Planning for resilience to extreme weather events in Oman,2000-2015

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Abstract

Natural disaster risk is increasing globally (UNISDR et al., 2014), hence attention on disaster risk reduction has increased too. A key outcome of the Third World Conference on Disaster Risk Reduction (2015) was the Hyogo Framework for Action (HFA) (UNISDR, 2015a), a plan to increase community resilience to disaster. The disaster management system in Oman is new, with little research conducted to date, hence the five thematic areas of the HFA plus the component of resilience were used to create a framework to guide this research into understanding the level of resilience to disaster in Oman and how this could be enhanced.

Understanding the recent performance of the relevant organisations is important to identify the strengths and the weaknesses of the disaster management system in Oman. Comparing the resilience performance of HFA components against the global average, and those in other Arab states helps to identify the real position of Oman in developing disaster resilience, and weaknesses that require attention. In the research, the hypothesis that disaster resilience performance was a function simply of national wealth and hazard frequency was rejected. Therefore, the factors impacting organisational performance with respect to resilience were investigated using Fuzzy Cognitive Mapping across a broad range of stakeholders. A conceptual model was then created from the identified variables based on the thematic areas of the HFA, from which the weakest and strongest areas of HFA performance in the disaster management system of Oman were identified, including consideration of how performance in one HFA theme area affects others. The research reveals a reactive disaster management system in Oman, and a need to improve prevention and preparedness. Finally, recommendations to improve community resilience to disaster in Oman are made.

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List of Abbreviations

Directory of Meteorology and Air Navigation	DGMAN
Disaster Risk Reduction	DRR
Early Warning Centre	EWC
Emergency Centre for Health Crisis	ECHE
Emergency Events Database	EM-DAT
Flash Flood Guidance	FFG
Fuzzy Cognitive Map	FCM
Global Assessment Report	GAR
Governance	G
Hydrological Research Centre	HRC
Hyogo Framework for Action	HFA
Indian Metrological Department	IMD
Intergovernmental Panel on Climate Change	IPCC
Joint Typhoon Warning Centre	JTWC
Medical Response and Public Health	MRPH
Ministry of Education	MOE
Ministry of Oil and Gas	MOOG
Ministry of Social Development	MOSD
Ministry of Transport	MOT
National Committee of Civil Defence	NCCD
Oman Charitable Organisation	OCO
Oman News Agency	ONA
Preparedness and Response	PR
Public Authority for Stores and Food Reserve	PASFR
Public Authority of Civil Defence and Ambulance	PACDA

Public Authority of Electricity and Water	PAEW
Public Awareness	PA
Risk Assessment	RA
Risk Management	RM
Social Network Analysis	SNA
Standard Operating Procedure	SOP
United Nations Development Program	UNDP
United Nations Office for Disaster Risk Reduction	UNISDR
World Meteorological Organization	WMO

Chapter 1 Research overview and introduction

1.1 Introduction

The community is the place where people live and share many characteristics and ties: language, locality, culture, and social interests (UNISDR, 2006). Different features characterise communities and make them different from others and in consequence make community needs different (UNISDR, 2006). Communities are adversely affected by hazards, but the severity of the impact of a natural hazard depends on the resilience of the community. Resilience is the ability of the community to withstand or cope with change and is dependent on the institutions and organisations that structure the community. Climate change is increasing the frequency and severity of hazardous weather events (IPPC, 2012). At the same time, rising populations and urbanisation are increasing the probability of an adverse weather event having a major negative social and economic impact (ECHO, 2015). Coastal areas are particularly vulnerable to cyclone storm surges. This thesis investigates the institutional and planning arrangements that have been put in place to protect coastal communities from such threats in Oman, specifically with reference to tropical cyclones.

Oman is at risk from tropical cyclones generated in the Arabian Sea (Membery, 2002). In 2007, coastal communities in Oman were unprepared when a category five tropical cyclone (Guno) made landfall in northern Oman and hit the capital city, Muscat (Al-Awadhi et al., 2009). The cyclone caused massive damage to infrastructure and killed 100 people (Evan and Camargo, 2010). The relative infrequency of these cyclones means that Oman is a vulnerable country to natural disasters, such as cyclones, as they do not occur often enough for resilient social structures to be in place. The country is seeking to build resilience to different types of disaster by changing planning laws and introducing disaster response measures (NCCD, 2013; DGMAN, 2014a). The concept of disaster planning, including mitigation and preparedness, is starting to take a central place in institutional strategies; and building resilience for individual and institutional systems is being recognised as important for reducing the risk of disaster. This shift in emphasis can be seen in several recent projects, such as the development of an early warning system and standard operating procedure (SOP). However, the institutional arrangements and cooperation for disaster management are widely perceived to be weak and in need of policies and actions to enhance institutional response to natural disaster risk. For example, the [disaster] planning regulations are not clear, and there are no roles to control the planning process, and there is no specific institution controlling the whole planning process from preparation to updating. Also, no systematic analysis of institutional responses to natural disaster risk, and specifically cyclones, has been conducted.

1.2 Research aims and objectives

The assumption behind this research is that there are some specific institutional and organisational structures and systems that affect the ability of organisations to respond to disasters through planning, based on the likelihood of hazards, and which determine the capacity and commitment of the organisations that can help communities. The institutional factors related to natural disaster risk management, including roles, organisation, and processes, do not currently facilitate the most effective possible management of natural disaster risk in Oman. Finding these key structures and systems, and changing them to increase community resilience, will help to improve the process of disaster management.

The focus of this study will be on the institutional arrangements that determine the co-operation in Oman that is necessary to build communities resilient to the effects of extreme weather disasters. At the end of the study we expect to have an improved understanding of the institutional system that exists to manage risk from natural hazards and develop community resilience strategies, and thus address the main goal of this study, which is to make Oman more resilient to extreme weather events.

Oman is a good place for this study because the institutions in Oman, and the organisations formed under them, are not connected, with each one having a different planning system. In particular, the co-operation and commitment between the institutions appear weak. Also, people in the coastal areas are particularly vulnerable because not only is there a hazard from cyclone storm surges, but also from flash floods, resulting from high rainfall in the mountains inland.

The study’s aim, concerning natural hazard (cyclone) risk, is to develop an understanding of the process of building community resilience through relevant institutions and the factors affecting this resilience building process. The research examines organisations in Oman with a role in building resilience to extreme weather events, with a particular focus on institutional arrangements and networks, primarily at the national level, and how these operate to build resilience to disasters at all levels. To address this aim the research seeks to analyse organisations working in disaster management, and then use this analysis to inform a critical evaluation of the institutional risk management processes. The research applied the Hyogo framework for action as an international arrangement to understand the resilience level in Oman, which is compared to resilience at international and regional levels.

The central research question addressed by this study is: **What institutional arrangements are needed to build community resilience to occasional severe hazards?** To answer the central question of this research, the research will address the following sub-research questions:

1. To what extent are organisations in Oman able to manage disasters? This then leads on to the practical question: what would be the best planning system and regulations for disaster management in Oman?
2. To what extent are organisations in Oman implementing HFA resilience components?
3. What are the institutional factors affecting the capacity of the organisations to respond to disasters? How can we improve them to build community resilience to disaster?

1.3 Research structure

This section introduces the different chapters of the study and the link between them. Figure 1.1 shows the organisation of the chapters in the thesis, and how they are linked to achieve the main objective of the thesis.

1.3.1 Chapter 1 Research overview and introduction

The chapter introduces the research questions and explains why Oman is a good place to conduct the research. The chapter presents the main question and the sub-questions for the theses and the framework of the research. The framework summarises the question, the research method, the data of the research and the training that the researcher needs.

1.3.2 Chapter 2 Theoretical approach

This chapter reviews the theoretical approach of the research. The chapter introduces the concepts of natural hazards, vulnerability, disaster management and planning for community resilience.

1.3.3 Chapter 3 Emergency management in Oman

This chapter reviews the literature that focuses on hazards and disaster management in Oman. It gives a contextual background and looks at the different types of natural hazards, vulnerability to them, and the disaster management system. The chapter will clarify the gaps in knowledge in Oman and the framework this research adopts to fill these gaps.

1.3.4 Chapter 4 Methodology

This chapter sets out the research methodology which is in three sections. Section 1 reviews the methods that have been used in the literature to analyse risk, risk assessment and disaster management at the institutional level. Section 2 explains the methods used to answer the sub-questions in this study for data collection and analysis. Section 3 explains why this study is important for the researcher and reflects on how the researcher’s background influences the nature of the research.

1.3.5 Analysis chapters

The research has three analytical chapters. The main aim of the research is to examine the challenges around the concept of resilience within the context of disaster risk reduction (DRR) in Oman. Chapter 5 assesses the organisational capacity and stakeholder involvement in disaster management in Oman. Chapter 6 studies the implementation of the Hyogo Framework for Action (HFA) in Oman. Chapter 7 investigates the factors affecting disaster management resilience in Oman.

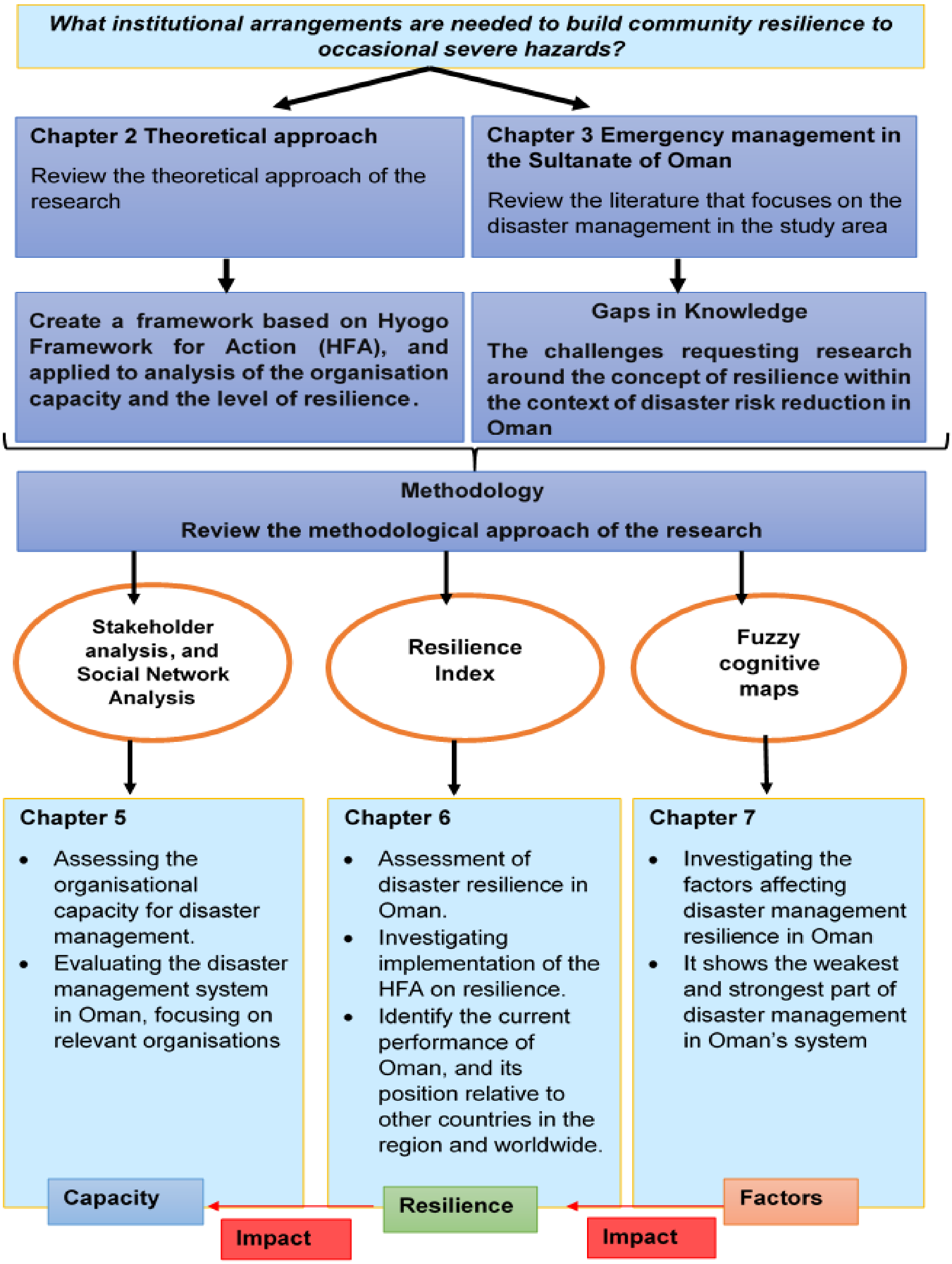

Figure 1.1 Structure of the research chapters and links between them

Chapter 2 Theoretical approach

2.1 Introduction

This chapter reviews the theoretical approaches which will be used in this study to understand community resilience to extreme weather events. The concept of resilience has been applied in this study to identify the capacity of the organisations in Oman and their ability to cope with these disasters. The chapter presents a theoretical approach to understanding the relation between the concept of resilience and the cycle of disaster risk reduction.

The Hyogo Framework for Action and Twigg (2009) have been applied in this thesis to understand the level of resilience to disaster in Oman, and to build the framework of the study. HFA has five priority actions to achieve the main strategic goal of building resilience and disaster risk reduction. Twigg (2009) simplified HFA and made it clearer and easier to implement. In this study, the HFA for action and the resilience components provided by Twigg (2009) are applied as a theoretical framework to investigate the capacity of the organisation and their resilience to disasters. The HFA and Twigg resilience components are applied in chapter 6 to discuss the implementation of the HFA in Oman, and the level of progress. In chapter 7 the theoretical theme is applied to investigate the factors affecting disaster management and resilience performance in Oman.

This chapter discusses Oman's natural hazards (section 2.2), disaster risk and disaster risk reduction (section 2.3), vulnerability (section 2.4), and resilience (section 2.5). The Hyogo Framework for Action is discussed in detail in section 2.6.

2.2 Natural hazards

Natural hazards like floods, earthquake and hurricane are regular events and only become disasters when they impact people or ecosystems (UNEP, 2002; O'Brien et al., 2006). Natural Disaster is “a natural event such as a flood, earthquake, or hurricane that causes extensive damage or loss of life” (Oxford, 2014). UNDHA (1994a) Identify a disaster as a severe interruption in the performance of society, causing great human, physical or environmental losses that exceed the ability of the affected society to deal with its resources.

Different approaches are used to classify natural disasters; one of these approaches divides natural hazards depending on the spatial scale of impact, small scale and large scale (Middleton and Sternberg, 2013). The small scale hazard can cause less damage and kill fewer people in a small area, like lightning strike and tornado (Middleton and Sternberg, 2013). Large-scale hazards like cyclones, droughts and volcanos can cause damage across a big area and kill many people (Middleton and Sternberg, 2013). Another approach, which is used by the Emergency Events Database (EM-DAT)1, is classifying natural hazards by type and subtype (Guha-Sapir et al., 2012). EM-DAT distinguishes natural hazards as geophysical, hydrological, metrological, climatological and biological (Guha-Spair et al., 2012). Table 2.1 displays the disasters classification used in the EM-DAT database (Guha-Sapir et al., 2012). It is clear that the atmosphere is the origin of risks in this classification, except for geophysical hazards (Middleton and Sternberg, 2013). However, a tsunami is generated by geophysical hazards and can cause flood risk in coastal areas.

[1] EM-DAT is the international disaster database (OFDA/CRED): www.emdat.be and is operated by the Université Catholique de Louvain, Brussels, Belgium

Table 2.1 EM-DAT disaster subgroup definition and classification.

Disaster Subgroup	Definition	Disaster main type
Geophysical	Event originating from solid earth	Earthquake, volcano, mass movement (dry)
Meteorological	Events caused by short-lived/small to meso-scale atmospheric processes (in the spectrum from minutes to days)	Storm
Hydrological	Events caused by deviations in the normal water cycle and overflow of bodies of water caused by wind set-up	Flood, mass movement (wet)
Climatological	Events caused by long-lived/ meso to macro scale atmospheric processes (in the spectrum from intra-seasonal to multi-decadal climate variability)	Extreme temperature, drought, wildfire
Biological	Disaster caused by the exposure of living organisms to germs and toxic substances	Epidemic, insect infestation, animal stampede

[Source (Guha-Spair et al., 2012)]

According to the UN, the number of natural disasters and the losses associated with them has increased globally (UNISDR et al., 2014). For example, the number of meteorological hazards increased intensely from 1900-2010. In the period 1900-1920, the number of meteorological hazards recorded by EM-DAT was 33 events, rising to 1,517 in the period 1981-2000, and to 1,044 in the next ten years. Table 2.2 shows some of the natural disasters by type from 1900-2010 (EM-DAT, 2014). The table displays that the number of atmospheric hazards hugely increased. Climate change, according to IPPC, affects the frequency, intensity, type, time and duration of this danger (IPCC, 2012). It is clear that climate change has led to climatological, metrological and hydrological hazards becoming more frequent and intense in the last two decades (UNISDR et al., 2014; Oh and Reuven, 2010).

Table 2.2 Natural disasters by type 1900-2010

Year	Geophysical	Hydrological	Meteorological	Climatological
1900-1920	75	12	33	18
1921-1940	72	29	75	18
1941-1960	120	124	190	18
1961-1980	232	528	526	201
1981-2000	590	1,779	1,517	614
2000-2010	352	1,949	1,044	501
Total	1,441	4,421	3,385	1370

[Source: (EM-DAT, 2014)]

Rapid urbanisation increases the number of people who live in hazard areas, increasing the socio-economic vulnerability and overall risk (UNEP, 2002; IPCC, 2012). Furthermore, a change in urbanisation patterns and economic conditions, for instance, increase of settlement in coastline and flood-prone areas, could increase the number of people vulnerable to disaster (UNEP, 2002; IPCC, 2012). Increase in the number of natural disasters and vulnerability to them can reduce the economic activity in the affected country (Oh and Reuveny, 2010; UNISDR et al., 2014). In 2011, the economic losses were estimated at $370 billion worldwide, significantly more than the losses of 2010, which were valued at $226 billion (UNISDR et al., 2014). Over the last 40 years, the total number of deaths due to natural disasters has exceeded 3.3 million, with some 304,000 fatalities in 2010 alone (UNISDR et al., 2014). Worldwide people are suffering from natural disasters due to the massive increase in socio-economic vulnerability (UNEP 2002; UNISDR et al., 2014). The number of people who have suffered from a natural disaster has increased in the last two decades.

For instance, the number of affected people in the 1990s was about 211 million; this number increased in the 2000s to 233 million (UNEP, 2002; EM-DAT, 2014). Earthquakes are causing the highest number of deaths worldwide (UNEP, 2002; EM-DAT, 2014), with the total number of people killed by earthquakes in the last decade estimated at 680,365 (EM-DAT, 2014). An earthquake in Bam, Iran in 2003 killed 43,000 people (Middleton and Sternberg, 2013). Next most significant are storms, which have killed some 173,718 people in the last decades. Notable events include Hurricane Katrina in 2005 which devastated New Orleans, Louisiana, causing more than $180 billion of damage and leaving more than a million people homeless (Oh and Reuveny 2010, Arrighi et al., 2013).

Floods come in different forms, such as river floods, flash flood, or floods caused by storm surge or cyclone, and have killed an estimated 62,458 people in the period 2000-2010 (EM-DAT, 2014). Large flood hazards are also created by tsunami which can leave huge numbers of people dead (Løvholt et al., 2012). For example, the 2004 Indian Ocean tsunami killed more than 220,000 people in 13 countries (Middleton and Sternberg, 2013).

