowspan="5">Dreiflüsse-Eck, Passau, Germany</td><td rowspan="5">74</td><td rowspan="5">45%</td><td>Female:</td><td>45</td><td>18-30:</td><td>20</td></tr>
<tr><td>Male:</td><td>27</td><td>31-45:</td><td>14</td></tr>
<tr><td>Unknown:</td><td>2</td><td>46-65:</td><td>30</td></tr>
<tr><td></td><td></td><td>Over 65:</td><td>8</td></tr>
<tr><td></td><td></td><td>Unknown:</td><td>2</td></tr>
<tr><td rowspan="4">Catcliffe, Sheffield, UK</td><td rowspan="4">32</td><td rowspan="4">56%</td><td>Female:</td><td>14</td><td>18-30:</td><td>2</td></tr>
<tr><td>Male:</td><td>18</td><td>31-45:</td><td>9</td></tr>
<tr><td></td><td></td><td>46-65:</td><td>8</td></tr>
<tr><td></td><td></td><td>Over 65:</td><td>13</td></tr>
</table>

SPSS (Statistical Package for the Social Sciences) was used to analyse the data. Mann–Whitney U, Chi-square, Fisher's exact test, Kendall's-Tau and ordinal regression were used where relevant.

5. Results

The findings focus firstly on the factors affecting flood perception and preparedness and secondly on the issue of trust, attitude towards government and hypothetic evacuation decisions.

5.1. Flood risk perception and flood preparedness

As mentioned earlier, many authors stress that risk perception and preparedness are influenced by flood experience (Table 1). Respondents were therefore asked about their previous experience of floods, their level of flood risk perception and to rate how well prepared they imagined they were to cope with future floods. All interviewees were living or working in flood prone areas and about half had experienced previous floods (Passau 45%; Catcliffe 56%). It was expected that those previously affected by floods would have higher risk perception (Table 1: H1a). The mean risk perception in Passau was 2.8 among flood affected people and 2.3 amongst non-affected. In Catcliffe, the mean among flood affected people was 3.7 and among non-affected 3.0. The combined data for UK and Germany shows a statistically significant difference in risk perception between flood affected and non-affected people (Mann-Whitney U test, $p = 0.017$) supporting the findings of others that personal disaster experience makes people aware of their vulnerability [11,20–22].

We asked whether personal experience also leads people to take action and thus enhances preparedness (Table 1: H1b). As described in section 2, there is strong evidence for a positive correlation between risk perception and flood preparedness [4,14–17,25]. In addition, it is highly plausible that the far-reaching experience of the Elbe Flood in Germany in 2002 has led many residents and businesses to prepare themselves better [52,53]. We found that the perceived level of own preparedness was significantly higher for people with flood experience than for people without prior flood experience (Mann-Whitney U all respondents, $p \leq 0.0001$; Passau $p \leq 0.005$; Catcliffe $p < 0.05$).

We then compared levels of risk perception and preparedness in Passau and Catcliffe. It is important to note that preparedness was selfreported, in other words own people's perception of preparedness. We have no means to find out if their responses were entirely credible or if some people may have felt defensive and exaggerated. However, the interviewer's subjective impression was that the majority of respondents gave accurate and truthful answers. Given the low levels of preparedness reported in both places this judgement seems reasonable. Based on the literature, we expected that risk perception would be higher in Germany as the flood in 2013 was more recent than the UK flood in 2007 and people's appreciation of hazard and vulnerability drops with time [55] (Table 1: H2). We found a statistically significant difference in risk perception between the two areas, but, most interestingly the reverse of that expected with people in Catcliffe showing a higher level of risk perception (3.4) than did people in Passau (2.5) (Mann–Whitney U, $p \leq 0.005$). Similarly, the perceived preparedness-level of the people in Passau was significantly lower than the preparedness-level of people in Catcliffe (Mean UK 2.8; Germany 2.1; Mann–Whitney U, $p \leq 0.025$).

The following table (Table 6) summarizes the test results of the hypotheses:

Table 6 Summary of results (in this table DE refers to Passau in Germany and UK refers to Catcliffe in UK. HC: hypothesis confirmed, HR: hypothesis rejected)

Hypothesis	Country	Test	P Value	Significance
PART 1 Perception and flood preparedness				
H1a	DE+UK	Mann-Whiteny U	≤ .05	HC
H1b	DE+UK	Mann-Whiteny U	≤ .001	HC
H2	DE vs UK	Mann-Whiteny U	≤ .005	HC
H3	DE+UK	Kendall's tau	≤ .005	HC
H4a	DE+UK	Kendall’s tau	≤ 1	HR
H4b	DE+UK	Kendall’s tau	≤ .05	HC
H5a	DE+UK	Mann-Whiteny U	≤ 1	HR
H5b	DE+UK	Mann-Whiteny U	≤ 1	HR
H6a	DE+UK	Kendall’s tau	≤ .5	HR
H6b	DE+UK	Kendall’s tau	≤ .5	HR
	UK	Kendall’s tau	≤ .1	HR
	DE	Kendall’s tau	≤ .05	HC
PART 2 Behaviour during the flood and trust in authority				
H7	DE vs UK	Mann-Whiteny U	≤ .5	HR
H8	DE+UK	Kendall’s tau	≤ 1	HR
H9	DE vs UK	Mann-Whiteny U	≤ .5	HR
H10	DE vs UK	Mann-Whiteny U	≤ .001	HC
H11	DE+UK	Mann-Whiteny U	≤ .5	HR
H12	DE+UK	Mann-Whiteny U	≤ .05	HC
H13	DE+UK	Kendall’s tau	≤ 1	HR
H14	DE+UK	Mann-Whiteny U	≤ 1	HR
H15	DE+UK	Chi-sq	≤ .005	HC
H16	DE+UK	Mann-Whiteny U	≤ .5	HR
H17	DE+UK	Kendall’s tau	≤ .005	HC

Fig. 4 shows that 46% of respondents in Passau had very low perceived flood preparedness compared to 22% in Catcliffe. Despite this difference, the perceived own flood preparedness is not very high in either Catcliffe or Passau, and the evidence from elsewhere suggests that people in risk prone areas rarely undertake mitigation measures voluntarily [4].

We tested if preparedness was related directly to risk perception and found a significant correlation when all the respondents from UK and Germany were considered together (H3: Kendalls Tau-b = 0.254, [2] P = 0.002). There was also a significant correlation for respondents in Passau (Tau = 0.305, p = 0.002) yet in Catcliffe no correlation was found between these two variables and the hypothesis was therefore not supported. Accordingly, also other researchers have found no statistically significant relation or only a weak relation between perception of flood risk and preparedness [4,14,52,53].

[2] Correlation is significant at the 0.01-level (2-tailed).

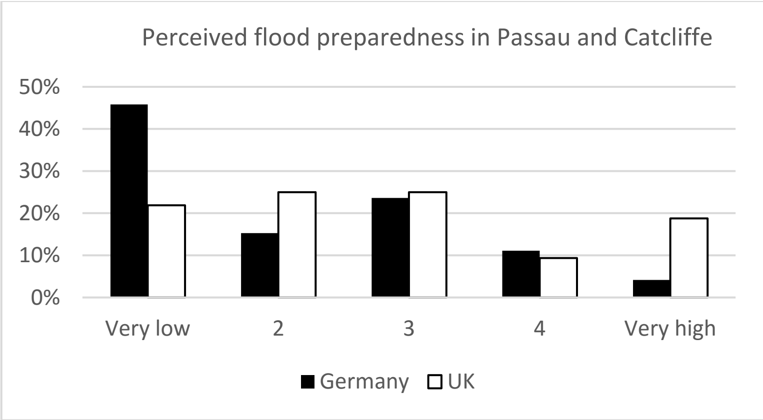


Figure 4 Flood preparedness in Passau and Catcliffe (Passau-Germany N=72, Catcliffe-UK N=32)

With respect to the four constellations of perception and preparation discussed in section 2, we pooled the data for Catcliffe and Passau in Table 7.

Table 7 Constellations of perception and preparedness

	No flood experience (N=53)			Flood experience (N=50)		
	Perception			**Perception**		
Germany + UK	Low 1, 2	Med 3	High 4, 5	Low 1, 2	Med 3	High 4, 5
Preparedness						
Low 1,2	40%	15%	17%	19%	2%	20%
Med. 3	9%	9%	2%	5%	8%	14%
High 4,5	2%	4%	2%	10%	8%	14%

As can be seen in Table 7, among the respondents without flood experience the most frequent constellation is the combination of low perception and low preparedness (40%). This indicates that many people don't perceive a high risk of flood and therefore don't see any need for a high level of preparedness, either. A further 32% perceive themselves to be at medium or high risk but are still unprepared.

This suggests that there may be an expectation-gap with respect to the government. Put differently, this can be seen as a window of opportunity for public authorities to support flood risk protection without the need for specific risk communication and awareness campaigns (as the respondents of this category already have medium-high risk perception).

Amongst respondents with flood experience, a much greater proportion perceives themselves to have a high level of preparedness (32%) compared to 8% of those with no flood experience. Whether this finding is partly due to cognitive dissonance (implying that they merely hope to be better prepared) is an open question. Overall, we see that even among those without flood experience there is both a high potential for better protection and a high need for better governmental support.

Other hypotheses about flood preparedness were tested, including the effect of age, gender and risk aversion. We expected older people to be better prepared (H4b) [19,24,33,56]. We found no significant correlation between age and risk perception (H4a, Tau = 0,046, p = 0.575) but older people, aged over 45, are more likely to have a higher preparedness level (H5, Tau = 0,215**, p = 0.01, N = 104). It was expected that women would display higher risk perception (H5a) and would consider themselves to be better prepared than men (H5b). However, our study found no difference in neither perception nor preparedness between men and women. Therefore both hypotheses are rejected with a P-value equal to 0,583 for H5a, and P equal to 0,644 for H5b.

Preparedness is expected to increase with increasing anxiety [24,88] and we tested if risk aversion as a related concept was correlated with flood perception (H6a), and preparedness (H6b). Respondents ranked themselves on a 5-point scale from risk averse to risk taker.) There was no correlation between risk aversion and flood perception. There was, however, a significant correlation between risk aversion and flood preparedness in Passau (Tau = - 0.250, [3] p = 0.013) and a less strong relationship in Catcliffe (p = 0.09).

5.2. Attitude towards government and reaction to government advice

Bubeck et al. [4] argue that flood prevention will require private households to take more flood mitigation measures. Respondents were asked if they considered flood preparedness was a task of the government or the responsibility of individual households. Respondents answered on a scale between 1 and 5 with 1 indicating full responsibility for individual households and 5 full responsibility on the side of the government. We expected flood experienced people would tend to be more independent and would take more responsibility for preparedness (H7).

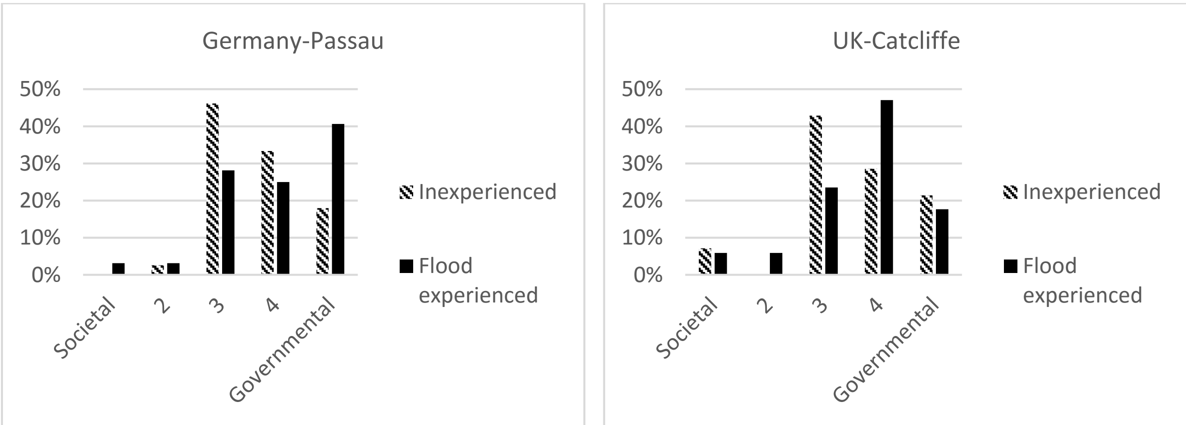


Figure 5 Preparation responsibility expectation among flood experienced and inexperienced

Fig. 5 shows that about two-thirds of respondents in both Passau and Catcliffe expect the government, rather than individuals, to take responsibility for flood preparedness. We wondered if the remaining 33% who think that individual families should be responsible rather than government would see themselves as better prepared (H8). Interestingly, there was no significant difference in preparedness between those who perceive a higher responsibility and those who think it is the job of government (P value = 0,726, N = 103). We also tested if there was a difference in flood preparedness between Passau and Catcliffe among those respondents who take responsibility for flood preparedness (H9), but we found no statistically significant correlation.

[3] Correlation is significant at the 0.05-level (2-tailed).

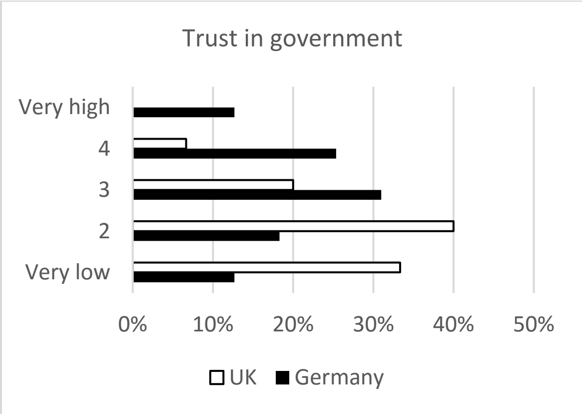
During emergencies, successful risk communication depends on public confidence in the authorities [89]. As data from the World Value Survey for 2006 show, both British and German citizens equally have low or very low trust in government (74% of citizens in Germany and 60% in UK). Due to differences in quality of governmental support in the study areas in each country, we anticipated that respondents in Passau would show higher trust in government than those in Catcliffe (H10). In the UK, respondents complained that the local authorities were slow to respond and there was little direct central government assistance, whereas in Germany volunteers organized by German Technical Relief Service reacted quickly and the Federal government provided generous financial aid [3]. As expected, we found a significant difference in trust in government between respondents in the two study areas (Passau mean = 3.1, Catcliffe mean = 2.0, Mann-Whitney $p = 0.000$).

In the specific case of an evacuation, low confidence in government can be dangerous. We confronted the interviewees with a hypothetical flood disaster and asked them whether and how quickly they would comply with a government order to evacuate. In total, 49% of all respondents ($N = 104$) had direct experience of their property being flooded (46% in Passau and 58% in Catcliffe). The interviewees were offered three choices: take the warning seriously and evacuate as quickly as possible (selected by 76%); take the warning seriously, but NOT hurry as the authorities usually exaggerate (20%); or not believe in warning (4%).

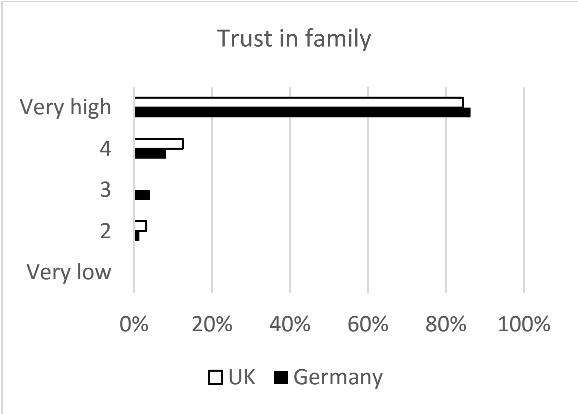
The relationship between the people's attitude toward the responsibility of flood preparedness is analysed in relation to their perception of risk and level of preparedness (H8 and 9). Moreover, we expected that people who see flood preparedness more as the task of citizens than government, would also rely less on government in times of crisis and therefore not evacuate immediately following a government evacuation order (H11). However, we found that this was not the case and that the greater propensity for independence and self-reliance does not affect the willingness to follow a government evacuation order in a hypothetical context (Mann-Whitney $p = 0.322$).

People with low trust in government have been found to be less likely to follow a government order to evacuate immediately (H12) [33]. Trust in government was measured on a 5-point scale from very low to very high. We found a significant relation between trust in government and immediate response to an evacuation order (Mann-Whitney $p = 0.02$) where 64% of people with low or very low trust in government would not evacuate immediately compared to the control group with higher trust in government. It is both interesting and important that low trust in government can spill-over to the willingness of people to immediately follow government advice in an emergency situation. Through hesitation and doubt valuable time can be lost.

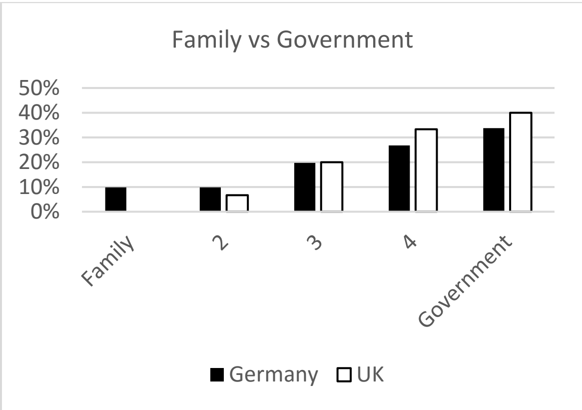
When public instructions in emergency situations meet with a lower level of acceptance: To whom do people respond instead? In a study of attitudes to volcano risk, Haynes et al. [90] found the public viewed friends and relatives as the most trusted source of information. To test this, we asked respondents, "Imagine there is a flood in your region and you get a government order to evacuate but a family member or a close friend/neighbour recommends you to stay at home and try to stop water entering the house. Whose advice would you follow?" It was expected that when people have higher trust in family than government (Fig. 6b), they should rather follow the advice of the family than of the government (H13). We found, however, that in both countries most people said they would prioritize government advice over family (Fig. 6c). The reason may be that the public assumes an informational advantage on the side of public authorities regarding the severeness of the flood risk [89,91]. Therefore, despite the generally low trust in government, people in the UK and Germany are likely to follow the advice of the authorities. Fig. 6d summarizes the key findings on trust and the effects on evacuation for the two studied areas. Apart from the lower levels of trust in government in UK the results are similar for each country.



a.



b.



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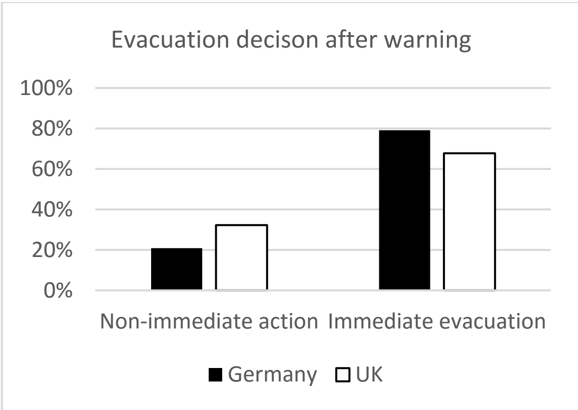

d.

Figure 6 (a) Trust in government (b) trust in family in normal time, (c) who do people follow in disaster time, (d) people who would immediately evacuate after being asked by government

Looking at demographic variables, we find that older people see themselves as better prepared for floods than do younger people (H4b). However there was no difference in the risk perception with age (H4a). Finally we checked whether older people are more likely to evacuate immediately on being told to by government (H14), but found no relationship (Mann-Whitney p = 0,897).

Various researchers [38,60] found that men are less likely to evacuate than women (H15). We also found a highly significant difference between women and men (Chi-square p = 0.003) where 64% of the people who said they would evacuate immediately were women and 36% were men. This is in line with other studies, which found women to be almost twice as likely to evacuate when given a mandatory order [63]. We also tested if risk averse people are more likely to evacuate immediately (H16), which was not confirmed.

Finally, we tested for further age effects. Zhao and Hu [64] and Christensen and Lægreid [44] found trust in government increases with age, although Maidl and Buchecker [24] stress citizens' trust in government varies with political and cultural circumstances rather than age. Using Kendall's Tau we tested if trust is correlated with age and found a significant relation (H17) for Germany and the UK combined (P = 0,005, correlation = - 0,232).

6. Discussion

Writing about seismic risk, Rossetto et al. [92] argue that "a large proportion of people the world over do nothing or very little to adjust to seismic hazards." Rossetto, Joffe and Solberg [92] argue that seismic adjustment adoption rates relate to feelings of community, self-worth, trust and control. Understanding such motivations and constraints is a step in understanding how to encourage risk mitigation. The low risk awareness of the residents living in flood-prone areas is usually considered as a main cause of low preparedness and inadequate response to floods, yet few studies have evaluated how risk communication programs affect these risk perceptions. Terpstra et al. [93]; in a study of flood risk in 3 Dutch provinces, found only weak support for the idea that risk communication programs can affect risk perceptions. Knocke and Kolivras [94] investigating flash floods in Virginia thought awareness of flash-flood risk could be improved through training, television campaigns fliers and the provision of better weather data.

In this empirical study, we analysed people's perception of flood risk, of their own preparedness and their attitude towards government advice in two cities, Catcliffe and Passau, which were both seriously affected by flooding. Although the sample sizes were relatively small (32 in Catcliffe and 74 in Three Rivers Corner) they are fairly representative of the populations living in both places.

Perception of risk is integral to determining the response to flood warnings and flood risk management. Efforts to increase community preparedness have largely failed when the authorities overlooked the subjective nature of public perception [17]. During the UK 2007 summer floods, the poor public response to Environment Agency warnings was thought to depend on whether people were aware of their own personal risk [16]. This lack of understanding by the agencies involved in the public's perception of risk can render warnings ineffective [33]. Modern theories of cognitive psychology suggest that perception and action are bi-directional and interdependent [95–97] and that cognitive function, i. e. understanding, resides in the interactions of perception and action [98]. This discrepancy between risk perception and preparedness was one key area we have explored and reported on. We found that although there were few significant differences between the two case studies, risk perception and risk preparedness was significantly higher in Catcliffe than in Passau and during the flood emergency people in Catcliffe see themselves acting more self-protectively (78%) than in Passau (42%). In both case studies, people who had direct experience of floods had a higher level of risk perception and preparedness compared to those with no previous experience, which is in line with findings from prior studies on risk perception. Although most respondents displayed low perception of flood risk and low level of their own perceived preparedness, the combination of high risk perception and low preparedness was the most frequent constellation among respondents with prior flood experience. Why do people with high risk perception don't do more to protect themselves? The causal pathways are more complex than a direct link between experience and preparedness and intervening variables, such as perception of hazard cycles and the time since previous events can modify behaviour. In turn, responsiveness depends on the perception of one's own agency to engage in effective protective actions and on the strength of belief that personal responsibility can be delegated to public emergency management. These issues need to be taken into account when developing communication and participative activities [99]. Interpreted this way, our findings indicate a window of opportunity for governmental support as the scope for private protection is limited but the risk awareness is already high.

A second prerequisite for effective public intervention is the citizens' attitude towards government and their trust in particular. With respect to self-reliance and independency, a majority of all respondents holds the opinion that flood preparedness is a major task of government. However, even among those who think differently we did not find a significantly larger level of perceived own flood preparedness. In both Catcliffe and Passau, trust in government was fairly low. Nevertheless, when people were asked the hypothetical question how they would react to a public evacuation order, almost 70% in Catcliffe and 80% of respondents in Passau would take immediate action to evacuate. In spite of this finding, trust matters: People with low trust in government don't follow government advice immediately whereas people with medium and high trust levels tend to follow government advice. Interestingly, the willingness to follow government order was more pronounced when we asked the conflicting question whether the respondents would follow a public evacuation order although their family recommended not doing so. This finding shows that only low levels of confidence have an impact on the context of the crisis. This is understandable, since the motives for distrust in state action are less relevant in the crisis context. Nevertheless, it is clear that too little trust in the state can lead to a hesitant, wait-and-see attitude and in extreme cases this can be dangerous. It is therefore important to understand where government measures are needed, where they encounter fertile ground and what conditions need to be created in parallel to achieve broad acceptance of measures.

As mentioned earlier, the frequency and severity of floods events is increasing in Germany and the UK and an adaptive response is required to preparedness and mitigation that involves all parties including the state, the insurance sector, businesses and households [3,29,100,101]. These adaptive responses call for a new social contract between public and private sector actors to respond to the challenges to flood risk management posed by climate change [102–104].

7. Conclusions

Summarising the results of the surveys in the UK and Germany, in both case studies, people who had direct experience of floods had a higher level of risk perception and preparedness compared to those who had no previous experience. We also found that older people had a higher level of risk perception and preparedness compared to younger people. Residents of both countries showed different perception-preparation patterns with respect to their prior flood experience. 35% of the people with no flood experience displayed medium or high risk perception but rated their own flood preparation low. As there is no need to convince this group (e.g. by costly awareness campaigns), policy makers can go ahead to support people's flood risk preparation, either by technical recommendations or financial support. In both Catcliffe and Passau, trust in government was fairly low. Nevertheless, if the government asked people to evacuate immediately, almost 70% in Catcliffe and 80% of respondents in Passau would take immediate action to evacuate. Furthermore, no matter how much people trust their family, if the government asked them to evacuate and their family said it was unnecessary, nearly 70% of respondents in both areas would follow government advice.

Meanwhile, it was interesting to see that low trust in government can spill-over to the willingness of people to follow government advice immediately in an emergency situation. Political decision makers should be well aware that a low level of public trust can translate in a significant loss of valuable time during a crisis situation. The decision to evacuate is significantly higher amongst women than men. Although there were few significant differences between the two case studies, risk perception and risk preparedness was significantly higher in Catcliffe than in Passau and during the flood emergency, people in Catcliffe acted more selfprotectively (78%) than in Passau (42%). In both areas people living in a flood hazard zone cannot easily get flood insurance coverage, and in Germany, to date the government compensates most people.

In general the people who had been directly affected by flood were dissatisfied with flood early warning. Many respondents in Passau complained about not receiving a flood warning in time and that the authorities had underestimated the severity of the situation. In the UK, people in Catcliffe also blamed government for not providing sufficient warning and were dissatisfied with the performance of the local authorities and Environment Agency. In each country respondents reported that the severity of the flood was under-estimated and the forecast of water levels was inaccurate and that the flood warning was not broadcasted early enough or sufficiently well enough to give them the opportunity to move their valuables or car to a safe place which meant they suffered higher economic damage to their business or home, and, in Passau, some people were even trapped on the upper floor of their apartment. According to respondents, the first source of information was word of mouth and personal observation of increasing water level, rather than siren or loud-speaker announcements. In Catcliffe, police officers evacuated people by knocking door by door at midnight and driving them out of flooding area.

Extreme events can be catalysts for policy change [105]. In the UK the 2007 flood was called a ‘game changer’ in the Pitt [16] and in Germany Kreibich et al. [28] described the 2002 flood in Germany as a ‘focusing event’ that concentrated minds on improving resilience. After both floods there were significant changes in flood awareness and preparedness amongst both residents and the authorities [106]. However, the findings of this study of floods in the UK 2007 and Germany 2013 suggest that few people in known flood hazard areas take personal responsibility to limit the damage from floods. Given the likely increased incidence of flooding in both the UK and Germany with climate change and given the possible withdrawal of state aid in Germany and the difficulty of getting insurance cover in both countries progress is needed in turning awareness into effective action.

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Article 3: Optimal Evacuation-Decisions Facing the Trade-Off between Early-Warning Precision, Evacuation-Cost and Trust – the Warning Compliance Model (WCM)

Abstract

In this article, we analyze the phenomenon of flood evacuation compliance from a both decision-theoretic and game-theoretic perspective presenting the Warning Compliance Model (WCM). This discrete decision model incorporates a Bayesian information system, which formalizes the statistical effects of a warning forecast based on the harmonious structure of a Hidden Markov Model (HMM). The game-theoretical part of the model incorporates the evacuation order decision of a local government and the people's compliance regarding their evacuation-decisions. The strengths of this novel approach lie in the joint consideration of probabilistic and communicative risk aspects of a dynamic setting, in the simultaneous consideration of escalation and de-escalation phases and of two differently exposed risk groups, which requires differential risk communication. For each scenario, we derive the explicit and generic solution of the model, which makes it possible to identify the scope for warning compliance and its effects independent from the parameter constellation. Applying empirical data from flood and risk studies yields plausible results for the escalation-scenario of the model and reveal the limits of compliance if people face a Black Swan flood event.