2.3 Disaster risk and Disaster risk reduction

Disaster risk implies possible losses in social, economic, and physical systems in a particular community from individual or multi-hazards (UNISDR, 2004a; UNISDR, 2009c; Schwieger et al., 2006). O'Keefe et al. (1976) discuss the interface between extreme natural events and vulnerable people, whilst Brooks and Adger (2003) state that “natural disaster is a result of the interactions between natural hazard and vulnerability”. Disaster risk is thus an outcome of the interaction between natural or human hazards (H), and vulnerability (V) (Schwieger et al., 2006; Cutter and Finch, 2008; Karmakar et al., 2010; Flanagan et al., 2011; Wamsler et al., 2013). Thus Disaster Risk (R) = Hazard (H) * Vulnerability (V).

Increasing understanding of disaster risk and socio-economic vulnerability has moved the focus from the traditional risk management toward disaster risk reduction (UNISDR, 2004a; Pearce, 2003). Pearce (2003) outlined four steps for this shift in disaster management. The first is the shift from the focus on the hazard to the vulnerability to disaster risk management. The second step is the shift from the reactive to the proactive which moves the focus from response and recovery to community planning. The third step is the shift from a science-driven approach to multidisciplinary one that addresses differential vulnerability in the community. Finally, the fourth step is the co-operation between disaster managers and community planners which emphasises stakeholder and public involvement in the decision-making (Pearce, 2003).

Merz et al. (2010) focus on potential future changes, believing that economic development and climate change should be included in risk management to reduce the disaster risk. Thus planning for the long and short term in the hazard area will lead to reduced disaster risk. For instance, the European Floods Directive focuses on flood risk reduction in the development management plans in an area with significant flood risk (Merz et al., 2010). The plan is looking to reduce the impact of the floods on the affected area for the long term, with a focus on mitigation and resilience building.

Disaster risk reduction has a conceptual framework of components giving possibilities to reduce vulnerabilities and disaster risk by preventing or limiting the adverse impacts of hazards, within the broad context of sustainable development. (UNISDR, 2009b). Salceda, in the UNISDR (2012) "*Handbook for local government leaders: How to make cities more resilient*, describes disaster risk reduction as "investment, not a cost as it increases business returns" (UNISDR, 2012, p.6). For instance, Salceda outlines that "Albay [Philippines] has seen a surge in investment, even after typhoons and volcanic eruptions. Risk reduction allows development to proceed amid disasters since they do not disrupt people's lives when the local government takes charge of the disaster" (UNISDR, 2012, p.6).

Disaster risk reduction was the main aim of the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015d), the principal outcome of the Third UN World Conference on disaster risk reduction in Sendai, Japan, on March 18, 2015. The Sendai conference built on the outcomes of two previous UN disaster conferences (Yokohama in 1994, and Kobe in 2005), and also sought to redress a perceived lack of attention to disaster risk reduction in the Millennium Development Goals. The Sendai framework, a non-binding agreement, recognises that whilst the state has primary responsibility for disaster risk reduction, other institutions, including those in local government and the private sector, have key roles to play. The framework outlines seven global targets to achieve the main expected outcome: “the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries” (UNISDR, 2015d. p.12). The framework also outlines four priorities for action: (i) Understanding disaster risk; (ii) Strengthening disaster risk governance to manage disaster risk; (iii) Investing in disaster risk reduction for resilience and; (iv) Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction (UNISDR, 2015d.p.14). The Sendai framework is further addressed in Chapter 8 which draws conclusions on building disaster risk resilience in Oman.

Disaster risk reduction was first documented by the report of the United Nations Disaster Relief Co-ordinator (UNDRO) in 1980 (Birkmann, 2013; UNDRO, 1980). The research carried out by Hewitt (1983), Susman et al. (1983), and O'Keefe et al. (1976) was important in the development of the socio-science related disaster risk field (Brinkmann 2013, p.13). Hewitt (1983) argues that disasters cannot happen by natural hazards alone. The disaster circumstance and the rehabilitation process have to be understood in the “context of normal socio-economic order” (Hewitt, 1983.p.viii. Birkmann 2013.p.14).

Two methods are used for risk mitigation: structural and non-structural (Brody et al., 2009; Poussin et al., 2012). The structural approach is the way of using engineering methods like dams to mitigate the risk of floods, flash floods or storm surge (Fleming et al., 2002; Brody et al., 2009; Poussin et al., 2012; Kryžanowski et al., 2014). Meanwhile, the non-structural approach uses development strategies such as land use planning tools, insurance programs and other policies for risk management (Brody et al., 2009). A non-structural approach is to link disaster risk, adaptation and flexibility using quantitative measures to facilitate citizen understanding of disasters (Brody et al., 2009).

Structural mitigation methods are "any construction, engineering or other mechanical change or improvement aimed at reducing hazard risk likelihood or consequence" (Coppola, 2011). These are engineering-based methods and are categorised based on the type of disaster risk (Coppola, 2011; Brody et al., 2009). Coppola (2011) outlines structural methods such as building codes and regulatory measures: relocation, structural modification, community shelters, construction of barriers, deflection, and retention systems. Kryžanowski et al. (2014) review types of structural flood-protection measures used in several European case studies. For example, protection measures were used between 2007 and 2010 to control Danube flooding. The primary protection system was located on the border with Austria and Hungary to fill the gap in the existing flood protection system (Kryžanowski et al., 2014). Bolin and Stanford (1991) focus on shelter and housing after a disaster and the related demographic factors that control access to shelters. For instance, Pune/India is a place vulnerable to flood risk due to its location at the confluence of three rivers, the Mutha, Mula, and Pavana (UNISDR, 2009b). Therefore, both a practical action to assess and reduce flood risk and a comprehensive plan for climate change adaptation and disaster management measures were implemented in the city (UNISDR, 2009b). The planned focus on the structural and planning measures efforts was complemented by improvement of flood monitoring, early warning system, and social protection for affected families (UNISDR, 2009b).

On the other hand, non-structural methods for disaster management are defined as the reduction in the likelihood or consequence of risk through modifications in human behaviour or natural processes, without requiring the use of engineered structures (Coppola, 2011). Several measures are used in this approach, such as regulatory measures, community awareness and education programs, information flow, and insurance programs. For instance, Escuder-Bueno et al. (2012) provide comprehensive quantitative tools for flood risk analysis by using social data to support the study of non-structural measures, to show the decision maker the impact of non-structural measures on the social and economic risk, in the aim of enhancing flood risk reduction. Integrating social research data is important to develop effective communication and information strategies and warning systems (Escuder-Bueno et al., 2012). Improving public awareness and communication can support emergency planning (Escuder-Bueno et al., 2012). Roberts (2010) outlines different measures for building resilience in Durban, South Africa: improving the warning systems, risk area mapping, education and communication are all important community resilience measures (Roberts, 2010). The Maldives is another place vulnerable to natural disaster. In 2004, the islands were devastated by the Indian Ocean tsunami (UNISDR, 2009b). Preparing for future disaster risk has since become an important crosscutting development concern in the islands. Therefore a Strategic National Action Plan (SNAP) for disaster risk reduction and climate change adaptation has been developed (UNISDR, 2009b). The strategy aims to promote teamwork among policymakers, experts and disaster risk reduction and climate change adaptation specialists, to develop complete risk management methods (UNISDR, 2009b). The strategy was developed following evaluation of existing programs and multi-sectoral consultation conducted with local government to evaluate the gaps and challenges (UNISDR, 2009b).

2.4 Vulnerability

The term vulnerability becomes an important topic in disaster management studies (Cutter et al., 2003; Rygel et al., 2006). Vulnerability is identified as the liability of a given population, system, or place to come to harm from exposure to the hazard, and directly affects the ability to prepare for, respond to, and recover from hazards and disasters (Cutter et al., 2003, Rygel et al., 2006). The International Strategy for Disaster Reduction (UNISDR) defines vulnerability as “the conditions determined by physical, social, economic and environmental factors or process, which increase the susceptibility of a community to the impact of hazards” (UNISDR, 2004a;

Plodinec, 2009). Furthermore, the United Nations Development (UNDP) characterised vulnerability as “a human condition or process resulting from physical, social, economic, and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard” (UNDP, 2004). The IPCC identifies vulnerability as “the degree to which the system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. The vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPPC, 2007).

Vulnerability is an important element in disaster management for short-term response to long-term recovery (Flanagan et al., 2011). Vulnerability is however characterised in a variety of ways. For example, Brooks and Adger (2003) measure vulnerability based on nine different factors: "economic well-being, health and nutrition, education, physical infrastructure, institutions, governance, conflict, and social capital, geographic and demographic factors, dependence on agriculture, natural resources and ecosystem, and technological capacity." At least four different approaches to vulnerability are evident in literature (Cutter et al., 2003; Rygel et al., 2006; Cutter et al. 2008; Flanagan et al., 2011). The first approach is the theory of risk/hazard, which has been derived from the work of Gilbert White and his students (Cutter et al., 2003). For three decades the focus was on a natural event exposure-based approach, which explains the disaster as an interaction between people and the environmental system. The approach is natural-centric and focuses on asking "who lives in the risk area and why?" An increase in vulnerability to the disaster is seen as a product of economic and political conditions (Cutter et al., 2003; Rygel et al., 2006, Cutter et al., 2009).

The pressure and release model is a model that integrates two different forces: vulnerability progression and environmental exposure to hazards (Blaikie, 1994). Vulnerability progression is measured in three levels: root causes, dynamic pressures, and unsafe conditions (Blaikie, 1994). This theory is considered to improve the understanding of risk volume (Cutter et al., 2003). The model gives a comprehensive understanding of vulnerability through a clear framework looking at the livelihood and vulnerability, and it gives weight to natural hazards (Cutter et al., 2003). However, the model is designed for explaining the vulnerability, not measuring it.

Literature has evaluated the risk volume (Figure 2.1) model for a long time (Blaikie, 1994; Merz et al., 2010; Rygel et al., 2006; Cutter et al., 2003). The model has been applied to fluvial flood risk management (Merz et al., 2010), and to cyclones (Fritz et al., 2010). Merz et al. (2010) examine the driving forces of such risk and how these forces increase disaster risk. For instance, in the case of flooding they consider the source "weather event that results in the flood", then the pathway "mechanisms that convey flood water" and the receptors, "people, industries and built, and natural environment that may be impacted by flooding". Fritz et al. (2010) investigated the major impact of cyclone Guno in Oman and indicated that it was due to economic and social conditions rather than the natural hazard itself. This theory, however, is more a descriptive analysis than practical assessment and fails to explain the "interaction between the social and natural system" (Cutter et al., 2003; Cutter et al., 2009). Thus a hazard of place theory was subsequently developed (Cutter, 1996). This theory assesses the interaction between "biophysical vulnerability (exposure) and social vulnerability" (Cutter et al., 2009). The theory describes vulnerability as "biophysical risk and social response within a specific geographic domain" (Rygel et al., 2006).

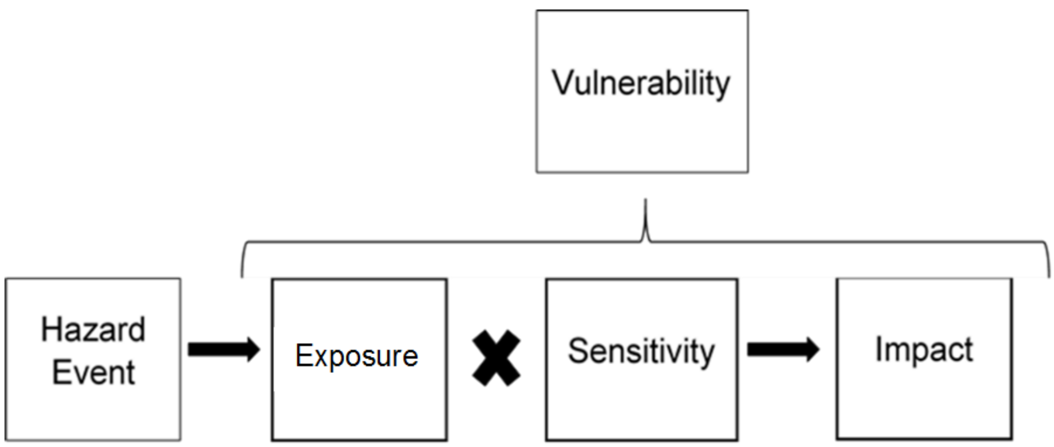

Figure 2.1 The risk volume paradigm

Cutter et al. (2000) used the hazard of place approach to assess the social vulnerability to natural hazard at the country level in the United States, whilst Rygel et al. (2006) used it to estimate social vulnerability to hurricane storm surge in a developed country. Then the hazard of place theory was applied in a place-based model to understand the community's resilience to natural hazards (Cutter et al., 2008). The hazard of place model “improves the comparative assessment of disaster resilience at local or community level" and the theory offers a practical approach applicable using geospatial analysis (Cutter et al., 2009). However, it fails to analyse the main reasons for social vulnerability (Cutter et al., 2009).

The double structure of vulnerability approach (Figure 2.2) was developed by Bohle (2001) and Ciurean et al. (2013). This approach claims that vulnerability is related to exposure and the process of coping with risk and the community's capacity to resist and recover from hazard events. The approach argues that vulnerability has an external side focused on exposure to risk and an internal side focused on coping and the capacity of the system to recover from the hazard (Ciurean et al., 2013; Bohle, 2001).

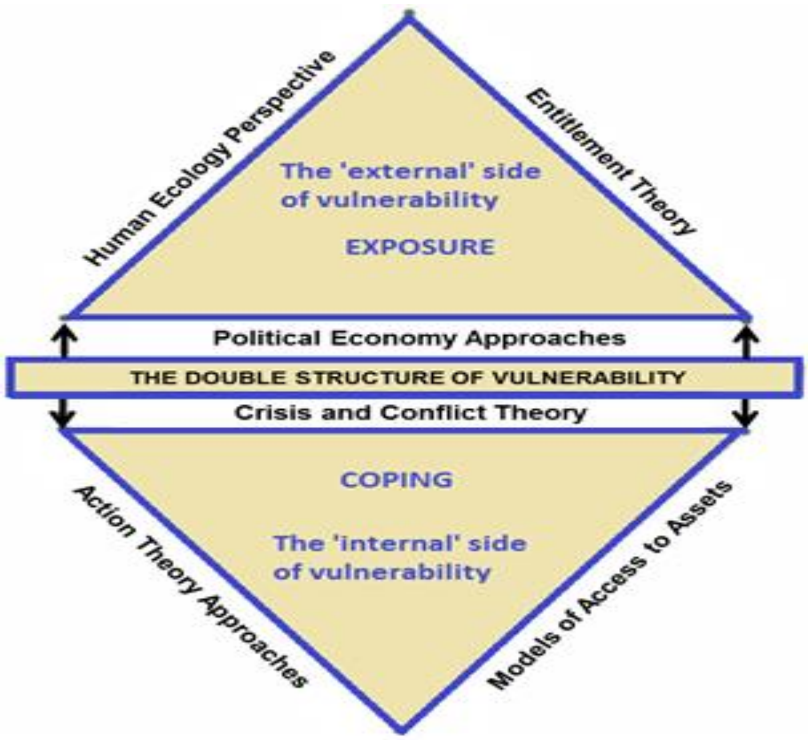

Figure 2.2 The double structure of vulnerability paradigm

The next theory of vulnerability/ sustainability was developed by Turner et al. (2003). The theory studies the vast perspective of local vulnerability to global change. It has been applied on a large scale - regional to global (Cutter et al., 2009). An application study by Guha-Sapir (2007) examines impacts of climate change on people including the health impacts of floods. The research focuses on how vulnerability to extreme weather events like floods can spread diseases like cholera and malaria (Guha-Sapir, 2007). The vulnerability/sustainability theory, however, fails to differentiate between social vulnerability and exposure and so is more useful for qualitative assessment than empirically based analysis (Cutter et al., 2009).

Table 2.3 summarises the vulnerability approaches and explains the different paradigms of interaction between vulnerability, the different systems (human, natural), and the relation between the exposure and coping.

Table 2.3 Summary of different models of vulnerability

Model	Explanation for disaster
Risk/ hazard	The interaction of people and the environmental system
Pressure/ Release	The interaction between the vulnerability progression and the physical exposure to hazards.
Risk Volume	Interaction between the social and natural system
Hazard of place	The interaction between the “biophysical vulnerability (exposure) and social vulnerability.”
Double structure of vulnerability	Interaction between exposure and coping
Vulnerability/ sustainability	Analyses the large perspective of local vulnerability to global change

2.5 Resilience

2.5.1 The concept of resilience

Resilience as a concept has gained increasing attention in recent decades, particularly driven by issues of climate change and security, but which also finds use in such diverse fields as ecology, engineering, psychology and finance. However, the definition of resilience is diverse and contested (Chandler and Coaffee, (2017). Resilience is often considered the capacity of a system, community or society exposed to hazards to respond to and recover from the effects of a hazard in a timely and efficient manner through a fully functioning system (Cutter et al., 2008; UNISDR, 2009b; Birkmann, 2013). Correia et al. (1991), defined resilience as “a measure of the recovery time of a system”. The term resilience originates from the Latin *resilio* meaning “to jump back” (Klein et al., 2003). Comfort et al. (2010) concluded the concept “holds the promise of the answer”.

The concept was first used in the physical sciences to indicate the behaviour of the spring (Gordon, 1978; Bodin and Wiman, 2004). Then the concept was adopted by psychologists (Rolf and Glantz, 2002; Brown, 2015) to study children at risk and the negative effects of an adverse life (Manyena 2009). Resilience has been applied by ecologists (Holling, 1995; Abel and Langston, 2001; Adger, 2003) to describe measures of the ability of systems to absorb changes. In community research, the term resilience is applied to describe the capacity of a community to cope successfully with substantial danger (Timmerman, 1981; Wildavsky, 1991; UNISDR, 2004c; UNISDR, 2005). Resilience has been defined in two different ways: the desired outcome (a safe and resilient community), or the process leading to the desired outcome (enabling individuals, communities to adapt and move toward) (Manyena, 2006; Twigg, 2015). Holling (1995) described two faces of resilience, the first being engineering resilience which is a more traditional conception focused on efficiency, constancy, and predictability; and the second face being ecosystem resilience focused on persistence, change, and unpredictability. Conversely, Zebrowski (2016) rejects the idea that resilience is a stable concept that has specific value and meaning, perceived either as positive, providing safety and security in an uncertain world, or negative, as neo-liberal states offload security responsibility on to citizens. Rather, Zebrowski, whose work is set within the context of twenty-first century security concerns, particularly conflict, see resilience as a concept where value and meaning are multiple and contested, and evolve dynamically over time, via a politically mediated set of processes.

Resilience is related to capacity, but the concept of resilience is clearly wider and goes beyond resources, plans and actions (Twigg, 2015). However, in daily use, the concepts of resilience and capacity are sometimes used loosely and interchangeably (Twigg, 2015). Table 2.4 summarises the different definitions of resilience published in the literature.

Table 2.4 Definitions of resilience classified by the domain.