1. Introduction

Natural disasters cause severe damage worldwide, with an upward trend (Alfieri et al. 2016; Bruine de Bruin et al.). Whenever natural catastrophes may endanger human life and sufficient warning time precedes the occurrence of the event, the immediate evacuation of the population is required. Evacuation can be defined as "the process of alerting, warning, deciding, preparing, departing and (temporarily) holding people, animals, personal belongings and corporate stock and supplies from an unsafe location at a relatively safer location given the actual circumstances" (Kolen & van Gelder, 2018). In the context of an evacuation, the questions of whether, and – if answered with yes – when and to what extent are among the most difficult decisions to be made by responsible actors such as (local) government and civil protection agencies. The decision problem can be divided into three different elements or tasks. First, the occurrence of the potentially dangerous event that could make an evacuation necessary must be predicted as accurately as possible by a *hazard forecast*. In practice, this task is performed by Early Warning Systems (EWS), which are usually developed and operated by research institutes and commercial (early warning) services specialized in this field. Whether timely evacuation is possible at all depends on the scientific and technical performance of these systems on the one hand and the specific characteristics of the concrete natural hazard on the other.

The second task comprises evacuation planning and the evacuation decision itself, which can be either a mandatory evacuation request ("order") or a voluntary evacuation request ("recommendation") but either way this decision is eventually based on a comprehensive *cost-benefit analysis* of public decision-makers, weighing up the advantages and disadvantages of an evacuation. While the potential lives to be saved play the primary role in this consideration, an evacuation can also involve securing critical assets and thus avoiding direct economic damage. However, the measures and operations, which have to be put in place within a short period, require a systematic preparation and planning in combination with pre-disaster risk communication with the potentially affected population living in the risk-prone area. For example, one of the most frequently reported bottlenecks for an effective evacuation is unnecessary traffic congestion, i.e. congestion which could have been overcome by timely planning of escape-routes as well as pre-disaster planning and training to overcome problems of coordination during the evacuation.

The third aspect, which constitutes a necessary precondition for a successful evacuation, concerns the acceptance and *evacuation compliance* of the population, which requires a good communication strategy but also a high credibility of the political decision makers. It should be understood that an evacuation, which usually involves leaving one's own home for up to several weeks, is a very consequential decision for those affected. There can be many reasons why potentially affected people do not comply with an evacuation order. The target group does not perceive the order or it does not take it seriously (enough) because it fails to understand the gravity of the situation and instead considers the measure to be exaggerated. On the other extreme, people may consider the order as too drastic an intervention in their private affairs and therefore give priority to their own crisis micro-management in the first instance (in particular to stay with vulnerable family members, pets or to protect their belongings), which can entail a dangerous loss of time. Further reasons are that people perceive their homes as a safe place, that they don’t know where to go or that they have distrust into the public decision makers’ “true objectives”. The last aspect is relevant if people think that e.g. tourists are more relevant to the local government’s decision or even in highly problematic contexts where the local government misuses an evacuation request in order to get rid of marginalized groups. Hence, evacuation compliance depends crucially on the population's trust and credibility in the official decision-makers.

“Approaching evacuation as a process and not as an outcome is key to understanding why some evacuate and some do not, and more important, to determining what can be done to motivate more compliance.” (Dash & Gladwin, 2007). Following Dash & Gladwin, the objective of this contribution is a model-based analysis of an interaction of the three before mentioned tasks of evacuation: hazard forecast and early warning, strategic evacuation-decision making as well as evacuation compliance. At the center of the warning response model is the evacuation decision of a public decision maker (local government) and the evacuation compliance of the potentially affected population.

The decision problem is as follows: A public decision maker (PDM), e.g. the local government of a hypothetical seaside town, receives a forecast or warning from a stylized EWS and has to decide whether to issue an non-mandatory evacuation order. We choose an approach from information economics and model the EWS as an *information system* (Bikhchandani et al. 2013). The sequence of events and the occurrence of informative signals (emissions or “warnings” in our context) can be depicted as a Hidden Markov Model (HMM). Both, the hazard and the evacuation decision, are scalable over two levels. The hazard, e.g. a flood, can have an severe impact affecting the residential area near the coast (this corresponds to state S1 where a proportion of γ% of the population would be affected by flood) or an extreme impact affecting all residents of the whole town (this corresponds to state S2 affecting the entirety of the local population). *Figure 1* illustrates the two potential levels of impact taking the example of New Jersey (left picture), a state which was severely hit by hurricanes in the past (e.g. hurricane Sandy in 2012) and which led to the identification of flood-risk zones by FEMA. The picture to the right in *Figure 1* shows the zones of Southeast Louisiana as an example for three risk categories (indicated by the colors red, orange and yellow). Depending on the specificities of the locations and the local vulnerability profile of the population, there are very often up to five or more categories. Although we use the case of two zones for the sake of simplicity it is to note that a higher number of risk or evacuation zones increases operational complexity, in particular it becomes more difficult to communicate each citizen which risk zone it belongs to and what this means in terms of preparation and reaction.

Accordingly, conditional on the received signal the authority can either issue a partial evacuation focusing at the residential area in the coastal (risk) zone or it can issue a full evacuation for the whole region. For the evacuation decision, the authority takes three types of cost into account: The potential damage to the population in the case of flooding in an non-evacuated region (either just the coastal region or the entire town), the cost of an evacuation incurred by the government and the burden for the population in the case of a false alarm. Further details are given in section 4.

Although the model has a relatively simple structure, it makes it possible to depict two different levels of risk and to derive an optimal decision for every outcome based on the Markov chain structure.

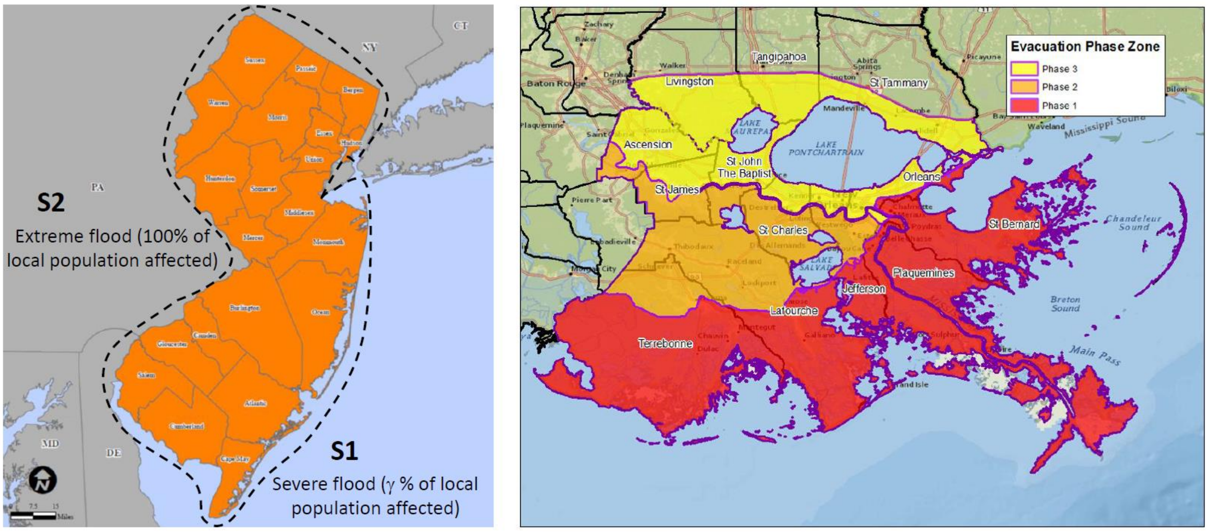


Figure 1 Examples of flood risk zones -left: New Jersey (FEMA 2012), right: Southeast Louisiana (State of Louisiana)

The scalability of the decision is an important feature of the model as this often constitutes a major problem in practice. Closely related is also the consideration of different population groups (heterogeneity). This aspect is considered very important in the literature, as different groups act from very different motives and under different circumstances. In the literature, a distinction is made above all between groups in risk areas and those outside risk areas, between vulnerable and (less) vulnerable groups, and groups that are differentiated according to socio-demographic criteria (age, gender, ethnicity). In our model, we limit ourselves to the first point and distinguish between people living inside and outside risk areas. This criterion is usually highly relevant for high tide and hurricanes, since coastal inhabitants are exposed to a higher risk and usually are well aware of this (official classification into risk zones). We would like to stress that we have not integrated the other criteria into the model primarily for reasons of complexity, and not because we consider these further group differentiations to be unimportant. On the contrary, our model approach can be extended to include these groups relatively easily, provided that data on hazard characteristics, local conditions and demographics are available.

In addition, the model also allows to analyze the de-escalation-decisions (return to “normal”), which are absent in most evacuation models. While a situation where no flood yet occurred corresponds to the escalation-phase (just evacuation-decisions have to be made), situation S2 represents the de-escalation-problem. Here, the whole town is already flooded and the people either evacuated the period before or they were “forced out of the region” by the flood itself which implied a high risk for life and health. Those who evacuated or were lucky to escape in time, now feel the urge to return as fast as possible. However, if the flood situation worsens again this can put these people at a new risk, which is a frequently overlooked issue in evacuation-modeling. As Sorensen & Sorensen state, „the time period for the span of withdrawal is elastic in that the evacuation may last for any amount of time, and may occur more than once or sequentially should there be secondary hazards or a reoccurrence or escalation of the original threat. For example, while the primary hazards form hurricanes are wind and storm surge flooding, secondary threats could include inland riverine flooding that might necessitate a second evacuation effort “(Sorensen & Sorensen, 2006). To protect the people from this kind of “second wave”, the government can decide whether to issue an order to remain outside the region. Note that an “evacuation-order” and a “remain-order” just differ with respect to the status quo (i.e. whether people are already out of the region or not) because in both cases the government aims to incite the population to be absent from home. In situation S1, just the coastal area is flooded. This situation represents a combination of escalation (relevant for the rest of the town, which is not yet flooded) and de-escalation (relevant for the inhabitants of the coastal area, who had to leave the region and are about to return). It is one central feature of this dynamic model that it comprises both escalation and de-escalation as well as the more intricate constellation in between. The challenge for the authority is to find an optimal policy – conditional on the current state and future prediction – which fits to both groups at the same time.

One further important element of our model is *trust* of the potentially affected population in the government’s communication. Although theoretically the government can enforce an evacuation order, police coercion is for sure the “means of last resort” for public officials. In principle, large-scale enforcement in a stressful situation will most probably fail due to lack of time, lack of staff, increased opposition by the public and personal discomfort of the executive personnel. Therefore, we assume in our model that the government cannot force people to evacuate but it can just influence them in a direct and indirect way while both channels depend on trust.

The first type of trust is the people’s trust in a competent impact assessment on the side of the government. While the (unconditional and conditional) event probabilities are common knowledge to all decision-makers of our setting, we assume an information asymmetry between the government and the public with respect to the *impact* of a potential flooding event. To put it plainly, people know how probable a flood event is but they do not know (as precisely as the regional government knows) how severely this flood could hit them. While probabilities and warnings are publicly issued by the weather forecasting service, the question how dangerous this event could be for a specific region is still a different aspect. By contrast, the local government has access to more and deeper expertise, which makes *competence-trust* valuable at this point. We see a concrete example and further justification for this assumption in the first wave of the current Corona-pandemics. Although data about the spread of the virus and the upsurge of infections was publicly available at any time, in many countries people were skeptical about the drastic restrictions and did not believe in potential damaging impacts for themselves. However, in a country like Germany, where trust in government is comparatively high, people showed a high degree of acceptance accordingly.

The second trust component is *reliability-trust*, which exerts an indirect effect on the public's evacuation decision because it affects the chance for a smooth evacuation. Wilson (2018): "Issuing mandatory evacuation orders (…) prior to the landfall of hurricanes can be as or even more disruptive and dangerous than the storm itself. For example, 107 of the 120 deaths attributable to Hurricane Rita occurred because of extreme temperatures in jammed traffic during the Houston's evacuation (…). More recently, Hurricane Irma in 2017 prompted the evacuation of up to 6.3 million Floridians, one of the largest such displacements in American history (…). The storm's aftermath raised serious questions about overburdened infrastructure and the social vulnerability of communities that were unable to leave via their own means (…)." Before all events unfold (let's say in an imaginary period zero) the government can invest in better evacuation conditions, such as improved evacuation planning and training, contracting for vehicle capacities (e.g. busses which can bring the people out of the affected region) or even the construction of additional roads. We assume that the government has a fixed budget for this investment but must decide about the allocation answering the question which region (coastal area versus rest of the city) should receive which share of it. As the public cannot directly observe all taken measures, it again has to trust that the government did the most to make a smooth evacuation possible. A low level of reliability trust leads to the conviction of the inhabitants of both regions that they have to cope with the congestion-problem on their own. This will eventually increase the expected degree of congestion and thus prevent a (possibly life-saving) evacuation. In the model we deal mainly with the first type of trust but treat congestion as an intensification of the evacuation problem.

The remainder of the article is organized as follows. After a brief outline of the related literature in section 2, we present the early warning or information system in section 3 and the decision-model and communication-game in section 4. In section 5, we derive the model's results, in particular the Nash-Equilibrium of the compliance-game. In section 6 we give a brief summary and discuss the implications and possible extensions of our approach.

2. Related literature and state of the art

This section gives a brief overview on the relevant literature in this field. We start with some stylized facts about EWS and refer to selected case studies, which looked at specific challenges such as information processing, information aggregation, information communication as well as coordination between experts, such as services for flood control, who bear a large part of the responsibility for the public when making proficient use out of this information. The second part refers to literature on evacuation decision making and evacuation compliance. Although slightly dominated by social scientists this is a very interdisciplinary area of research, which comprise empirical studies, simulation models and guidelines.

Literature on EWS and in particular models, which aim at improved forecasts, abound. An EWS belongs to the so-called non-structural measures of hazard protection (as compared to structural measures, such as dams or levees in the case of flood, which constitute a physical barrier). According to Salit et al. (2013) and Mileti & Sorensen (1990), an EWS for flood risk comprises three basic components: “the detection system (collection and analysis of information, flood forecasting), the management system (composed of national and local emergency management officials) and the response system (transmission and reception of warnings to the population concerned)” (Salit et al. 2013). With respect to the last there is again a long list of requirements concerning the interface between sender and receiver of the message. These requirements refer to issuance and dissemination (outreach), perception, comprehension and interpretation, personalization (anticipating the receiver’s interpretation as people contextualize the information for themselves and ask questions such as: What does this message mean to me? Do I need further information?) and sender credibility. Warnings must be perceivable and clear (Sorensen 2000) and an EWS has to be adopted to the local conditions (Salit et al. (2013).

Although floods and hurricanes are easier to predict than e.g. earthquakes, there are numerous examples of wrong forecasts also for these two types of events. The difficulty with hurricanes is that they can change their direction shortly before landfall. A well-known example is hurricane Rita in the Gulf of Mexico in the year 2005: “Although originally projected to hit the Houston/Galveston area, Rita took an easterly turn while still in the Gulf, a shift in direction that spared these metropolitan areas a direct hit” (Carpender et al. 2006, p. 777). There is a comparable level of uncertainty for floods as the movement of water masses, which break their path through inhabited districts, can be highly dynamic and therefore difficult to predict (Salit et al. 2013).

With respect to the subtopic *evacuation* and *evacuation decisions*, research over the last two decades has constantly shifted towards a stronger focus on risk communication and people’s reactions to the combined events of an upcoming hazard and an evacuation order. From a practical perspective, there are guidelines such as the MEND-guide for humanitarian interventions who provide useful orientation for decision makers (Goldschmidt et al. 2014). In natural disasters all around the world the number of fatalities among those who did not evacuate in time is still remarkable. Therefore, research focused on the guiding question which group of people typically don’t evacuate in time, which are their characteristics and what can be done to influence their decision in an effective way. Basically, there are two main strands of literature: empirical case studies and evacuation simulation models. The former looks at specific events in a specific country and runs post-event surveys to understand people’s perceptions and motivations. Among the key insights is that personal risk perception plays an influential role in the evacuation decision (Dash & Gladwin 2007), that people tend to “hedge” their risk in the sense that they collect information from different sources, cross-check information and tend to wait for a clearer picture unless they are fully convinced. A special focus lies on vulnerable groups with restricted mobility but also those who are socially vulnerable, such as marginalized groups.

With respect to government communication in general and evacuation orders in particular, the impact of the official nature of an evacuation order on people’s decisions seems to be quite differentiated. Basically, people trust public authorities, they trust local authorities more than central government, they show a higher willingness to follow government orders even if this is in conflict with family’s/peers recommendation and they closely screen the authority’s credibility.

For the context of evacuation decisions, *evacuation compliance*, *acceptance* and *trust* in public authorities and government agencies was subject to quite a number of contributions. The two main strands of literature focus on intention-based and credibility-based trust. People can doubt the intention of public officials if they feel that the government abuses the event as a pretext for the pursuit of other goals or that different groups of stakeholders (other than the directly affected population, such as tourists, investors, voters etc.) are the true addressees of a consequential measure. Although we do not focus on intention-based trust, we nevertheless take explicitly potential conflicts of interests into account. In our model, the government can pursue different objectives. While saving lives and protecting the population from injuries is the government's primary objective, there are also secondary objectives, which can be "added to" the primary one by assigning weights and thus influencing the final decision. Secondary goals can also focus on the population to prevent nuisance or even deprivation caused by an evacuation. Alternatively, secondary goals can focus on the prevention of economic losses in the affected region. The Corona-crisis 2020 illustrates in a very evident way that the trade-off between impairments of the population and economic losses must not be ignored.

With respect to credibility-based trust, the impact of false alarms is a frequently studied topic. The problem that people cease to take a warning seriously, if they experienced a false alarm is known as the *Crying Wolf*-phenomenon (Roulston & Smith 2004). Although it is difficult to empirically analyze the effects of sequential observations if the events at question are very rare, there were some occasions, which can shed some light into this issue. Studies find a rather modest effect of the Crying Wolf-phenomenon indicating that false alarms don't exert a crushing effect on the sender's credibility but rather shift some weight moderately into the direction of other information sources. Hence, people learn that they should not trust entirely the public announcements although they are still willing to trust to a sufficient degree.

To the best of our knowledge, competence trust and compliance as conceptualized in this paper have not yet been under study in the context of evacuation modelling. Regarding competence trust, the idea that people hold their own belief about the severity of a risk is close to approaches dealing with subjective risk perception (SRP). In SRP, the salience of communicated risk depends, among other factors, on the credibility of the source (e.g. media, government), which in turn leads to changes of subjective probabilities (Lindell & Prater 2002). However, our approach assumes objective risk perception, i.e. there are neither information asymmetries nor (preference-based) distortions of the event probabilities. In our model, we assume an information asymmetry between government and public regarding the impact of a potential flood. If people trust the government's competence regarding the impact assessment, they interpret an evacuation-order (and equally a remain-order) as an indicator of the (partially) unknown future impact.

The account of *simulation models* takes a formal approach and models evacuation decisions with a strong focus on congestion (Santos & Aguirre 2004). For example, Teo et al. (2015) present an agent-based evacuation model; their model also incorporates government advice. However, the task of the government is to find the optimal assignment of people to avoid congestion.

In our model, we deal with the problem of congestion in a rather different way. We neither focus on a routing model, nor do we solve a problem of pure coordination. Instead, congestion represents a further bottleneck, which can be effectively influenced by the government as a third party and which can influence the public's incentives for evacuation via the trust channel. With respect to cost-benefit-analyses in the context of forecasting models, our approach is akin to the classic Quickest Change Detection (QCD) problem (Li 2012). A QCD-problem distinguishes between two states ("regimes") of a system. These are two conditions of which one is harmless but the other is problematic and should therefore be avoided. For example, an economy can be on its way into a recession or just experience a random and transient decline in output. Or a patient can show symptoms which indicate an infection but which can also just be due to other factors. The first, problematic, reason requires a more comprehensive and also more painful therapy than the second. The decision maker's task is then to detect the switch to the problematic regime as fast as possible. A QCD-problem is a dynamic setting where time approaches a fixed terminal date. In our approach, timing is not relevant for the decision but time rather structures the sequence of the events. In addition, our approach has the Markov chain-properties.

3. Problem structure and information system

This section describes the statistical part of the model, the Information System (IS).

3.1 The information ("warning") system

The basic structure of the problem, in particular the randomness and sequence of events, follows the properties of a Hidden-Markov-Model (HMM). Markov-models are stochastic automata, which share the property that future developments just depend on the current state and not from preceding states. A Markov-model is characterized by stochastic transitions between states, which are characterized by transition probabilities. In a HMM, the decision maker cannot directly observe the states but receives a signal ("omission") which makes inferences about the true state possible (Zucchini & MacDonald 2009). *Figure 2* represents the three-state, first-order HHM for the decision problem described in the introduction.

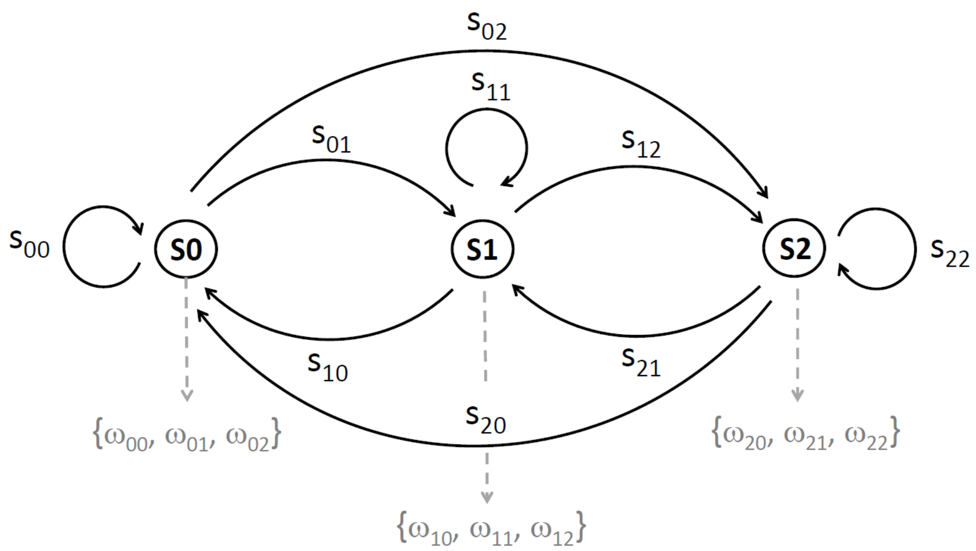


Figure 2 Hidden-Markov-Chain

There are nine possible transitions between the three states. The initial state is S0, which corresponds to the situation where either no or just a harmless flood occurs. The state S1 represents a severe flood, which affects just the coastal region (the "risk zone" A) and the state S2 stands for an extreme flood with extraordinary water-levels affecting the whole town (regions A and B). The transition from state *i* to state *j* is depicted by the variable s_{ij}. Starting from S0, three transitions to the state in the next period are possible: Either we remain in S0 (this corresponds to transition s_{00}), which is the most probable transition, or we are hit by a flood event and end up in state S1 (s_{01}) or even in state S2 (s_{02}). According to *Figure 2*, every state is reachable from any other state, which is a realistic model of natural disaster events. For example in the case of a tsunami or a hurricane, which can rapidly change its direction, the direct transition s_{02} would be highly relevant whereas for floods, which develop over time (depending on precipitation, the confluence of rivers etc.), also the other two sequences $\{s_{01}, s_{12}\}$ are plausible. In general, a probability of occurrence refers to 1 year and to a pre-defined area. It is usual that intensity and frequency are mapped on the same scale so that events of extraordinary intensity are also extraordinarily rare. This is why the frequency of a flood (e.g. a 100-year flood) is used as a proxy for severeness. Most risk-metrics for natural disasters are just restricted to the meteorological or geophysical factors and thus provide information about the occurrence of an extreme weather event or specific constellations thereof. However, in general these metrics do not include information about the vulnerability of the specific location. Recently so-called impact forecasts are increasingly coming into focus, which do not only answer the question "What is the weather?" but also "What is the weather doing?" (Merz et al. 2020). Our probabilities are best understood as joint event and impact forecasts.

We term state S0 the *escalation-state* because the two transitions leaving S0 move towards the dangerous states S1 and S2. In the escalation-state S0, the decision-maker has to decide whether to order evacuation for (at least one of) the groups or not. State S2 represents the opposite case, the *de-escalation-state*. As described above, in S2 just return-decisions have to be made. In the diagram, the arrows in the opposite direction, indicating the "way back to normal", consider the de-escalation phases. Finally, we call state S1 the *mixed state*, because it comprises both escalation and de-escalation. All available transitions can alternatively depicted in a more efficient way as a *Transition-Matrix* $\boldsymbol{S}$ (*Table 1*). If a Markov chain is *ergodic*, a property which will be fulfilled for the numerical applications of our model, it has a unique stationary distribution, which can be determined by solving the equation $\boldsymbol{S}^T \pi = \pi$, where $\pi = (\pi_0, \pi_1, \pi_2)^T$. The resulting distribution π^* tells us the "average" probability for each state (S0, S1 or S2), which remains unchanged when time progresses (Zucchini & MacDonald 2009).

We now turn to the main part of the information system as illustrated in *Table 1*. The grey variables in brackets indicate the warnings, which are available one period before the forecasted event occurs. The variable ω_{ik} reads as "the (warning) signal received in state *i* predicts state *k* as the state of the next period". For flood, the time between two events could be between 12 and 24 hours; in the last case the warning represents a classic day-ahead forecast.

The warning signal ω_{ik} is a discrete, trinary random variable $\omega_{ik} \in \{0,1,2\}$, which is sufficiently informative in a sense described below. The quality or precision of the information system is described by the conditional probability $q(\omega_{ik} \mid s_{ij})$, which is the probability that a warning signal predicts the transition from the current state *i* to the future state *k* given that the true future state is *j*. The so-called

Likelihood-Matrix $\boldsymbol{L}$ (*Table 1*) summarizes all constellations for this conditional probability. It is straightforward that the rows of this matrix add up to 1.

Table 1 Transition matrix and Likelihood-Matrix

$$\boldsymbol{S} = \begin{array}{c|ccc} & S0 & S1 & S2 \\ \hline S0 & s_{00} & s_{01} & s_{02} \\ S1 & s_{10} & s_{11} & s_{12} \\ S2 & s_{20} & s_{21} & s_{22} \end{array} \qquad \boldsymbol{L}_i = \begin{array}{c|ccc} & \omega_{i0} & \omega_{i1} & \omega_{i2} \\ \hline s_{i0} & q(\omega_{i0} \mid s_{i0}) & q(\omega_{i1} \mid s_{i0}) & q(\omega_{i2} \mid s_{i0}) \\ s_{i1} & q(\omega_{i0} \mid s_{i1}) & q(\omega_{i1} \mid s_{i1}) & q(\omega_{i2} \mid s_{i1}) \\ s_{i2} & q(\omega_{i0} \mid s_{i2}) & q(\omega_{i1} \mid s_{i2}) & q(\omega_{i2} \mid s_{i2}) \end{array} \qquad (1)$$

For the information system to be sufficiently informative, it is required that the warning signals display a minimal degree of precision with respect to the state of nature they predict. In concrete terms, we impose the following *Informativeness-Condition* (IC) on the information system (expression (2)).

Informativeness-Condition (IC): $$q(\omega_{ij} \mid s_{ij}) > q(\omega_{i-j} \mid s_{ij}) \qquad (2)$$

Assume the transition s_{ij}, i.e. the true future state is state *j*. Then the warning should have higher probability to signal state *j* than to signal any other state *–j*. If IC is fulfilled, the information-system is valuable or useful for the decision maker in the sense that it generates "better than random" results, which is an empirically correct assumption regarding the forecasting precision of EWS in practice.

Both, the prior transition probabilities and the Likelihood-Matrix are common knowledge of all decision makers of our setting: the (local) government G and the populations of the two regions, which we term group A and group B. In each period, all actors know the current state, the issued warning signal with respect to the next state (both pieces of information are summarized in the variable ω_{ik}) and the Likelihood-Matrix. The warning signal is issued e.g. by a weather forecasting service and is therefore publicly observable. With this information, the DMs can calculate the up-dated posteriori-probability according to *Bayes' Theorem* $p(s_{ij} \mid \omega_{ik}) = \dfrac{s_{ij}\, q(\omega_{ik} \mid s_{ij})}{s_{ij}\, q(\omega_{ik} \mid s_{ij}) + \sum_{-j \neq j} s_{i-j}\, q(\omega_{ik} \mid s_{i-j})}$. Formally, for a given state *i*, we combine $\boldsymbol{S}$ and $\boldsymbol{L}$ and thus derive the conditional Posterior-Matrix $\boldsymbol{P}$ according to expression (3).

$$\boldsymbol{S} \bullet \boldsymbol{L}_i \rightarrow \boldsymbol{P}_i = \begin{pmatrix} p(s_{i0} \mid \omega_{i0}) & p(s_{i0} \mid \omega_{i1}) & p(s_{i0} \mid \omega_{i2}) \\ p(s_{i1} \mid \omega_{i0}) & p(s_{i1} \mid \omega_{i1}) & p(s_{i1} \mid \omega_{i2}) \\ p(s_{i2} \mid \omega_{i0}) & p(s_{i2} \mid \omega_{i1}) & p(s_{i2} \mid \omega_{i2}) \end{pmatrix} \qquad (3)$$

3.2 Rough calibration based on minimal assumptions

Although this model serves mainly analytical purposes to understand the basic factors of interactive decision making on theoretical grounds, we nevertheless strive to achieve a rough calibration and put the model into an empirically plausible "frame". Throughout this paper we use two types of calibration.

We use a set of simple and arbitrary numbers as parameter values if our main purpose is to show the main mechanism of the model, how it works and to illustrate a comprehensive range of potential solutions. We call these parameter values "arbitrary numbers". With respect to model validation, we apply (and partly adjust) parameter values where we could find some reference or benchmark data. We call this set of numbers "hypothetical data" and apply it where we want to illustrate, for example, which of the derived solutions comes closest to a real world-setting.

Now, what is the data availability with respect to the parameters of an information system as described in Section 3.1? First, it is needless to say that EWS are complex and specific tools with still a very low level of standardization for data generation and data sharing. Although many EWS use probabilistic forecasting and apply Bayesian tools, which makes them to a minimum degree compatible to our approach, unfortunately there are no databases existing which could be used for parametrization. However, at least for an escalation to scenario S1 of an extreme flood, i.e. for the transition s_{01}, there are some insights from the *European Flood Awareness System* about the expected frequency of severe coastal inundation (Merz et al. 2020, p. 16). A flood, which heavily affects the coastal residents roughly corresponds to a frequency of 20 to 80 years, depending on geological and geographical factors of the built environment, the technical resilience of the region and the flood protection measures. As our model takes vulnerability as given, we take a 50-year-flood as a plausible case, which corresponds to an expected rate of occurrence of 2% per year and 0.0055% per day respectively. For the case of an extreme flood it is even more difficult to identify a good proxy for at least two reasons. First, there is less experience and data with extreme events and second, very extreme floods result from more complex hazard scenarios. Most frequently, they can be caused by meteorological compound events of severe convective storms, marine gusts and long periods of heavy precipitation. In addition, hurricanes can cause extreme floods and one of the most deterrent candidates are Tsunamis. EWS for Tsunamis determine the earliest arrivals, the time of arrival, the wave amplitude and the propagation of a tsunami (Chaturvedi et al. 2017, p. 84). For such very extreme events, the range lies between 200 and 1.000 years but even reaches up to 10.000 years. The latter number refers to a flood protection exercise in the Netherlands, executed by the Task Force for Flood Event Management (FLOODsite, p. 115). We again take a medium value as an average guess and take a 500-year flood (daily event probability of 0.00055%) as an appropriate proxy. Hence, the first row of the transition-matrix gets the entries 0.99993950, 0.0000550 and 0.0000055 (see *Figure 4*). For transitions starting in state S1 and S2, it is not possible to extract benchmark numbers from literature or flood reports because the further worsening of an already bad situation (transition s_{12}) is usually not registered as a separate event. In addition, the warning process during a de-escalation is partly different from an escalation because a warning system has to fall below a certain threshold before the alarm is deactivated and the region is declared safe again. Hence, although it is important to understand the interactions and dynamics of the de-escalation events, too, evidence is scarce. For this reason we filled the rest of the Transition-Matrix together with two flood experts, taking the warning bias (threshold-deactivation of the EWS) into consideration. The left matrix in expression (4) shows the calibrated *Transition-Matrix* ***S.*** For these values, we get $\pi^* = \left(\pi_0 = 99.9797\%,\ \pi_1 = 0.0167861\%,\ \pi_2 = 0.00347298\%\right)$ as the stationary distribution of the Markov Model.

$$\boldsymbol{S} = \begin{pmatrix} 0.99994 & 5.5\times10^{-5} & 5.5\times10^{-6} \\ 0.3500 & 0.6000 & 0.0500 \\ 0.0500 & 0.3500 & 0.6000 \end{pmatrix} \quad \boldsymbol{L} = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & m \end{pmatrix} \quad \boldsymbol{L}_0 = \begin{pmatrix} 0.9800 & 0.0155 & 0.0045 \\ 0.3334 & 0.5511 & 0.1155 \\ 0.1056 & 0.2444 & 0.6500 \end{pmatrix} \qquad (4)$$

In the next step we look for empirical values of the Likelihood-Matrix, i.e. data which tells us something about the precision and effectiveness of flood-EWS, also called *EWS-verification*. In verification of weather warning, most approaches apply contingency tables and corresponding scores, as e.g. the equitable threat score (ETS) in UK and a combination of ETS, the probability of detection (POD), the false alarm ratio (FAR) together with the frequency bias is used in Austria (Wilson 2018, Wilson & Giles 2013). The most advantageous account was provided by Wilson & Giles (2013). The authors evaluated contingency-table data between 2009 and 2011 of a Canadian flood-EWS in order to arrive at an improved warning index. For a severe flood-event they derive a HIT-rate of 75% and a False-Alarm (FA)-rate of 2%. For an extreme flood the EWS-precision is lower according to the literature. Although, for example, nearly all tsunamis can be detected by modern EWS, there is uncertainty about under- and overestimating the wave height and the exact localization. Here the uncertainty can be considerable with fluctuations between 30-50% (Lauterjung & Letz, 2017, p. 41). Therefore we consider this uncertainty and adjust for noise. We assume a HIT-rate of 60% and a FA-rate of 6% for S2. We use these values for our study but have to adjust the calculation because our setting considers three states (including warning states). Matrix $\boldsymbol{L}$ (matrix with letter-entries in the middle of expression (4)) represents a general Likelihood-Matrix which helps to understand the calculations. The HIT-rate for state S1 is calculated by taking the HITS (cells e + f + h + m) and divide them by HITS and misses (cells d + g). For state S2 we have the same procedure but different cells are relevant, here we have m divided by (m + g + h). The FA-rates are the ratio of the false alarms in the numerator and the false alarms together with the "correct negatives" in the denominator. This corresponds to the ratios (b + c)/(a + b + c) for S1 and (c + f)/(a + b + c + d + e + f) for S2. We further have to consider the *Informativeness-Condition* (IC), which requires a > b > c, m > h > g, e > d and e > f. The right part of expression (4) shows all entries of the matrix $\boldsymbol{L}_0$, which fulfill the ensemble of the before mentioned conditions. The likelihood-matrices for the mixed-scenario (S1) and the de-escalation-scenario (S2) could not be derived in a similarly precise way. Here again we took $\boldsymbol{L}_0$ as anchor and consulted the two flood experts. The resulting matrices are shown in expression (5).

$$\boldsymbol{L}_1 = \begin{pmatrix} 0.75 & 0.24 & 0.01 \\ 0.35 & 0.60 & 0.05 \\ 0.05 & 0.30 & 0.65 \end{pmatrix}; \quad \boldsymbol{L}_2 = \begin{pmatrix} 0.55 & 0.35 & 0.10 \\ 0.20 & 0.60 & 0.20 \\ 0.01 & 0.19 & 0.80 \end{pmatrix} \qquad (5)$$

Expressions (4) and (5) comprise the "hypothetical dataset" for the IS-validation. By applying Bayes' rule we get the corresponding conditional Posterior-Matrices $\boldsymbol{P}_0$, $\boldsymbol{P}_1$ and $\boldsymbol{P}_2$ as given by expression (6).

$$\boldsymbol{P}_0 = \begin{pmatrix} 0.99997 & 0.99824 & 0.99815 \\ 2.4\times10^{-5} & 1.7\times10^{-3} & 1.1\times10^{-3} \\ 1.4\times10^{-6} & 8.6\times10^{-5} & 7.1\times10^{-4} \end{pmatrix}; \quad \boldsymbol{P}_1 = \begin{pmatrix} 0.625 & 0.225 & 0.043 \\ 0.365 & 0.704 & 0.266 \\ 0.010 & 0.070 & 0.691 \end{pmatrix}; \quad \boldsymbol{P}_2 = \begin{pmatrix} 0.266 & 0.051 & 0.009 \\ 0.676 & 0.615 & 0.126 \\ 0.058 & 0.334 & 0.865 \end{pmatrix} \qquad (6)$$

Altogether, these numbers are oriented at real EWS-data reflecting current performance of an EWS for (coastal) flood risk without imposing too many restrictions, which otherwise bear the risk to be unjustified on empirical grounds. In the first place, this model provides the formal "infrastructure" for an analysis and if transferred to a concrete context, assumptions can be fine-tuned towards the specific forecasting technology and data basis as illustrated by the reference above.

4. Decision Model

In this section, we briefly describe the objective functions and strategies of the local government G and the citizens of the two regions A and B. For the ease of exposition, we talk about "group A" and "group B" and an objective function reflects the (dis)utility of one representative member of each group. As all objective functions are scenario-dependent, for each type of decision maker we have an objective function for the escalation-state (S0), the mixed-state (S1) and the de-escalation state (S2). In the model, we express all types of payoffs in disutility-units, such as damage, deprivation and economic loss. Therefore, the resulting objective functions are *cost functions*, where the term "cost" is just shorthand for disutility reflecting different forms of negative consequences for the individuals. In each state, the groups and the local government G observe the warning signal ω_{ik}, update the priors accordingly and make their respective decision. For the description of the model structure but even for the derivation of the equilibrium conditions it is not necessary to take the warning-levels explicitly into consideration. Therefore, for the most part of this section, we suppress the warning-level *k* in the notation and just use the short form p_{ij} to describe the conditional probabilities $p_{ij} \equiv p(s_{ij} \mid \omega_{ik})$ of a transition to state *j* given the current state *i* and "any" warning-level *k*. This way, the analysis is more general but also more comprehensible. Later, we evaluate the p_{ij}-values for different warning-levels.

4.1 Decision variables, payoff parameters and trust variables

Decision variables

The discrete, binary decision variable $v_A \in \{0,1\}$ for group A (and v_B for group B respectively) describes the decision of a representative member of group A. The choice $v_{A,B} = 1$ always represents the cautious option of the decision, which is "evacuation" in the escalation-state and "stay evacuated" in the de-escalation-state. Accordingly, $v_{A,B} = 0$ represents the risky option of a decision corresponding to "no evacuation" in the escalation-state and "return home" in the de-escalation-state. While both groups choose an *action strategy*, the government G chooses a *communication strategy*. In particular, G picks one out of three types of requests $E \in \{\text{E0}, \text{E1}, \text{E2}\}$. The request E0 is equivalent to the message "no evacuation necessary in both regions" in the escalation-state and "return to both regions is possible" in the de-escalation-state. Although G has a trinary strategy set, each group receives a binary signal $E_{A,B} \in \{0,1\}$. For request E0, the received signals are identical $(E_A = 0, E_B = 0)$ because the order is the same for both groups. Request E1 is equivalent to the message "evacuation in region A but no evacuation necessary in region B" in the escalation-state and to "stay evacuated in region A but return to region B is possible" in the de-escalation-state. Hence, request E1 generates the signals $(E_A = 1, E_B = 0)$. Finally, request E2 corresponds to the message "evacuation in both regions" in the escalation-state and "stay evacuated in both regions" in the de-escalation-state. By observing the request E2, each group receives the same signal $(E_A = 1, E_B = 1)$. Note that there is no possibility for the signal-combination $(E_A = 0, E_B = 1)$ because this would imply a contradiction (if evacuation is ordered to the whole town, this automatically includes group A, too).

The described communication strategies of the government include both active and passive communication. With respect to the request E1, the government has to take into consideration that the very same message has different content for each group, i.e. the signals vary. However, as the analysis in section 5 shows, even an identical signal (as in the case of the requests E0 and E2) can cause different reactions by the two groups because their risk situation is different.

Payoffs

With respect to the disutility of the citizens, we distinguish three types of cost. The most important cost component is *D*, which is relevant if a person is hit by a flood. It represents potential death and injury or strong deprivation (in the case of lack of food, water, medicine). The other two cost components refer to the cost of evacuation and capture the inconvenience, nuisance or deprivation with less relevance for health. The parameter c^m reflects the direct cost of the evacuation itself ("cost for moving", therefore the index m) and c^d reflects the deprivation of one evacuated period. This cost term takes into account the fact that those affected by an evacuation are exposed to a particularly difficult and stressful situation together with the nuisance that the normal course of everyday life is disrupted. The superscript *d* therefore stands for either deprivation or disruption. We assume a clear-cut order of the cost-components $0 < c^m < c^d < D$.

The government takes the before mentioned disutility-components into account, too. In addition, G cares for two types of economic losses. The loss-parameter ℓ^L reflects the economic opportunity cost of an unjustified evacuation due to foregone business revenues in the region. The loss parameter ℓ^H captures the loss of human capital if people are hit by a flood. In addition to the direct physical damage *D*, affected people are either not available or not productive for a time span after the flood because they are in hospitals, suffer at home from injuries or psychical stress or they have to care for their peers. Note that all cost components refer to one period (the focal period of planning) except the human-capital-loss, which reflects a medium-term future loss. To consider this difference, we add a discount factor $0 < \delta < 1$ to the human capital-loss component. The superscripts *L* and *H* stand for "low" and "high", which should help to order the cost components visually. We assume $0 < \ell^L < \delta\ell^H < D$.

Direct evacuation cost are not included in the government's decision because civil protection is the primary task of the local government. In addition, there are often soft budget constraints for disaster situations. Extra funds are made available by the central government because policy makers, and in particular their voters, will not tolerate a high death toll. However, budget issues always play a role and in the context of disasters, they most probably affect future decisions. As done in section 3, we also want to roughly calibrate these five cost components to get an approximate order of magnitude. The values used as a basis are provided by *Table 2*.

Table 2 Calibration of cost parameters

Variabl	Value [€]	Description
D	$\approx 5\times10^{6}$	Value of Statistical Life (VSL); Viscusi & Aldy (2003)
c^{m}	$\approx 1.6\times10^{2}$	Lost net value of production (day); Schröter et al. (2008)
c^{d}	$\approx 2.5\times10^{3}$	Lost net value of production x deprivation factor
ℓ^{L}	$\approx 1.25\times10^{3}$	Lost net value of production (week); Schröter et al. (2008)
ℓ^{H}	$\approx 5\times10^{4}$	Disability Adjusted Life Years (DALY); Cropper & Sahin (2009)

Expected flood impact μ and competence trust in the government

As already mentioned above, there is an information asymmetry between the government and the two groups with respect to the expected impact $\mu \in [0,1]$ of a potential flood. Although there are event probabilities available, there can remain doubts whether and how severely even an extreme flood could harm and affect individuals (Dow & Cutter 2000). In the context of flood risk, people often wrongly estimate the speed and power of water flows, the effects of an impairment of critical infrastructure and the destabilizing impact of high water levels on buildings (which is why people often prefer sheltering in high buildings to evacuation). The expected impact of a flood as perceived by group A is given by $\mu_A = \tau_A^c E_A + (1-\tau_A^c)\hat{\mu}_A$, $\mu_A \in [0,1]$. The variable $\tau_A^c \in [0,1]$ reflects the *competence trust* in the government's impact assessment and the variable $E_A \in \{0,1\}$ is the received binary signal, which directly results from G's request as described above. The variable $\hat{\mu}_A(\omega)$ is the independent belief of group A about the potential impact of a flood, which the individuals infer from the warning-level ω. The higher τ_A^c, the higher the willingness of group A to take the government's request into account, i.e. to interpret the government's request as credible information about flood risk (Basolo et al. 2009). The lower the trust parameter, the more weight is placed on the independent guess $\hat{\mu}_A(\omega)$. In the special case of full trust ($\tau_A^c = 1$), the expected impact equals the binary signal E_A, i.e. $\mu_A = E_A$ and $\mu_A \in \{0,1\}$. Note that a sufficiently high trust-level can either increase or reduce the motivation to evacuate (or to stay in the region if already evacuated), dependent on the type of request. In the opposite case of full distrust ($\tau_A^c = 0$), the expected impact equals the independent belief $(\mu_A = \hat{\mu}_A(\omega))$. As the independent belief $\hat{\mu}_A(\omega)$ depends on the warning-level, we need further assumptions about this parameter. In the case of "no warning" ($\omega = 0$), the independent belief of both groups is zero $(\hat{\mu}_A(\omega=0) = \hat{\mu}_A(\omega=0) = 0)$. In the case of a flood-warning for region A ($\omega = 1$) we assume an arbitrary value $0 < \hat{\mu}_A(\omega=1) < 1$ for group A, which depends on prior flood experience and the risk expertise of the population. As we neither look at path dependent outcomes nor incorporate issues of risk experience and risk communication, we treat this variable as exogenous. From the perspective of group B, the impact is expected to be very low, indicated by the variable $0 < \varepsilon << 1$, which stands for a very low probability. Hence, $0 < \hat{\mu}_B(\omega = 1) = \varepsilon << 1$. In the case of a level-2-warning ($\omega = 2$), group B expects an impact similar to the belief of group A for a level-1-warning, $0 < \hat{\mu}_B(\omega = 2) < 1$, and group A expects a "near to certain" strike based on the belief $0 << \hat{\mu}_A(\omega = 2) = 1 - \varepsilon$. If not otherwise stated, we make the assumption $\tau_A^c \geq \tau_B^c$, which implies that the parameters for competence-trust of both groups are either identical or the trust-level of group A is higher because the people in the risk-zone expect that the government has a special focus on this region.

Expected congestion $(1 - \varphi)$ *and reliability trust in the government*

The second type of trust considered in ECM is the government's reliability with respect to evacuation preparation and congestion management. Let $\varphi \in [0,1]$ be a measure of *evacuation effectivity*, which is equal to zero if the roads are fully congested (in this case evacuation is impossible) and equal to one if there is no congestion at all. The complement $(1 - \varphi)$ is then a measure of congestion. Depending on whether one group or both groups leave the region at the same time, there is congestion to the extent of $1 - \varphi = \gamma v_A + (1-\gamma) v_B$. The government has the possibility to mitigate the congestion problem by an investment $I \in [0,1]$ into improved evacuation planning and emergency logistics, $1 - \varphi = [\gamma v_A + (1-\gamma) v_B]\ (1 - I)$. These measures comprise e.g. very detailed scenario planning, evacuation training with employees, special contracts with bus companies or even rent contracts to have helicopters available. We assume that this investment, i.e. the complete package of measures, is not observable to the public. A full investment, $I = 1$, stands for a perfect preparation-level, which can reduce the congestion-problem completely. No investment, $I = 0$, as the other extreme, implies that G has done absolutely nothing to improve the situation. In this case, the groups turn in on themselves. The required budget for an investment-level I is given by $B(I) = -Log[1 - I]$. This function implies $B(I = 0) = 0$ and $B(I = 1) = \infty$, i.e. the perfect preparation-level comes at an infinitively high cost. As the public cannot observe the investment-level, both groups need to trust the government to have taken the necessary precautions (Hamm et al. 2019). The trust-parameter for *reliability trust* $\tau^r \in [0,1]$ is assumed identical for both groups. Hence, from the perspective of both groups, the *expected evacuation effectivity* is given by $\varphi = 1 - [\gamma v_A + (1-\gamma) v_B]\ (1 - \tau^r)$.

4.2 Cost functions of group A and B

Escalation-scenario S0

The cost-functions for both strategies of group A and S0 are given by the expressions (7) and (8).

$$C_A^{S0}(v_A = 1) = p_{00}\left(2c^m + c^d\right) + \left(p_{01} + p_{02}\right)\left(c^m + (1-\varphi_A)\mu_A D + \left(1 - (1-\varphi_A)\mu_A\right)c^d\right) \quad (7)$$

$$C_A^{S0}(v_A = 0) = \left(p_{01} + p_{02}\right)\mu_A D \quad (8)$$

If group A evacuates ($v_A = 1$) although the evacuation is unnecessary (to be expected with probability p_{00}), the group incurs twice the moving-cost c^m (the group moves out of the region but returns when the false alarm is realized) and once the cost for evacuation-deprivation c^d. These two cost-elements are not involved in the case of no evacuation ($v_A = 0$). When the group evacuates and the region is hit by a flood (to be expected with probability $p_{01} + p_{02}$), it incurs the moving-cost and either physical damage $\mu_A D$, if evacuation fails due to congestion (determined by $1-\varphi_A$), or the evacuation-cost c^d if the evacuation can be executed without congestion (to be expected with probability φ_A). If the group does not evacuate but a flood occurs, the group suffers from the high damage cost. Note that the value of the damage cost depends on the expected impact because we look at the problem from the group's perspective. The cost functions for group B in scenario S0 look nearly identical (9), the only difference is that group B is not affected by a flood in region A (expected with probability p_{01}), which implies a lower risk of damage but a higher risk of unnecessary evacuation.

$$C_B^{S0}(v_B=1)=\left(p_{00}+p_{01}\right)\left(2c^m+c^d\right)+p_{02}\left(c^m+(1-\varphi_B)\mu_B D+\left(1-(1-\varphi_B)\mu_B\right)c^d\right) \tag{9}$$

$$C_B^{S0}(v_B=0)=p_{02}\,\mu_A D \tag{10}$$

Mixed-scenario S1

In the de-escalation-state S1, region A is already flooded and the citizens are no longer there: Either they evacuated in a controlled manner (depending on their evacuation-strategy in S0) or the flood "forced" them out of the region. In this case, they had to hastily abandon their homes, had to be saved by rescue services or did not survive. The following cost functions, as depicted by (11) and (12), are therefore only relevant for those in group A who were able to leave the region unharmed and are now waiting to return. Remember that in a de-escalation-state the strategy $v=1$ corresponds to "stay evacuated" and $v=0$ means "return home".

$$C_A^{S1}(v_A=1)=c^d \tag{11}$$

$$C_A^{S1}(v_A=0)=c^m+\left(p_{01}+p_{02}\right)\mu_A D \tag{12}$$

If group A stays evacuated it suffers from evacuation-deprivation c^d. If A returns, it incurs the cost for moving back, c^m, and risks to be hit a second time by a returning flood ("second wave"). We don't consider congestion for the way back because there is less rush and – what is more important – if people get stuck on their way back they are still in a safe area. The cost functions of group B are the same as in scenario S0 because also in S1 region B is not flooded.

De-escalation-scenario S2

In S2, both groups face a de-escalation scenario. The cost-functions for A are the same as in S1 and those for group B, expressions (13) and (14), are equivalent.

$$C_B^{S2}(v_B=1)=c^d \tag{13}$$

$$C_B^{S2}(v_B=0)=c^m+p_{02}\,\mu_A D \tag{14}$$

4.3 Social cost function of the government G

In the ECM, the government has the role of a policy-maker who seeks to minimize the social cost. Basically, the "ingredients" to the social cost function are similar to the cost functions of both groups with mainly three differences. First, the government cannot decide about evacuation due to the strict no-enforcement-assumption. However, G seeks to optimally influence the groups' decisions by its communication-strategy E and this requires that G needs to know the parameter constellations for which no, partial or full evacuation is socially optimal. Second, the government communicates E to both groups at the same time; therefore the social cost function is an average of the outcomes in both regions, weighted by the population share γ. Third, G puts weight $\alpha \in [0,1]$ on the population's deprivation (caused by an evacuation) but also weight $\beta \in [0,1]$ on the economic losses. Hence, for $\alpha = 1$ and $\beta = 0$, the groups objectives and the government's objectives come closest (although they are still not identical due to the information asymmetries). The physical damage parameter D has an explicit weight of 1, however the implicit weight of D of course depends on α and β. Fourth, the government has full information on the trust-sensitive parameters μ and φ as G knows the expected impact ($\mu = 1$) and its own investment I into congestion reduction. The last parameter, which is specific to G's decision, refers to the de-escalation-scenario.

Escalation-scenario S0

$$\begin{aligned} C_G^{S0} = p_{00}\Big[\big(\gamma v_A + (1-\gamma)v_B\big)\big(\alpha(2c^m + c^d) + \beta\ell^L\big)\Big] + \ldots \\ + (p_{01} + p_{02})\gamma\Big[v_A\big((1-\varphi)(D + \beta\delta\ell^H + \alpha c^m) + \varphi\alpha(c^m + c^d)\big) + (1-v_A)(D + \beta\delta\ell^H)\Big] + \ldots \\ + p_{01}(1-\gamma)\Big[v_B\big(\alpha(2c^m + c^d) + \beta\ell^L\big)\Big] + \ldots \\ + p_{02}(1-\gamma)\Big[v_B\big((1-\varphi)(D + \beta\delta\ell^H + \alpha c^m) + \varphi\alpha(c^m + c^d)\big) + (1-v_B)(D + \beta\delta\ell^H)\Big] \end{aligned} \quad (15)$$

The first two summands refer to group A (weighted by γ), the last two summands refer to group B (weighted by $1-\gamma$). In the case that an evacuation is unnecessary, the economic opportunity cost $\beta\ell^L$ occurs as an additional factor and if a necessary evacuation has not taken place – either due to congestion or due to a wrong decision) the medium-term cost $\beta\delta\ell^H$ come on top of D (both loss parameters are weighted by β as explained above).

Mixed-scenario S1 and D*e-escalation-scenario* S2

For the social cost-functions in S1 (but also for S2 below), there appears one further parameter in the de-escalation-scenario. Suppose that group A was already affected by a flood and now has to decide whether to return. The return-decision can just be made by those who successfully evacuated, hence by a share of φ_A^{t-1} percent of the population of group A. The time-index $t-1$ indicates that the share of people who make the return-decision depends on both, the evacuation strategy and the evacuation-success of the period before. Therefore, the values $\varphi_{A,B}^{t-1}$ result endogenously from the equilibrium evacuation-strategies as well as from the equilibrium congestion-rate (see section 5). Apart from this detail, the social cost functions for scenario S1 and S2 are straightforward.

$$C_G^{S1} = p_{10}\,\gamma\,\varphi_A^{t-1}\left(v_A(\alpha c^d + \beta \ell^L) + (1-v_A)\alpha c^m\right) + \ldots$$
$$+ (p_{11} + p_{12})\gamma\varphi_A^{t-1}\left(v_A \alpha c^d + (1-v_A)(D + \beta\delta\ell^H + \alpha c^m)\right) + \ldots$$
$$+ (p_{10} + p_{11})(1-\gamma)\left[v_B\left(\alpha(2c^m + c^d) + \beta\ell^L\right)\right] + \ldots$$
$$+ p_{12}(1-\gamma)\left[v_B\left((1-\varphi)(D + \beta\delta\ell^H + \alpha c^m) + \varphi\alpha(c^m + c^d)\right) + (1-v_B)(D + \beta\delta\ell^H)\right] \quad (16)$$

$$C_G^{S2} = p_{20}\,\gamma\,\varphi_A^{t-1}\left(v_A(\alpha c^d + \beta \ell^L) + (1-v_A)\alpha c^m\right) + \ldots$$
$$+ (p_{21} + p_{22})\gamma\varphi_A^{t-1}\left(v_A \alpha c^d + (1-v_A)(D + \beta\delta\ell^H + \alpha c^m)\right) + \ldots$$
$$+ (p_{20} + p_{21})(1-\gamma)\varphi_B^{t-1}\left(v_B(\alpha c^d + \beta\ell^L) + (1-v_B)\alpha c^m\right) + \ldots$$
$$+ p_{22}(1-\gamma)\varphi_B^{t-1}\left(v_B \alpha c^d + (1-v_B)(D + \beta\delta\ell^H + \alpha c^m)\right) \quad (17)$$

5. Equilibrium analysis and game results

In this section, we derive the Nash-Equilibria (NE) of the Stackelberg-game for the scenarios S0, S1 and S2. We restrict the analysis on pure equilibria and solve the game by backward-induction, starting with the sub-equilibrium on stage 2 (group-interactions) and moving forward to stage 1 to identify the optimal evacuation-order of the government. The optimal government's investment decision (stage 0) will be derived in section 6.

In the escalation-scenario S0, both groups play a subgame on stage 2 because the groups influence each other via the evacuation-effectiveness parameter $\varphi \in [0,1]$, which is defined by expression (18). Note that although each group forms an ex ante belief about this parameter (φ_A and φ_B respectively), in equilibrium there results just one level of evacuation-effectiveness for the whole city.

$$\varphi_{v_A,v_B} = 1 - \left(\gamma v_A + (1-\gamma)v_B\right)(1-y) \quad (18)$$

According to expression (18), for $y = 0$ evacuation-effectiveness is partially reduced to $\varphi_{1,0}$ if just group A decides to evacuate ($v_A = 1$ and $v_B = 0$) and it is fully reduced to $\varphi_{1,1}$ if both groups evacuate ($v_A = 1$ and $v_B = 0$). As we assume $0 < \gamma < 0.5$, there will be less people in the street if group A evacuates compared to group B. Hence, $0 < \varphi_{1,1} < \varphi_{0,1} < \varphi_{1,0} < 1$. As already described above, by investing a share $y \in [0,1]$ of a given budget in improving the traffic conditions, the government can reduce congestion. As the citizens cannot observe the investment they form a belief $\tau_{A,B}^r$ about it, which reflects the public's trust in G's reliability.