Source	Domain	Definition
Gordon (1978)	Physical	The ability to store strain energy and deflect elastically under a load without breaking or being deformed
Bodin and Wiman (2004)	Physical	The speed with which a system returns to equilibrium after displacement irrespective of how many oscillations are required
Holling (1973)	Ecological system	The persistence of relationships within a system; a measure of the ability of systems to absorb changes in state variables, driving variables, and parameters, and persist
Holling (1995)	Ecological system	Buffer capacity or the ability of a system to absorb perturbation, or the magnitude of disturbance that can be absorbed before a system changes its structure
Abel and Langston (2001)	Ecological system	The ability to persist through future disturbances
Alliance (2010)	Ecological system	The magnitude of change or disturbance that a system can experience without shifting into an alternate state that has different structural and functional properties and supplies different bundles of the ecosystem services that benefit people
Adger (2000)	Ecological and social systems	The ability of communities to withstand external shocks to their social infrastructure
Brooks and Adger (2003)	Ecological and social systems	The ability to persist (i.e. to absorb shocks and stresses and still maintain the functioning of society and the integrity of ecological systems) and the ability to adapt to change, unforeseen circumstances, and risks
Wildavsky (1991)	Community	Resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back.
Buckle (2000)	Community	The capacity of a group or organisation to withstand loss or damage or to recover from the impact of an emergency or disaster. The higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be.

Cont. / Table 2.4.

Source	Domain	Definition
Turner et al. (2003)	Community	The concept [of resilience] has been used to characterise a system's ability to bounce back to reference state after a disturbance and the capacity of a system to maintain certain structures and functions despite disturbance.
UNISDR (2004b)	Community	The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity to learn from past disasters for better future protection and to improve risk reduction measures.
IPPC (2007)	Community	Resilience is the flip side of vulnerability – a resilient system or population is not sensitive to climate variability and change and can adapt.
DFID (2011)	Community	The ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses-such as earthquakes, drought or violent conflict-without compromising their long-term prospects.
Zebrowski (2016)	Community	Resilience strategies stress community participation rather than state secrecy and that they aim to harness the inherent resilience of vital systems to self-organize responses in a bottom-up fashion.
Mulligan et al. (2016)	Community	Resilience is a pervasive normative concept within governance and management circles, where it is often used to try to foster a sense of security and/or an entrepreneurial stance of flexibility and adaptability.

2.5.2 Planning for community resilience to disaster

Planning for community resilience to disaster is a process linking the different community levels together for the same aim, reducing disaster risk. Planning for community resilience is a process for the community, and from the community, and building a resilient community needs cooperation from different systems and institutions (UNISDR, 2006; UNISDR, 2012). It is essential for sustainability and will improve the environmental, social and economic capacity to manage disasters (UNISDR, 2012). For example, the UK policy paper: Climate resilient infrastructure: preparing for a changing climate, "encourages a much stronger focus on adapting national infrastructure to the impacts of climate change as part of a green economy" (DEFRA, 2011). The policy outlines that developing resilience in infrastructure like roads will keep transportation running more smoothly during extreme events (DEFRA, 2011).

Much recent literature emphasises the term resilience and its development in disaster studies (Wamsler et al., 2013). The term resilience is strongly applied to disaster risk reduction (UNISDR, 2005; UNISDR, 2012; Birkmann, 2013; Wamsler et al., 2013; UNISDR, 2013b) in efforts to reduce disaster risk by reducing the source of the risk. Developing cities to be resilient to natural hazards will increase the feeling of security amongst inhabitants (Wamsler et al., 2013; UNISDR, 2009a). Therefore, it is important to understand community resilience in all governance levels, national, regional and local level, in both negative and positive faces. Hence, building resilience is assumed to be necessary at all levels of the system for more sustainability (Walker et al., 2004).

Resilient communities are less vulnerable to disasters so determining how the resilience community can be achieved is important (Cutter and Finch, 2008). Walker et al. (2004) outlined four elements of resilience: latitude, resistance, precariousness, and panarchy. Latitude is defined as "the maximum amount a system can be changed before losing its ability to recover 'before crossing a threshold which, if breached, makes recovery difficult or impossible". The second component focuses on the resistance of the system to be changed (Walker et al., 2004). The precariousness is "how close the current system is to a limit or threshold" (Walker et al., 2004). Panarchy, meanwhile, refers to a hierarchical structure and non-stop interaction between the human system and the physical system (Gunderson, 2001; Cutter and Finch, 2008; Walker et al., 2004; Gotts, 2007). Also, because of the cross-scales interaction in panarchy, system resilience would be influenced hierarchically by both systems (Walker et al., 2004; Cutter and Finch, 2008). The interaction between different systems can be very complex, such as the interaction between humans and the ecosystem, which are significant factors in disaster management and vulnerability (Twigg, 2015). Resilience encourages a better understanding of different interactive systems (Twigg, 2015).

Although they have different theoretical backgrounds, disaster planning and community planning are both concerned with physical and socio-economic systems so integrating disaster planning into community planning, by linking their common features, can lead to improved community safety (Pearce, 2003). For example, disaster risk mitigation strategies can be linked with development strategies. Integrating the community in disaster planning is important because they know about the place where they live and what they need (Pearce, 2003). Godschalk et al. (1998) outline four options for integrating community planning to make a sustainable disaster mitigation plan: stakeholder contribution, planning elements, planning theme, and mitigation strategy. To develop the requisite knowledge of such an approach, UNISDR (2006) employs participatory rural appraisal (PRA) to document local knowledge and experience about risk. PRA techniques have proved useful because they reveal "significant knowledge and coping capacity" in the community (UNISDR, 2006). Communication and interaction at the community level make these approaches more successful and accepted by the community (UNISDR, 2006). The decision-making to cope with disaster risk thus depends on collecting, analysing and communicating risk information effectively (Fleischhauer et al., 2012). However, failure in risk governance impairs community resilience and its adaptive capacity.

Integrating resilience into planning to achieve disaster-resilient cities is advocated in literature (Balica et al., 2012; Wamsler et al., 2013). Balica et al. (2012) discuss that different systems carry out different operations from different types of resources, and different interacted components. Furthermore, linking the natural, socio-economic, and institutional systems will lead to better understanding of opportunity for reducing disasters risk (Balica et al., 2012). For instance, San Francisco, USA uses a "Resilience wheel" (Figure 2.3) with eight functional areas to represent the partners both inside and outside government and the organisations' missions connected with other stakeholders who may work in different sectors. The wheel is used to understand the resilience of the individual, organisation, and community in a complex city with a diverse network of stakeholders, but also shows "that it can be difficult to frame the opportunity of resilience in a way that allows all stakeholders to align it to their current mission and goals" (UNISDR, 2012).

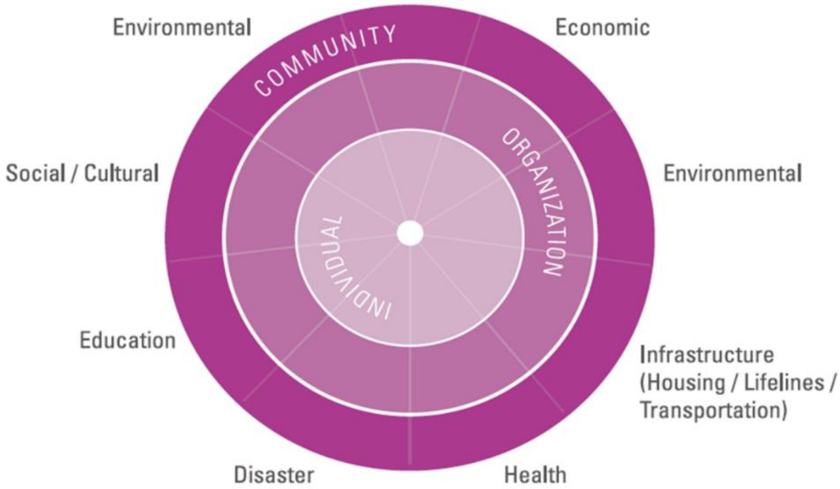

Figure 2.3 Resilience wheel.

[Source: (UNISDR, 2012)]

The place-based model (Figure 2.4) modified by Cutter et al. (2008) is useful to understand the link between disaster, place vulnerability and disaster mitigation. The disaster resilience of place model simplifies the process of disaster resilience at the community level (Cutter et al., 2008). Although the primary focus of the model is social resilience, the model interconnects the natural system, social system and built environment in a complete process of building community resilience to disaster (Cutter et al., 2008). The key feature of this resilience model is the "inherent and antecedent condition and process" (Cutter et al., 2008). Finally, the model claims that exogenous factors such as policies and regulation influence the community resilience (Cutter et al., 2008).

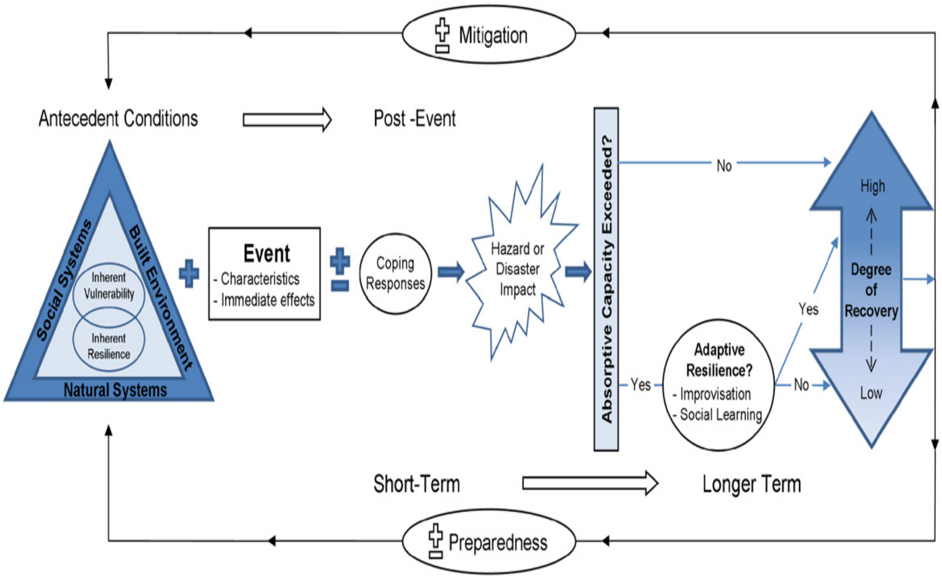

Figure 2.4 Place-based model of risk reduction.

[Source: (Cutter et al., 2008)]

The United Nations (UN), from 1990, started to take significant action to improve awareness about the social and economic impact of natural hazards, to cope with disaster risk (UNISDR, 2004a; UNISDR, 2004c). In 1994, the Yokohama strategy was produced as the guideline of natural prevention, preparedness and mitigation and became the foundation of natural disaster reduction policy and practice (UNDHA, 1994b; UNISDR, 2004a; UNISDR, 2004c). The strategy principles focused on risk assessment, disaster prevention and preparedness, strengthening development, and integrating disaster prevention and preparedness within the aspects of development policy and planning, early warning systems, reducing vulnerability, and environmental protection and sustainable development (UNDHA, 1994b). Recently, the Hyogo framework (HFW) has been produced with a focus on the elements that were missing in the Yokohama strategy (UNISDR, 2005).

Building communities and nations resilient to natural disasters, with a “substantial reduction of disaster losses, in lives, and the social, economic and environmental assets of communities, and countries” is the expected outcome of the Hyogo framework (UNISDR, 2005; UNISDR, 2009b). Figure 2.5 shows the UNISDR (2004a) disaster risk reduction framework and the links between processes, and the goal of more sustainable and resilient communities. Five elements have been identified as particular challenges (UNISDR, 2005). These challenges are governance, including organisational and policy frameworks; risk identification, assessment and monitoring, and early warning; and knowledge management and education. Additional challenges includereducing underlying risk factors, and preparedness for effective response and recovery (UNISDR, 2005).

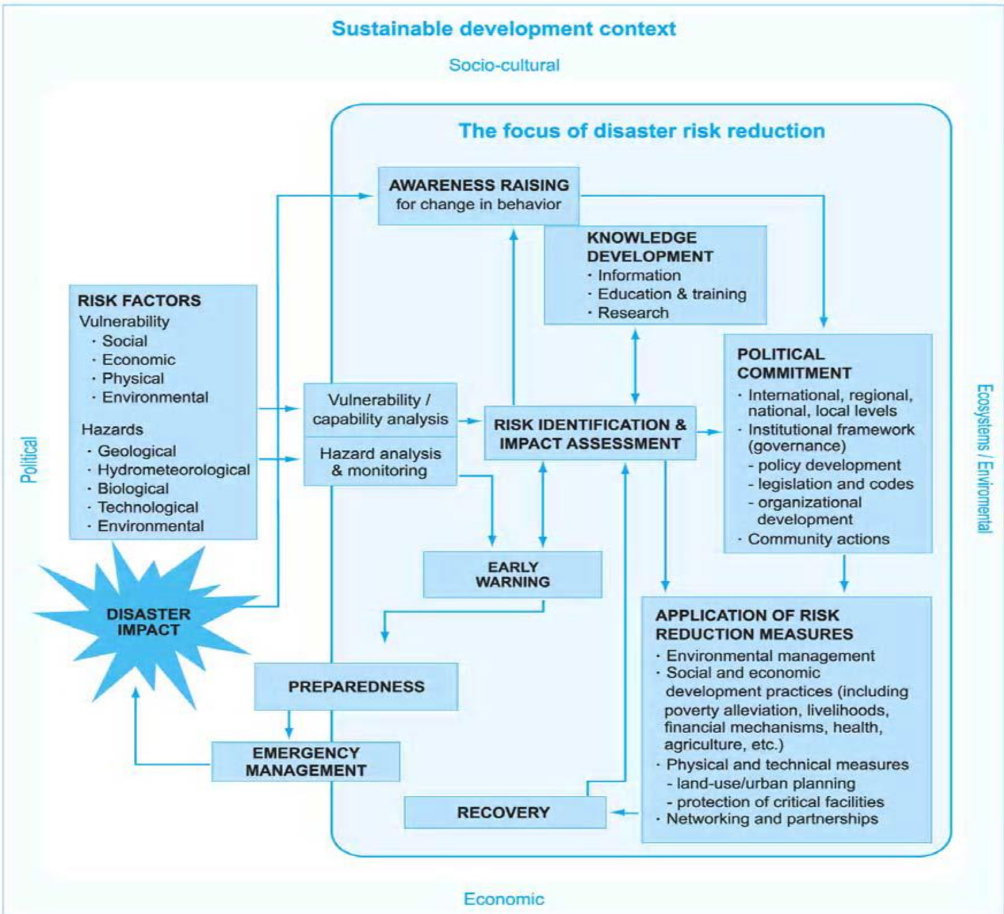

Figure 2.5 The UNISDR (2004a) disaster risk reduction framework

This led to development of a 2025 strategic framework that focuses on: “a world in which nations and communities are resilient to the risks of disasters and climate change, enabling them to develop and prosper sustainably” (UNISDR, 2013b). Valdes et al. (UNISDR, 2012), in their practice handbook: *How to make cities more resilient*, identify some essential goals for building community resilience:

1. Building institutional capacity and commitment through explicit policies and legislation that controls the work of institutions.
2. Integrating planning policies and disaster reduction, such as building codes and land use policies.
3. Understanding risk by identifying the hazard and assessing risk, monitoring and early warning system. It is essential to update hazard and vulnerability assessment and integrate these into development strategies and to make this information available to the public.
4. Improving community awareness about natural hazards. Knowledge starts at an early age through education and generation experience.
5. Enhancing evacuation plans by improving policies, information flow and shelters. The evacuation plan must be clear, fast and known by the public.
6. Preparation for recovery by enhancing investment in disaster reduction through food security, recovery funding and catastrophic insurance to reduce the economic risk after the event; for instance, building Ethiopia's resilience to drought, through social protection, food security and insurance (UNISDR et al., 2014).

2.6 The Hyogo Framework for Action

The Hyogo Framework for Action is the UN strategy of building resilience and risk reduction. HFA is the outcome of the World Conference on Disaster Reduction (WCDR) held in Kobe, Japan (2005) (UNISDR, 2005). HFA was adopted to fill the gaps and challenges of the Yokohama Strategy[2], which provided the landmark guidance on reducing disaster risk and impacts of disasters (UNISDR, 2005). The HFA is a ten-year strategy for making communities safer from natural disaster and takes a systematic and comprehensive approach (UNISDR, 2005). HFA is the key instrument of implementing the expected outcome of substantial reduction of disaster losses in lives and the social, economic and environmental assets of communities and countries (UNISDR, 2005). The HFA emphasises three

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[2] The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster

Prevention, Preparedness and Mitigation and its Plan of Action, 1994 (UNDHA, 1994b) strategic goals, and five priorities for action to attain the expected outcome (Table 2.5).

The HFA action priorities are as follows. Priority HFA1: Make disaster risk reduction a priority to ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation (UNISDR, 2005). Countries are responsible for developing policies, legislation, and institutional frameworks. Strong communities at national and local levels are required to save lives and livelihoods vulnerable to natural hazards (UNISDR, 2005). Priority HFA2: Know the risks and take action, which can be achieved through identifying, assessing and monitoring disaster risks and enhancing early warning (UNISDR, 2005). Countries are responsible for developing the method and tools for identifying risk. The tools need to be improved as do statistical data about disasters, risk maps, and vulnerability indicators (UNISDR, 2005). The information about risks is important to build effective early warning systems which globally are an important component of disaster risk reduction (UNISDR, 2005). Priority HFA3: Build understanding and awareness through using knowledge, innovation and education to build a culture of safety and resilience at all levels (UNISDR, 2005). This priority can be achieved through a national public awareness strategy for disaster risk reduction that reaches all communities and people of all education levels (UNISDR, 2005). School curricula at all levels can include disaster risk reduction elements, and instructors should be trained in disaster risk reduction at national through to local levels (UNISDR, 2005). Priority HFA4: Reduce the underlying risk factors (UNISDR, 2005). This priority must encourage the sustainable use and management of ecosystems, land use and natural resources, and integrate disaster risk reduction strategies and climate change. Countries can build resilience through investing in simple, well-known measures to reduce risk and vulnerability (UNISDR, 2005). Countries are responsible for protecting critical public facilities, applying recovery systems and developing social safety, and integrating disaster risk into land-use planning and building codes (UNISDR, 2005). The final priority is HFA5: Be Prepared and Ready to Act through strengthened disaster preparedness for effective response at all levels (UNISDR, 2005). Countries are responsible for developing and testing emergency plans, and establishing emergency funds to support preparedness, response and recovery activities (UNISDR, 2005). Effective preparedness plans and exercises including evacuation drills are important to cope with all types and size of disaster that repeatedly occur in many communities (UNISDR, 2005). The assessment of the degree of HFA implementation and the level of progress is outlined in the "World into Action: the Guidance for Implementing the Hyogo Framework for Action" (UNISDR, 2007). Table 2.5 summarises the HFA strategic goals and priorities.

Table 2.5 Goals and action priorities of the Hyogo Framework 2005-2015

Mechanism	Description
Expected Outcome	The substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries
Strategic Goals	The integration of disaster risk reduction into sustainable development policies and planning
	Development and strengthening of institutions, mechanisms and capacities to build resilience to hazards
	The systematic incorporation of risk reduction approaches into the implementation of emergency preparedness, response and recovery programs
Priorities for Action	HFA1: Make Disaster Risk Reduction a Priority.
	IHFA2: Know the Risks and Take Action.
	HFA3: Build Understanding and Awareness.
	HFA4: Reduce Risk.
	HFA5: Be Prepared and Ready to Act.

Twigg (2009) provides a framework of resilience components divided into five thematic areas intended to cover all aspects of resilience, based on HFA priorities for action. Twigg's framework simplified HFA priorities for action. Twigg's five thematic areas are: 1. Governance, 2. Risk Assessment, 3. Knowledge and Education, 4. Risk Management and Vulnerability Reduction, and 5. Disaster Preparedness and Response. Each thematic area is subdivided into main components of resilience, characteristics, and enabling environments for building resilience. Table 2.6 summarises the thematic areas and the components of the resilience framework of Twigg

(2009), and is developed under different levels and issues to make them simple and easier to understand. This framework integrates development with disaster risk reduction, community participation, institutional building and sustainable livelihood.

Table 2.6 Themes and resilience components of Twigg's (2009) framework

Thematic Areas	Components of Resilience
Governance	• Policy, planning, priorities and political commitment
	• Legal and regulatory systems
	• Integration with development policies and planning
	• Integration with emergency response and recovery
	• Institutional mechanisms, capacities, and structures; allocation of responsibilities
	• Partnerships
	• Accountability and community participation
Risk Assessment	• Hazards/risk data and assessment
	• Vulnerability/capacity and impact data and assessment
	• Scientific and technical capacities and innovation
Knowledge and Education	• Public awareness, knowledge and skills
	• Information management and sharing
	• Education and training
	• Cultures, attitudes, motivation
	• Learning and research
Risk Management and Vulnerability Reduction	• Environmental and natural resource management
	• Health and well being
	• Sustainable livelihoods
	• Social protection
	• Financial instruments
	• Physical protection; structural and technical measures
	• Planning regimes
Disaster Preparedness and Response	• Organizational capacities and coordination
	• Early warning systems
	• Preparedness and contingency planning
	• Emergency resources and infrastructure
	• Emergency response and recovery
	• Participation, voluntarism, accountability

Chapter 3 Emergency management in the Sultanate of Oman

3.1 Introduction

The Sultanate of Oman is affected by different types of natural hazards, which are having an increasing social and economic impact due to the rapidly growing population. The emergency system has existed for many years. However, the actual disaster management system has only been developed recently after the damage caused by cyclone Gonu in 2007, and cyclone Phet in 2010. The new disaster management system in Oman is coordinated by the National Committee of Civil Defence (NCCD).

This chapter will review the background of disaster management in Oman. The chapter will discuss the natural hazards affecting Oman in Section 3.3, vulnerability in Section 3.4, and the disaster management system in Section 3.5, and the gaps of knowledge that form the basis for the research in this thesis in Section 3.6.

3.2 The Sultanate of Oman

The Sultanate of Oman is located in the south-eastern part of the Arab Peninsula. Its shoreline extends from Hurmuz in the north to the Republic of Yemen in the south. It is open to three seas: the Arabian Gulf (Persian Gulf), Oman Sea and Arab Sea. The country is bordered by the UAE and Saudi Arabia in the west, the Republic of Yemen in the south, the Strait of Hurmuz in the north, and the Arab Sea in the east.

The total area of the Sultanate of Oman is approximately 309.5 thousand square kilometres. Much of Oman is covered by a vast gravel desert plain, with a coastal plain and mountain ranges along the north (Al Hajar Mountains) and southeast coast. The climate is very hot in the summer season from mid-April to October, with the temperature reaching 50°C. At low elevation, the humidity may be as high as 90 percent. In the winter the weather is mild, and the temperature ranges between 15°C and 23°C.

Figure 3.1 Sultanate of Oman.

[Source: US Central Intelligence Agency]

3.3 Natural hazards in Oman

The Arabian Peninsula is an example of an arid area affected by multiple hazards (Middleton and Sternberg, 2013). It has a dry climate with extreme temperature (Al-Sarmi and Washington, 2014), limited seasonal rainfall, and a wide expanse of desert (the Empty Quarter) (Almazroui et al., 2012). Climatological natural hazards have become a difficult problem for the people in the arid and semi-arid areas (Middleton and Sternberg, 2013; Hughes and Diaz, 2008). Climatological natural hazards can affect large areas of these dry lands (Middleton and Sternberg, 2013; Almazroui et al., 2012), causing a wide range of economic losses and social impacts (Middleton and Sternberg, 2013; Ravi et al., 2010; Almazroui et al., 2012). The extreme temperature and limited rainfall can cause drought and lack of water (Ravi et al., 2010; Middleton and Sternberg, 2013).

Meteorological and hydrological hazards also cause huge damage in the Arabian Peninsula (Momani and Fadil, 2010). In 2009, floods in Jeddah, Saudi Arabia were caused by extreme rainfall in the city lasting for more than 6 hours. The floods killed 122 people and cost the country billions of dollars (Momani and Fadil, 2010). Oman is also affected by meteorological hazards like cyclones and storm from the Arabian Sea, as well as sandstorms from the desert (Evan and Camargo, 2010; DGMAN, 2014a). Hydrological hazards, such as flash floods caused by extreme rainfall, also cause damage and have socio-economic impacts (Al-Qurashi et al., 2008; Momani and Fadil, 2010). However, the flood risk is caused by a combination of meteorological events and planning mistakes (Momani and Fadil, 2010; Al-Kalbani, 2011)

The location of the Arabian Peninsula in the Arabian Sea and the Indian Ocean puts countries like Oman and Yemen at risk from tropical cyclones and storms (Membery, 2001; Byju and Kumar, 2011; Evan and Camargo, 2010). For example, a tropical cyclone in 1996 struck Ras Madrakah in Oman and affected Yemen, resulting in major floods which killed 300 people (DGMAN, 2014a)

Moreover, the Arabian Peninsula is located near an active seismic plate, at the transition between the Zagros continental collision and the Makran oceanic subduction, which can cause other natural hazards (Yamini-Fard et al., 2007; McIntyre et al., 2007; Mokhtari et al., 2008). For example, many Kuwaiti ships were sunk in the Arabian Gulf in 1871 because of a tsunami following a strong earthquake in Iran. In September 2009, a 5.1 Ms earthquake in Bushehr, Iran affected Kuwait City 300km away (Bou-Rabee and VanMarcke, 2001). The north of Oman is also at risk of seismic hazards (Sain and Singh, 2011). In 1945, an 8.1 earthquake caused a tsunami that affected the coastline of north Oman (Bou-Rabee and VanMarcke, 2001; Sain and Singh, 2011; Mokhtari et al., 2008) and a 2m high wave reached Muscat, the capital of Oman (Bou-Rabee and VanMarcke, 2001).

3.3.1 Seismic Hazards

Oman is located in the south-eastern part of the Arabian tectonic plate (El-Hussain et al., 2012) (see Figure 3.1). The Arabian plate is one of the smallest of the plates that make up the surface of the earth (Al-Shaqsi, 2015). The plate contains a crystalline basement of Precambrian continental crust about 40-50 km thick (Warren and Miller, 2007). The plate is surrounded by an active tectonic zone of three parts (Figure 3.2): first, the divergent boundaries in the Red Sea and the Gulf of Aden (El-Hussain et al., 2012; Deif and El-Hussain, 2012); second, the convergent margin along the Zagros-Bitlis zone; third, the Makran subduction zone and Owen fracture zone (El-Hussain et al., 2012; Deif and El-Hussain, 2012). Oman is affected by seismic activates in the boundary of the plate. There are also some seismic activities inside the plate in the mountains of Oman (El-Hussain et al., 2012; Deif and El-Hussain, 2012).

In general, Oman has low seismic activity; however, historically the country has experienced earthquakes and tsunamis in north Oman (El-Hussain et al., 2012; Deif and El-Hussain, 2012). The most harmful earthquake recorded in Oman was in 879 AD in Sohar. Later, an earthquake in 1483 destroyed Qalhat in north Oman and an earthquake in 1883 strongly affected the southern part of the mountains and was felt in Muscat and Nizwa, and destroyed nine villages (El-Hussain et al., 2012; Deif and El-Hussain, 2012). According to Deif and El-Hussain (2012), mountains in the northern part of Oman are in a seismically active zone, and there is the possibility of a new strong event in this area (El-Hussain et al., 2012). The two events on 10 and 11 March 2002 of magnitudes 4.5 and 5.1, which were felt in the UAE, support this possibility of occurrence (Deif and El-Hussain, 2012).

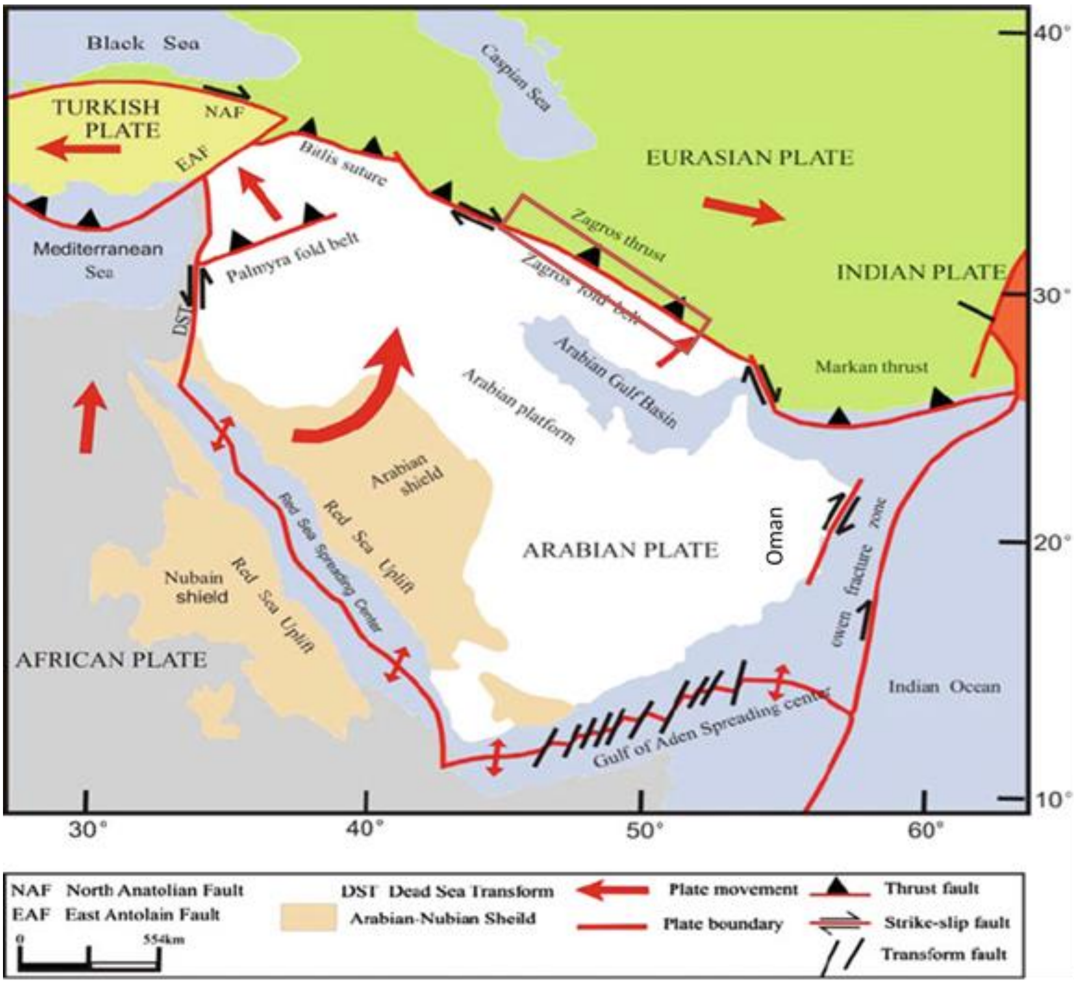


Figure 3.2 Oman in the Arabian Plate and the surrounding seismic zone.

[Source: (El-Hussain et al., 2012)]

However, the risk from the Makran subduction in the sea of Oman is greater (Mokhtari et al., 2008; Okal et al., 2006). The Makran subduction is located in the north of the Arabian Sea and offshore Iran and Pakistan (Mokhtari et al., 2008; Smith et al., 2013). The Arabian plate split from the African plate along the Red Sea and subducts the Eurasian plate (Smith et al., 2013), over a distance of 300 Km (Mokhtari et al., 2008). Massive earthquakes can occur in the Makran subduction zone, causing a tsunami. A tsunami is a shock event usually caused by an earthquake in the sea and leads to a huge wave (Alam et al., 2012). For example, in 1945, an earthquake with magnitude 8.1 in the Makran subduction caused an enormous tsunami, leading to extensive damage in Iran, India and Oman (Mokhtari et al., 2008, Smith et al., 2013). The 2m high waves reached Muscat less than one hour after the shock (Mokhtari et al., 2008). Another earthquake occurred in

1947, with magnitude 7.3 (Mokhtari et al., 2008). Based on the limited historical records it is considered that an earthquake similar to a Sumatra tsunami-earthquake could occur in the Makran subduction zone (Smith et al., 2013). This could cause a massive tsunami that could affect the coastlines of Iran, Pakistan, India, and Oman (Alam et al., 2012; Mokhtari et al., 2008; Smith et al., 2013). Figure 3.3 shows the location of the Makran subduction.

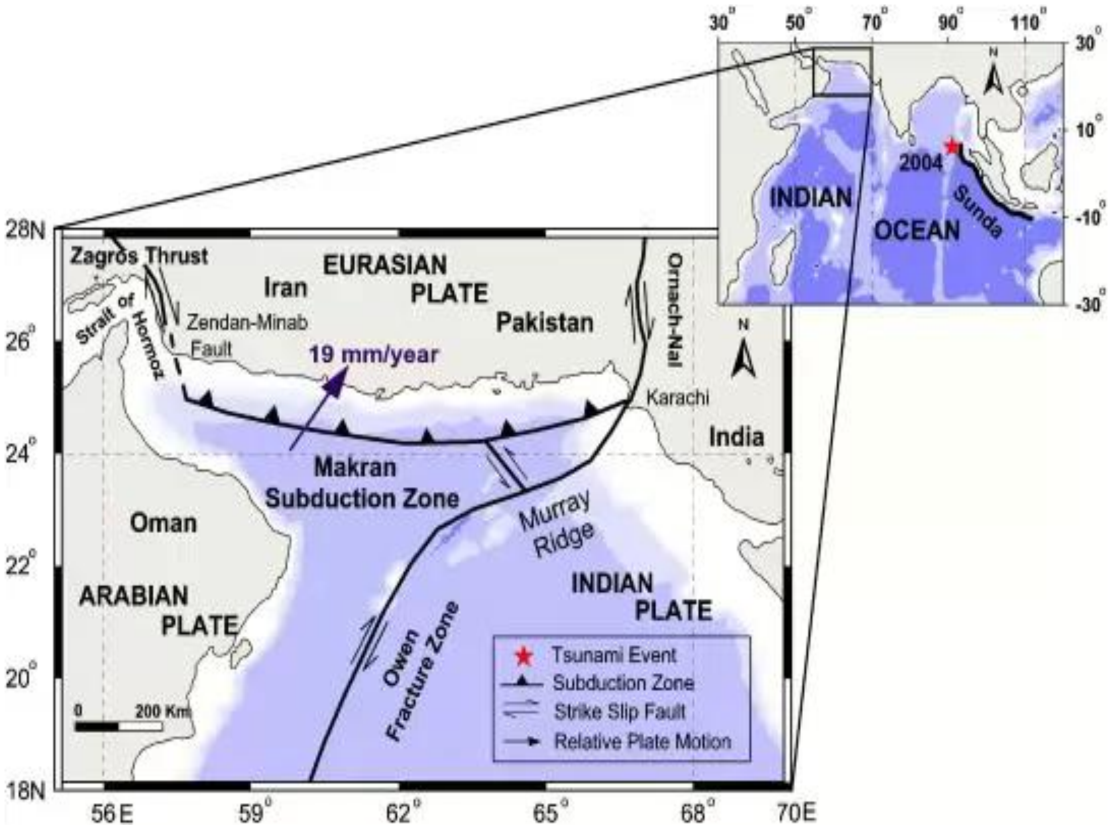


Figure 3.3 The Makran subduction in the Arabian Sea.

[Source: planetsave.com]

In 2004, Oman was slightly affected by the Indian Ocean Tsunami (Alam et al., 2012; Okal et al., 2006), a disaster that resulted in thousands of deaths in countries around the Indian Ocean (Alam et al., 2012). A field survey by Okal et al. (2006) records the impact of the tsunami in Oman. The survey covered 41 sites of inundation over 750 km of coastline and found that the wave was 3.3 m high in Salalah and extended 36 m inland, and 2.3 m high at Al- Labki, with inland inundation recorded at 447 m (Okal et al., 2006). The 2004 tsunami damaged fishing boats and some vehicles on the beach (Okal et al., 2006).

3.3.2 Tropical Cyclones

Tropical cyclones and storms are common in Oman. They affect the coastal area from Muscat in the north to Salalah in the south, with occasional cyclones in the Gulf of Oman, at the southern extreme of the Persian Gulf (see Figure 3.1 for a regional map). They are associated with extreme winds, storm surges and major flash floods that have caused loss of life and substantial damage to infrastructure. For example, in 2007, tropical cyclone Guno, the most powerful cyclone recorded in the Arabian Sea in the last 100 years struck the coast of Oman (IMD, 1999). Guno caused an estimated $4 billion in damage, and 100 people lost their lives (Evan and Camargo, 2010). Guno was followed by cyclone Phet in 2010, which, like Guno, made landfall in North Oman.

Tropical storms, less intense than a cyclone, are common, and some that have hit the Omani coastline over the last century or so have also resulted in major losses. For instance, in 2002 a tropical storm hit Salalah in the south of Oman. The storm caused massive damage in the area due to the unusually high rainfall, estimated at 58.6 mm in the city and about 250.6 mm in the mountains (Al-Habsi et al., 2015). Historically many severe storms have hit Oman and caused considerable damage. Another example, from 1890, is a severe cyclonic storm that entered the sea of Oman then moved to northern Oman, an unusual track for cyclones in the Oman region (Membery, 2001). The storm killed 734 people and had an economic cost equivalent to billions of dollars in today’s terms (Membery, 2001). Table 3.1 displays the Indian Metrological Department (IMD) cyclones classification, which indicates wind speed as a key criterion in the typology. In the Arabian Sea region, all these cyclone types, and indeed the majority of cyclones themselves, form near the Laccadive Islands (~11° N, 73° E) in two seasons: the pre-monsoon and the post-monsoon (Galvin 2008b). However, some of the recorded cyclones formed in the Bay of Bengal, then moved across India, and then re-formed in the Arabian Sea. For example, in November 1966 a cyclone started in the Bay of Bengal before eventually making landfall on the southeast coastline of Oman at Salalah (IMD, 1979).

Table 3.1 Indian Metrological Department cyclones classification.

Name	Wind speed	Description
1.Deep Depression	28-33 knots	
(52 - 61 km/h)	A system causing cyclonic disturbance in which the maximum sustained wind speed lies in the range 28 knots (52 km/h) to 33 knots (61 km/h) may be called a "deep depression".	
2.Cyclonic storm	34 - 47 knots (62 - 88 km/h)	Generic term for a non-frontal synoptic scale cyclone originating over tropical or subtropical waters with organised convection and definite cyclonic surface wind circulation. The term is also used for a storm in the north Indian Ocean with maximum sustained wind speed over 33 knots.
3.Severe cyclonic storm	48 - 63 knots (89 - 118 km/h)	A cyclonic disturbance in which the maximum average surface winds speed is in the range of 48 to 63 knots (89 to 118 km/h).
4. Very severe cyclonic storm	64 - 119 knots (119 - 221 km/h)	A cyclonic disturbance in which maximum wind average is 64 knots to 119 knots (119 to 221 km/h).