In a first step we ignore the concrete warning-level and derive a general solution for each of the three situations S0, S1 and S2. The last requirements, $0 < p_{i0}, p_{i1}, p_{i2} < 1$ and $p_{i0} + p_{i1} + p_{i2} = 1$, are both straightforward and were already prescribed by section 3. Without loss of generality, we henceforth substitute p_{i0} according to $p_{i0} = 1 - p_{i1} - p_{i2}$.

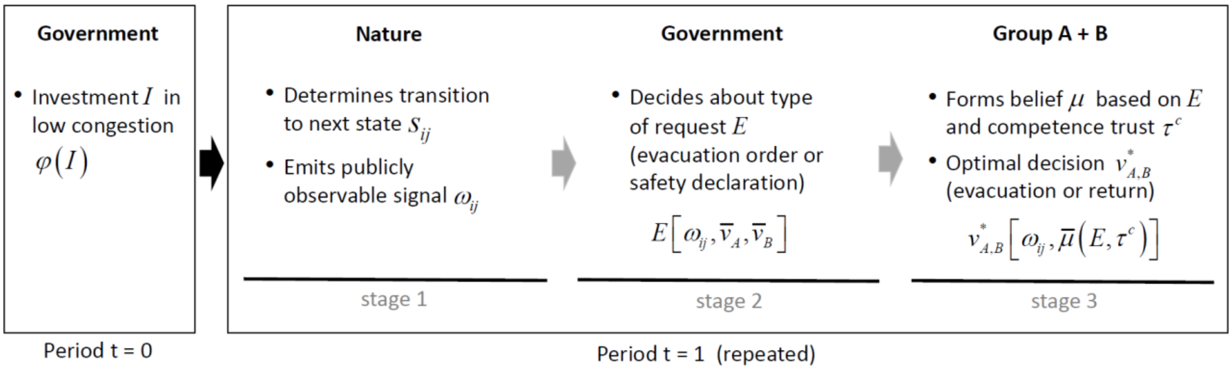


Figure 3 Game structure and sequence of events

5.1 Optimal strategies in the Escalation-Scenario S0

Optimal group strategies

We first define three terms $0 \leq T^{S0}_{A,B} \leq 1$, which constitute critical thresholds for the conditional probability p_{02} as given by

$$T^{S0}_{A1} \equiv \frac{2c^m + c^d}{c^m + \mu_A[\varphi_{10} D + (1-\varphi_{10})c^d]} - p_{01} \qquad (19)$$

$$T^{S0}_{B1} \equiv \frac{2c^m + c^d}{c^m + \mu_B[\varphi_{01} D + (1-\varphi_{01})c^d]},$$

(20)

$$T^{S0}_{B2} \equiv \frac{2c^m + c^d}{c^m + \mu_B[\varphi_{11} D + (1-\varphi_{11})c^d]}$$

(21)

Lemma 1a: For the threshold-terms (19) – (21) the following order applies: $T^{S0}_{A1} < T^{S0}_{B1} < T^{S0}_{B2}$.

Proof: The order can be easily verified by taking into consideration the parameter assumptions made above: $0 < \varphi_{1,1} < \varphi_{0,1} < \varphi_{1,0} < 1$, $0 < p_{01} < 1$, $\hat{\mu}_B \leq \hat{\mu}_A$ and $\tau^c_A \geq \tau^c_B$. ■

We can then state the following *Proposition 1a*.

Proposition 1a (Group-Equilibrium in S0)

The group-equilibrium of the sub-game on stage 2 for scenario S0 is given by

$$\left(v^*_A = 0, v^*_B = 0\right) \text{ if } p_{02} < T^{S0}_{A1}; \qquad (22)$$

$$\left(v^*_A = 1, v^*_B = 0\right) \text{ if } T^{S0}_{A1} < p_{02} < T^{S0}_{B2}; \qquad (23)$$

$\left(v_A^* = 0, v_B^* = 0\right)$ if $T_{B2}^{S0} < p_{02}$ (24)

Proof: For $(v_A = 0, v_B = 0)$ to be a NE, two conditions (I) $C_A^{S0}(v_A = 0, v_B = 0) < C_A^{S0}(v_A = 1, v_B = 0)$ and (II) $C_B^{S0}(v_A = 0, v_B = 0) < C_B^{S0}(v_A = 0, v_B = 1)$ must be fulfilled. In words, both groups must strictly prefer not to evacuate provided that the other group sticks to the no-evacuation-strategy, too. For each condition, there is a critical threshold for p_{02}: (I) $p_{02} < T_{A1}^{S0}$ and (II) $p_{02} < T_{B1}^{S0}$. Hence, a NE where no group evacuates requires $p_{02} < Min[T_{A1}^{S0} - p_{01}, T_{B1}^{S0}]$. According to *Lemma 1a,* it follows that $T_{A1}^{S0} < T_{B1}^{S0}$ and thus T_{A1}^{S0} is the required upper bound (if p_{02} is lower than T_{A1}^{S0}, it is also lower than T_{B1}^{S0} but not vice versa). Hence, if group A does not evacuate, then group B certainly does not either.

For $(v_A = 1, v_B = 0)$ to be a NE, two conditions (III) $C_A^{S0}(v_A = 1, v_B = 0) < C_A^{S0}(v_A = 0, v_B = 0)$ and (IV) $C_B^{S0}(v_A = 1, v_B = 0) < C_B^{S0}(v_A = 1, v_B = 1)$ must be fulfilled. Under this condition, group A must strictly prefer to evacuate given that group B does not and group B should not prefer to evacuate given that group A does. Again there result two conditions, constituting a critical threshold for p_{02}. The first is identical to (I) above with a reversed sign, and the second leads to (IV) $p_{02} < T_{B2}^{S0}$. Hence, $T_{A1}^{S0} < T_{B2}^{S0}$ is a necessary condition for the existence of a NE and according to *Lemma 1a*, this condition holds true.

The strategy-combination $(v_A = 1, v_B = 1)$ is a NE if the conditions (V) $C_A^{S0}(v_A = 1, v_B = 1) < C_A^{S0}(v_A = 0, v_B = 1)$ and (VI) $C_B^{S0}(v_A = 1, v_B = 1) < C_B^{S0}(v_A = 1, v_B = 0)$ are fulfilled. Both groups prefer to evacuate, given that the other group does so, too. The second condition is the same as condition (IV) above, just with the reversed sign. The first condition requires $p_{02} > T_{A1}^{S0}$ Hence, a NE for both groups evacuating requires $Max[T_{A1}^{S0}, T_{B2}^{S0}] < p_{02}$. According to *Lemma 1a,* we know that $T_{A1}^{S0} < T_{B2}^{S0}$ and thus T_{B2}^{S0} is the lower bound (if p_{02} exceeds T_{B2}^{S0}, it exceeds T_{A1}^{S0} anyway). Hence, if group B evacuates, then group A will certainly evacuate, too. This completes the proof of *Proposition 1a*. ■

Optimal government strategies

The optimal decisions of both groups on stage 2 are anticipated by G (the government), which tries to minimize the social cost by deciding about its communication-strategy E. The procedure comprises two steps: First, we derive the critical thresholds for which G prefers the outcomes “no evacuation”, “partial evacuation” and “full evacuation”. Second, once we know the government’s objectives, we derive the optimal communication-strategy of stage 1 of the Stackelberg-game. We first define two terms $0 \leq T_G^{S0} \leq 1$, which constitute critical thresholds for the conditional probability p_{02} as given by

$$T_{G1}^{S0} \equiv \frac{\alpha(2c^m + c^d) + \beta\ell^L}{\alpha(c^m + c^d) + \beta\ell^L + \varphi_{10}(D + \beta\delta\ell^H - \alpha c^d)} - p_{01} \tag{25}$$

$$T_{G2}^{S0} \equiv \frac{\gamma p_{01}(\varphi_{10} - \varphi_{11})\left[D + \beta\delta\ell^H - \alpha c^d\right] + (1-\gamma)\left[\alpha(2c^m + c^d) + \beta\ell^L\right]}{(\varphi_{11} - \gamma\varphi_{10})\left[D + \beta\delta\ell^H - \alpha c^d\right] + (1-\gamma)\left[\alpha(2c^m + c^d) + \beta\ell^L\right]} \tag{26}$$

Lemma 1b: Let $\gamma < \tilde{\gamma}_G^{S0} \equiv \frac{\varphi_{11}(D+\beta\delta\ell^H - \alpha c^d) - \alpha c^m}{\varphi_{10}(D+\beta\delta\ell^H - \alpha c^d) - \alpha c^m}$. Then for the threshold-terms (25) and (26) the order $T_{G1}^{S0} < T_{G2}^{S0}$ applies.

Proof: See Appendix 1.

Proposition 1b defines the socially optimal strategy-combinations as envisaged by the government. To distinguish socially optimal strategies from individually optimal (Nash-equilibrium) strategies, we use a small circle ($\circ$) as superscript.

Proposition 1b (Optimal Government-Strategies in S0)

$$\left(v_A^\circ = 0, v_B^\circ = 0\right) \text{ if } 0 < p_{02} < T_{G1}^{S0}; \tag{27}$$

$$\left(v_A^\circ = 1, v_B^\circ = 0\right) \text{ if } T_{G1}^{S0} < p_{02} < T_{G2}^{S0}; \tag{28}$$

$$\left(v_A^\circ = 0, v_B^\circ = 0\right) \text{ if } T_{G2}^{S0} < p_{02} \tag{29}$$

Proof: If "no evacuation" of both groups $(v_A = 0, v_B = 0)$ minimizes the social cost-function, the social cost must be lower than in the two alternatives, (I) $C_G^{S0}(v_A = 0, v_B = 0) < C_G^{S0}(v_A = 1, v_B = 0)$ and (II) $C_G^{S0}(v_A = 0, v_B = 0) < C_G^{S0}(v_A = 1, v_B = 1)$. Condition (I) requires $p_{02} < T_{G1}^{S0}$ and condition (II) requires $p_{02} < T_{G2}^{S0}$. According to *Lemma 1b* $T_{G1}^{S0} < T_{G2}^{S0}$ holds and therefore $T_{G1}^{S0} - p_{01}$ is the upper bound for p_{02} in (21). The government prefers that just group A evacuates $(v_A = 1, v_B = 0)$ if the following two inequalities hold: (III) $C_G^{S0}(v_A = 1, v_B = 0) < C_G^{S0}(v_A = 0, v_B = 0)$ and (IV) $C_G^{S0}(v_A = 1, v_B = 0) < C_G^{S0}(v_A = 1, v_B = 1)$. Inequality (III) is the inverse constellation to (I) and condition (IV) requires $p_{02} < T_{G2}^{S0}$. According to Lemma 1b, we know that $T_{G1}^{S0} < T_{G3}^{S0}$, therefore p_{02} lies in between in constellation (22). If the inverse constellation of (IV) holds true, (v) $p_{02} > T_{G2}^{S0}$, joint evacuation $(v_A = 1, v_B = 1)$ minimizes the social cost. With $T_{G1}^{S0} < T_{G2}^{S0}$ from *Lemma 1b*, we identify T_{G2}^{S0} as the lower bound for p_{02}. This completes the proof. ■

5.2 Optimal strategies in the Mixed-Scenario S1

Optimal group strategies

We first define two terms $0 \le T_{A,B}^{S1} \le 1$, which constitute critical thresholds for the conditional probability p_{12} as given by

$$T_A^{S1} \equiv \frac{c^d - c^m}{\mu_A D} - p_{11} \tag{30}$$

$$T_B^{S1} \equiv \frac{2c^m + c^d}{c^m + \mu_B[\varphi_{01} D + (1 - \varphi_{01})c^d]} \tag{31}$$

In situation S1, congestion is no longer a strategic issue between the two groups and therefore their objective functions are not interdependent. Thus, we are left with just one critical threshold for each group. Note that the optimal group strategies in S1 and S2 do not constitute a Nash-equilibrium because these are independent optimal strategies.

Lemma 2a: $0 < T_A^{S1} < T_B^{S1} < 1 \quad \forall\, p_{11} \in [0,1]$.

Proof: We just sketch the proof by contradiction. As T_B^{S1} does not depend on p_{11}, it is sufficient to show that $T_A^{S1}(p_{11}=0) < T_B^{S1}$. In order to get the opposite result $T_A^{S1}(p_{11}=0) < T_B^{S1}$, μ_B must exceed a lower bound $\tilde{\mu}_B^{S1}$. However, it is straightforward to show $\nexists \mu_B \in [0, \mu_A] : \mu_B > \tilde{\mu}_B^{S1} \wedge 0 < T_B^{S1} < 1$. ■

We then can state the following *Proposition 2a*. We skip the proof because it follows the same structure as for *Proposition 1a*.

Proposition 2a (Group-strategies in S1)

The optimal group-strategies for scenario S1 are given by

$$\left(v_A^* = 0, v_B^* = 0\right) \text{ if } p_{12} < T_A^{S1} \tag{32}$$

$$\left(v_A^* = 1, v_B^* = 0\right) \text{ if } T_A^{S1} < p_{12} < T_B^{S1} \tag{33}$$

$$\left(v_A^* = 0, v_B^* = 0\right) \text{ if } T_B^{S1} < p_{12} \tag{34}$$

Optimal government strategies

For the government we get the following two critical thresholds $0 \le T_G^{S1} \le 1$ for situation S1, as given by (35) and (36).

$$T_{G1}^{S1} \equiv \frac{\alpha(c^d - c^m) + \beta\ell^L}{D + \beta\delta\ell^H + \beta\ell^L} - p_{11} \tag{35}$$

$$T_{G2}^{S1} \equiv \frac{\alpha(2c^m + c^d) + \beta\ell^L}{\alpha(c^m + c^d) + \beta\ell^L + \left(D + \beta\delta\ell^H - \alpha c^d\right)\varphi_{11}} \tag{36}$$

Lemma 2b: For the critical thresholds (35) and (36), it holds $T_{G1}^{S1} < T_{G2}^{S1}$.

Proof: We again provide the proof by contradiction. As T_{G2}^{S1} does not depend on p_{11}, it is sufficient to show that $T_{G1}^{S1}(p_{11}=0) < T_{G2}^{S1}$. In order to get the opposite result $T_{G1}^{S1}(p_{11}=0) > T_{G2}^{S1}$, φ_{11} must exceed a lower bound $\tilde{\varphi}_{11}^{S1}$. However, for our assumptions any, value $\varphi_{11} > \tilde{\varphi}_{11}^{S1}$ will strictly exceed 1. We conclude $\nexists \varphi_{11} \in [0,1] : \tilde{\varphi}_{11}^{S1} < \varphi_{11} < 1$, which completes the proof. ■

Proposition 2b defines the socially optimal strategy-combinations from the government's perspective for situation S1. We skip the proof because it follows the same structure as for *Proposition 1b*.

Proposition 2b (Optimal Government-Strategies in S1)

$$\left(v_A^{\circ} = 0, v_B^{\circ} = 0\right) \text{ if } 0 < p_{12} < T_{G1}^{S1}; \tag{38}$$

$$\left(v_A^{\circ}=1, v_B^{\circ}=0\right) \text{ if } T_{G1}^{S1} < p_{12} < T_{G2}^{S1}; \tag{39}$$

$$\left(v_A^{\circ}=0, v_B^{\circ}=0\right) \text{ if } T_{G2}^{S1} < p_{12} \tag{40}$$

5.3 Optimal strategies in the De-Escalation-Scenario S2

Following our standard procedure, the two terms $0 \le T_{A,B}^{S2} \le 1$ constitute the critical thresholds for the conditional probability p_{22} in the de-escalation-state. In S2, both groups already evacuated. For group A the expression is identical to situation S1 and group B also makes the decision whether to stay evacuated or return into region B.

$$T_A^{S2} \equiv \frac{c^d - c^m}{\mu_A D} - p_{11} \tag{41}$$

$$T_B^{S2} \equiv \frac{c^d - c^m}{\mu_B D} \tag{42}$$

Due to $\mu_B \le \mu_A$ it is straightforward that $T_A^{S2} \le T_B^{S2}$. This brings us directly to *Proposition 3a*.

Proposition 3a (Group-strategies in S2)

The optimal group-strategies for scenario S2 are given by

$$\left(v_A^{*}=0, v_B^{*}=0\right) \text{ if } p_{22} < T_A^{S2} \tag{43}$$

$$\left(v_A^{*}=1, v_B^{*}=0\right) \text{ if } T_A^{S2} < p_{22} < T_B^{S2} \tag{44}$$

$$\left(v_A^{*}=0, v_B^{*}=0\right) \text{ if } T_B^{S2} < p_{22} \tag{45}$$

Optimal government strategies

For the government we get the following two critical thresholds $0 \le T_G^{S2} \le 1$ for situation S2, as given by (46) and (47).

$$T_{G1}^{S2} \equiv T_{G1}^{S1} \equiv \frac{\alpha(c^d - c^m) + \beta\ell^L}{D + \beta\delta\ell^H + \beta\ell^L} - p_{11} \tag{46}$$

$$T_{G2}^{S2} \equiv \frac{\alpha(c^d - c^m) + \beta\ell^L}{D + \beta\delta\ell^H + \beta\ell^L} \tag{47}$$

Proposition 3b defines the socially optimal strategy-combinations from the government's perspective for situation S2.

Proposition 3b (Optimal Government-Strategies in S2)

$$\left(v_A^\circ = 0, v_B^\circ = 0\right) \text{ if } 0 < p_{22} < T_{G1}^{S2}; \quad (48)$$

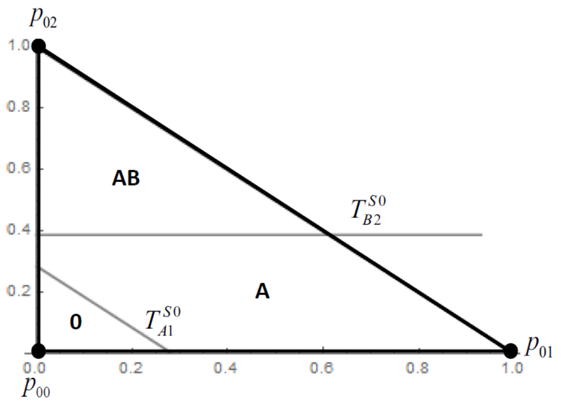
$$\left(v_A^\circ = 1, v_B^\circ = 0\right) \text{ if } T_{G1}^{S2} < p_{22} < T_{G2}^{S2}; \quad (49)$$

$$\left(v_A^\circ = 0, v_B^\circ = 0\right) \text{ if } T_{G2}^{S2} < p_{22} \quad (50)$$

5.4 Zones of Compliance (ZoC)

Illustration in a probability triangle

In this section we analyze the scope for compliance in the government's interaction with both groups. For the main part of this subsection, we refer to the escalation-scenario S0. The left diagram of *Figure 4* shows the critical thresholds of both groups in S0 graphically in a probability triangle. The edges and the corner points of the triangle are highlighted in black. Any constellation of the conditional posterior probabilities, i.e. the discrete, conditional probability distribution $\left\{\wp_{s|\omega} : p_{i0}, p_{i1}, p_{i2}\right\}$, can be marked in this triangle as a probability-point P with coordinates (p_{i1}, p_{i2}). The higher one of these probabilities, the closer it is to "its corner". Assume for example that we are in state S0 and we receive "no warning" (ω_{00}). In this case, the first column of the conditional posterior matrix $\boldsymbol{P_0}$ (6) applies and gives back the probability-point $\mathrm{P} = (p_{00}, p_{01}, p_{02}) = (0.999975, 0.000024, 0.000001)$. As the probability $p_{00} \equiv 1 - p_{01} - p_{02}$ comes close to 1, this point would we drawn in the origin of ordinates.



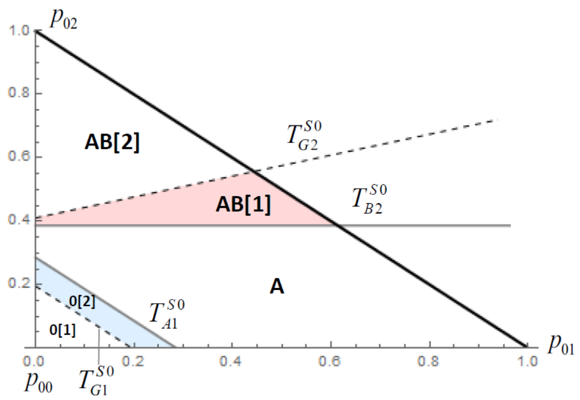


Figure 4 Probability triangle for optimal decisions, just groups (left) and with authority (right)

We now just need to spot the conditional probability in the plane and can directly infer the decisions of both groups. If P lies below T_{A1}^{S0} in the area labeled "0", then no group evacuates. If P is located between T_{A1}^{S0} and T_{B2}^{S0}, which corresponds to the area "A", just group A evacuates but group B does not. The last possibility is that the point lies above T_{B2}^{S0} in the upper corner "AB". In this case, both groups prefer to evacuate.

In the right diagram of *Figure 4* we added the critical thresholds of G as dotted lines. As both lines do not coincide with the groups' thresholds, there are constellations in which the groups and the government's preferences deviate from each other. These *zones of conflicting interest* are highlighted in the diagram. In zone 0[2] G prefers that group A evacuates, which is not the preferred strategy of group A. There is the exact opposite constellation in zone AB[1]: Here, G does not want group B to evacuate, however group B prefers evacuation. The conflicting interest between authority and groups results from three causes: the two information asymmetries (related to flood impact and anti-congestion investment) and the weighting factors α and β. With respect to the information asymmetries, people should be always better off to follow the government (whether they actually do depends on trust) but with respect to the preference parameters this is not necessarily the case. For example, it is possible that G puts highest weight on economic loss ($\beta = 1$) and lowest weight on citizens' deprivation ($\alpha = 0$). In such a case, G could act too cautiously not to endanger business activities too much and show less consideration for the affected population. However, in our model also economic losses have a short and long-term component and we assume that the long-term losses due to flood injuries exceed the short-run losses. Therefore, the outcomes of the compliance-game show a very low sensitivity with respect to changes in α and β.

Government communication and compliance

For its communication-decision in scenario S0, the government is guided by *Proposition 1b*. However, G's communication must also be effective. The request of G is *effective* under two conditions. First, the respective addressee (group A, group B or both groups) of the request is *impact-sensitive* (p_{i2} >

($T^{Si}_{A,B}(\mu_{A,B} = 1)$) and the level of *competence-trust* is *high enough* ($\tau^{c}_{A,B} > \tilde{\tau}_{A,B}$). The first condition refers to a situation where a group expects maximal impact (remember, impact is the subjective probability that "an event really hits me") but does not evaluate the consequences high enough compared to the less precautious alternative. In such a situation, impact-communication is effectless, even with the highest level of trust. The second requirement, a sufficiently high trust-level, is straightforward. If a group is impact-sensitive, their decision can theoretically be influenced but whether this influence is successful depends on the group's perception of the credibility and trustfulness of the sender. The lower the trust-level $\tau^{c}_{A,B}$, the more weight is put on the "autonomous" impact parameter $0 < \hat{\mu}_{A,B} < 1$ (the groups judge the impact on their own). We define $E^* | \oplus$ as the optimal strategy of G if the communication is *effective* and $E^* | \odot$ if communication is ineffective. Expression (51) summarizes the optimal strategies of the government.

$$E^* | \oplus = \begin{cases} E0 \vee (v^{\circ}_A = 0, v^{\circ}_B = 0) \\ E1 \vee (v^{\circ}_A = 1, v^{\circ}_B = 0) \\ E2 \vee (v^{\circ}_A = 1, v^{\circ}_B = 1) \end{cases} \qquad E^* | \odot = E^{\Omega} \equiv \{E0, E1, E2\} \tag{51}$$

If communication is effective, the government chooses the optimal strategy according to its objective. This strategy minimizes the social cost-function according to *Proposition 1b*. If, however, communication is ineffective, the chosen strategy is irrelevant and therefore the whole strategy-set applies. We use the symbol $E^* | \odot$ to indicate ineffective communication and E^{Ω} as a symbol for the universal set, which comprises the entire set of signals.

Before we present the equilibrium, we first illustrate graphically how to determine the government's optimal decision. For this example illustration we just focus on T_{A1}^{S0} as the decision-threshold, which determines whether just group A decides about evacuation. As known from expression (25), this threshold corresponds to a line with negative slope 1. To make the scope for communication visible, we express μ_A by its explicit term $\mu_A = \tau_A^c\, E_A + (1-\tau_A^c)\, \hat{\mu}_A$, which contains the binary signal $E_A \in \{0,1\}$ (as presented in section 4.1). As long as there is a minimum-level of trust ($\tau_A^c > 0$), the threshold-line T_{A1}^{S0} extends to a range or spectrum of threshold-lines with the lower and upper bound defined by $E_A = 1$ and $E_A = 0$ respectively. Diagram (a) of *figure 5* gives an example of such a threshold-spectrum. With respect to the threshold-line of group A (T_{A1}^{S0}), the spectrum is highlighted by blue color together with its lower bound $T_{A1}^{S0}(E_A = 1)$ and upper bound, $T_{A1}^{S0}(E_A = 0)$. The dotted line in the middle of the spectrum indicates the autonomous impact-level $\hat{\mu}_A$, which determines the decision if trust is absent. In the diagram, we also depict the threshold-lines of the government T_{G1}^{S0} (low black solid line) and an arbitrary probability-point P.

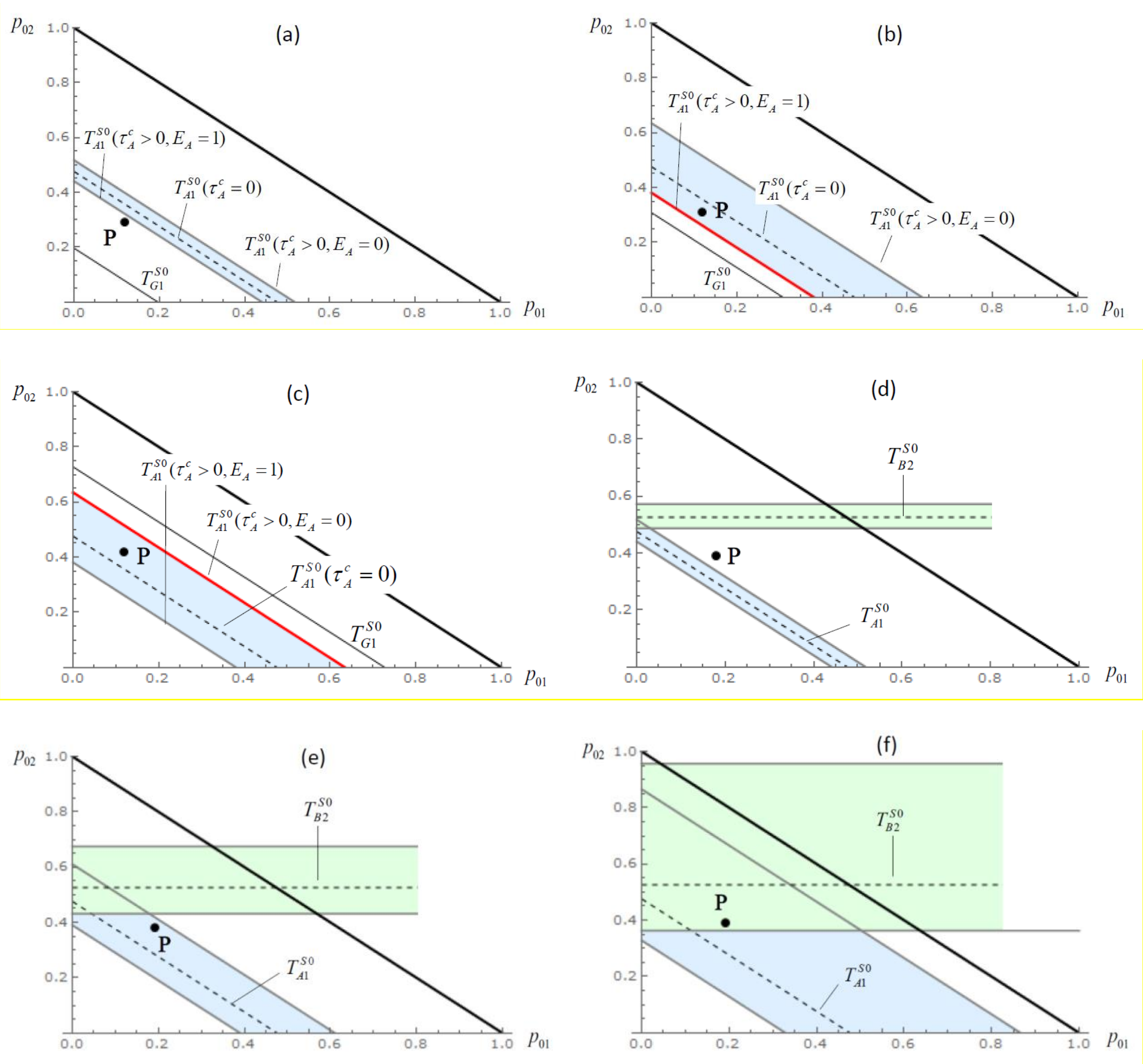


Figure 5 Zones of Compliance (ZoC) for different constellations

If the probability-point P lies within this range, the government can directly influence the group's decision with its request. Therefore, we call the threshold-spectrum "*zone of compliance*" (*ZoC*). Diagram (a) represents the case of a too narrow range (small *ZoC*) where the probability-point P lies outside *ZoC* ($\mathrm{P} \notin ZoC_{A1}^{S0}$). P is located below ZoC_{A1}^{S0} but above T_{G1}^{S0}, i.e. in this situation group A does not evacuate (regardless of any request) although G wants it to do so. Hence, in this case the trust-level is not high enough and the authority cannot convince the group. Diagram (b) shows the same situation with the only difference that the trust-level is higher. The higher trust-level widens *ZoC* so that P is now located inside of this range ($\mathrm{P} \in ZoC_{A1}^{S0}$). Although group A would be reluctant to evacuate in the case of an autonomous decision without trust (P lies below the dotted line), by sending the signal $E_A = 1$ (more precisely, G sends signal $E1$, which is received as $E_A = 1$ by group A), the government can realize the lower bound of *ZoC* (straight red line at the bottom of *ZoC*).

In diagram (c) we just switched the order of T_{A1}^{S0} and T_{G1}^{S0} with the consequence that now G prefers no evacuation of group A. By sending the signal $E_A = 0$ (signal $E_A = 0$ from group A's perspective), the government can realize the upper bound of *ZoC* (red black line at the top of *ZoC*). To summarize, given group A's equilibrium strategy T_{A1}^{S0}, its trust-level τ_A^c, the government's objective T_{G1}^{S0} and a current projection defined by P: As long as $\mathrm{P} \in ZoC_{A1}^{S0}$, the authority has influence on the decision of group A. Note that there is just a need to intervene by communication if P lies *between* the critical thresholds T_{A1}^{S0} and T_{G1}^{S0} (otherwise there is no conflict of interest, regardless of the scope for compliance).

The diagrams (d) – (f) show the critical thresholds and *ZoC*s for both groups; the *ZoC* of group A is colored blue and *ZoC* of group B is colored green. The only difference between these three pictures is again the trust-level while the position of P remains unchanged. In diagram (d) the trust-level is too low and the probability point lies outside both *ZoC*s. The optimal group strategies are evacuation for group A ($v_A^* = 1$) and no evacuation for group B ($v_B^* = 0$). These decisions are not influenced by G, which means that G's optimal strategy is $E^* | \odot = E^{\Omega} \equiv \{E0, E1, E2\}$. In words: As G's communication is ineffective, G can communicate anything; the signals do not matter. In diagram (e), the trust-levels of both groups are higher and now P lies inside ZoC_{A1}^{S0} but still outside of ZoC_{B2}^{S0}. Here G has influence on the decision of group A but not on the decision of B. In diagram (f), both *ZoC*s overlap. In this constellation, G has influence on the decisions of both groups. This overlapping constellation can easily occur for high levels of trust because in this case the groups are willing to adapt their impact-expectations mainly to the government's judgement. Therefore, this represents the best possible constellation for G because it can directly influence both groups by one signal.

5.5 Nash-Equilibrium (NE) of the Evacuation-Compliance-Game

We can now combine the interim results as stated by *Proposition 1a* and *Proposition 1b* to derive the main result of the *Evacuation-Compliance-Game*. As the general structure of the solution is not altered by the scenarios, we state the result for all three scenarios (S0, S1 and S2) together. Assume that the current situation is state Si and the decision makers receive the warning ω_{ij}. The Transition-Matrix $\boldsymbol{S}$, the Likelihood-Matrix $\boldsymbol{L}_i$ and the conditional Posterior-Matrix $\boldsymbol{P}_i$ are defined as described above. The probability-point $\mathrm{P}_{s_i|\omega_{ij}} = (\bar{p}_{i1}, \bar{p}_{i2})$ respresents the ω_{ij}-column of $\boldsymbol{P}_i$. Furthermore, the actors' payoffs are given as described in sections 4.1 – 4.3 and for both groups and the government there are critical thresholds T_A^{Si}, T_B^{Si}, T_{G1}^{Si} and T_{G2}^{Si}. Let $\hat{v}_A^*$ and $\hat{v}_B^*$ be the optimal group strategies under autonomous conditions (according to Propositions 1a, 2a and 3a), i.e. without government or with zero trust in the government ($\tau_A^c = \tau_B^c = 0$). ZoC_A^{Si} and ZoC_B^{Si} represent the *Zones of Compliance* of both groups. The time-structure of the Compliance-Game is given by *Figure 3*.

Result (NE of ECG)

The following strategies represent a *Nash-Equilibrium* of the underlying subgame on stage 1 and stage 2 of *Figure 3*.

$$\mathrm{P}_{s_i|\omega_{ij}} \in \left\{ZoC_A^{Si} \cap ZoC_B^{Si}\right\} \;\wedge\; \begin{array}{ccc} T_{G2}^{Si}(\overline{p}_{i1}) \le \overline{p}_{i2} & \Rightarrow & \left\{E^* = E2, v_A^* = 1, v_B^* = 1\right\} \\ T_{G1}^{Si}(\overline{p}_{i1}) \le \overline{p}_{i2} < T_{G2}^{Si}(\overline{p}_{i1}) & \Rightarrow & \left\{E^* = E1, v_A^* = 1, v_B^* = 0\right\} \\ \overline{p}_{i2} < T_{G1}^{Si}(\overline{p}_{i1}) & \Rightarrow & \left\{E^* = E0, v_A^* = 0, v_B^* = 0\right\} \end{array} \tag{52}$$

$$\mathrm{P}_{s_i|\omega_{ij}} \in ZoC_A^{Si} \;\wedge\; \mathrm{P}_{s_i|\omega_{ij}} \notin ZoC_B^{Si} \;\wedge\; \begin{array}{ccc} T_{G1}^{Si}(\overline{p}_{i1}) \le \overline{p}_{i2} & \Rightarrow & \left(E^* = \{E1, E2\}, v_A^* = 1, v_B^* = \hat{v}_B^*\right) \\ \overline{p}_{i2} < T_{G1}^{Si}(\overline{p}_{i1}) & \Rightarrow & \left(E^* = E0, v_A^* = 0, v_B^* = \hat{v}_B^*\right) \end{array} \tag{53}$$

$$\mathrm{P}_{s_i|\omega_{ij}} \notin ZoC_A^{Si} \;\wedge\; \mathrm{P}_{s_i|\omega_{ij}} \in ZoC_B^{Si} \;\wedge\; \begin{array}{ccc} T_{G2}^{Si}(\overline{p}_{i1}) \le \overline{p}_{i2} & \Rightarrow & \left(E^* = E2, v_A^* = \hat{v}_A^*, v_B^* = 1\right) \\ \overline{p}_{i2} < T_{G2}^{Si}(\overline{p}_{i1}) & \Rightarrow & \left(E^* = \{E0, E1\}, v_A^* = \hat{v}_A^*, v_B^* = 0\right) \end{array} \tag{54}$$

$$\mathrm{P}_{s_i|\omega_{ij}} \notin \left\{ZoC_A^{Si} \;\cup\; ZoC_B^{Si}\right\} \;\Rightarrow\; \left(E^* = E^\Omega = \{E0, E1, E2\}, v_A^* = \hat{v}_A^*, v_B^* = \hat{v}_B^*\right) \tag{55}$$

The equilibrium-conditions read as follows: Expression (52) considers the case where the probability-points lies in an area where the two *ZoC*s overlap. In this case, the government can advise both groups according to its own preferences, which can be summarized by the relative position of P and the critical thresholds of G. Note that the groups' preferences do not matter for this constellation: Even if there is no conflict of interest (i.e. the groups pursue the same goal as G) the government still needs to care about its communication because the groups follow the government with any order. In constellation (53), P lies in the *ZoC* of group A but not in the zone of B. In this case the government just communicates to group A. Expression (54) represents the analogue constellation for group B; G's communication just focusses on group B but group A cannot be reached. The final constellation, (55), represents the case where P lies outside both *ZoC*s. In this case, G has no communicative influence. Hence, in equilibrium the government communicates the universal set (signals are ignored by both groups) and the groups play their autonomous equilibrium strategies $\hat{v}_A^*$ and $\hat{v}_B^*$.

5.6 Equilibrium-analysis based on the empirical reference-data

In this section we take a closer look at the derived equilibrium-conditions by applying the reference-data introduced in sections 3.2 and 4.1. For the most part we focus on the escalation-scenario S0 with a warning-level 1 and 2 because we consider these two situations to be the most frequent and relevant ones. For the standard parameters we chose the values $\alpha = .5, \beta = .5, \gamma = .3, \hat{\mu}_{A,B} = .5, I = .5$ and rather low trust-levels between $\tau^c_{A,B} \approx [0.2, 0.4]$. The situation ω_{01} is depicted in *Figure 6(a)*. It can be seen that G would strongly advise evacuation but group A would also evacuate anyway. At a minimum trust-level of $\tau^c_A \approx .3$, which is illustrated in the graph, the *ZoC* is wide enough to embrace the probability-point. This means that – although group A would evacuate from alone – the government should advise evacuation to avoid misunderstandings: Compliant citizens could wrongly interpret a missing evacuation order as an all-clear signal. To summarize, for a warning-level 1 the risk-decision of group A and G are in line, but this needs an affirmation from the government if trust and compliance are sufficiently high. The critical threshold of group B is not shown in the graph because the (horizontal) *ZoC* of group B starts at a probability-value $p_{02} = 0.01$ and is thus far above the probability-point. In other words, in the case of a level-1-warning in S0, group B is very far from evacuating.

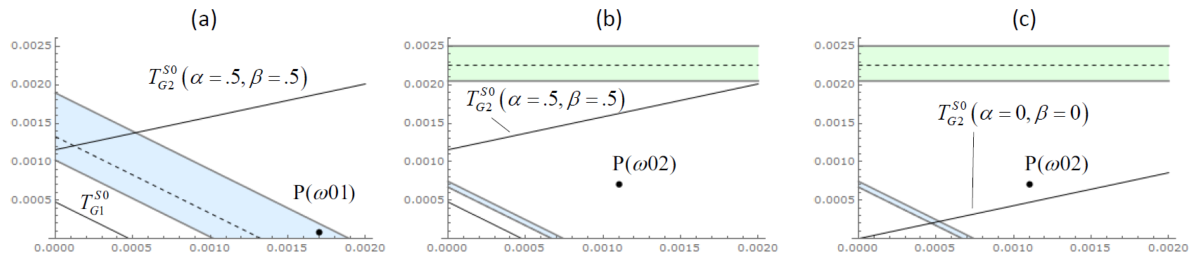


Figure 6 Variation of warning-level and preference-parameters for S0

But how does this change if the coastal city receives a level-2-warning? This situation is illustrated in diagram (b). The probability-point slightly moves to the upper-left and the critical threshold of group A shrinks downwards because the autonomous impact-expectation is close to 1 ($\mu^W_A = 1 - \varepsilon$). This means that group A would try whatever possible to get out of the region. However, for the chosen parameters, group B would not evacuate and the probability-point still remains below the critical threshold of the government. Hence, in spite of a level-2-warning, region B would not evacuate. Is this decision too risky? Above all, this decision takes into account the trade-off between physical damage and potential death on the one hand but also the cost of evacuation, which comprise deprivation and economic losses, on the other hand. If we ignore this trade-off and just take injuries and fatalities into consideration, the decision would be different as shown by *Figure 6*(c). Here we changed the government's preference parameters and eliminated any other factor ($\alpha = 0, \beta = 0$) so that physical damage alone determines the decision. We see that a government, which exclusively cares for lives, would order evacuation of region B. This, however, is without success because the probability-point is not covered by the *ZoC* of group B. Even maximal trust would not be sufficient to change this situation: Full trust ($\tau^c_B = 1$) would expand the *ZoC* and thus move the lower bound downwards, but only up to the value $p_{02} = 0.0011$, which is still above the probability-point. For the case of a level-2-warning we conclude that for the empirical reference data, which we took as a basis for our study, we find ourselves in the conflicting trade-off between "protection from damage" and "damage through protection" and the bad news is that this conflict cannot be overcome by trust and compliance. For the other two situations S1 and S2, we get quite clear results, which is mainly due to the high probability values of the (conditional) posterior probabilities. Once region A or region B is affected by a flood, the government and the groups decide to stay evacuated and not to return. These situations are so clear – in the sense that the probability-point is largely out of sight – that there is no issue for compliance. However, there is one constellation where compliance matters and this is exactly due to the high exposure: For our parameter constellation in S1, group B is close to evacuate when a warning-1-level is received. However, even for low values of trust the zone of compliance covers the probability-point so that unnecessary evacuation should not occur.

6. Summary and Discussion

In this contribution we presented the Warning-Compliance-Model (WCM) as a novel and comprehensive approach to study probabilistic and communicative aspects of public risk management and compliance within one coherent framework. The random events were modeled using a Hidden Markov chain and depicted both the escalation and de-escalation phases of hypothetical severe flood events. At the same time, the performance of the EWS can be taken into account by determining the Likelihood-Matrix accordingly. Since approaches of the literature on EWS-verification usually work with contingency tables, the information system of the WCM can also be linked empirically.

The second part of the model included the communication game between the government and the two population groups under consideration. First, the optimal strategies of the groups were determined for all states of the Hidden Markov chain, representing either the evacuation decision or the decision to return to the region. On the part of the government, the socially desired solutions were determined from the perspective of the policy maker. The model is kept as simple as possible from a technical point of view and allows the explicit derivation of the stationary solutions of the model in a generic form. The methodological core of the communication game is the compliance of the population with the (non-enforceable) orders of the government. Compliance helps the two groups (A and B) to overcome their information asymmetry vis-à-vis the state, provided their trust in the authority is sufficiently high. The higher the trust in the state, the more willing the two groups are to follow the instructions for a given probability distribution (as depicted in a compact form by the probability point).

First, it is clear that compliance is only necessary when the interests of the population and the state diverge. Nevertheless, it should be noted that even if interests are aligned and trust is sufficiently high (compliance without conflict of interest), the state must communicate affirmatively to avoid misunderstandings. Since in this model - but ultimately also in all real world communication - silence also represents a signal, it would be dangerous if the state did nothing, in the deceptive certainty that the population itself already knew best what to do. In this respect it is clear that not only compliance is needed for an effective communication strategy, but also an effective communication strategy is needed to give a compliant group orientation during a crisis. Second, if there is a conflict of interest, it is no longer the distance between the critical thresholds that determines the outcome of the communication game, but whether the probability-point lies in the Zone of Compliance. In other words: Not the interests or preferences of the state per se, but the credibility of its message together with the objective probability of the risk ultimately determine whether compliance can arise.

The application of empirical data from flood and risk studies to the model provides plausible results for the escalation scenario. For the de-escalation phase, the assumptions made and the probabilities suggested by the experts led to the clear result that the population in region A would already evacuate on its own initiative, but that the state would also order this evacuation. Since the probability point in this constellation lies with the Zone of Compliance for already rather low trust values, this is a quite clear case for the necessity of affirmative communication as described above.

The results for an announced Black Swan flood show that the inhabitants of region B would not react to an S2 warning. Remarkably, however, the government would not issue an evacuation order either, taking into account economic follow-up costs and the particular burden on the people that an evacuation would entail. Only when the government considers the costs of an evacuation to be very low compared to the expected consequences for life and limb caused by an extreme flood the authority would order an evacuation. In this case, however, the critical threshold lines of state and population group B, which in the model indicate readiness to evacuate, fall far apart. In order for Group B to be persuaded to evacuate via compliance, it must have a very high level of trust, since otherwise the probability-point of a black swan event would no longer lie in the (from the citizens' point of view) impact-relevant area. What does all this imply for improved disaster management? The Warning-Compliance-Model illustrates the intricate interaction between objective event probabilities, the precision of forecasting technology, the authority's and public's preferences as well as the role of trust in a communication game. The model can be very helpful to determine the effects of e.g. a higher EWS-precision or a higher trust-level on the scope for compliance and hence on the outcome in the case of a severe or disastrous flood event. Furthermore, the model shows that many different and important problems in the context of flood evacuation, which are predominantly looked separately and from a purely empirical perspective, such as risk communication, the crying-wolf-phenomenon or conflicts of interest, can be better seen as elements of one comprehensive picture. The WCM is best understood as a first step to identify the interlinkages between these different areas. More concrete, policy makers could consider some implications of this study for the development or training application of Evacuation Maps (Wilson 2018). As different geographic areas correspond to different risk profiles and this in turn will influence people's expectations, it is possible to derive a rough and preliminary guess of people's probable decisions and the corresponding level of (expected) compliance. One further implication of the results of this study relates to risk communication. Risk communication in advance increases the impact expectation, which in turn requires less compliance. However, since both, compliance and risk communication, will depend on the same type of trust (competence trust in the authorities), this will enable the government to better empower people to make independent decisions before a crisis. This strategy, however, is particularly dependent on public trust, because it also means that too little trust in competence destroys both options: The population will not be convinced, either in advance or in the event of an approaching crisis, that the flood could affect them.

Finally, we also want to briefly discuss potentially problematic assumptions of the model as well as promising model extensions. As already mentioned we admit that the assumption of a representative decision maker for each group simplifies away some interesting and important aspects. It is promising to take the heterogeneity of people into account because differences in preferences of stakeholders will have an impact on their willingness to evacuate (e.g. vulnerable people, such as assisted care individuals, or gender differences (Bateman & Edwards 2002). We also assume that the assignments of buildings and individuals to zones is clear-cut. However, this is far from straightforward: "A study before Hurricane Irene found that 83% of adults without a high-school education (e.g. 46% of East Harlem's population in 2006) could not identify their evacuation zone." (Wilson 2018, p.9). Similarly, special forms of evacuation such as long term resettlements and relocations (Sorensen & Sorensen, 2006) are less well representable in the model, either. With respect to the preferences, we assume in our model that just the government takes economic losses into account. However, this will also be an important motive for small businesses. Finally, it could be very promising to apply more psychological approaches like risk perception theory, prospect theory or protection motivation theory to this framework. One complicating challenge of such an extension is that this introduces path-dependence into the model so that the derived closed-form solutions are just relevant for the described stationary solutions. Nevertheless, risk perception is ultimately a history-dependent phenomenon and it should be feasible to add this component to the Warning Compliance Model.

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Appendix 1

Proof of Lemma 1b: To proof $T_{G1}^{S0} < T_{G2}^{S0}$ we first show that $T_{G1}^{S0} < T_{G2}^{S0}(\gamma = 0)$, which is true for $\varphi_{11} < \varphi_{10}$. Increasing γ shifts T_{G2}^{S0} upwards. The highest admissible value for T_{G2}^{S0} is 1, because otherwise it would be an irrelevant threshold for p_{02}. Setting $T_{G2}^{S0} = 1$ and solving for γ provides us with the upper limit $\gamma < \tilde{\gamma}_G^{S0} \equiv \frac{\varphi_{11}(D+\beta\delta\ell^H-\alpha c^d)-\alpha c^m}{\varphi_{10}(D+\beta\delta\ell^H-\alpha c^d)-\alpha c^m}$. As both, T_{G1}^{S0} and T_{G2}^{S0} vary linearly in p_{01}, it remains to show that $dT_{G2}^{S0}(\gamma = \tilde{\gamma}_G^{S0}) / dp_{01} > dT_{G1}^{S0} / dp_{01} = -1$, which completes the proof. ■

Appendix 2

Proof of Proposition 2a: For $(v_A = 0, v_B = 0)$ to be a NE, two conditions (I) $C_A^{S1}(v_A = 0, v_B = 0) < C_A^{S1}(v_A = 1, v_B = 0)$ and (II) $C_B^{S1}(v_A = 0, v_B = 0) < C_B^{S1}(v_A = 0, v_B = 1)$ must be fulfilled. In words, both groups must strictly prefer not to evacuate provided that the other group sticks to the no-evacuation-strategy, too. For each condition, there is a critical threshold for p_{12}: (I) $p_{12} < T_{A1}^{S1}$ and (II) $p_{12} < T_{B1}^{S1}$. Hence, a NE where no group evacuates requires $p_{12} < Min[T_{A1}^{S1}, T_{B1}^{S1}]$. According to *Lemma 2a,* it follows that $T_{A1}^{S1} < T_{B1}^{S1}$ and thus T_{A1}^{S1} is the required upper bound (if p_{02} is lower than T_{A1}^{S1}, it is also lower than T_{B1}^{S1} but not vice versa). Hence, if group A does not evacuate, then group B certainly does not either. ■

Article 4: Were the floods in the UK 2007 and Germany 2013 game-changers?

Abstract

This paper examines recovery after major floods in the UK and Germany. It focuses on two areas that were badly hit by flooding: Catcliffe, near Sheffield in the United Kingdom and Passau in Bavaria, Germany. It reports on surveys of residents and businesses in each place and on surveys of national flood experts in both countries. The two events were comparable in terms of impacts, levels of preparedness and government response and show similar patterns of speed and quality of recovery. In Germany it took about 18 months for ≥90% of residents to get back to normal, while in the UK it took a year longer. This difference may be related to funding; in the UK, over 90% of funding came from household insurance while in Germany over 60% came from federal aid, which may have been quicker. In both countries the economy had recovered to near normal within 12-18 months. The majority of people surveyed in both countries (74% in Germany and 67% in the UK) believe that their homes and businesses are as just as vulnerable now as they were before the respective floods. However, in the UK, half of the respondents thought their neighbourhood was safer and better prepared compared to only 11% in Germany. This may be because substantial progress has been made in improving protection in the UK in areas flooded in 2007.

Both floods were considered to be "game-changers" and resulted in a heightened awareness of flood risk, increased investment in flood defences and an increasing emphasis on citizens taking more responsibility for flood preparedness. However, the Environment Agency in the UK lacks powers to prevent development in flood prone areas, in Germany there are issues of coordination across large catchments that cross state boundaries and the insurance sector could play a bigger role in 'building back better'. Many homes and businesses continue to be at risk from major floods and more progress needs to be made in making them more resilient.

1. Introduction

The aim of this paper is to report the speed and quality of recovery of communities affected by floods, following events in the UK in 2007 and in Germany in 2013. The study focuses on two places that were severely flooded: Sheffield and Rotherham in South Yorkshire, UK, and Passau, in Bavaria, near the Austrian border, Germany. Both places have been flooded numerous times. Sheffield was flooded most recently in 2000 and 2007, while Passau, at the confluence of the rivers Inn, Ilz and Danube, was flooded in 2002 and 2013. In both places, face-to-face surveys were conducted with local residents and business people who experienced flooding and online surveys were conducted with flood experts.

Recovery is defined as ‘returning to a normal state after a period of difficulty’ and most (lay) people think about disaster recovery as a return to normality [1] and an attempt to bring the post disaster situation to some level of acceptability [2] and normal level of performance [3]. In this paper, since complete restoration may take a very long time, we argue that a concept of ‘close to normality’ is more meaningful and we therefore define recovery as being when 90% of displaced people have returned to their repaired homes, 90% of disrupted businesses are back in operation and 90% of the affected working population has returned to work.

However, a different question is whether getting back to normal conditions is at all a meaningful goal. Post-disaster ‘normal’ may not be a return to the same status as before the event; in fact, this may be undesirable if the quality of a system could be improved to enhance resilience. Recovery from disaster may be envisaged as a process of resilience building, whereby the capacity of a community to spring back after the initial shock of a disaster is increased [4]. Floods can act as catalysts for human adaptation [5] and there is a ‘window of opportunity’ in the early phase of recovery to improve resilience or ‘build back better’ [6]. A balance must be achieved between speed and enhanced resilience [7].

It has been suggested that the basic functions of a community should be restored within two years to ensure successful recovery [8]. Within this period, governments are required to manage a disaster and restore functionality of critical systems, and so issues relating to an event are pushed high up the policy agenda [9].

2. UK floods 2007

During the summer of 2007, a series of destructive storms hit many parts of the UK [10]. Average rainfall across the country was more than double the seasonal average and some areas received a month’s precipitation in 24 h [11]. In the north of England, flooding was particularly severe along the Trent catchment in and around Hull, Sheffield and Doncaster. In the south, Gloucester, Tewkesbury, Cheltenham and Oxfordshire were flooded along the Severn–Avon catchment and the Upper Thames valley (table 1). The 2007 flood events cost the UK economy USD 3.3–4.9 billion [13]. Thirteen people died and hundreds had to be rescued. Around 48 500 homes were affected, each costing on average USD 32 000 to repair. The repair cost for flooded businesses averaged between USD 95 and 142 000. While almost every business was adequately covered by insurance, a quarter of affected homes were not fully insured [14].

Table 1 Flooding by region, UK [12]

UK Region	**Households**	**Businesses**	**Cities**	**Buildings**
Yorkshire/Humberside	23,479	3,718	Hull	6,500
			Sheffield	5,800
			Doncaster	5,171
West Midlands	8,450	1,453	Gloucester	1,150
South West	4,915	1,000	Tewkesbury	1,150
			W. Oxfordshire	1,655
East Midlands	4,581	290	Derby	
South East	5,896	129	Oxford	
London	1,108	302	London	

In Sheffield, the River Don burst its banks, flooding mainly commercial and industrial units. Catcliffe, our UK study area, is a village suburb northeast of Sheffield. During the night of 25 June, the River Rother overtopped its banks, flooding nearly 200 homes in Catcliffe (about 50% of total in Catcliffe). Flood depths were so high that about 100 bungalows were almost completely submerged the lowest parts of the village [12]. Over 700 residents were evacuated after cracks appeared in the dam at Ulley reservoir [15] and the M1 motorway was closed [16].

In both Sheffield and Hull, the drainage systems were unable to cope, in part because of inadequate maintenance [17]. In Hull and the East Riding, 20% of homes were flooded [10]. In Yorkshire, four major and 55 secondary substations were flooded, disrupting the electricity supply to 130 000 people, including residents in Catcliffe, for more than a fortnight [18]. The flooding also had psychological impacts and long-term mental health effects [19–21]. A survey of 2265 people in South Yorkshire reported that mental health issues were significantly higher among flood victims [22].

In the UK, two million homes were at flood risk (in a 1 : 100 year flood hazard area) in 2005 [23]. By 2018, largely because of continued construction on flood plains, that estimate had risen to 5.5 million homes [24]. In terms of awareness and preparedness, The Pitt Review [25] found clear evidence that the UK was inadequately prepared for the 2007 floods. In the UK, population growth has driven extensive building on flood plains despite scientific understanding of the associated hazard. The review also presented evidence that storm drains in new housing developments had not been checked and adopted by the appropriate water authorities, drains and rivers in urban areas were blocked, while culverts and ditches in rural areas had not been kept clear and maintained [26]. UK businesses at risk of flooding also showed a lack of preparedness that affected their rate of recovery [27]. A case study of businesses near Catcliffe concluded that in spite of some level of preparedness against direct impacts, there is considerable lack of preparatory measures for the indirect effects of flooding and business interruption [28].

3. German floods 2013

In May 2013, total rainfall amounted to three times the monthly average throughout Germany and record river levels were recorded throughout the country. Most major catchments in Germany, apart from the Rhine, experienced some level of flooding. Flooding progressed along the Elbe catchment, a main artery flowing north through Germany to the North Sea, and along the Danube catchment, flowing east through southern Germany into Central and Eastern Europe. In Germany, disaster alerts were declared periodically between May and June in eight of Germany's 16 federal states [29].

The 2013 floods affected 600 000 people, caused 14 fatalities and cost the German economy USD 6.7–9.1 billion. In total, 80 630 residents in eight federal states were evacuated. In terms of financial loss, Saxony-Anhalt, Saxony and Bavaria were the three most affected German states (table 2). Private households incurred approximately 22% of all losses, with an average loss per household of USD 56 000. In Passau, the location of this case study, flooding was particularly severe (over 1 in 100-year return period) where dyke breaches caused large-scale inundations [30]. Passau is situated at the confluence of the rivers Danube, Inn and Ilz, and the highest water level (12.85 m) since 1501 was recorded. Passau's Old Town in the heart of the city was at the centre of the flood zone and water reached the second floor of some buildings [31]. The 2013 floods were not as severe, however, as the 2002 floods, which caused 20 fatalities and the evacuation of 337 000 people [32]. Improvements in structural defences meant most places experienced less damage in 2013. However, some areas, including Passau, were not as fortunate. The German transport network was severely affected, and over 700km of roads and 150 bridges were damaged and the German Railways Corporation was forced to close 60 routes. Psychological impacts were also significant and a survey of 710 residents affected by flooding across Germany in 2013 found that, in terms of recovery, the amount of damage was less important than psychological factors [33].