[Source: (IMD, 2015)]

Figure 3.4 shows the seasonal distribution of the Arabian Sea tracks and illustrates that while some form in the Bay of Bengal, the majority originate in the Arabian Sea itself.

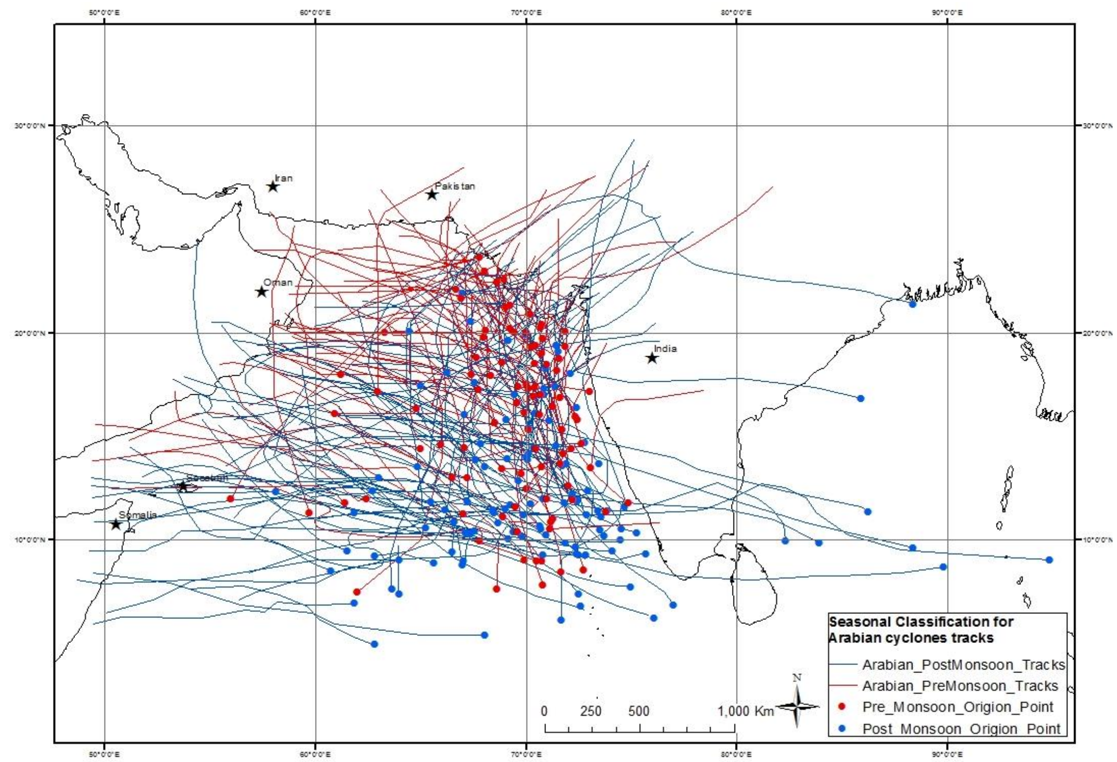


Figure 3.4 Seasonal distribution of Arabian Sea cyclone tracks

The pre-monsoon season lasts from the end of April to June, when the southwest wind rises, and the sea surface becomes very warm (Galvin, 2008a). The post-monsoon season lasts from September to December, when the southwest wind declines and the northeast wind develops over the Arabian Sea (Galvin, 2008a). Table 3.2 summarises the monsoon seasons over the Arabian Sea.

During the pre-monsoon, the strength of the southwest winds increases the potential of cyclone formation in the Arabian Sea (Galvin, 2008b; Membery, 1998). Membery (1998) analysed the frequency of the tropical storms and cyclones affecting the coastline of Oman from 1890 to 1996. Membery (1998) found that nearly half of the Arabian Sea cyclones formed between 14 May and 16 June, with the rest of the tropical cyclones formed during the post-monsoon (Galvin, 2008b). Evan and Camargo (2010) reviewed the Joint Typhoon Warning Centre (JTWC) best-track data for tropical cyclones and storms in the Arabian Sea, 1979-2008. Evan and Camargo (2010) disclosed that out of 41 cyclonic storms formed in the Arabian Sea, 23 made landfall with an intensity equivalent to a tropical depression or stronger. Of these, there were eight severe cyclonic storms, seven very severe storms, and one super cyclonic storm. The study found that, on average, 1-2 cyclones formed in the Arabian Sea per year (Evan and Camargo, 2010).

Table 3.2 The monsoon seasons in the Arabian Sea

Months	Monsoon
January – March	The winter monsoon transition period
	The peak of the winter monsoon in January with strong north-easterly wind over India and the Arabian sea
May - June	Pre-Monsoon
	The south-westerly wind rises, and the sea surface temperature becomes very warm in the Arabian sea. During this period the tropical system is expected in the Arabian sea
July - September	The summer monsoon transition period
	The peak of the summer monsoon is in August, with strong south-westerly wind across the Arabian Sea and Bay of Bengal
October – December	post-monsoon
	The tropical system is expected in this period when the south-westerly wind decreases, and the north-easterly wind rises over the Arabian sea

[Source:(Galvin, 2008a)]

The historical cyclone record of the IMD shows that a number of extreme cyclones have hit Oman in the last 100 years (Membery, 2001; Membery, 1997; Ice, 1975). Temporal analysis of the cyclones in the Arab Sea for the period (1980-1994) was conducted by Membery (1997). The data was improved by adding the data obtained from the IMD for the period (1870-2015). Table 3.3 shows that the highest number of cyclones in the Arabian Sea was recorded in May, with six cyclones in the period 1870- 2015.

Table 3.3 Storm Frequency on the Omani coastline, 1980-2015

	J	F	M	A	M	J	J	A	S	O	N	D	Total
S+C	0	0	0	0	10	11	1	1	2	8	8	2	43
C	0	0	0	0	6	6	0	0	0	4	3	1	20

[Source: Membery (1997) and adapted by the author].

In 1890, a super cyclone hit Muscat (north Oman), bringing about 286 mm of rain, causing economic losses estimated at the time of 9 million dollars and taking 727 lives. The floods in Muscat were massive and turned into a health hazard, causing a cholera epidemic which killed more than 100 people (Membery, 1997). In 1959, a severe cyclone hit Salalah, bringing about 117 mm of rain. The cyclone destroyed two ships coming from Zanzibar and killed about 150 people, most of them women and children (Membery, 2001). In 1963, a tropical cyclone in Salalah (south Oman) brought 269.4mm of rain, while in 1995 a low-pressure storm brought 300 mm of rain in the north Oman Mountains (DGMAN, 2014a). The Guno cyclone on June 6, 2007 was the most powerful cyclone to strike Oman, recorded as TC5, which is equal to a hurricane of the 5th degree (Al-Kalbani 2011, Al-Awadhi, 2010). Figure 3.5, and Table 3.4 show the notable Arabian Sea cyclones that have made landfall along the coast of Oman (1890-2010).

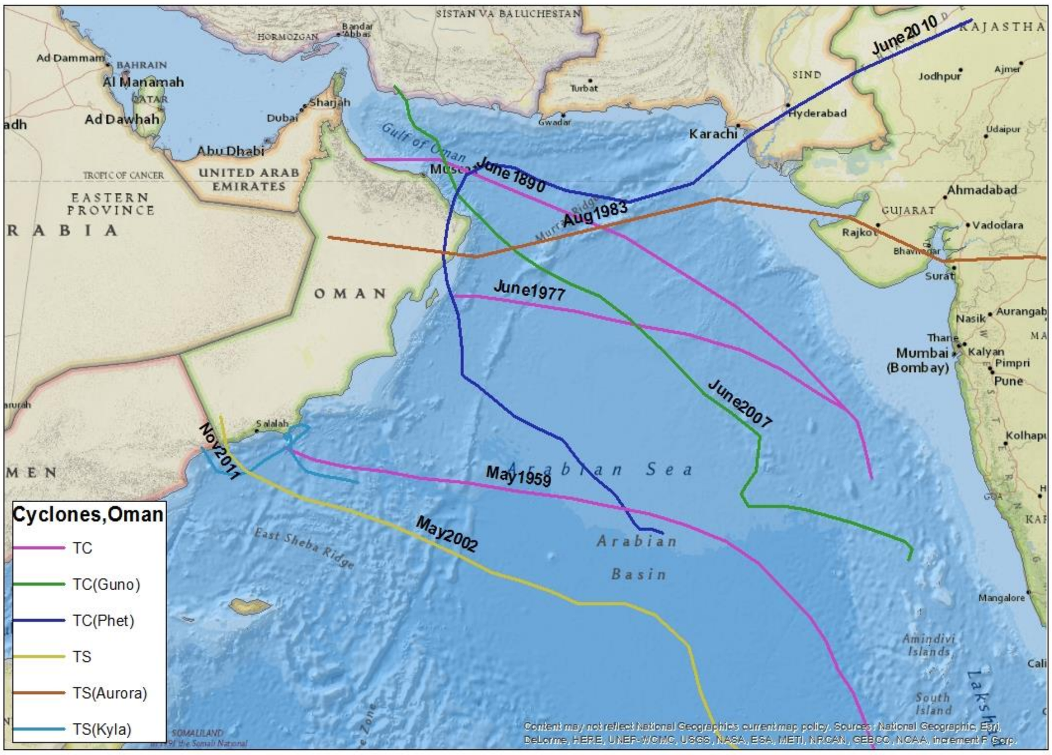


Figure 3.5 Notable Arabian Sea cyclones making landfall in Oman, 1890-2010

[Source: GIS base map, cyclone direction by author]

Table 3.4 Notable Arabian Sea cyclones making landfall in Oman 1890-2010

DATE	Disaster	No. killed	Damage	Cost (US $)
June 5, 1890	Tropical cyclone	727	Palm trees, boats, and houses collapsed	9 million at that time.
May 24, 1959	Tropical cyclone	141	Two ships coming from Zanzibar sank in the Arabian Sea	NA
June 13, 1977	Tropical cyclone	105	Buildings damaged on Masirah island, including the military base.	NA
Aug 10, 1983	Tropical storm (Aurora)	NA	NA	NA
May 10, 2002	Tropical storm	7	Hundreds of cattle drowned and several cars were swept away	25 million
June 6, 2007	Super cyclone (Guno)	50	Damaged 25,419 houses and over 13,000 vehicles	4.2 billion
June 3, 2010	Tropical cyclone (Phet)	16	Roads and power lines damaged.	780 million
Nov 2, 2011	Tropical storm (Kyla)	14	Flash flooding caused damage to roads and buildings.	80 million
Oct 31, 2014	Cyclone (Nilofar)	4	Flash flooding caused damage to vehicles, roads, and buildings	NA
June 12, 2015	Cyclonic Storm (Ashobaa)	NA	Flash flooding caused damage to vehicles, roads, and buildings	NA

Source: Membery (2001), Membery (2002), EM-DAT (2014), Al-Maskari (2010), and DGMAN

3.3.3 Flash Floods

Flash floods are the most common type of floods in Oman (Al-Riyami, 1996; Al-Kalbani, 2011). Flash flood "Is the amount of rainfall for a given duration over a small basin needed to create minor flooding (bank full) conditions at the outlet of the basin" (HRC, 2012). Flash floods can carry large loads of waste such as logs which damage the infrastructure (Middleton and Sternberg, 2013). For instance, in May 1981, extreme rainfall produced strong flooding in Muscat that caused damage to the roads (Al-Kalbani 2011).

Climate change in drylands is affecting hydrological characteristics (McIntyre et al., 2007), and increases the flood risk (McIntyre et al., 2007; Al-Qurashi et al., 2008). The flash flood risk in Oman has increased because of the rapid urbanisation and migration to urban areas in the last 4 decades (Al-Harthy, 2011), with poor planning and infrastructure development in flood areas (Al-Harthy, 2011; Al-Kalbani, 2011). Furthermore, the risk of flash floods and their impacts on the economy and people has also increased due to development in the floodplain (McIntyre et al., 2007; Middleton and Sternberg, 2013). Table 3.5 shows some historical records for notable floods in Oman.

Table 3.5 Statistic of some notable floods in Oman

Year	Location	Duration	No. Killed	Displaced	Flood Reason
1989	Muscat	3	2		Depression
1997	Dibba	3	4		Depression
2002	Salalah	3	9	100	Tropical Storm
2003	Nizwa, Muscat	6	30		Depression
2007	Muscat	7	61	60000	Cyclone Guno
2010	Muscat	2	24	200	Cyclone Phet
2011	Muscat	2	16		Extreme Rainfall

[Source: www.dartmouth.edu/~floods]

3.4 Vulnerability assessment in Oman

Although there is a general lack of literature about vulnerability and risk assessment in Oman, it has been discussed by some researchers (Al-

Rawas and Valeo, 2009; Al-Rawas and Valeo, 2010; Al-Hatrushi and Al-Alawi, 2009; Al-Shaqsi, 2015). Climate, topography and urbanisation have been outlined as the main factors responsible for the high impact of floods in the Omani drylands (Al-Rawas and Valeo, 2009; McIntyre et al., 2007).

Vulnerability in Oman is multidimensional (Al-Shaqsi, 2015), comprising physical, economic and social variables (Al-Shaqsi, 2015; DGMAN, 2014a). Al-Shaqsi (2015) outlines the main reasons for the vulnerability in Oman.

Urbanisation is a relatively new issue in Oman, and it is linked to the development of the economy (Al-Awadhi, 2007). There are several rapidly growing industrial cities in Oman, and many people have moved to live in these areas (Al-Awadhi, 2007; Al-Shaqsi, 2015). Al-Shaqsi (2015) outlines that modernisation and industrialisation increase the rapid immigration from the rural areas to cities. Consequently, such immigration increases the disaster vulnerability in urbanised areas for many reasons. For example, the basic services are not designed to cater for rapid urbanisation, and are ill-prepared to face an emergency. Al-Shaqsi (2015) highlights the inadequacy of the general public's awareness of disaster. The people in Oman do not appreciate that a cyclone is different from just "heavy rain" and can cause a flash flood (Al-Shaqsi, 2015). For example, during cyclone Phet 2010, seven people were killed because of flash floods.

Modernisation in Oman has led to an increase in employment in the construction industry (Al-Shaqs, 2015). The majority of the workforce come from the sub-Indian continent, and most of them have a low level of education and are poor. This group of people tend to live in temporary wooden housing (Al-Shaqsi, 2015), which cannot protect them from severe winds and heavy rainfall (Al-Shaqsi, 2015). For example, during Guno, about 57% of the fatalities occurred among these people (Al-Shaqsi, 2015).

McIntyre et al. (2007) and Al-Rawas (2009) discuss how the climatic conditions in different regions of Oman affect rainfall. Al-Rawas (2009) made a comparative study between north Oman and south Oman and summarised the reasons for different rainfall between the two regions. Except for tropical storms, which can reach any part of Oman, the cold frontal systems during winter and early spring and convective rainstorms that occur at any time of the year, mostly in the summer, are the main causes of rainfall in Oman (Al-Rawas, 2009; Al-Rawas and Valeo, 2010). South Oman (Dhofar), meanwhile, is affected by the "on-shore monsoon currents" from June to September, which cause a frequent drizzle in the region (Al-Rawas and Valeo, 2010). The different climatic criteria make it problematic to have a single flood model for all regions, and a different model is required for each region (Al-Rawas, 2009).

In a comparative study between Al-Rustaq, the Oman watershed and Calgary, Canada, (Al-Rawas, 2009) investigated the difference between rainfall in the dry mountains and coastal region by developing "a temporal distribution of the total rainfall during a storm event". The purpose of the investigation was to solve engineering and hydrological problems such as drainage systems in urban storms (Al-Rawas and Valeo, 2009). The study showed that the intensity of rainfall in the mountains is higher than in the coastal area (Al-Rawas, 2009). Al-Rawas and Valeo (2009) demonstrated that the high intensity of the storm precipitation in Oman is at the beginning of the storm and affects the density of floods in the arid region.

In terms of the impact of urbanisation on floods in Oman, most studies highlight concerns about peak flood discharge (Al-Rawas, 2009; Al-Kalbani, 2011). Land-use has changed significantly since 1970, and urbanisation has accelerated since 1980 (Al-Awadhi, 2010; Al-Hatrushi and Al-Alawi, 2009). Rapid urbanisation and land-use change are the main causes of increased peak flood discharge (Al-Hatrushi and Al-Alawi; 2009; Al-Awadhi et al., 2009; Al-Awadhi, 2010). Green spaces have declined by 84% in urban areas of Muscat, and there is no strong legislation to prevent this from happening (Al-Awadhi, 2010).

In a case study of Wadi Uday, Muscat, Al-Hatrushi and Al-Alawi (2009) evaluated the impact of land-use change. They outlined rapid increase in the urban area and change of land use from agriculture to the commercial and residential building, with consequent increase of flood-peak discharges due to loss of green cover (Al-Hatrushi and Al-Alawi, 2009). The poor discharge system in the city causes artificial lakes to form, even with normal levels of seasonal rain (Al-Kalbani, 2011). The higher speed of flood runoff, especially during storm events, affects the urban area (Al-Hatrushi and Al-Alawi 2009). Al-Awadhi et al. (2009) assessed the impact of cyclone Guno floods in the urban area in Muscat. The high impact was caused by extreme flash floods in urban infrastructure and built-up areas and residential places (Al-Awadhi, 2010). The flood hazards happen because the city is built on the floodplain without making a suitable discharge system for the increase in water flow during peak flood intensity (Al-Awadhi, 2010, Al-Kalbani, 2011). The massive and high-intensity floods in Guno destroyed roads, bridges and buildings (Al-Awadhi, 2010). Al-Kalbani (2011) discussed the floods in Al-Seeb, Muscat using Wadi Al-Khoud as a case study. Al-Kalbani (2011) investigated the best way of monitoring and managing the wadi floods by building an efficient database for the watershed and flooded area. Al-Kalbani (2011) argues for the importance of government action to control flood hazards by integrating flood risks into planning strategies. For example, action can be taken by setting clear land use policies for land cover change (Al-Rawas, 2013, Al-Hatrushi and Al-Alawi, 2009), and improving the discharge system (Al-Kalbani, 2011).

The Hydrology Department of Oman, together with the World Meteorological Organization (WMO) and the US Hydrological Research Centre (HRC), began working on the flood monitoring system in Oman to reduce damage and prepare flood guidance (HRC, 2012). The Flash Flood Guidance (FFG) system is designed to reduce the loss of life and property caused by flood destruction (HRC, 2012). The system supports the warning system, which will be used during periods of heavy rainfall (HRC, 2012). Moreover, floods are not the only potential disaster in Oman. After the Indian Ocean tsunami in 2004, His Majesty Sultan Qaboos issued an order for the ministries council to create a multi-hazard early warning system in Oman. The order was given to the General Directory of Meteorology and Air Navigation (DGMAN) (Al-Rumhi and Al-Harthy, 2014).

DGMAN (2014a) worked on the development of vulnerability risk assessment from different perspectives: human, environmental, social, economic, and infrastructure. For example, after assessing social vulnerability, they found that Muttrah was the most vulnerable place because of the social structure and the fact that many people living there did not speak Arabic, and so they would not be able to understand early warnings broadcasts.

The early warning system focused on monitoring two types of disasters, tsunami and storms, through risk assessment and based on scenarios (DGMAN, 2014a). The risk assessment covered a selected area in the coastline of Oman including Sohar, Musandam, Sawadi, Muscat, Quariyat, Sur, Masirah, Al Duqum, and Salalah (DGMAN, 2014d). Figure 3.6 is an example of the risk and vulnerability maps.

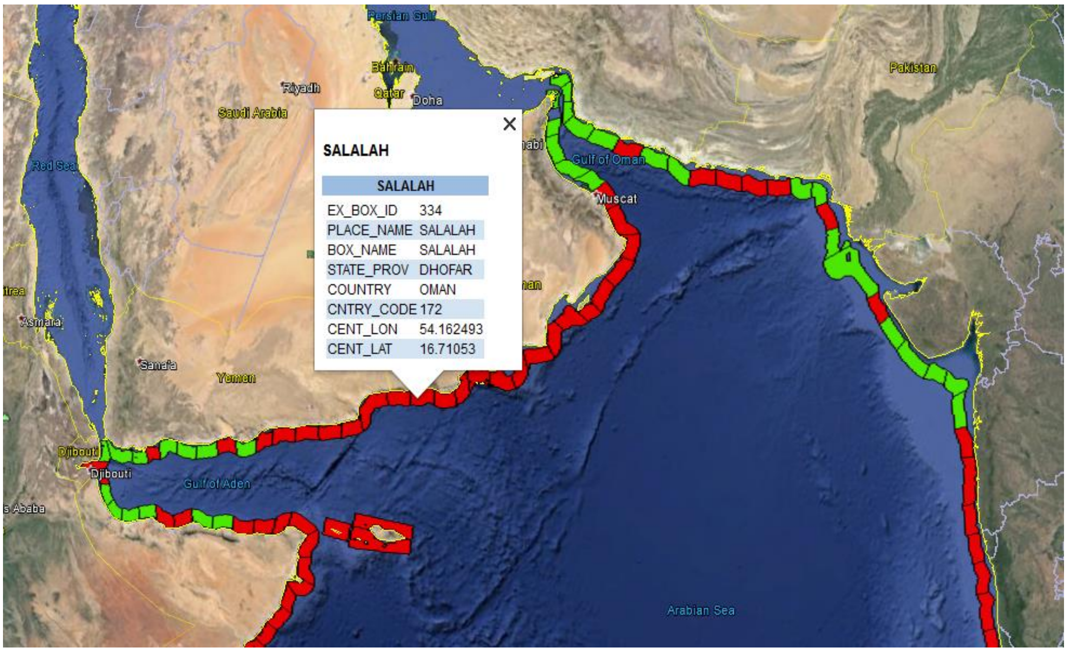


Figure 3.6 Tsunami risk zone map

[Source: Fauzi (2014)].

The second project implemented by DGMAN is the standard operating procedure (SOP) for natural disasters. The project focused on developing the actions needed during and after the event. The major aims of the project were to reduce the impacts of natural hazards, improve public awareness of both individuals and institutions, and to develop cooperation between institutions. The project has stakeholders from different institutions, but some of the institutions are still not collaborating[3]. In an interview[4] with the Ministry of Education stakeholder, the interviewee explained that: "they focus on the development of the actions procedure for the schools in the risk zone during the tsunami and other natural hazards. The safety of the students and school staff is the main point of the procedure, as well as the building capacity. For instance, they work on building a strategy for improving student awareness about the hazards and best way of evacuation during the tsunami." However, the information flow and the systematic platform are the main issues in the institution. Thus, the standard operating procedures recognised that a reliable, rapid, redundant and frequent dissemination system is key to the success of the national disaster management system for public safety[5]. The SOP recognised that public awareness also plays an important role in the preparedness program, for example, including disaster risk reduction education in the education system is essential.

3.5 Disaster management in Oman

Arab countries have noticed the global increase in the number of the hazards, and their own vulnerability (UNISDR, 2004c; UNISDR, 2013a). In 2013 the Arab countries began a partnership with the UNISDR and UNDP to take action for building community resilience to disasters through the Aqaba Declaration on Disaster Risk Reduction in Cities (UNISDR, 2013a). The Aqaba declaration on disaster risk reduction in cities called for four basic objectives to be met by Arabian states to reduce disaster risks in the cities (UNISDR, 2013a). The declaration outlines principles of engagement of civil society organisations in disaster management, along with

3 Based on an interview with Al Maskari, S. and Al Yahyai, S. (2014) 'Early warning system in Oman'.

4 Interview with Nadira Al Harthi from the Ministry of Education

5 Recommendations for Standard Operating Procedure (SOP) Workshop II Muscat, 8-9 June 2014

strengthening capacities and enhancing community awareness. Sustainable development principles must be strongly linked to urban development planning across all sectors, including infrastructure, environment, energy and socio-economic development, to increase resilience to disaster. Furthermore, the countries should provide sufficient investment in disaster risk reduction (DRR) activities. For example, the multi-hazards that affect the Arab countries, as well as the risks of climate change, should be recognised in their planning strategies (UNISDR, 2013a).

The Arab Peninsula countries have already started implementing disaster management (Al-Shaqsi, 2015; Alamri, 2010). Disaster management in the region has focused on human-made hazards (Al-Shaqsi, 2015; Alamri, 2010). For example, Saudi Arabia has drawn attention to terrorist attacks because of numerous terrorist incidents (Alamri, 2010). Saudi Arabia also started recently to introduce policies for natural disaster management after frequent floods, for example, the Jeddah floods in 2009 (Alamri, 2010; Momani and Fadil, 2010).

Several events in the Indian Ocean and the Arabian Sea have encouraged decision makers in Oman to develop natural disaster management plans for Oman (Al-Shaqsi, 2015). The tsunami in the Indian Ocean in 2004, which started in Sumatra and reached Oman, and Cyclone Gonu in 2007 in Oman encouraged Oman to improve emergency management planning for natural disasters (Al-Shaqsi, 2015). Al-Shaqsi (2015) reviewed the emergency management system in Oman and outlined some important lessons from his research. One of the lessons identified by Al-Shaqsi (2015) is the need to enhance emergency management in Oman to make it proactive rather than reactive. A key finding of Al-Shaqsi (2015) is the need to integrate the concept of emergency management into the development process in Oman. Emergency management is not viewed as an essential part of the development process in Oman (Al-Shaqsi, 2015). Furthermore, although emergency management legislation has existed in Oman for years, the implementation of some sections is still lagging behind (Al-Shaqsi, 2015). Emergency management is not about expansive high technology measures, but rather an integrated system based on ensuring the “basics of life” like water, food, and shelter (Al-Shaqsi, 2015).

3.5.1 Crises and emergency management in Oman

The first record of establishing a national–level emergency management system in Oman was in 1989 (NCCD, 2010; Al-Shaqsi, 2015). The idea of establishing a National Emergency Commission was initiated in 1988 by four main government departments: the Royal Oman Police, the Ministry of the Interior, the Ministry of Health, and the Ministry of Social Affairs (NCCD, 2010; Al-Shaqsi, 2015). The committee was unique in the region (Gulf countries) at that time (NCCD, 2010; Al-Shaqsi, 2015). In the same year, the National Committee of Natural Disasters was established in Oman. However, the first real test of emergency management in Oman was during the 1977 super cyclone in Masirah (NCCD, 2010).

Between 1988 and 1999, there was a gap in emergency management in Oman. There are no records of any emergency activities. Al-Shaqsi (2013), assumes that this period was one of complacency regarding emergency management initiatives in Oman. Emergency management measures stalled as a result of changes in global and regional diplomatic forces after the Gulf War and the ensuing financial crisis in 1991 (Al-Shaqsi, 2015).

In 1999, the National Emergency Committee was revitalised and merged with the National Commission for Natural Disasters to become the National Civil Defence Commission (NCCD) (Al-Shaqsi, 2015). The NCCD was developed under the leadership of the Royal Oman Police and was not active during some periods because it was first established as a governmental body to react to national disasters and emergencies (Al-Shaqsi, 2015). It was a section within the civil defence directorate of the Royal Oman Police, and it did not engage in disaster preparedness activities in Oman (Al-Shaqsi, 2015). In 2002, the NCCD became a separate executive office (NCCD, 2010; Al-Shaqsi, 2015). Al-Shaqsi (2013), explains this movement as a reaction to the global expansion of the concept of emergency management following the 9/11 terrorist attacks. In 2003, subcommittees were formed to carry out emergency preparedness activities at the regional level (NCCD, 2010; Al-Shaqsi, 2015). Since 2003, small emergency response teams have been formed within the framework of the Royal Oman Police (Al-Shaqsi, 2015).

In 2007, super cyclone Gonu hit Oman, and the NCCD undertook the first national-level disaster management action. After Gonu, Sultan Qaboos issued a new decree for the restructuring of the NCCD. The new structure requires the NCCD to be more proactive in terms of emergency preparedness measures rather than just responding to disasters (Al-Shaqsi, 2015). In 2010, cyclone Phet hit Oman. His Majesty Sultan Qaboos issued a royal order to form a national disaster management system in Oman (NCCD, 2010). The national committee headed by the Royal Oman Police included the NCCD members and the organisations concerned with disaster management. An order was issued to review the national emergency management system and to establish procedures to maintain full emergency preparedness (NCCD, 2010). Table 3.6 reviews the legislative instruments adopted to develop and enhance the performance of the emergency management system in Oman.

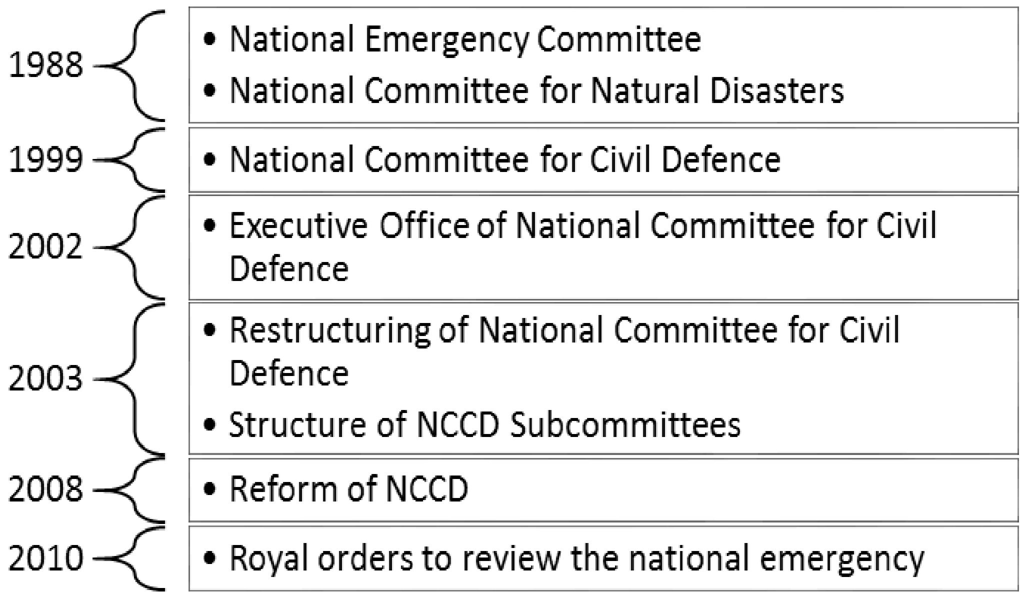


Figure 3.7 Timeline of Emergency Management in Oman

Table 3.6 Legal framework for emergency management system in Oman

Royal Decree	
Royal Decree No. 32/88	Orders the establishment of the National Emergency Committee.
Royal Decree No. 73/88	Amends Royal Decree No. 32/88. Replaced the name "National Emergency Committee" with the name "National Committee for Natural Disasters".
Royal Decree No. 75/99	Amends the Civil Defence Law Replaces the name "National Committee for Natural Disasters" with the name "National Committee for Civil Defence (NCCD)".
Royal Decree No. 51/2003	Orders the restructuring of the National Civil Defense Committee.
Royal directives	In June 2010, during Cyclone Phet, His Majesty ordered instructions for reviewing national emergencies.
Cabinet Order	
(Session 9/2008)	Orders the restructuring of the National Civil Defense Committee. Orders the adoption of procedures to handle radiological, chemical and biological substances.
Inspector General of Police and Customs' Ministerial	
Order No.50/2002	Orders the establishment of the Executive Office for the NCCD to undertake all the coordination duties related to the NCCD's mission.
Order No.117/2003	Orders the establishment of NCCD Subcommittees in the Governorates and Regions.
Order No.158/2003	Amends the Ministerial Order No.117/2003
Order No.11/2005	Outlined the NCCD Executive Office terms of references
Order No.63/2005	Orders the addition of one member to the NCCD Subcommittees
Order No.45/2008	Orders the restructure of the NCCD Subcommittees and delineating their terms of reference.
Order No.72/2008	Orders the addition of one member to the NCCD Subcommittees in the Governorates and Regions.

3.5.2 The National Disaster Management System (NDMS)

The National Committee for Civil Defence (NCCD) is responsible for emergency management in Oman through a comprehensive system working on disaster risk reduction. The NCCD has a Chairman who is the

Inspector General of the Royal Oman Police. The daily operation of the NCCD is coordinated by the executive office of the National Committee for Civil Defence (NCCD). The National Disaster Management System is the systematic platform of the NCCD for disaster management in Oman. The system comprises the executive office of the National Committee for Civil Defence (NCCD), the Sectors (Figure 3.9), and the Sub-committees.

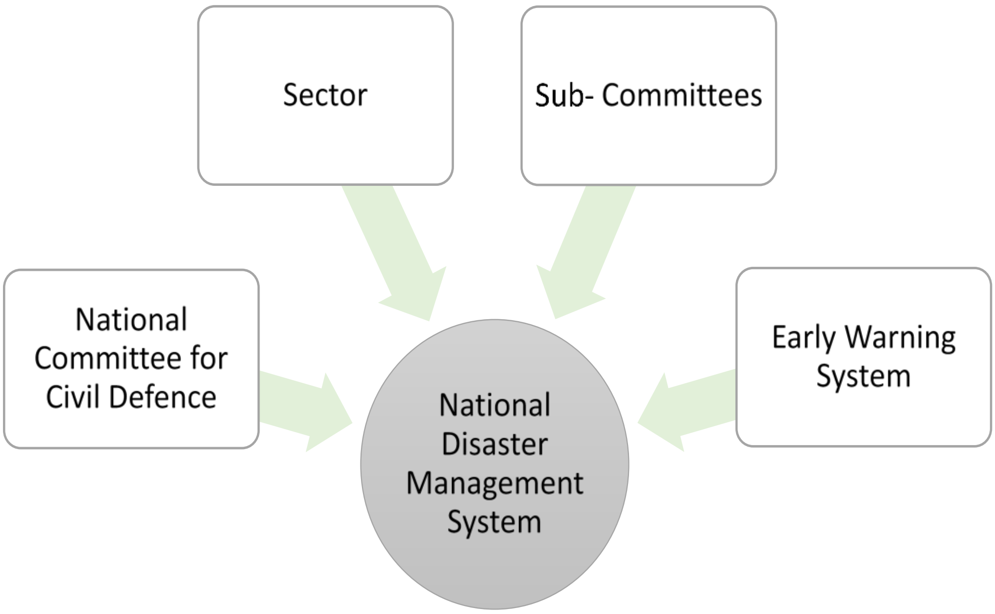


Figure 3.8 Structure of the National Disaster Management System in Oman

The executive office of the National Committee for Civil Defence (NCCD) is responsible for follow-up and coordinating efforts to strengthen national capacities and capabilities for emergency management. The NCCD executive office is also responsible for integrating its component services and ensuring their readiness to achieve the goals and objectives of the NCCD.

NCCD sub-committees are responsible for managing emergencies at the regional level, also for organising and mobilising the resources, the capacities, and the response teams to control and reduce the disaster risk.

The sectors are permanent working groups (Figure 3.9) responsible for planning and preparing and responding to emergencies. They are organised into eight groups: the early warning centre, media and public awareness, search and rescue, medical response and public health, relief and shelter, basic services (infrastructure), a group dealing with victims and missing people, and a group handling hazardous materials. These sectors consist of subsectors that represent the government and non-government organisations. However, only seven sectors have taken action or started their missions.

1. Media and Public Awareness

Media and Public Awareness is responsible for emergency information management in the media. They are responsible for providing the appropriate information about the disaster and potential risk. The Ministry of Information is the head of the sector, with the participation of the General Authority for Radio and Television, Oman News Agency, and the information and media sections of other organisations.

2. Search and Rescue

Search and Rescue is responsible for managing and taking action on rescue calls. They are responsible for building national capacities in emergencies and evacuation. The Public Authority for Civil Defence and Ambulance is the head of the sector, with the participation of the Ministry of Defence, and other relative government and non-government organisations.

3. Early Warning System

The Early Warning System is responsible for monitoring and evaluating natural hazards and man-made hazards. The early warning centre consists of sub-centres. Sub-centres dealing with natural hazards, include the Seismological Centre at Sultan Qaboos University, the Numerical Forecasting Centre of the Meteorological Department, and the Ministry of Municipalities, which is responsible for monitoring floods and the Hydrology Network. The Early Warning centre is also responsible for monitoring man-made hazards through such as the Radiation Monitoring Centre at the Ministry of the Environment and the Authority of Civil Defence and Ambulance (ACDA), which deals with fire and chemical hazards.

4. Medical Response and Public Health

Medical Response and Public Health are responsible for providing medical services for the victims. They deal with injuries, diseases and epidemics which can appear due to disaster. They are responsible for improving health services and keeping them running constantly during emergencies. The Ministry of Health is the head of the sector, with the participation of all health institutions in the government and private sector, such as the health services in the Ministry of Defence.

5. Relief and Shelter

Relief and Shelter is the sector responsible for the organisation of shelters, and the provision, transfer and distribution of relief materials. The sector is organised by the Ministry of Social Development, with the participation of the Public Authority for Stores and Food Reserve (PASFR), Oman Charitable Organisation (OCO), and other related organisations, such as the Ministry of Education for school buildings.

6. Basic Services (Infrastructure)

The infrastructure sector is responsible for overseeing supply of sustainable basic services (roads, power, water, communication, gas and oil, and sewage) to the affected area. The Public Authority of Electricity and Water (PAEW) is the head of the sector, with the participation of related government organisations, the private sector, and non-government organisations.

7. Victims and Missing People

The Victims and Missing People sector is responsible for investigating reports of victims and missing people during the disaster and providing information about them. It is responsible for identifying the victims and looking after their bodies and contacting their families. The General Directorate of Inquiries and Investigations is the head of the sector, with the participation of the Forensic Medicine Section, the Public Health Section, and the Medical Response and Public Health Sector.

8. Hazardous Materials (Chemical, Radiation, and Biological Hazards)

The sector is responsible for organising and coordinating preparedness and responses to hazardous material accidents (chemical, radiation, and biological hazards). These hazards need special procedures and capacities to control and manage the risk. The Public Authority of Civil Defence and Ambulance has responsibility for controlling and managing this sector, with the participation of the Ministry of Environment and climate affairs.