Table 2 Flooding by State Germany [17]

German State	Houses	Economic Loss USD million	Evacuated
Bavaria	13,000	1,805	13,600
Saxony	13,000	2,654	23,300
Saxony-Anhalt	ND	3,725	40,000
Baden -Wuerttemberg	3,697	102	200 +
Brandenburg	1,100	127	3,500
Thuringia	ND	624	ND
Lower Saxony	ND	88	ND
Hesse	ND	29	ND

In Germany, three million people live in areas that are considered flood-prone, with a 1 in 10 year probability of experiencing potentially damaging and life-threatening river floods [34–36]. There were improvements in preparedness after the 2002 floods [37] and a survey of residents in Saxony found significant improvements in preparedness between 2002 and 2013 [38]. In 2013, 23% were very well prepared compared to only 3% in 2002 and 78% of respondents said they were completely unprepared in 2002, compared to only 19% in 2013. More significantly, there was major investment in flood protection. In the Elbe catchment area, dykes were rebuilt or reinforced, and mobile flood barriers were used to hold back water in the Elbe, Danube and Vltava [39].

Table 3 compares the UK 2007 and German 2013 floods and shows that the scale of the floods was comparable, with the German floods perhaps twice as severe in terms of people displaced and economic loss. The main difference was that Government aid in Germany was considerably higher than in the UK [41].

Table 3 Comparison of the impact of flooding in UK and Germany [33,34,40].

	UK 2007	**Germany 2013**
Extent	6 out of 9 Regions	8 out of 16 States
Fatalities	13	14
People Displaced	38,000	80,000
GDP, PPP (event year)	USD 2.2 tn	USD 3.6 tn
Economic Loss	USD 3.3 – 4.9 bn	USD 6.7 9.1 bn
Insurance Loss	USD 2.6 bn	USD 1.8 bn
Average cost per house	USD 32,000	USD 56,000
Insurance Households	75%	32%
Government Aid	USD 180 mn	USD 8.9 bn
Flood risk homes 2018	5.5 mn	3 mn

4. Methodology

4.1 Surveys of households and businesses

Interview surveys were conducted with people living or working in two places badly affected by the floods Sheffield in South Yorkshire, UK and Passau in Bavaria, Germany. Within these cities, residential areas in the flooded zones near the river were chosen because people there were more likely to have experienced flooding or be aware of the risks. Nearly two-thirds of people surveyed lived within 1km of the river that flooded (65% UK; 63% Germany) and about half had experienced being flooded (44% UK; 55% Germany). In Sheffield, Catcliffe, a village close to the River Rother between Sheffield and Rotherham was targeted. Although Sheffield city centre was flooded very few people still live there. Sheffield has undergone huge economic changes in the past 12 years and few people working in businesses in 2007 would have still been there at the time of the survey in 2018. By contrast, in Passau many people still live in the historic centre and Dreiflüsse-Eck, the 'Three Rivers Corner', was targeted. Although Catcliffe is a low density commuter village and Dreiflüsse-Eck is in the historic centre of Passau, both areas are of similar size, 30–37 ha. They also had similar populations, 2100 and 2990 and similar age profiles. In Catcliffe, 52% of properties were flooded and in Dreiflüsse-Eck approximately 70% were flooded (table 4).

Table 4 Comparison of floods in Catcliffe and Dreiflüsse-Eck (Three Rivers Corner).

	Catcliffe, Sheffield/Rotherham	Dreiflüsse-Eck (Altstadt), Passau
Character	low density commuter village	high density, historic city centre
Location	2.5 miles from Rotherham and 4 miles from Sheffield city centre	historic centre of Passau at confluence of Danube, Inn and Ilz
Date flood	25-Jun-07	03-Jun-13
Population 2011	2,108	2,990
Population year of flood	1,971	2,981
Population 18-64 (%)	64	66 [42]
Area	30 ha	37
Flooded area	16 ha [43]	26 ha [44]
Flooded area %	52	70
Properties total/flooded	372/195	800/560 [45]
Evacuation	Forcible evacuation due to fears dam failure	Water supply failure meant 60 inmates of Passau prison had to be transferred

We used maps of flooded areas to identify households and businesses to target for interview in advance and we also made appointments by telephone to meet and interview people working in local organizations affected by the flooding, including the library, church, cafes, the supermarket, bars, garages and the cinema. Over 90% of the surveys were conducted face-to-face with residents and local business people who had experienced some level of flooding. The remaining interviews were conducted on the telephone.

People living and/or working in the affected places were asked three simple questions.

- When do you feel you got back to or almost to normal? How many months was this after the flood? If you are still recovering, how long do you think it will take?

- Do you feel your home is safer and better able to cope with another flood, less able or about the same?
- Do you think the local area has been made safer and more resilient, or about the same or worse?

The interviews in Catcliffe were conducted over 4 days in early November 2018 and in Dreiflüsse-Eck over 5 days in early April 2019. In both countries, native language speakers who were familiar with the flood risk management supported the interviewer, a non-native speaker, to make sure there were no misunderstandings.

Although the sample sizes were relatively small (32 in Catcliffe and 74 in Dreiflüsse-Eck) they are fairly representative of the populations living in both places. In the Catcliffe, 44% of respondents were female compared to 62% in Passau. In the Sheffield, 51% of inhabitants were female and in Passau 52%. In Catcliffe, 76% of respondents travelled to work by car compared to 37% in Germany. This corresponds roughly with the modal split in the two places; in 2018, 60% travelled to work by car in the Sheffield City Region and 51% travelled by car in Passau. The educational level of people surveyed in Catcliffe was also very similar to that of adults in Rotherham and Sheffield [46–50].

4.2 Surveys of flood experts

Separate surveys, with more detailed questions, were also conducted with recognized flood experts in each country. These included environment agency personnel, insurance assessors, academics and flood risk management consultants. One hundred and fifty experts were contacted by email in the UK, 27 responded, a response rate of 18% and in Germany 110 experts were contacted and 21 responded, a response rate of 19%. Participants were asked how long it took for different aspects of society, including permanent housing, the economy and critical infrastructure, to get back to normal, defined here as a 90% return to the pre-disaster state or a new stable norm? Experts were asked specific questions about the speed and quality of recovery.

1. How long did it take or will it take for the aforementioned sectors to recover 90% or more or to get to a new stable norm?
2. How have the aforementioned sectors changed compared to before the disaster? (5-point scale, much worse to much better plus do not know).

They were also asked questions about the impact of the disaster, the role and performance of the state, the impact of insurance sector on the speed of recovery, and finally about the amount and speed of funding. Statistical tests were used to measure the significance of the results. For ordinal data, for example, impact and vulnerability, the non-parametric Mann–Whitney *U*-test for two sample cases was used. The Kruskal–Wallis ANOVA was applied to multiple samples, for example, to compare quality of recovery in different sectors. For interval data, for example, speed of recovery, the *T*-test was used.

5. Results

5.1 Impact of the floods

There is a growing understanding that speedy recovery and enhanced resilience is associated with a complex interaction of factors including the speed and adequacy of funding, governance, decision-making and preparedness [51]. Nevertheless, the severity of the flood impacts is also important [52–54].

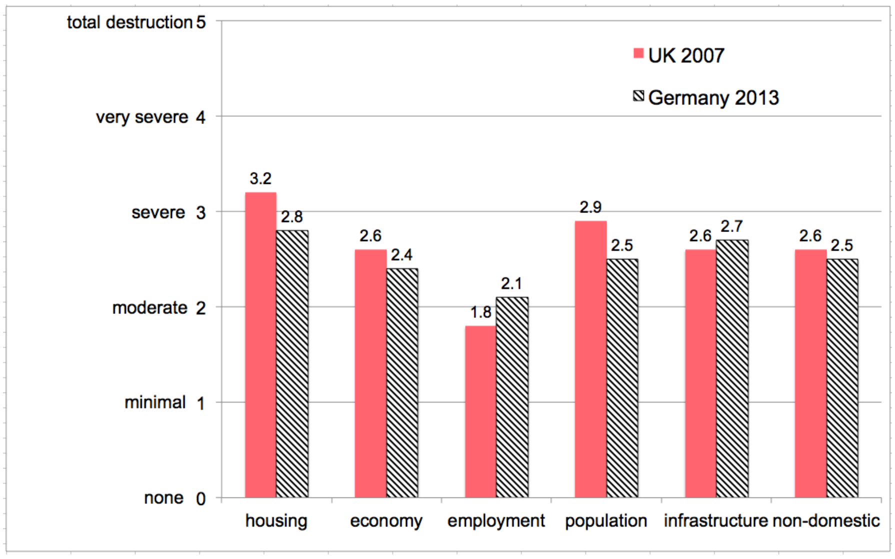

Figure 1 Impact of the 2007 floods in the UK and the 2013 floods in Germany, experts' opinion

Experts in the UK and Germany were, therefore, asked about the impacts, in terms of damage and loss to different socio-economic sectors, of the UK 2007 and the German 2013 floods. Figure 1 shows that, in the opinion of experts, some sectors, for example, housing, suffered a greater impact than others (Kruskal–Wallis ANOVA $p<0.001$). Employment was not as severely affected and one might, therefore, expect it to recover more quickly. The pattern of damage across all sectors was remarkably similar in the two case studies (in all sectors Mann–Whitney U-test $p>0.05$).

5.2 Speed of recovery

A key measure of recovery is the time taken for a household or an area to return to normal after a flood. The survey of local residents showed that the speed of recovery was similar in the two case studies, but slightly faster in Germany, although the difference was not statistically significant (t-test $p>0.1$). In both countries, over half the respondents recovered within 1 year. In Germany, it took about 18months for 90% or more of residents to get back to normal, while in the UK, it took a year longer (figure 2). This difference may be related to the funding mechanism. In the UK, over 90% of funding came from household insurance while in Germany over 60% came from federal aid, which may have been quicker. Of the surveyed residents, in the UK 89% had household insurance that covered flood damage, compared to only 21% of respondents in Germany.

Figure 2 shows a close correlation between local residents' memories of how long it took to get rehoused and experts' impressions of the speed of housing recovery for both the UK and Germany (t-test UK and Germany $p>0.05$). Any small difference may result from a difference in the wording of the question to each group. Residents were asked to say exactly how long it took to get into their own home while experts were asked to say how long on average they thought it took people to be rehoused. It is interesting to see that experts tend to underestimate the rate of recovery of the first two years. However, expert opinions and respondents' experience match for a period of 3–5 years or longer.

Figure 2 Speed of recovery - Residents and Experts

Experts were also asked about the rate of recovery in various socio-economic sectors for both countries. Figure 3 shows the pattern of recovery for the three key sectors of housing, the economy and infrastructure. In both the UK and Germany, experts considered that it took slightly longer for housing to recover than the economy and infrastructure, but any difference between sectors was not statistically significant (ANOVA UK $p=0.2$, Germany $p=0.3$). In both countries, the economy had recovered to near normal within 12–18 months.

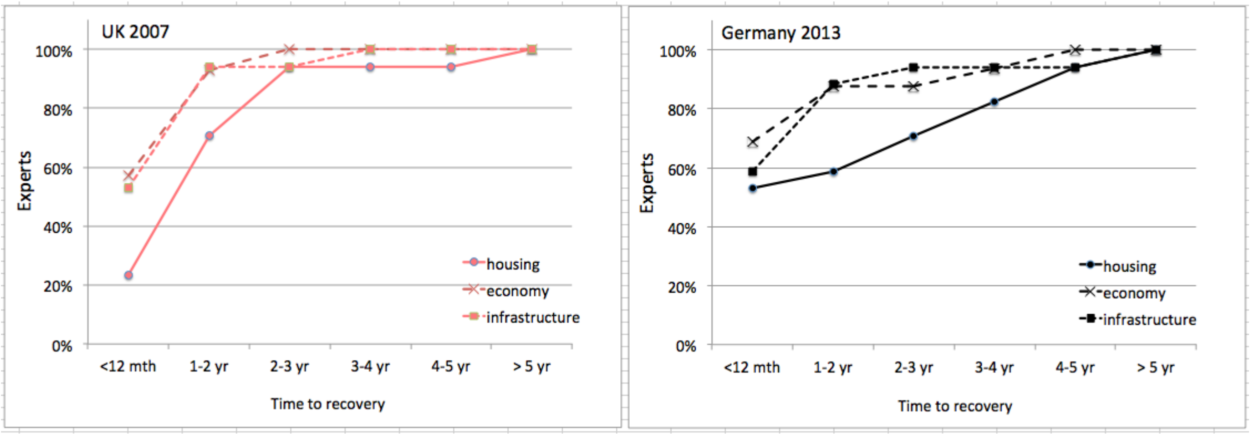

Figure 3 Speed of recovery by sector

These findings are supported by other research. In the UK, at the end of May, 11–12 months after the floods, local authorities estimated that about 75% of households were back in their homes [25] and the economy of the Yorkshire and Humberside Region had returned to pre-disaster production levels within 14 months [55]. In Germany, a survey of 752 flood-prone residents 18 months after the event revealed that 52% of respondents had almost fully repaired the damage to their buildings and 28% of respondents said they were back to normal [33]. Only 20% of respondents were some way from completion or indicated that the flood event still strongly affected them.

5.3 Quality of recovery

Residents were asked about their perception of changes (since the flood) to the flood safety of their home and neighbourhood on a five-point scale, from much safer and better prepared too much worse.

Most interesting, the reported pattern of vulnerability of the home is almost the same in the UK and Germany (Mann–Whitney U-Test p=0.94). Almost the same proportion of residents in the UK (29%) and Germany (26%) believe that their homes are now safer and better prepared than prior to the flood (figure 4). However, the majority of participants in both countries (74% in Germany and 67% in the UK) believe that they are as just as vulnerable now as they were before the flood. These results are supported by a survey of nearly 1000 residents in Saxony [37]. After the 2013 floods, 68% of residents said that their situation in terms of safety and amenity was the same. However, 30% said it was worse or much worse. Similar percentages were obtained for recovery after the 2002 floods (same 69%, worse or much worse 28%).

There was a clear and significant difference in opinion between case studies (Mann–Whitney U-Test p<0.01) in terms of the vulnerability and preparedness of their neighbourhood (figure 4). In the UK half of the respondents thought their neighbourhood was safer and better prepared compared to only 11% in Germany, where 86% thought their neighbourhood was just as vulnerable. This difference in perception may be explained by differences in terms of flood protection and mitigation measures between the two case studies.

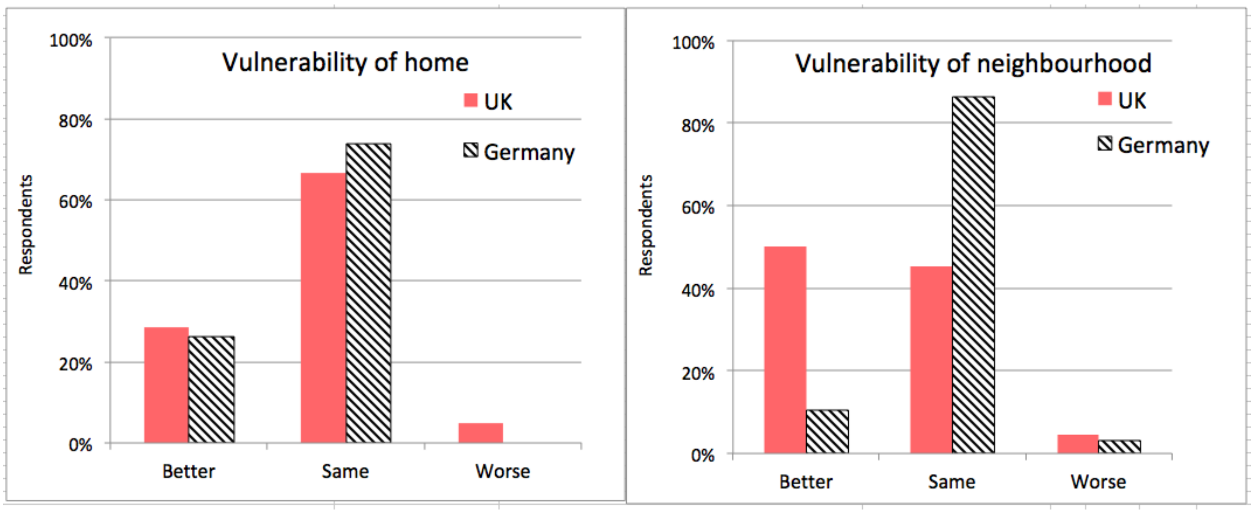

Figure 4 Residents' opinions about vulnerability of their home and neighbourhood

Experts in the UK and Germany were asked detailed questions about how different aspects of society and the economy had changed compared to before the disaster. Figure 5 shows that experts in Germany believe that there has been a modest improvement in all sectors after the 2013 floods (Mean=3.2–3.5, Mann–Whitney *U*-test $p = <0.05$). However, in the UK, experts thought only housing and infrastructure had shown any improvement since the 2007 floods.

Local people were also asked about their level of preparedness. In Catcliffe, 50% of respondents felt they were at high or very high risk of flooding compared to 27% in Passau. Yet only 28% of respondents in Catcliffe and only 15% in Passau felt they and their families were well or very well prepared for future floods.

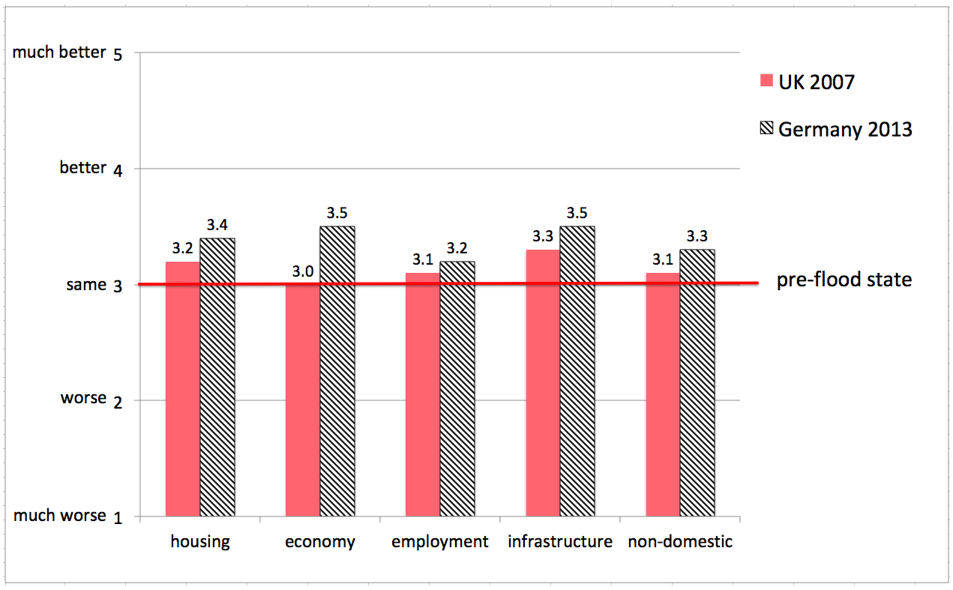

Figure 5 Experts' assessments about change in socio-economic sectors 2007

5.4 Funding recovery: role of the state and the insurance sector

There was a clear difference in funding between the UK and Germany; 63% of experts in the UK considered funding to be inadequate compared to only 6% in Germany. Only 19% of expert respondents in the UK and 5% in Germany thought funding was too slow (figure 6). The key difference between the two countries, however, was the source of funding. In Germany, flood insurance penetration was relatively low at 32% in 2013 compared to 75% in the UK in 2007, which meant recovery in Germany was more reliant on state aid and the Federal Government had to come to the aid of flood victims. These figures correspond closely to those in the case study areas. In Catcliffe, 79% of respondents were insured compared to only 21% in Passau.

The total flood aid budget in Germany was 8 billion, of which 1.5 billion was earmarked to repair federal infrastructure and the rest was split evenly between the federal government and the states [56]. The UK 2007 floods were exceptional and insurers have said that because so many properties were flooded (55 000) it took time to both visit and repair them all, thereby delaying recovery [25]. Nevertheless, over half the experts in the UK (54%) and over a third in Germany (39%) thought that insurance reduced recovery time by 12 months or more (figure 7).

Experts in Germany thought that the Federal and State authorities performed better than UK experts felt the UK local and national government performed. Figure 7 shows that 64% of experts in Germany thought the State performed well or very well compared to only 12% in the UK. Experts in the UK and Germany were also asked what they thought went particularly well or badly in managing the floods. What is striking is that their comments are remarkably similar (table 5). Experts in both countries highlighted an improvement in storm forecasts and warnings compared with previous floods, improved collaboration and coordination between agencies and emergency services, mutual support that meant communities were more resilient and recovered quicker and finally the initiation of flood resilience improvements. In terms of things that went badly experts in both the UK and Germany highlighted the overwhelming scale of the floods, coordination difficulties and long-term psychological issues. On the other hand, the states and task forces were unprepared and under resourced for the scale of the disasters;

flood defences were inadequate and critical infrastructure was vulnerable; and in both countries some flood victims suffered long-term psychological effects.

The benefits of flood insurance are clear: insurance not only compensates for loss but also reduces risk by mapping flood hazard, declining cover and thus encouraging better practice [57]. The Association of British Insurers (ABI) estimate that the average payout for the UK 2007 floods was between £15 000 and £45 000 against an average household insurance premium of £339 [14]. The impact on wellbeing is also significant. A study into the health impacts of flooding in 30 different locations in England and Wales concluded that having adequate insurance cover reduced stress, and incurring uninsured losses had negative health effects [19]. A health impacts survey for the Pitt Review found that being displaced for long periods had a significant effect on people's wellbeing.

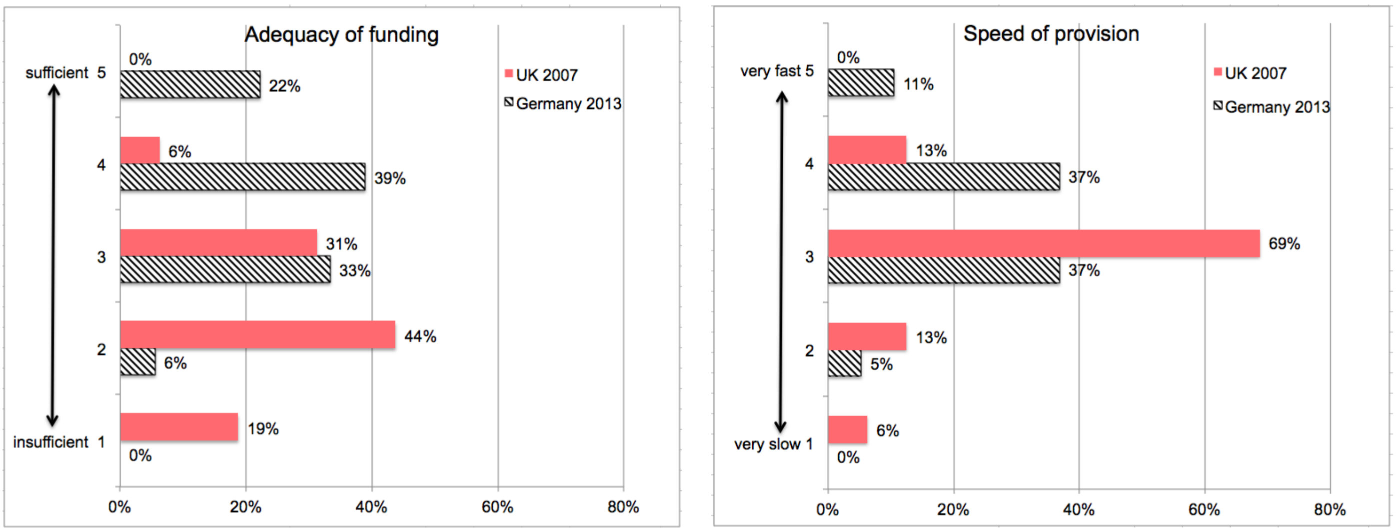

Figure 6 Adequacy and speed of funding recovery

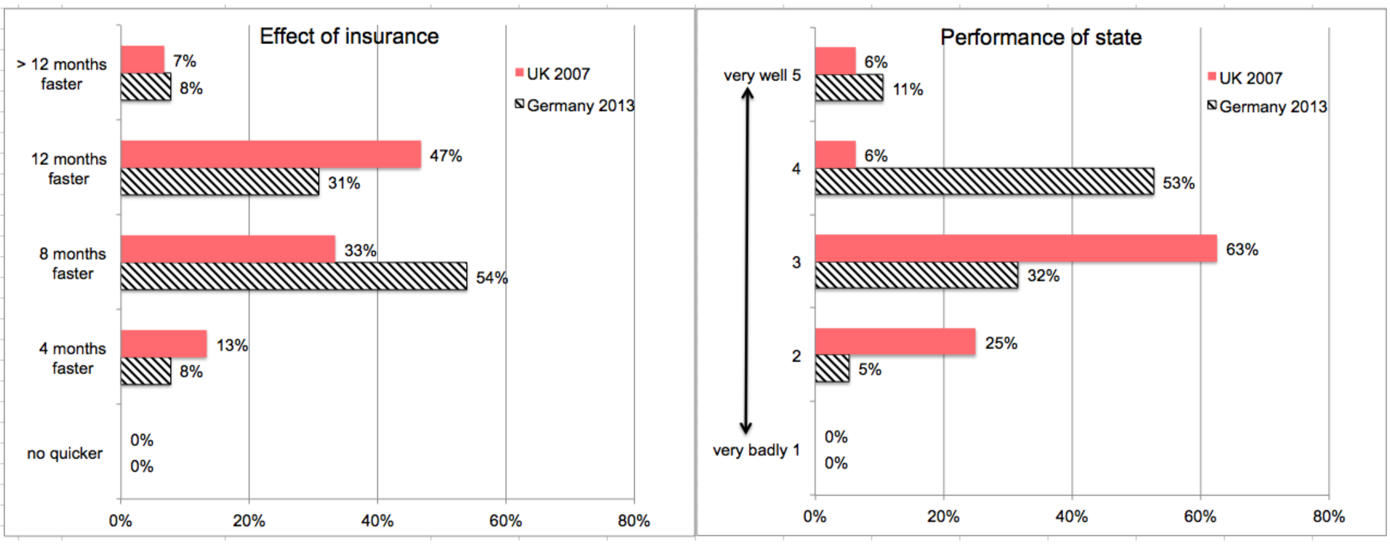

Figure 7 Effect of insurance and role of the state

Table 5 Comments by experts on what went well and what went badly

Germany (21 Experts)	UK (27 Experts)
Things that went well	
– Forecast and warning much better than in 2002 – Cooperation among authorities, and authorities with rescue team – Long term volunteers support – Coordination between volunteers and the city – Better preparedness than 2002 – Awareness and preparation have increased a lot since 2002 – 2013 flood damage was 1/3 of 2002 due to better preparation – Tipping point in disaster preparedness and prevention in regard to flooding and storm surge	– Warning and evacuation better than in 1953 – Swift response of Fire service and Environment Agency – Improved management of communications, better collaboration, better reporting from media – Coordination private and public /charity sector – Local authority wardens worked to build community resilience – Community support and response via social media – Insurance company's initial response rapid – Home insurance helped no end – Floods set in motion a number of important improvements to warning and informing capabilities and more resilient infrastructure
Things that went badly	
– Task forces unprepared for scale of flood – State aid for uninsured injured parties undermines incentive for personal provision – Wrong warning of flood height and flood characteristic surprised residents at night – Some coordination problem in the field due to differences in mentality – Better communication is needed with public, disaster financing and insurance – Getting flood help is too bureaucratic during disaster – Dike defence is not always successful – Slow dyke constructions along the Danube – Long term psychological effects	– State not resourced to deal with severity of flooding across multiple river basins – Local authority almost invisible – Lack of infrastructure preparedness to floods and importance of recovery as an issue to be considered – Co-ordination and preparation poor, few had signed up to flood warnings, few understood division of responsibilities – Water infrastructure inadequate and response of the water company was defensive – Delay to visit and repair all flooded properties, meant people were displaced for a long time – Blocked drains caused flooding – Government grants poorly administered and few people benefitted from available money – Lack of understanding of resilient construction – Inappropriate responses to the recovery and repair of traditionally constructed buildings – Long term psychological issues

In Germany, despite a comparatively lower level of insurance, insurance companies also played an important role in the recovery process, paying 1.8 billion in compensation [37]. Both countries have a private market approach to flood insurance. However, the continued availability of domestic flood insurance at a reasonable cost has been under pressure for some years following an increase in the number and severity of flood events [58]. The increased incidence of flooding presented insurers with a dilemma. Insurers could either carry on facing repeated huge claims from a minority of claimants, or exclude hazardous areas with a high probability of flooding. FloodRe is the current UK approach to deal with the issue that some homes are at such a high risk of flood that they are uninsurable. FloodRe is a not-for-profit reinsurer run by the insurance industry and funding for the scheme comes from a levy on insurers according to their market share. It is only intended to cover those properties most at risk—about 1–2% of domestic households [59,60]. It is still unclear how sustainable this approach is as the levy will taper off and cease by 2040 [61] and FloodRe does nothing to encourage property owners to take flood mitigation measures [62].