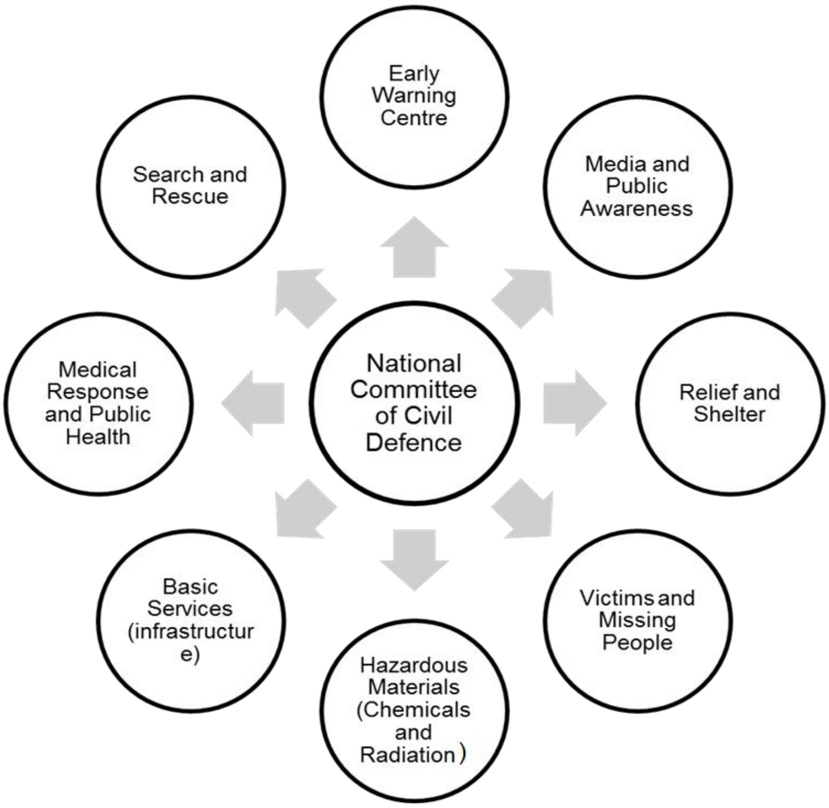


Figure 3.9 Sectors of NCCD permanent working groups

3.6 Gaps in knowledge (planning resilience)

From the previous literature review, it is clear that most studies focus on the physical system, such as understanding the natural factors relating to the hazards, the impact of urbanisation in the flood system and the impact of floods in the urban area. However, there are gaps in the research about disaster management in Oman. Planning for community resilience to a natural disaster is an important topic, due to the increase in the frequency of natural hazards (UNISDR, 2014) and change in community structures and land cover (Al-Kalbani, 2011; UNISDR, 2004b). UNISDR (2005), provides the framework for building community resilience to disasters. In Oman, it is clear that there is a disaster management platform, with a hierarchical system. The Institutional system is taking a pragmatic approach to building resilience and forming a sustainable strategy for development, which will lead to community safety. Oman, as a country vulnerable to natural disasters, is looking forward toward developing structures and procedures for safety and resilience during natural disasters (NCCD, 2013; DGMAN, 2014d). However, no research or report has yet discussed organisational performance and community resilience to disasters in Oman. In consequence, the factors affecting resilience and organisational capacity in Oman are fuzzy.

One of the main gaps requiring research is the institutional system in Oman. Al-Shaqsi (2015) has reviewed emergency management in Oman; however, some points are not clear. The ability and the capacity of the organisations are not well studied in the literature. There is a need to analyse organisational capacity to understand to what extent these organisations are able to manage the disasters and determine the best planning systems and regulations for disaster management in Oman.

The concept of resilience is widely used within the concept of disaster risk reduction. The Hyogo Framework for Action: Building resilience to disaster (UNISDR, 2005) identifies a clear process of building resilient communities to disaster. However, literature reviews on resilience in Oman are absent, and no reports on the implementation of the Hyogo Framework for Action (HFA) exist. Resilience in Oman is mentioned only in the synthesis report of HFA implementation in the Arab states (UNISDR, 2015a). It is important to understand the level of resilience to disaster, as this can affect the capacity of the organisations to respond. This needs to be clarified by measuring implementation of the components of the HFA index in order to understand the resilience of the organisations and the community to disaster.

Identifying the factors that are affecting disaster management resilience is important to this research, to identify the best planning system and regulation for disaster management in Oman. The factors affecting management can be natural, human, and organisational, and can cause a negative or positive change in the emergency system, and this needs to be clarified.

In conclusion, the main objective of this study is to fill the gaps in knowledge about community resilience to disaster and the challenges of building community resilience in Oman. The thesis will investigate the progress and the performance of the organisations within the Hyogo Framework for Action. The study will also examine how best to achieve preparedness and build community resilience to catastrophic events.

3.7 The research framework

The Hyogo framework (UNISDR, 2005a) is used to create the framework for this study. The framework is applied to understand the organisational capacity and the level of resilience. Figure 3.10 shows the framework applied in this study to assess the level of resilience in the organisations working in disaster risk reduction in Oman. The study uses this framework along with the resilience components developed by Twigg (2009). The research will analyse the relative capacity of the organisations to implement disaster risk management in Oman. The research framework also focuses on building organisation resilience and the implementation of the Hyogo Framework. Building resilience is important to enhance the capacity of the organisations; it also has a positive impact on the performance of the relevant organisations. It is necessary to understand the factors with negative and positive impact on the process of building resilience in order to develop and enhance the resilience to disaster by focusing on improving the positive factors and eliminating the negative factors.

The framework will be used to answer the research questions in three chapters. Chapter 5 will focus on the capacity of the organisations, Chapter 6 will investigate resilience, and its impact on the capacity of the organisations, and Chapter 7 will examine the negative and positive factors affecting the resilience building process, and the change caused by the identified factors to the system.

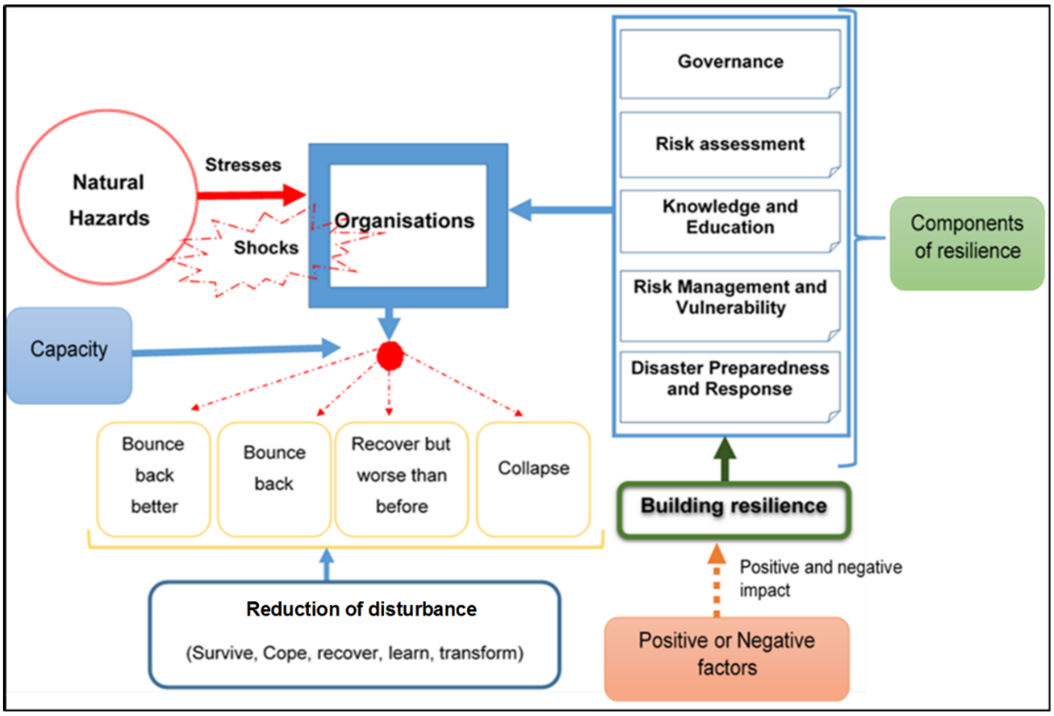


Figure 3.10 Framework for building resilience in the organisations

[Framework created by the researcher]

Chapter 4 Methodology

4.1 Introduction

This chapter presents the methodological framework used to fill the identified gaps in knowledge and address the research questions. The study seeks to answer the main question about the institutional arrangement needed to build community resilience to the occasional severe hazard. The main research question is approached through three main sub-questions, addressed through a stakeholder approach.

The research methods were applied on the organisations related to disaster management in Oman. Some methods were also applied to the public to better evaluate the data and information collected from the organisations. This chapter presents the methodological approach in section 4.2 and its theoretical background in section 4.3. Data collection methods are described in section 4.4.

4.2 Methodological approach

Whilst quantitative methods are widespread in disaster risk research, qualitative methods are often more appropriate, and hence widely used, in research that addresses community and institutional risk factors (Fleischhauer et al., 2012; Harries and Penning-Rowsell, 2011). Understanding how stakeholders are involved in decision making, planning and wider governance that influences resilience and adaptation capacity is clearly important and a challenge best addressed through methods that enable investigation of individual and institutional behaviours and perceptions.

Fleischhauer et al. (2012) for example, used qualitative methods with stakeholders in flood risk management to understand flood risk governance and effectiveness of flood risk mitigation strategies. Similarly, Harries and Rowsell (2011) applied semi-structured interview methods with risk managers to investigate factors affecting the decision making for flood risk reduction in England. The in-depth interview method was used to reveal the stakeholders' perspectives and reasons that affect their decisions (Harries and Rowsell, 2011)

Q method is another "quantitative technique for eliciting, evaluating, and comparing human subjectivity" (Robbins and Krueger, 2000). It is a method used to understand social behaviour through integrating qualitative and quantitative techniques (Webler et al., 2009). Q method uses a card-sorting technique that categorises the stakeholders based on practical analysis rather than theoretical views (Barry and Proops, 1999; Webler et al., 2009). Webler et al. (2009) explain how Q can be used to empower local communities to become more efficient in disaster recovery decision-making. The Q method collects data based on interviews with stakeholders to understand their thinking (Webler et al., 2009), but it cannot be used in linking different stakeholders and institutions.

The approach of this research is to apply mixed methods, with stakeholder involvement. These methods produce the primary data and the information needed to answer the sub-questions of the research. The involvement of stakeholders is key to understanding the disaster management system in Oman, its performance, and perceived strengths and weaknesses.

Stakeholder analysis methods are applied in chapter five to assess the organisations' capacity and the stakeholder involvement in disaster management in Oman. Three different stakeholder analysis tools are used: frameworks, power matrices and social networks. The frameworks and power matrices are applied to understand the roles and responsibilities, and the position of the stakeholders, whilst social network analysis is also applied to study the interaction of the organisation and the influence of the interaction in the organisation's capacity. In chapter six a statistical approach is applied to calculate a resilience index for Oman. The weighted mean index is applied to measure the implementation of the Hyogo Framework for Action in Oman. In chapter seven, Fuzzy Cognitive Mapping (FCM), a method of collecting and analysing systems data, is applied to identify the factors affecting disaster management resilience in Oman.

4.3 Theoretical background of the method

Different methods are applied in this study. The theoretical background of these approaches is discussed in the following sections. Figure 4.1 shows the methods applied in the research to answer the sub research questions.

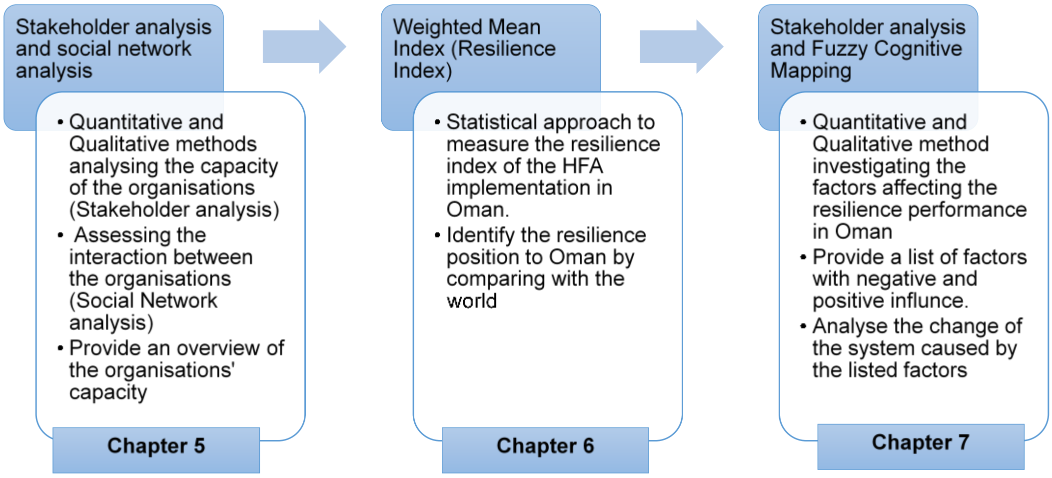


Figure 4.1 Research methods used in this thesis

4.3.1 Stakeholder analysis

Stakeholder is a popular term used in many literature studies (Freeman, 1984; Carroll and Buchholtz, 1993; Starik, 1994; Donaldson and Preston, 1995; Carroll and Näsi, 1997; Clarkson, 1998; Reed, 1999; Gibson, 2000; Stoney and Winstanley, 2001; Reed, 2002).

Table 4.1, modified from Friedman and Miles (2006), shows examples of stakeholder definitions chronologically ordered. An early definition of stakeholders is: “Those groups without whose support the organisation would cease to exist”, from Stanford Research Institution (1963) (Friedman and Miles, 2006).Many researchers adapted this definition. However, most of the recent definitions build on Freeman’s (1984) definition of stakeholders being those who can affect or are affected by the decision making (Rowley, 1997; Reed et al., 2009; Freeman et al., 2010). This definition is “more balanced and much broader than that of the Stanford Research Institution” (Friedman and Miles, 2006). Friedman and Miles’ (2006) understanding of the Freeman (1984) definition is that the phrase “affect or affected by” opens out the idea of who should be considered as a stakeholder to include those outside the decision making organisation and so is broader than a specific individual or group. The definition is made even broader by Gray et al. (1996) who define the stakeholder as “any group or individual that can be influenced by, or can itself influence, the activities of the organisation”. Similarly, the definitions of Carroll and Buchholtz (1993) and Wicks et al. (1994) consider the interests of the stakeholders and how they affect the organisation.

Table 4.1 Definitions of stakeholders

Stakeholder definition	Author
Those groups without whose support the organisation would cease to exist.	Stanford Research Institution
Wide: those who can affect the achievement of an organisation’s objectives and those who are affected by the achievement of an organisation’s objectives	Freeman and Reed (1983)
Narrow: on which the organisation is dependent for its continual survival	
Can affect or are affected by the achievements of the organisation objectives	Freeman (1984)
Any naturally occurring entity that affects or is affected by organisational performance	Starik (1994)
Interact with and give meaning and definition to the corporation	Wicks et al. (1994)
Those individuals with explicit or implicit contracts with the firm	Donaldson and Preston (1995)
Identified through the actual or potential harms and benefits that they experience or anticipate experiencing as a result of the firm's actions or inactions	
Any human agency that can be influenced by, or can itself influence, the activities of the organisation in question.	Gray et al. (1996)
Any individual or group who affects or is affected by organisation and its processes, activates, and functions	Carroll and Näsi (1997)
Those with an ‘interest for which a valid normative claim can be advanced.’	Reed (1999)

Carroll and Näsi (1997) defined stakeholders as “those individuals and groups which have a valid stake in the organisation”, [..] have a legitimate interest, or stake, in what the firm is doing and how it is accomplishing its objective. Then, the contribution of Starik (1994) pushes the definition to the broadest end of the spectrum (Friedman and Miles, 2006). The definition of Starik (1994) is based on a connection between Freeman (1984) and Carroll and Buchholtz (1993). Starik (1994) suggests that the stakeholder can be “any naturally accruing entity which affects or is affected by the organisation’s performance”. Starik’s (1994) assessment is that the environment wants the “political-economic” voice. Starik (1994) argues the moral aspect of considering the environment as a stakeholder (Friedman and Miles, 2006; Freeman et al., 2010). In contrast, Phillips’ (2003) argument is that considering the environment as a stakeholder will not help managers make decisions on what they should do with the environment. Furthermore, Phillips (2003) claims that not every moral concern has to be included in stakeholder theory, and providing an extra description in the stakeholder definition will not help to address the problems degrading the environment.

Nevertheless, stakeholder definitions have to attempt to cover many different issues, which has caused many problems and raised certain implications. Donaldson and Preston (1995) considered these differences and implications, and categorised definitions of stakeholders based on three approaches: descriptive, normative, and instrumental.

Normative, instrumental, and descriptive stakeholders

Three different approaches are used to differentiate stakeholder definitions (Reed, 2002; Friedman and Miles, 2006). The different approaches to defining stakeholders were first discussed by Donaldson and Preston (1995) who pointed out some important problems and implications associated with the stakeholder concept. They suggested four theses of stakeholder theory: descriptive, instrumental, normative, and managerial. The descriptive is used to describe the characteristics and behaviours of the stakeholders. The instrumental is used to identify the connection between the stakeholders. Meanwhile, the normative is used to describe the fundamental identification of moral or philosophical guidelines for the management of corporations (Donaldson and Preston, 1995; Mitchell et al., 1997). The managerial approach recommends attitudes and structures that attend to the legitimate interests of all appropriate stakeholders.

These theoretical approaches are found in the stakeholder literature, and the confusion is associated with the theoretical approaches being "combined without acknowledgement" (Donaldson and Preston, 1995). For example, Freeman (1984) discussed that the changes in the strategic issues require a rethinking of the traditional picture of the organisation. The opinion of Freeman (1984) creates a discursive approach to the theory (Donaldson and Preston, 1995). Reed (2002) notes that distinction between the stakeholder definitions follows logical lines:

(a) Descriptive stakeholders are defined by whether they are affected by the firm/or can potentially affect the firm, whether the effect of the firm's activities or the decision making.
(b) Instrumental stakeholders are defined regarding the need for the management to take them into consideration when trying to achieve their goals.
(c) Normative stakeholders can be defined as having valid normative claims on the firm.

Although the argument of Donaldson and Preston (1995) is widely used in the literature, Reed (2002) highlighted one weakness, namely the lack of a strong epistemological basis for distinction between different forms of stakeholder. Reed thus suggested the terms positive, strategic, and normative to provide this strong epistemological basis. Thus, to this point, Donaldson and Preston (1995), and Reed (2002) advocate that the normative approach is the strongest (Friedman and Miles 2006). The normative can give epistemological justification for the stakeholder theory, without rejecting the instrumental and descriptive approach (Friedman and Miles, 2006). However, it is recommended that the three approaches are considered as nested within each other (Friedman and Miles, 2006). Figure 4.2 shows the three approaches to stakeholder analysis.