After the 2002 floods, the German Insurance Association (GDV) took an important step in flood risk assessment. Advances in geo-information sciences and data availability meant that more detailed probabilistic flood modelling became feasible which meant premiums could be more reliably priced and the risk could be transferred from the state to the private insurance and reinsurance sectors [63]. Insurance penetration although still low in Germany (41% nationwide in 2018) is set to rise substantially as the federal government will no longer offer compensation to the uninsured [64]. Bavaria has announced that, from 1 July 2019, it will no longer provide emergency financial aid following natural disasters to victims who could have purchased insurance [37]. Since 2013, federal states, insurance associations and the insurance industry have adopted numerous measures to increase risk awareness among homeowners and businesses in Germany. The GDV regularly updates and improves its flood mapping and state governments have launched extensive information campaigns.

The insurance sector could play a bigger role in both countries in 'building back better'. Risk reflective insurance premium pricing could encourage engagement with mitigation measures [65], for example through insurance discounts once the measures are installed. In Germany, insured households are more likely to undertake risk reduction measures than uninsured, suggesting that flood insurance does set an incentive for policyholders to take action. However, in Germany insurance companies do little to encourage precautionary measures [40] and in the UK only 55% of insurance brokers thought insurers should allow customers to pay towards more resilient repairs [66].

6. Flood resilience and management

Flood risk is similar in the UK and Germany and the costliest natural hazard in both countries. Yet there are clear economic benefits of improving flood resilience. For example, the monetary benefit of measures designed to keep water out of those properties with an annual chance of flooding of 2% or above outweighs the investment cost by a factor of at least 5 [67]. Significant areas of both Germany and the UK remain reliant on flood protection measures that are at risk [68] and both countries now have broadly similar risk management approaches, namely 'Making Space for Water' in the UK [69] and 'Room for Rivers' in Germany [70], that primarily replace traditional engineered flood defences with a mix of natural flood management measures including regulating land use and promoting flood insurance as a risk transfer mechanism [71]. Both countries are improving their hazard mapping and beginning to tighten land use and planning controls to discourage or prevent development on flood plains. Table 6 lists the key reforms and initiatives and the following section describes the changes in detail.

Table 6 Comparison of post flood initiatives and reforms

Germany	UK
– More effective flood warnings	– Met Office and the Environment Agency joint provision of better flood warnings and mapping
– Elimination of weak point in flood defences; dykes rebuilt or reinforced and mobile flood barriers	– Sector Resilience Plans identify critical infrastructure at risk of flooding
– Nationales Hochwasserschutzprogramm for flood protection	– £2.3bn flood defence spending programme 2014
– Increasing levels of household flood insurance	– Flood Re. Insurance for homes as high risk.
– Mitigation and preparedness measures within properties	– Recommendations to improve property resilience.
– Hazard mapping to control spatial planning and development	– New policy of withdrawal and relocation

6.1 UK flood resilience and management

Progress is being made in improving flood resilience in the UK. Following the 2007 floods in the UK, the Environment Agency warned that the average annual cost of flood damage could rise by 60% by 2035, unless funding for defences was doubled to £1bn a year [72]. The Pitt Review recommended putting communities at the heart of flood management through the strengthening of Regional Flood and Coastal Committees. It also recommended technological advances in managing flood risk [73], developing engagement processes with those exposed to flood risk [74] and recommended addressing the 'recovery gap', which sees residents having to negotiate a maze of agencies and companies involved in flood recovery [75]. In response to the near misses with infrastructure failure in 2007, the UK government initiated sector resilience plans that set out the resilience of critical infrastructure to hazards [76]. These plans are produced annually and assess the risk and vulnerability of each infrastructure sector, the desirable level of resilience, a programme of actions for achieving the desired resilience level and methods of reporting progress [18].

The Flood and Water Management Act 2010 implemented the Pitt Review's recommendations and made unitary authorities and county councils (i.e. upper-tier authorities) the Lead Local Flood Authorities for developing a local flood risk management strategy, cooperating with other risk management authorities, investigating flooding in its area, maintaining a register of structures vulnerable to flood and carrying out works to manage flood risk. An evaluation of the response to the Act by DEFRA concluded that although these arrangements were proving effective their application in different authorities was patchy [77]. In December 2014, the Government announced a £2.3bn flood defence spending programme, meeting the Environment Agency's predicted long-term investment need [78]. The Met Office and the Environment Agency have set up a 'world class' joint office to provide more accurate flood warnings and mapping and the Environment Agency has instigated a series of further developments including making flood warnings available on Facebook [79].

However, the picture is not entirely positive. The Pitt Review called for flood resilience to become the norm and the Bon field Report [80] recommended a package of measures to improve property resilience. But houses are still being built on flood plains and even the most detailed house survey only provides basic information about flood risk and fails to indicate how badly a property could be affected in the event of a serious flood [81]. There is a growing impression that although the UK Environment Agency has made great strides, it does not have strong enough powers, for example it is unable to veto plans to build on a flood plain. Building regulations need tightening and there are concerns about the use of unrealistic hard edge flood mapping that ignores the risk outside perceived flood-prone areas. Most recently, the Environment Agency in the UK has launched a new long-term strategy for flood and coastal resilience that acknowledges that some communities pose such high flood risk that they may need relocating [80].

6.2 German flood resilience and management

In Germany, after the 2002 floods, a number of weaknesses were identified, including deficient flood warnings, poor maintenance of flood protection and a lack of risk awareness. Efforts were made to develop an integrated system of flood management [82] and improvements were made to warnings and dissemination of information, which led to some households being better prepared for the event in 2013. Several legislative initiatives were launched, including the German Flood Protection Act of 2005 and the EU Floods Directive of 2007, that considered both structural and non-structural means of mitigating damage. An evaluation of these post-2002 improvements showed that there had been a greater consideration of flood hazards in spatial planning and urban development, comprehensive mitigation and preparedness measures within properties, more effective flood warnings, a more coordinated disaster response and more targeted maintenance of flood defence systems [34]. These led to better flood management in 2013 and, thus, reduced damage, estimated to be 6–8 billion compared with over 11 billion in 2002. However, in many cases, buildings that were flooded in 2002 were flooded again in 2013 because no improvements to flood resilience had been carried out. There was a lack of awareness about how structures could be made more flood-resistant and little incentive to inform building owners about how this might be done. There are also few rewards to rebuild in a better, more flood-resilient way [83].

After the 2013 floods, the federal government approved a national flood protection programme, the Nationales Hochwasserschutzprogramm, due for completion by the end of 2020. The programme includes dyke relocation, controlled flood retention and the elimination of weak points in existing flood protection [84]. The total budget for the programme is 5.4 billion. Similar to the UK, there is an increasing emphasis in Germany on citizens' taking responsibility for their own flood preparedness and protection. A survey of 889 households affected by the 2013 floods explored ways of encouraging citizens to take responsibility and improve household resilience in partnership with the State [85]. There is evidence homeowners are willing to make investments in mitigation [86] and research suggests that to increase take-up communication in Germany should focus on the potential of flood mitigation measures to effectively reduce or avoid flood damage, as well as on information about how to implement such measures in practice [31].

7. Conclusion

7.1 Speed of recovery

Summarizing the results of the surveys of residents and experts in the UK and Germany, the impact of the floods across various sectors and the speed and quality of recovery was remarkably similar in both case studies. In both case studies, over half the respondents recovered within 1 year. In Germany, it took about 18 months for 90% or more of residents to get back to normal, while in the UK it took a year longer. In Germany, 93% had returned to normal in under 2 years, while in the UK, 78% had recovered in the same time period. These differences may be related to funding; in the UK, over 90% of funding came from household insurance while in Germany over 60% came from federal aid, which may have been quicker. In both countries, the economy had recovered to near normal within 12–18 months.

Comparing the speed of recovery in different sectors, experts in the UK and Germany consider that employment and infrastructure recovered more rapidly than housing, although the differences were not that pronounced.

7.2 Changes in resilience

Only a small proportion of residents in the UK (29%) and Germany (26%) believe that their homes are now safer and better prepared than prior to the flood. The majority of people surveyed in both countries (74% in Germany and 67% in the UK) believe that their homes and businesses are as just as vulnerable now as they were before the respective floods. This reflects the fact that most homes were repaired without the addition of any flood protection or damage alleviation measures. By contrast, half the respondents in the UK (50%) thought their neighbourhood was safer and better prepared compared to only 11% in Germany, where 86% thought their neighbourhood or town was just as vulnerable. In the UK, the survey was conducted in an area where the Environment Agency has installed major flood protection measures since 2007.

7.3 Were the floods 'gamechangers'

Extreme events can be catalysts for policy change and both floods provoked significant changes in flood awareness and preparedness [87,88]. In the UK, the 2007 flood was called a 'game changer' and in Germany the 2013 flood in Germany was described as a 'focusing event' [89]. It is fair to conclude that both floods may be considered as 'game-changers' and resulted in a heightened awareness of flood risk, increased investment in flood defences, clearer and more accurate flood warnings and an increasing emphasis on citizens taking more responsibility for flood preparedness [90]. In the UK, after a period of considerable investment in flood protection the Environment Agency is currently consulting on a new policy of strategic withdrawal. In Germany, flood insurance may soon become the norm as the federal government reconsiders its role in providing aid.

In Catcliffe, substantial progress has been made in improving flood protection since 2007 [91] by raising the piling along the River Rother and by building a new slipway on the Ulley reservoir. Local volunteers have also helped clear debris from drains and culverts. In Dreiflüsse-Eck damage to historic buildings, including the theatre, the new town hall, museums and university, increased political pressure on the Federal government to increase spending on the Altstadt-Passau Flood Action Programme 2020 and the Danube Flood Protection Programme [92].

However, with several years' hindsight, it is apparent that important aspects of flood management and risk reduction remain unclear and that much still needs to be done. In the UK, the Environment Agency lacks powers to prevent development in flood risk areas, householders with homes at risk are not installing mitigation measures and the FloodRe approach to uninsurable homes is unsustainable. In Germany, there are issues of coordination across large catchments that cross regional, state or national borders and some of the risk reduction measures have proved to be ineffective [93]. Many homes and businesses continue to be at risk from major floods and more progress needs to be made in making them more resilient and in both countries the insurance sector could play a much bigger role in ‘building back better’. Homes and businesses will continue to be damaged in major floods. The speed of recovery will most probably remain the same and it will be difficult to reduce recovery time for badly flooded homes to less than 18 months. Further progress needs to be made in making homes and businesses more resilient.

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Article 5: Tourism Recovery Scorecard (TOURS) – Benchmarking and monitoring progress on disaster recovery in tourism destinations

Abstract

After a disaster, tourism declines and tourist stakeholders suffer because tourists cancel their reservations and choose to go elsewhere. A key part of managing recovery of tourism destinations is restoring the destination image and reputation which can be affected by negative or inaccurate media coverage. This paper reports the results of surveys with tourism sector stakeholders aimed at measuring recovery in three tourism destinations affected by two back-to-back disasters: the Bohol earthquake and tropical cyclone Haiyan in 2013 in the Philippines. The authors developed a methodological framework for the Tourism Recovery Scorecard (TOURS), which can be used as a crisis communication tool for benchmarking and monitoring progress on post disaster recovery of a tourism destination. Three main dimensions of safety, physical recovery and business recovery are considered in the Scorecard, each containing key factors that are important to tourists and meaningful to tourism operators.

1. Introduction

Natural and man-made disasters, including the impacts of geological events, climatic disasters, terrorism and war, have the potential to severely affect the image of a tourism destination. How the tourism destination, prepares for and adjusts to disaster situations has not received a great deal of attention in tourism management research, even though most if not all destinations face the prospect of either a natural or human-induced disaster at some time in their history. Faulkner & Vikulov [23] report how after cyclonic flooding washed out Katherine Gorge in Northern Territory Australia, the tourism industry was faced with the huge challenge of restoring operations to normal. Despite the effectiveness of a "Katherine Back On-track" campaign, tourism operators incurred significant short-term financial losses because the perception of Katherine being washed-out lasted for some time beyond the reality. Following the Indian Ocean 2004 tsunami, widespread international media attention resulted in an immediate drop in tourist visits in the year following the tsunami (e.g. [26,49,39,52]). There was a rebound to near pre-tsunami tourism arrivals once resorts had been repaired or reconstructed [49]. In addition to natural disasters, terrorism attacks since the events of September 11th, 2001, which dramatically impacted the tourism industry, illustrate the need for better crisis communication and perception management of such incidents [41].

The impacts of disasters on the tourism market are often out of proportion with their actual disruptive effects because of exaggeration by the media [14,19,32]. The damage to businesses caused by the disaster escalates with negative media coverage and a ruined destination image [45]. As a result, the recovery of destinations usually takes longer than the time needed to restore services to normality [22]. The effectiveness with which the tourism industry in a disaster area handles a crisis in terms of a crisis communication strategy has a major bearing on how quickly the destination is restored to normal and businesses recover [5,7,21,40,9]. Media reports have the potential to have a devastating impact on disaster-affected destinations and present a severe challenge to the marketability of a destination and even result in a collateral marketing crisis in neighbouring destinations [10,11]. As a result, trusted government organisations such as the chamber of commerce or private sector operators, such as destination marketing organisations, tour operators, travel agencies, hotel associations and individual hotels must have targeted communication plans and strategies to address media reports and be able to directly address tourists' concerns in the aftermath of disasters. The efficacy of a crisis communication strategy in managing risk perception hinges to a large extent on the degree to which communication plans have been integrated within disaster risk management policies and strategies and the industry is able to communicate true positive messages to the market [22,16,6]. This explains why some models for tourism disaster plans (see, for example, [28,53]) tend to emphasise market communication considerations.

Proactive policy-making, planning and implementation of disaster risk reduction (DRR) are likely to enhance the sector's ability to recover from crises and disasters. However, particularly for tourism destinations, disasters can have longer-term effects and recovering from a crisis goes beyond the task of repairing the physical damage and building back better. It has also a lot to do with managing the media and restoring the destination's image and encouraging visitors to return. Factual, up-to-date information about safety and the status of infrastructure, attractions, accommodation, restaurants and other facilities ensure tourists are aware of areas which are not affected so they have alternative destinations within the same area if they need to evaluate their travel plans. Providing access to objective and reliable information also helps to combat media sensationalism and ensures visitors can make an informed choice. This paper reports the development of a set of indicators, gathering data to measure these indicators, drawing recovery graphs and reporting this data in a 'Tourism Recovery Scorecard' to report the level of readiness of the destination to welcome tourists back. The main aim of the paper is to develop and test the methodology behind the assessment in a pilot study that was carried out in three tourism destinations in the Philippines.

2. Measuring tourism destination recovery

There are numerous sets of indicators on sustainable tourism destination management (e.g. [51], but most make little mention of tourism destination safety or disaster resilience, two concepts which would seem to be central to a sustainable tourist sector. Research into tourism crisis indicators in sustainable tourism has tended to focus on identifying those indicators that monitor the negative impacts of tourism on the destination rather than on indicators that measure recovery after disaster [20,29,42,47]. On the other hand, within the field of disaster risk reduction (DRR), various disaster recovery indicator frameworks with considerable variation in their structure, content and complexity have been proposed and applied for establishing baselines and benchmarking disaster recovery of communities and geographic regions in general (e.g. [13,15,17,30,37,38]). The indicator frameworks developed in these studies depend largely on the context to which disaster recovery applied and the disciplinary background of the authors. For the most part, disaster recovery is not confined to infrastructure systems alone, but encompasess also social entities: the city dwellers, decision makers, and political groups.

Relatively fewer studies have focused on indicator frameworks for disaster recovery of tourism destinations. To develop a comprehensive indicator framework that conceptualises a tourist destination's recovery as a human-environment (or socio-ecological) system, the concept of resilience and recovery has been explored in several studies related to tourism. For example, in relation to the management of tourism protected areas [46] or community governance [43]. Organisational or business resilience has been another focus of tourism researchers. In the context of Indonesia, and as part of a longitudinal study, Dahles and Susilowati [18] established three different resilience attributes, namely survival, adaptation and innovation. The ability to innovate was also of particular importance in the recovery of businesses following the Christchurch (New Zealand) earthquake [35]. Taking a slightly different approach Biggs et al. [12] aimed to measure the resilience of tourism businesses, for example by assessing financial and social capital, and self-reported lifestyle benefits. Various best practices were developed specifically targeted at the tourism industry with considerable variation in their structure and content were reviewed and for establishing baselines and comparing disaster recovery of different tourism destinations (Table 1).

Table 1 Examples of selected best practices developed for disaster risk reduction in the tourism sector

Tool	Year	Purpose	Organisation/ Source
Handbook on Natural Disaster Reduction in Tourist Areas.	1998	Awareness raising, and provision of a range of useful templates, for example for disaster communication and press releases	World Tourism Organisation and World Meteorological Organisation
Tourism Risk Management for the Asia Pacific Region: An Authoritative Guide for Managing Crisis and Disasters	2006	Targeted at government decision-makers and tourism industry members in Asia and the Pacific. Offers a broad coverage of threats and hazards relevant to the tourism industry, and strategic ways to respond to them.	APEC
Bounce back: Tourism Risk, Crisis and Recovery Management Guide	2011	Information on crisis/risk management and resources, including media templates and checklists.	PATA http://www.pata-thailand.org/ source/PATA_Bounce_Back_Crisis_Recovery_Guide.pdf
Visitor Action Plan to prepare for natural disasters, a guide for tourism organisations	2011	For regional tourism organisations and councils to achieve better integration of systems and structures	Becken and Hughey [8]

Utilizing the above studies and best practices a framework of targets and indicators for measuring recovery in tourism were identified for post disaster recovery of tourism destinations. This framework has been operationalized in the Philippines in a Scorecard approach that can be used in benchmarking the impacts of the event along key dimensions of tourism recovery and monitoring progress on the level of recovery of a tourism destination. The Scorecard approach provides a monitoring tool to identify the level of recovery by gathering and analysing data on the recovery of a destination and report this evidence in a form stakeholders can understand easily and use to recover tourism in the affected area. Thus, the Tourism Recovery Scorecard (TOURS) is designed to be used by tourism stakeholders, including tour operators, government and public sector and visitors to tourism destinations with two key aims: Firstly, devising an efficient and cost effective way of gathering reliable information at repeated time intervals; and secondly, reporting this data in a clear simple and highly visual way that tourist, tourist media and tour operators can immediately understand.

Tourist destination recovery is defined here in terms of a return to a feeling of safety and normality, clearance and repair of physical infrastructure and the recovery of tourist numbers and hotel bookings. Disaster recovery can be considered for multiple time frames (i.e. immediate, short-term, mid-term, long-term). In the implementation of TOURS, we considered the immediate aftermath of an event as well as periodic surveys within the short- to mid-term following an event as the most appropriate benchmarks for informing tourists of the post disaster situation, as this corresponds to the timelines that are most likely to coincide with media coverage of disaster impacts in a tourism destination. In addition, three dimensions of recovery are used in TOURS: safety, physical recovery and business recovery. This classification corresponds to various concepts of resilience into economic, physical and psychological dimensions (for example [37,38]). Of course there is no single 'right' way to classify indicators and other researchers have grouped indictors of resilience and recovery in various other ways. Paton [36] conceptualises resilience as the capacity community members, businesses and societal institutions to respond to crises. Cutter et al. [17] classify their 'baseline resilience indicators' into 5 groups: social economic, institutional, infrastructure resilience, and community capital. The UN Office of Disaster Risk Reduction [48], p. 25) defines disaster recovery in terms of livelihoods, health, economic, physical social, cultural and environmental assets, systems and activities. Platt et al. [37] grouped their 12 indicators of recovery monitored using data from satellite imagery into 6 groups: transport, buildings, transitional shelter, services, environment and livelihoods. What is important though is that the categories of things or activities the groupings signify are intelligible and relevant to the intended audience. Our initial conception categorised indicators of recovery into 3 groups: perception of danger, visible damage and tourism economy. The names of these dimensions changed during the study to safety, physical recovery and business recovery.

Trusted government agencies, such as the chamber of commerce or the department of tourism, as well as key private sector stakeholders, such as hotels and hotel associations, tour operators, and national and international travel agencies, are the imagined main 'stakeholders' for this information. These groups need trusted information and evidence to attract tourists back and to return the tourist sector to how it was before the event. It was also imagined that if this system were to be adopted in the Philippines, or elsewhere, the scorecard would be updated at regular intervals, possibly each month, and reported in a press release and on tourist agency websites.

3. Pilot application in Philippines

The study area is in the Central Visayas region of the Philippines (Fig. 1), specifically Bohol, Cebu and Bantayan islands, which are popular tourist destinations in the Philippines. The yearly high season of tourism in the study area ranges from December to April because of the cooler and pleasant weather, while the low season ranges from May to November due to the hot temperatures and high rainfall amounts, and even extreme weather such as torrential downpours and typhoons.

The Philippines is one of the most disaster prone countries in the world. It ranks fifth in the world in terms of number of natural disaster events per year [25]; an average of 20 typhoons hit Philippines every year [31] and the World Bank Risk Index (2016) ranks the Philippines as the third most at risk-prone country in the world in terms of natural disaster after Vanantu and Tonga [50].

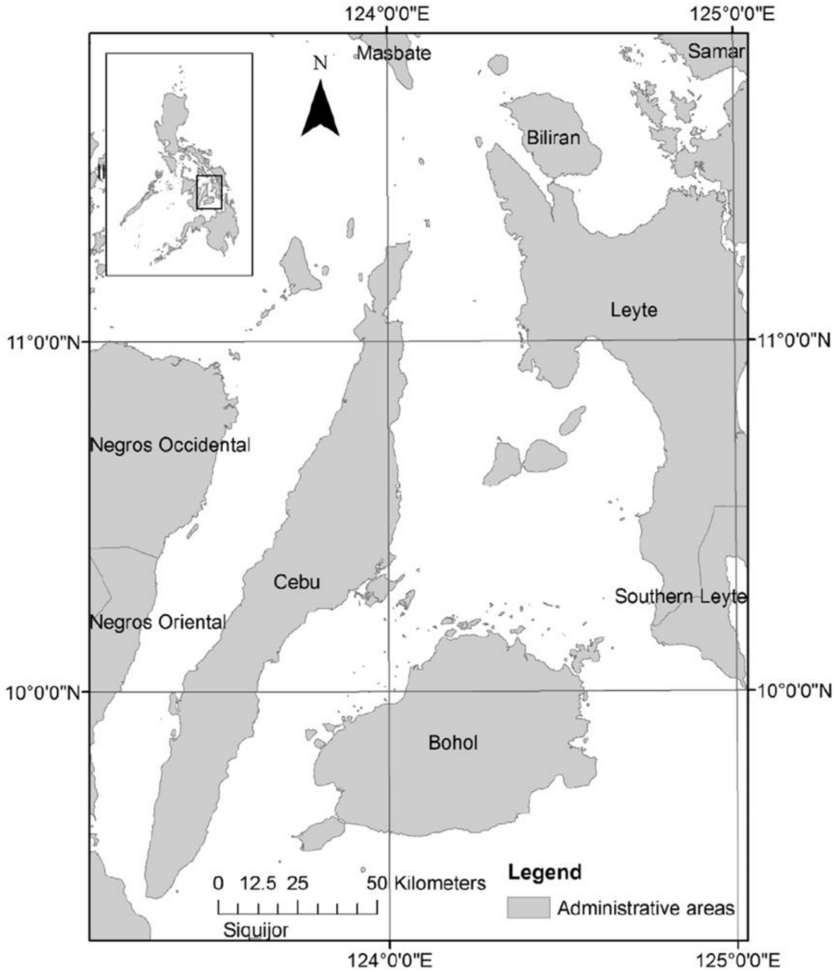

Figure 1 Study area. Central Visayas region in the Philippines

The study area in the central Visayas region of the Philippines was devastated by a magnitude 7.2 earthquake (Bohol earthquake) and a super typhoon (Haiyan) on 15 October 2013 and 8 November 2013, respectively. The twin disasters led to extreme loss of life and widespread damage to the infrastructure and natural landscapes. While the Bohol earthquake earthquake affected the whole Central Visayas region, its impact was highest in Bohol, where the epicentre of the shallow earthquake was located, and in Cebu. According to official reports by the National Disaster Risk Reduction and Management Council (NDRRMC), 222 were reported dead, 8 were missing, and 976 people were injured. In all, more than 73,000 structures were damaged, of which more than 14,500 were totally destroyed [33,34]. On 7 November, just 3 weeks after the Bohol earthquake, Super Typhoon Haiyan struck the region. Although the storm's eye missed the area affected by the earthquake, it sent some 40,000 Boholanos still living in temporary shelters back to evacuation centres and disrupted relief efforts in the province (Matus, 2013). Tropical Cyclone Haiyan (8 November 2013) caused catastrophic damage throughout much of the islands in the Visayas, reaching speeds more than 185 kph devastating cities on its paths as well as damaging tourism infrastructure such as coastal resorts. Haiyan is the strongest storm recorded at landfall, and the deadliest Philippine typhoon on record killing at least 6300 people in that country alone. It destroyed 550,000 homes and caused damage losses of $2.9 billion (NDRRMC, 2014).

According to a World Bank survey in 2013 [24] p XIV) the Central Visayas region suffered from major economic impact, and hundreds of tourists were left stranded by the storm for days. The impact of the storm on tourism made for a week of international headlines, frightening away tourists across the central Philippines and triggering mass cancellations [44]. Resorts at major destinations such as Boracay, Palawan, Cebu and Bohol saw cancellation rates of 30–40%, according to Cesar Cruz, President of the Philippine Tour Operators Association in Manila." [4] p1). Slow progress of government response to the postdisaster recovery was reported even after one year since the disasters [1,2]. Many tourists were hesitant to visit the Visayas islands, due to their perception that the islands were not ready for tourists (Philistar, 2016). Due to the major impact to the tourism industry by these events, this area is an ideal study area for us to monitor and assess its postdisaster tourism recovery.

Despite the magnitude of the events tourist numbers actually increased in all of the Philippines by one-third the following year (2014). As shown in Fig. 2 the trend in international tourist arrivals in the Philippines from 1996 to 2015 shows a fairly constant 8% increase. The twin disasters of 2013 appear to have resulted in only a minor dip in this trend to 3% increase (2013–2014). Interestingly, tourism receipts actually increased by 23% from 276 million USD in 2013 to 340 million USD in 2013 in the Philippines, indicating other non-affected destinations in the Philippines more than absorbed the temporary disruption to tourism in the Visayas as a result of the Bohol earthquake and Haiyan typhoon. At first sight this seems a surprising finding, however, there is evidence from other places that disasters have only a relatively small impact on the national economy. Nevertheless, the impact on the regional or local economy can be devastating. It is crucial, therefore, that reliable data is collected and tools are developed that measure recovery on the local and regional level, and only at the aggregate national level. In 2013 in the Philippines, after the twin disasters of earthquake and typhoon, it is important for the survivors, the residents and tourist industry, that the destination recovers swiftly and, just as importantly, that progress is reported effectively to convince tourists that it is safe and convenient to return.

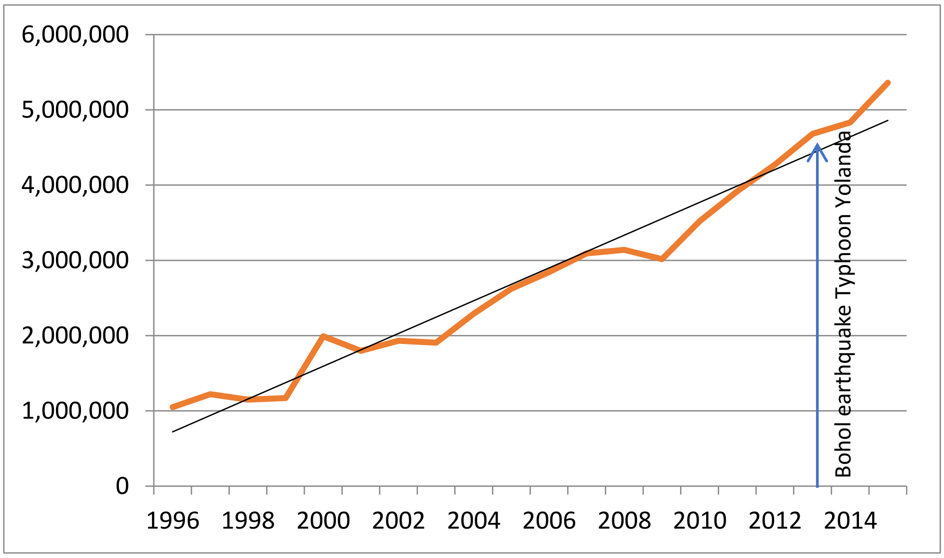

Figure 2 Philippines tourist arrivals (Source: FFCCCII, 2014)

4. TOURS implementation in the Philippines

A research team from the Karlsruhe Institute of Technology (KIT) conducted a stakeholder survey in August 2016, 2.5 years after the 2013 Bohol earthquake and Typhoon Haiyan. One of the difficulties of doing research this long after an event is the reliability of survivors' memories, since the interviewees memories of the timing of recovery might unreliable and they might exaggerate or underestimate time intervals. In our survey we carefully selected respondents in the tourism industry who were present at the time of the event and we thought would be a reliable witness of the disaster recovery.

Five indicators were used to measure each of the three dimensions of recovery: safety, physical recovery and business recovery, plus an overview indicator for each dimension resulting in a total of 18 indicators in the TOURS survey tool (see Table 2). During both workshops and key informant interviews in the Philippines, a total of 40 people, working in the tourism sector were surveyed (see Table 2). To help benchmark the survey and trigger the responders' memories of the recovery following these events, we referred to two 'snapshot' timings. We have labelled these two timelines as: Right After (the event) and New Year. In terms of recovery timelines, Right After is the immediate response phase following the event, while New Year is the transition period between short- and medium-term recovery, which occurred 2.5 months after the event or around the time of New Year. These labels provided clear associations to the participants in our surveys for which we could establish specific timelines. For example, New was the first tourist season after the disaster and responders are likely to remember this time more clearly. Having a snapshot right after the disaster provided a measure of the severity of damage in the destination, against which we could assess the recovery after 2.5 months.

Two rating scales were used– a binary scale where the respondent said whether the indicator had recovered or not and a 10 rating point in which respondents said by what percentage a particular indicator, for example electricity supply, had recovered. The binary scale was an attempt to get more reliable results and make it easier and quicker for interviewees to respond by devising questions demanding only Yes or No answers, where YES indicated a full recovery. For example, people were asked if electricity was fully restored by the first New Year after disaster or not. The first survey was conducted in a workshop in Bohol City with 17 participants. They reported that Bohol had experienced difficulties after the earthquake and faced severe economic problems when tourist numbers fell after the disaster. The result of the questionnaire was not as expected. The interviewees had great difficulty being forced to choose simple Yes or No answers. They wanted to be able to say by how much an indicator had recovered, since many aspects of the destination were not fully recovered by New Year, but had recovered sufficiently to welcome tourists.

In the second workshop, held in Cebu city, we had another opportunity to evaluate the questionnaire by using it with people from public and private tourism sectors, including tour operators and hotel managers. One of the advantages of this gathering was although the workshop was held in Cebu city; participants also came from Bantayan, Bohol and Manila. In this workshop in Cebu, as well as binary yes-no questions, interviewees were asked to score the level of recovery on a scale of 0–10, in which 10 meant fully recovered. In total the field trip collected 40 interview responses, 20 for binary scale and 20 using the rating scale.

Table 2 Indicators used in the survey in the Philippines

Safety	To what extent:
Reputation	was he destination was reported as safe on: TV, Radio, Print Media; Social Media; Word of Mouth
Hazard	did you feel safe in relation to future natural hazards?
Health	was health and spread of disease controlled?
Security	was the destination safe in terms of crime/ terrorism?
Stability	was the destination politically stable?
Overview	did the destination feel safe for tourists?
Physical recovery	To what extent:
Roads	was debris cleared where tourists go?
Electricity	was electricity restored?
Water	was drinking water restored?
Attractions	have attractions been restored?
Transport	have transport systems been restored for: Flights; Ferries; Public Transport; Private Car?
Housing	have people been rehoused?
Overview	does the destination look recovered?
Business recovery	To what extent:
Foreign	has foreign tourism recovered?
Local	has local tourism recovered?
Occupancy	have hotel bookings recovered?
Services	have restaurants, shopping, tourism agencies/services; ATM recovered
Telecoms	have mobile phone networks recovered
Overview	has tourism recovered?

Table 3 shows the breakdown of informants by role, which workshop they attended and which form of questionnaire; rating or binary scale was applied. It should be emphasised that this sample is too small to provide an adequate assessment of recovery in the three destinations in the pilot. A much larger sample would have been needed to provide valid and reliable data. This however, was not the purpose of the study. The main aim was methodological – to develop a set of indicators to measure recovery and a scorecard reporting system.

Table 3 Key informants interviewed and answering questionnaire

International	Tourism Experts	3
National	Governmental Organizations	6
Tour Operators and Others	National	7
Hotel and Resorts	Bohol	8
	Cebu	8
	Bantayan	6
	International	2
Total		40

	Rating Scale	Binary Scale
Cebu	12	3
Bohol	6	11
Bantayan	2	6
Total	20	20

5. Results

Fig. 3 shows the comparison of rating and binary scale in Cebu city, each color represent one dimension of recovery and each dot is related to one of the sub-indicators of each dimension. Fig. 3 compares overall recovery in the three cities, Cebu, Bohol and Bantayan for Right After the disaster and New Year. Comparing average recovery right after the disaster using the two scales in Cebu, it is clear that the 10-point rating scale provides much more credible and consistent results than the binary scale. The rating scale scoring was consistent between different respondents whereas the binary scale gave widely divergent scoring (See Fig. 3). It would appear that the over simplification required of the respondents in using the binary scale gave unreliable and inaccurate readings of recovery. The following results, therefore, only used rating scale data.

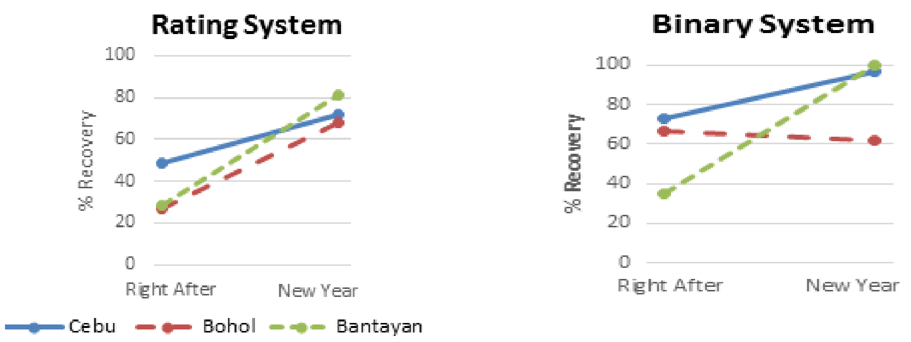

Figure 3 Comparison of rating and binary scales in all three cities

Table 4 shows summary results for the three cities. Cebu was the least damaged of the three cities according to the respondents interviewed (48% physical and 41% business) and felt the safest of the three. Bohol and Banatayan were assessed as having a fairly similar level of damage right after the disaster. By New Year all three cities had recovered dramatically with Bantayan showing the biggest improvement on all three dimensions.

Table 4 Summary recovery for 3 cities and 3 dimensions

Undamaged Right After disaster			
	Safety	Physical	Business
Cebu	57%	48%	42%
Bohol	30%	23%	29%
Bantayan	36%	25%	25%

Recovery by New Year			
	Safety	Physical	Business
Cebu	75%	72%	70%
Bohol	67%	67%	70%
Bantayan	87%	79%	79%

Fig. 4 compares the recovery in the three cities for the two time snapshots – the percentage undamaged right after the disaster and at New Year, 2.5 months after the disaster. In Fig. 4 each of the corners of the triangles represents one of the three dimensions of recovery (safety, physical recovery and business recovery) and the outer black triangle represents full or 100% recovery. The smaller dotted triangle in the centre, showing the situation right after the disaster shows, Cebu had the least damage compared to the other two cities and Bohol and Bantayan are very similar on all three dimensions. By New Year, after 2.5 months, Bohol had recovered to the same level as Cebu but Bantayan is less recovered and less ready to welcome tourists.

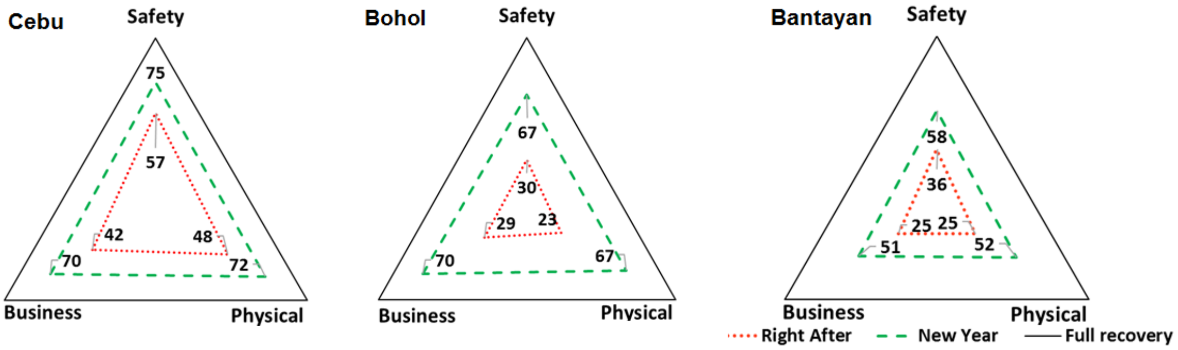

Figure 4 Comparison of recovery Right After disaster with New Year

Each recovery dimension has five indicators (See Table 1). For example, physical recovery includes road, electricity and water, attractions, transport, and housing recovery. There is also an ‘overview’ indicator for each of the three dimensions in which the interviewees are asked, for example, about “Overall Physical Recovery”. The results of physical recovery are shown in Fig. 5 as an example.

Fig. 5 shows the breakdown of different components of physical recovery from right after the event to New Year. The slope of the lines indicate the speed of recovery with steeper slopes showing a faster recovery rate. It can be seen that across all three cities electricity was restored most quickly by New Year (30% in Cebu, 63% in Bohol and 80% in Bantayan). In Cebu with the exception of electricity, all of the physical recovery indicators recovered at almost the same speed, whereas in Bohol the recovery rates are much more variable from right after the event to New Year. Electricity and water show the fastest recovery rate to over 80% by New Year, whereas as other indicators such as housing recover at a much slower rate, in this case short of 40% by New Year. This is due to the earthquake in Bohol that impacted the physical infrastructure and the rate at which infrastructure was restored and people were rehoused was slower than in Cebu. Bantayan, which was most heavily impacted by Typhoon Haiyan, also indicates the slowest recovery. In Bantayan as was also evident from our site visit, housing recovery has been very slow and by New Year had recovered only 10%.

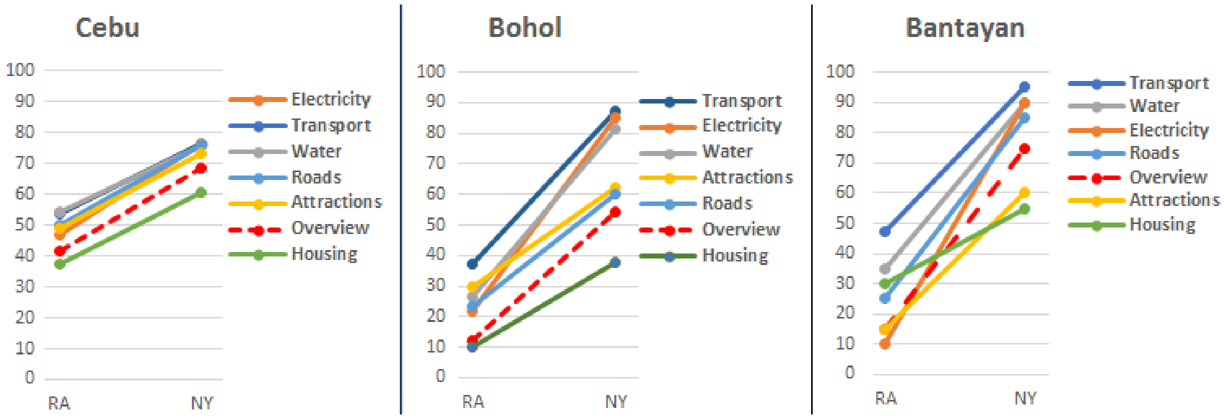

Figure 5 Comparison of speed of recovery after disaster for physical recovery sub-indicators in three cities.

The recovery across the three different destinations is shown in Fig. 6. It can be seen that across all destinations business recovery had the highest speed of recovery by New Year followed by physical recovery with safety having the slowest recovery.

Figure 6 Comparison of recovery for all indicators in Bohol, Cebu and Bantayan.


BOHOL
Safety
Reputation
Feeling safe
Health
Security
Stability
Roads / Debris
Physical
Electricity / Water
Attractions
Transportation
Rehousing
Business
International / Occupancy
Local Tourism
Hotels / Restautants
Banks/Shopping
Telecomms
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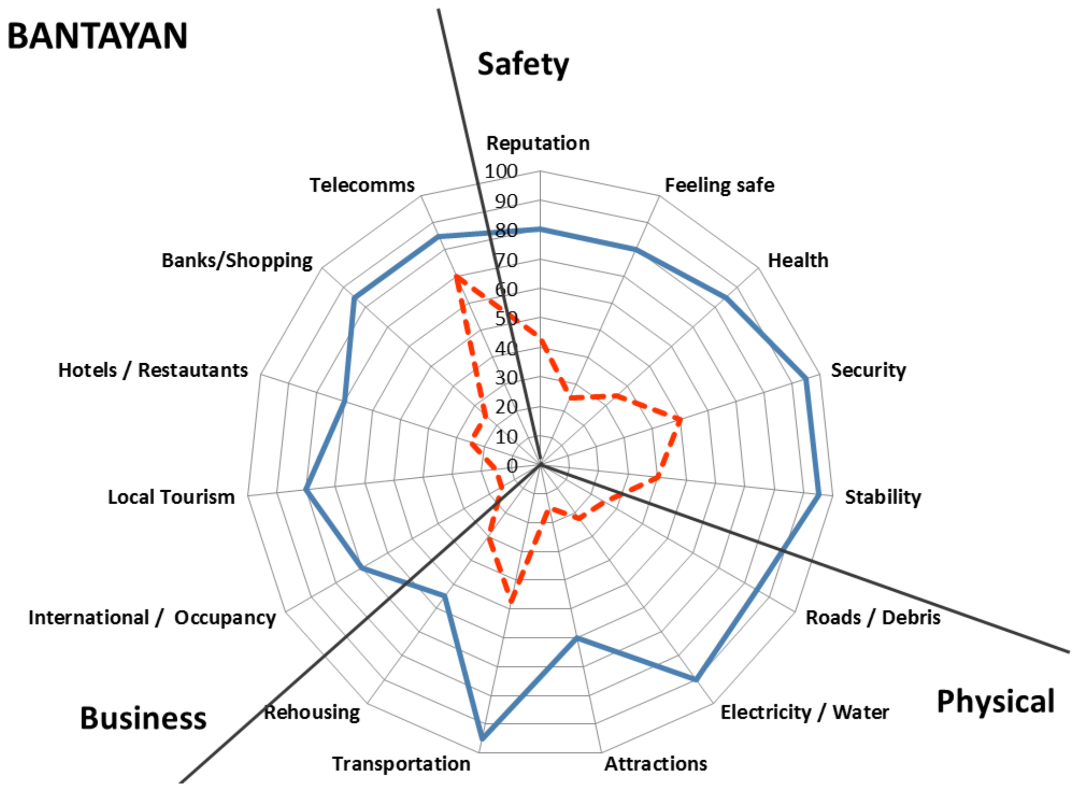
2,0
1,0
0,0


BANTAYAN
Safety
Reputation
Feeling safe
Health
Security
Stability
Roads / Debris
Physical
Electricity / Water
Attractions
Transportation
Rehousing
Business
International / Occupancy
Local Tourism
Hotels / Restautants
Banks/Shopping
Telecomms
100
90
80
70
60
50
40
30
20
10
0

The focus of recovery seems to have been mainly on business recovery and reinstating services for foreign and local tourists including shopping centres, telecommunications and banking facilities, because the economy of the area is dependent on tourism. Physical recovery also needed to be improved, in terms of removing debris and repairing roads and bridges and reinstating public transportation. However, changing people's perception of safety according to the respondents interviewed needs more time. It is apparent though that news reports via social media, word of mouth, TV and radio have a large role both nationally and internationally in improving people's perceptions.

5.1. Safety

The feeling of safety in relation to future natural hazards was equally bad in Bohol and Bantayan immediately after the disaster (10%) whereas it was five times as high in Cebu (51%), but by New Year, the feeling of safety in Bohol and Banatayan had improved to the same levels in Cebu (between 70–80%). The difference seems to be the positive effect of the media promoting the perception of safety in all these destinations in the period following the event.

5.2. Physical recovery

Bantayan seems to have made the fastest physical recovery. However, the sample in Bantayan is much too small to have confidence in this finding. Nevertheless, despite the initial heavy damage, water and electricity supply and the town centre and tourist attractions were recovered quickly in both destinations. However, debris still needed to be cleared in places tourists visit in both destinations (Bohol 60% recovered and Banatayan 58% recovered). Cebu was less damaged than the other two destinations and most indicators had recovered to 75% or more of the pre-disaster level by New Year. Yet the overall impression on physical recovery was only 68%. Cebu is a large city and the north part was seriously damaged while others parts were relatively undamaged. Some of the respondents were unhappy with progress in the entire city and maybe this affected their overall impression of recovery. Another factor was progress on rehousing displaced families was relatively slow and was only at 61% by New Year.

5.3. Business recovery

Local tourism recovered equally fast in all 3 destinations, and by New Year all three were welcoming Philipinos from all around the country. But booking rates for hotels in Bohol increased by 44% (from 18% to 62%) compared to 31% in Bantayan (15–47%). Nevertheless international tourist numbers, although still only half pre-disaster rates, increased a similar amount in Bohol and Banatayan (from 15% to 47% or 48%).

One of the most interesting findings was that when people are asked to think about recovery of the detailed indicators one by one, they are happier answering, have better recall and give more accurate answers about the speed of the recovery process than when they are asked summary questions about whole areas of recovery. To illustrate this, the average recovery for the sum of the detailed is compared with the “overview” summary measurement in Fig. 7.

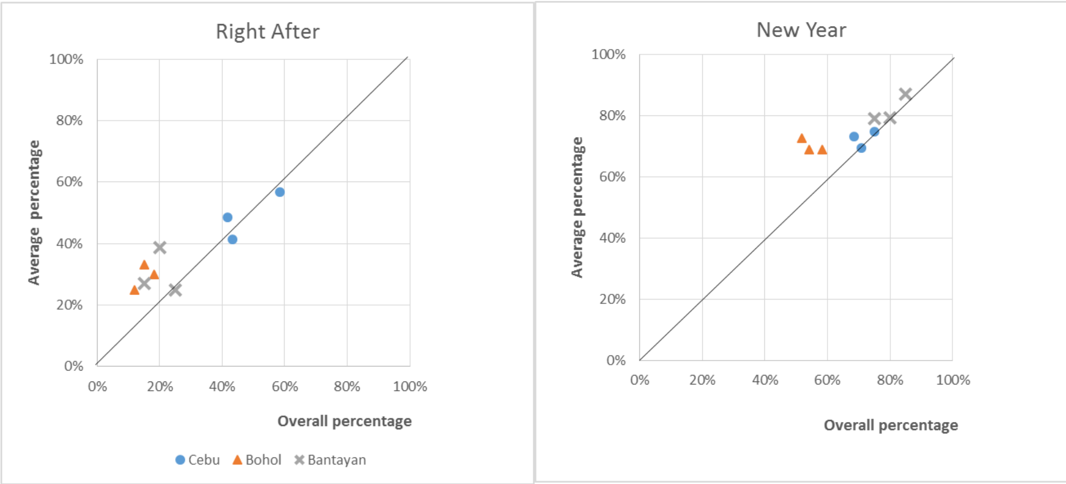


Figure 7 Overall impression compared to average of individual indicators.

6. Discussion

The discussion is organised in terms of a series of questions.

6.1. Did key informant interviews with stakeholders provide valid and reliable data?

As described earlier the methodology used was a survey with a small group of 40 carefully chosen 'expert' stakeholders from the tourism sector. They represented a wide range of organisations: 6 were from the national government tourism department, 7 were tour operators, 24 were local hoteliers or tour operators and 3 were international tourism experts, all of whom had experienced the disaster and been involved in the recovery in different capacities. The question is; did they provide valid, accurate and reliable data or were their answers biased and either overly positive of negative?

Key informant interview is a technique that is widely used to gather people's perceptions of a phenomenon. For example Platt et al. [37] used key informants to measure recovery and resilience over 9 sectors after the Indian Ocean tsunami 2004 and the Pakistan earthquake 2005. The key informants were 10–12 community leaders in each of the local towns that suffered major losses. Although the key informants' assessments were subjective and relied on memory, the data was extremely accurate and corresponded closely to that obtained from detailed satellite imagery analysis.

In any reporting of this kind there is a trade-off between simplicity and detail. Our initial instinct was that the indicators used to measure and the scorecard used to report should be as simple as possible. We therefore developed a binary set of indicators and a simple traffic light type scorecard. In the event, the pilot study in the Philippines suggests that one can over simplify. The two key methodological findings were that the tourist professionals we interviewed were uncomfortable being asked to give simple binary answers and that their overall perceptions of recovery were more pessimistic than their more detailed assessments of each indicator would suggest. Firstly, they much preferred to be able to give graduated answers, for example roads were 70% cleared. Secondly they were significantly more pessimistic when asked to assess overall recovery on each of the three dimensions – safety, physical and business recovery, than the average of individual indicators would suggest. Typically their overall assessment of recovery was 10% less than the average of the detailed dimensions. We concluded that a detailed survey instrument allowing graduated assessments of 15 indicators gives a more valid and reliable measure of recovery than a simple binary assessment of three summary dimensions.

6.2. Was the speed of recovery different in the three cities?

By New Year Cebu had recovered the most followed by Bohol and then Banatayan (see Table 4). But according to official damage reports, and confirmed by the interview data, Cebu was significantly less damaged than the other two destinations. So the scale of damage goes some way to explaining why Cebu had recovered so well by New Year. The combined effects of the two disasters almost equally damaged Bohol and Bantayan, from the evidence of the interviews. However, we know from news reports that although Bohol was badly hit by the earthquake, some parts of the city were undamaged by typhoon. In contrast Banatayan was much more heavily affected being nearer to the storm track [24]. But scale of damage is not the only issue; a secondary factor may be size of settlement. Cebu and Bohol are much larger than Bantayan; the respective population of the three cities in 2015 was Bohol 1.3 million; Cebu 866,000 and Banatayan 125,000. Larger cities can mobilise more resources in terms of expertise and finance to aid recovery and this is likely be an important factor in speeding recovery.

6.3. How consistent was the scoring between respondents?

There was most agreement between respondents in Bantayan and least in Cebu. Nevertheless, the level of agreement between the respondents overall was fairly high, with the following exceptions. In Cebu the respondents disagreed most about the speed of business recovery. They also disagreed about a number of safety indicators. In Bohol respondents disagreed both about the level of damage and of recovery for transportation and telecommunication networks. They agreed about the overall level of safety right after the disaster. In Bantayan there was disagreement in the "right after" disaster timeframe about the role of social media as well as local tourist business recovery by New Year.

6.4. At what scale should recovery be reported?

A key issue in developing a system to monitor and report recovery is the question of scale. Much of the current reporting of disaster recovery in the international press is at the countrywide scale. For most disasters this is too coarse. For example, in the Philippines the impact of the two disasters was centred on the island of Bohol and on Central Visayas [24]. The Philippines comprises over 7000 islands, only one of which, Bohol, was impacted by the earthquake and relatively few were seriously affected by Typhoon Haiyan. The way many visitors think about tourist places, and the way the tourism industry packages holidays, is in terms of destinations. This, therefore, is the scale adopted here. However, we need to acknowledge that the level of damage and recovery is not even over the whole of a destination. Bohol is a large island and Cebu a large city and some parts were more damaged than others.

6.5. How should the results be communicated to tourism operators, the media and to potential tourists?

It is imagined that in a tourist destination that had suffered a major natural disaster the recovery assessment described in this paper, using key informants to assess a range of 15–18 indicators, be conducted at regular monthly intervals. Based on our field study experience selection of key informants for the survey is of critical importance to the validity and credibility of results. Careful stakeholder mapping must be carried out beforehand to select a diverse, well-informed, reliable and representative group of stakeholders so that the survey results are trust worthy and are used. Statistical analysis should be carried out with outliers removed from the responses. As part of the communication strategy the visual representation of possible scorecards must be investigated. Initially we had thought that these might be in the form of a 'traffic light' red to green scale rather like the energy rating scale. This format is currently being used to report disaster casualties and loss (See Fig. 8).

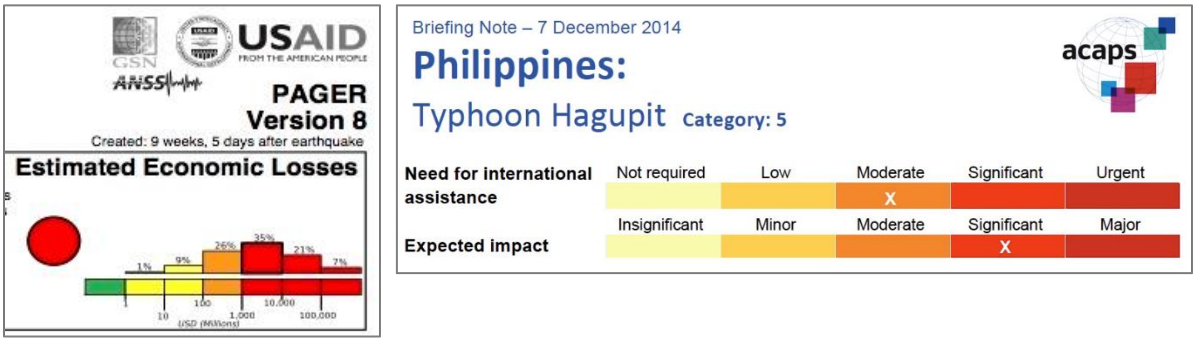


Figure 8 Examples of disaster scorecards (USGS 2016; [3])

7. Conclusion

The main aim of this study was to develop a method of monitoring tourism recovery after natural disasters using key informant surveys. Accurate, timely and 'user-friendly' reporting of recovery is a crucial part of supporting the perception of recovery in a tourist destination with fact-based information.

The main conclusion is that key informant interviews with a relatively small group of stakeholders, can give reliable and accurate data that would support a simple cost effective means of providing regular recovery progress reports. The main advantage of key informant survey as a method is that it is extremely efficient, quick and cheap in terms of data gathering and analysis. This is important, since what is being proposed is a simple cost effective technique that can be repeated in frequent regular intervals, for example once a month, during the first couple of years of recovery.

8. Recommendations

The approach developed in this pilot study has wide applicability to other tourist destinations in other countries and other types of natural disaster.

8.1. Method of assessment

Since it is envisaged that the main audience for this recovery reporting is people working in the tourism sector, for example hoteliers, tour operators and tourist agencies, reporting using 15 indicators in spider graph is preferred to the simple traffic light system of reporting. However, further work needs to be done to establish which method of reporting might work best for tourists planning to visit places recently affected by disasters and it may prove that a simple traffic light system is preferable.

8.2. Responsible authority

The key issue for communicating this sort of information is 'can it be trusted?' People will quickly get a feel for this, and if it is not considered useful and trustworthy it will be ignored. It is recommended therefore recommended that the government tourist board in the disaster affected country, in this case the Philippines, set up a system of regular systematic data collection and reporting based on a carefully chosen set of key informants in each of the main tourist resorts. It is further recommended that the number of informants need only be in the region of 10–12 in each place to provide reliable data. Over time this agency, if it provides accessible, transparent information that corresponds to people's own individual perceptions, will gain in authority and credibility.

8.3. Communicating to end-user tourists

It is recommended that further work be conducted to establish the best way of communicating recovery to tourists contemplating a holiday in a resort recovering from a disaster. In particular, a simple traffic light system should be trialled and compared to the kind of more detailed reporting proposed for the TOURS system.

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