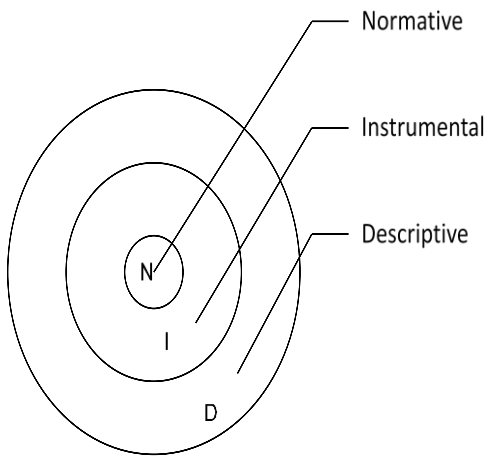


Figure 4.2 Three aspects of stakeholder theory

[Source: 9 Donaldson and Preston, 1995)]

4.3.2 Stakeholder analysis

Stakeholder analysis has become very popular and is adopted in many fields from business management to policy, environmental management, and development (Brugha and Varvasovszky, 2000; Mushove and Vogel, 2005; Reed, 2008). Researchers identify stakeholder analysis as a process or approach to support decision making (Yang, 2014). Table 4.2 gives different definitions of stakeholder analysis; most discussed the issues of identifying stakeholders, the interest and influence of stakeholders, and understanding the system (Brugha and Varvasovszky, 2000; Yang, 2014, Lienert et al., 2013). Some researchers argue the influence of stakeholders in the decision-making process (Brugha and Varvasovszky, 2000; Reed et al., 2009; Prell et al., 2009). Reed et al. (2009), discuss the influence of the stakeholder in decision making, within policy, development, and natural resources management.

In policy development, stakeholder analysis is an approach adapted from the organisational management literature of the 1970s and 1980s, by policy scientists who were concerned with the distribution of power and the role of interest groups in the decision-making and policy process (Varvasovszky and Brugha, 2000; Brugha and Varvasovszky, 2000). The policy analyst uses stakeholder analysis as a tool for a comprehensive analysis to produce new knowledge in the policy-making process, and this requires a strong time dimension for the interests.

Table 4.2 Different definitions of stakeholder analysis

Definition	Author
[…] a holistic approach or procedure for gaining an understanding of a system (.) by means of identifying the key actors or stakeholders and assessing their respective interests in the system.	Grimble and Wellard (1997)
[…] has been developed in response to the challenge of multiple interests and objectives and added to the basket of approaches available for the analysis and formulation of development policy and practice.	Grimble and Wellard (1997)
[…] an approach, a tool or set of tools for generating knowledge about actors to understand their behaviour, intentions, interrelations and interests; and for assessing the influence and resources, they bring to bear on decision making or implementation processes.	Brugha and Varvasovszky (2000)
[…] a range of tools or an approach for understanding a system by identifying the key actors or stakeholders by their attributes, interrelationships and assessing their respective interests related to the system, issue or resource.	Mushove and Vogel (2005)
[…] a process that: defines aspects of a social and natural system […], identifies stakeholders, and prioritises stakeholders for involvement in the decision-making process.	Reed (2008)
[…] approach used to understand environmental systems by defining the aspects of the system under study; identifying who has a stake in those aspects of the system, and prioritising stakeholders for involvement in decisions about those aspects of the system	Prell et al. (2009)

The application of stakeholder analysis in development and environmental management focused on understanding power dynamics and improving the transparency and equity of decision-making in development projects (Reed et al., 2009). Stakeholder analysis in development and environmental management is an issue of participation, including public participation in the decision making (Mushove and Vogel, 2005). It has been used in development and environmental management to empower the interests of marginal and less powerful groups to enable them to have greater influence in decision making (Mushove and Vogel, 2005, Reed et al., 2009). However, the agenda of those convening the process can cause stakeholder analysis to disempower or marginalise certain groups (Reed et al., 2009).

Nevertheless, stakeholder analysis is frequently used, and for many reasons. It is a systematic, critical, and sensitive approach (Reed et al., 2009). It is a participatory approach used to understand the nature of the stakeholder claims and their relationships with each other (Mushove and Vogel, 2005, Reed et al., 2009). Moreover, i is a participatory and powerful approach to policy analysis and planning (Grimble and Wellard, 1997; Reed et al., 2009).

The stakeholders in this study are organisations related to the disaster management system. They are different types of stakeholders, some of them are descriptive stakeholders, and can influence decision making in the organisations. Other stakeholders are instrumental and normative, with clear goals and standards for achieving a better disaster management system in Oman. Stakeholder analysis is applied in this study to classify the stakeholders based on their roles and responsibilities, and their position in the system. It is, therefore, the approach applied in this study to understand the performance of organisations related to disaster management in Oman. It is used also to understand the existing overall system, and its strengths and weaknesses. The analysis method will be discussed in chapter 5.

4.3.3 Social network analysis

Social network analysis is defined as “a method based on the assumption that relationships among the interacting units are important” (Wasserman and Faust, 1994). It is a method that focuses on the relationship between actors and the patterns and implications of these relations (Wasserman and Faust, 1994; Prell, 2011). A social network has actors connected to each other through significant relations (Marin and Wellman, 2011). The social network is constructed from nodes and ties, where nodes are the institutions and the stakeholders (Clark, 2006).

Much research applies social network analysis to express the relationship between interacting units. It is used to understand how actors are positioned in a network, and how the relations are structured into an overall network pattern (Prell et al., 2009; Wasserman and Faust, 1994). It has been applied by Schmeer (1999) to analyse stakeholder characteristics and to define the social network as ‘‘a process of systematically gathering and analysing qualitative information to determine whose interests should be taken into account when developing and/or implementing policy or program’’. Applying this method gives a better understanding of the actors’ roles and actions, analyses driving forces and existing coordination between stakeholders, as well as identifying the strength of the communication between the actors, which can affect the operation and planning (Caniato et al., 2014). Furthermore, the method encompasses theories, models, and applications that express relational concepts or processes (Wasserman and Faust, 1994; Lienert et al., 2013).

In policy analysis, social network analysis concentrates on the structural patterns between actors (Lienert et al., 2013). In natural resources management, the method can be used to ensure that key players in the network are not marginalised, identify the conflict between actors, and select representatives based on the network structure (Reed et al., 2009).

This method is used to understand the interaction between the organisations working in disaster management. It is capable of identifying the structural pattern of the actors involved in the disaster management process. It can be relevant to this study by helping to understand the different patterns of relational ties and structural characteristics of the particular network (Reed et al., 2009; Prell et al., 2009; Lienert et al., 2013). Understanding the structural patterns of networks can lead to conclusions about the impact of the actors on information transfer and the influence of each actor on other actors (Reed et al., 2009; Prell et al., 2009; Lienert et al., 2013). Actors with strong relationships strongly influence each other, support each other in times of emergency, have similar ideas and plans, communicate successfully and highly trust each other (Prell et al., 2009). Social analysis is also used to identify centrality, which indicates the power of the network to connect the different actors (Marin and Wellman, 2011).

Three indicators of centrality: degree centrality, centralisation, and betweenness, are used as measures (Marin and Wellman, 2011).

In this study, social network analysis will be used to identify the functional level of the organisations during extreme weather events by identifying weak and strong relationships between the institutions, and by analysing the organisational planning systems and planning regulations. The analysis method will be discussed in chapter 5**.**

4.3.4 Fuzzy cognitive maps

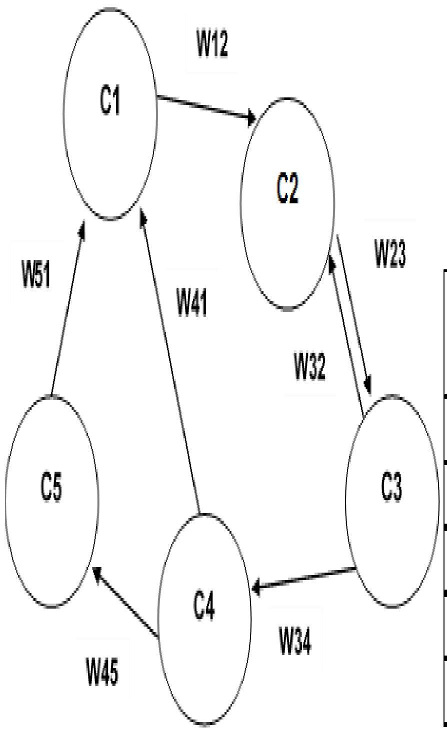
Fuzzy Cognitive Mapping (FCM) is an effective approach for modelling complex systems, representing causal reasoning, and takes advantage of knowledge and experience (Groumpos, 2010; Groumpos, 2015; Kontogianni et al., 2012; Kosko, 1986; Papageorgiou and Stylios, 2008; Van Vliet et al., 2010; Wu et al., 2017). Axelrod (1976) was the first to apply the digraphs to show causal relationships between variables, producing cognitive maps, a formal way of representing knowledge and modelling decision making in the political system (Aguilar, 2005; Homenda and Jastrzebska, 2017). Kosko (1986) modified Axelrod's (1976) cognitive maps by adding fuzzy logic and so introduced the fuzzy cognitive map. Kosko (1986) identifies the FCM as "fuzzy-graph structures for representing causal reasoning". Table 4.3 presents some FCM definitions.

Table 4.3 Definitions of Fuzzy Cognitive Maps

Definition	Scholar
[…] are fuzzy-graph structures for representing causal reasoning.	Kosko (1986)
[…] are a modelling methodology based on exploiting knowledge and experience	Papageorgiou and Stylios (2008)
[…] represent key-factors and characteristics of the modelled complex system and stand for: events, goals, inputs, outputs, states, variables and trends of the complex system being modelled.	Groumpos (2010)
[…] is a modelling technique, arising from the combination of Fuzzy Logic and Neural Networks.	Groumpos (2015)
[…] effective tools for modelling complex systems and supporting decisions.	Wu et al. (2017)

A fuzzy cognitive map (FCM) is thus a graphical presentation of knowledge or perception of a given system and how it functions (Kontogianni et al., 2012; Michael, 2009). FCM structure consists of n concepts representing the important elements of the system (Figure 4.3). The concepts are connecting direct lines with a fuzzy value (weight) showing the relation (Wji) between factors, which describe the influence of concept Ci on concept Cj. The influence value range is -1 to +1 (Kontogianni et al., 2012; Vergini and Groumpos, 2016; Stylios et al., 1997; Groumpos, 2010, Groumpos, 2015; Kosko, 1986; Papageorgiou and Stylios, 2008; van Vliet et al., 2010; Wu et al., 2017).

Once the FCM has stabilised, the result can show the trends within the system (Michael, 2009). However, using an adjacency connection matrix for storing the weights can also offer the probability of simulations and building scenarios (Kontogianni et al., 2012).



To/From	C1	C2	C3	C4	C5
C1	0	1	0	0	0
C2	0	0	1	0	0
C3	0	1	0	1	0
C4	1	0	0	0	1
C5	1	0	0	0	0

Figure 4.3. A simple Fuzzy Cognitive Map, and adjacency connection matrix

FCM is a qualitative modelling tool that can describe any system (Özesmi and Özesmi, 2004; Papageorgiou and Stylios, 2008). Özesmi and Özesmi (2004) identified four cases that make the method usable in any system. First, is thecase where hard to identify human behaviour plays a significantrole. Second, is the case where scientific data is missing, but local and traditional knowledge is available. Third, is the case of very complex questions, where no simple answer is available despite many different positions being included, and fourth, the case where public opinion is needed. Papageorgiou and Stylios (2008) provide three requirements for using the model for describing a system. The first requirement is the signed causality indicating positive and negative relationships; second, the fuzzy values of the strength of causal relationships; and third, the dynamic effects of the causal links, that a change affecting one concept can affect other concepts. FCM is a useful approach because it is easy to build and flexible in representing concepts, whilst it is easy to use and understandable by the non-expert. It is relevant to complex management and knowledge issues, and can handle the dynamic effects because feedback is incorporated in the model system structure (Papageorgiou and Salmeron, 2013; van Vliet et al., 2010).

FCM has been applied in many different fields, where it can be used to explain the decision-making behaviour and predict future decisions and actions. It is also used to reflect on how a given situation is represented, to promote necessary changes, and as a strategic method for decision making in a complex situation (Papageorgiou and Salmeron, 2013; Markovskii, 2008). Kardaras and Mentzas (1997) used the method to analyse business performance indicators. Özesmi and Özesmi (2004) used FCM to address environmental problems based on people's knowledge. In medical research Kannappan et al. (2011) applied FCM for modelling and predicting autistic spectrum disorder in children. In addition, Yaman and Polat (2009) applied the method to model the effects-based operations in military planning.

In this research, FCM is applied to identify the factors affecting disaster management in Oman. FCM is used to study the dynamic effect of each factor on other factors. Chapter 7 will discuss the analysis approach of the method in more detail.

4.4 Data collection

A set of primary and secondary data is collected to achieve the aim and objectives of this study.

4.4.1 Primary data

A mixed-method approach is used to collect the primary data from the fieldwork.

1. Semi-structured interview

According to Bernard (2017), the semi-structured interview is the best method in situations where it is not possible to interview the stakeholder multiple times. The semi-structured interview requires the same skills as conducting an unstructured interview, but it is based on an interview guide (Bernard, 2017). The interview guide provides a set of clear instructions for collecting reliable and comparable qualitative data (Cohen and Crabtree, 2006).

In this research an interview form (appendix 4) was used to collect information about organisations dealing with disaster management in Oman. The interviews focused on the analysis of the organisations performance relating to preparedness for, and response to, the disasters in Oman. The interviews were conducted with 12 stakeholders (decision makers) in the NCCD sectors.

The interviews started with an explanation of the project for the participants, and ethical consent considerations were explained (e.g. right to withdraw, anonymity). The interview then focused on three themes. First, the importance of disaster management in the institution. This part focused on the process and knowledge of decision making in the institutions. The questions in this part were about the degree of knowledge of decision making in the institution and how decision influence decision making in the national committee. Also a question about the role of the decision maker in disaster management. The second theme explored data and experience used in disaster management in the institution. This part focused on the sources of data and the challenges of gathering data, information flow and data sharing, the experiences of disaster management in the institution and how this affects decision making, and what the institution needs to develop the work in disaster management. The third theme addressed cooperation with other institutions. This part focused on the type of cooperation between institutions, the degree of communication, the level of institutional responsibility, and the factors which improve cooperation. The outcome of the interviews was used to analyse the organisations roles and challenges, and the information flow between the different organisations. The method is applied in chapter 5 where it is explained in detail.

2. Questionnaire

A questionnaire is a type of structured interview with a set of questions related to the topic of study (Bernard, 2017). This method aims to give the stakeholders the opportunity to assess the organisations by responding to questions based on clear themes.

The questionnaires applied in this research were used to collect data from stakeholders working in related organisations, and from local people.

In chapter 5, the method is used to collect data to analyse the interaction and cooperation between the organisations. Social network analysis is applied to the questionnaire data to identify organisations with high betweenness and closeness, and to analyse the type of cooperation between organisations.

The questionnaire method was also applied to collect data analysed in chapter 6, which assesses organisations resilience in Oman. The questionnaires applied in this chapter were created based on the Hyogo Framework for Action. They were distributed between stakeholders working in the organisation, and local people randomly selected from different coastal and internal areas. The local people questionnaires were applied to measure peoples' satisfaction with disaster management in Oman. The resilience index (explained in chapter 6) was applied to analyse the collected data.

3. Workshop

Two workshops were conducted using Fuzzy Cognitive Maps as an approach to collect data about the factors affecting disaster management in Oman. The workshops were applied in the study area as a pilot (2015) and main (2016) workshop with data collect from stakeholders working in related organisation used to identify the positive and negative factors affecting the disaster management resilience in Oman, and to create an aggregate model combining different stakeholder perspectives.

The details of the workshops are presented in chapter 7, and appendix 3, whilst Table 4.4 summaries the number of stakeholders participated in each method of data collection.

Table 4.4 Summary of methods used to collect the primary data.

Data collection method	Type of Stakeholder	Number of participants	Time of collection
Interview	Sectors decision maker	12	2015
Pilot workshop (1)	Stakeholders working in the organisation	15	2015
Questionnaires	Stakeholders working in the organisation	19	2016
	Local people	35	2016
Main workshop (2)	Stakeholders working in the organisation	16	2016

4.4.2 Secondary data

Literature on disaster management in Oman was collected from the relevant organisations (grey literature). The collected documents detail, for example, existing policies and regulations, plans of disaster management, and reports about existing projects related to disaster management in Oman. However, very little such secondary data was collected as little exists, and it is entirely absent for some organisations.

The collected information is used in chapter 5 to assess the organisation's roles and responsibilities with the data collected from the interviews. It is also used in chapter 6 as examples of the progress made in some organisations.

Chapter 5 Assessment of stakeholder involvement and organisational capacity in disaster management, Oman

5.1 Introduction

The disaster management system in Oman was first established in 1988[6] (NCCD, 2010). However, the current disaster management system was developed after cyclone Gonu in 2007, and cyclone Phet in 2011 (Al-Shaqsi, 2015). The system is ‘top-down’ and coordinated by the National Committee for Civil Defence (NCCD) as discussed in chapter three. The capacity of the relative organisations is not well studied in the literature. Al-Shaqsi (2015) reviewed the disaster management system in his research and outlined that the need to integrate the emergency management into the development process is not appreciated as an important part of the process. This can lead to an ineffective, reactive approach to disaster (Al-Shaqsi, 2015).

Chapter five evaluates the disaster management system in Oman, focusing on relevant organisations. This investigation aims to explore how organisations with disaster management responsibilities in Oman operate, and to develop an understanding of their collective capacity to plan for and respond to a disaster.

Throughout this chapter, stakeholder analysis and social network analysis are used to assess the organisational capacity in disaster management. These methods are particularly useful for studying the capability of organisations, and for understanding the organisation's networks of interaction and cooperation. They are also used to understand the information flow between organisations and the quality of that information.

This chapter is organised as follows. Section 5.2 discusses the data and the methods used for data collection. Both primary and secondary data are gathered on the disaster management system in each organisation. The section analyses the stakeholders, and related organisations involved, and

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[6] Chapter 3 reviews the historical timeline of emergency management in Oman

discusses the method of data collection: interviews and questionnaire used during the interview. Section 5.3 presents the three different methods used for data analysis. Section 5.4 presents the findings of the research and analyses the organisations' capacity in four areas. These are: the roles and challenges of organisations (Section 5.4.1); the power and interest matrix that points out how key player organisations can influence the disaster management process in Oman (Section 5.4.2); the flow and quality of information between organisations (Section 5.4.3); and the interaction and cooperation between organisations (Section 5.4.4). The chapter then draws conclusions on the organisational capacity to address disasters in Oman, prior to Chapter 6, which considers how effectively that capacity has been used to developed disaster resilience.

5.2 Data collection

A mixture of primary and secondary data has been used in this study. The secondary data collection focused on the plans and policies of the organisations, and what they have done in past events in Oman as actions to control the disaster. Then, interviews were conducted with individuals in the stakeholder organisations listed in Table 5.1. The stakeholders in this study are those 12 government organisations with decision-making responsibilities relevant to natural disaster management. The organisations are part of the NCCD sectors which have been discussed in detail in chapter 3. The organisations are all coordinated by the National Committee for Civil Defence (NCCD), which controls the disaster management process in Oman. The questions in the interview aimed to gain the best information and data for analysing the capacity of the disaster management organisations in Oman. The interview questions focused on the structure of the disaster management system in the organisation, the information used in the decision making, and the relationship between the organisation and the other relative organisations.

Table 5.1 Stakeholder organisations and interviewee roles

Sector	Organisation	Role of the interviewee
NCCD	Executive Office of the NCCD	Director of the Executive Office of the NCCD
Early Warning Centre (EWC)	Meteorology department	Director of Meteorology Department, Deputy chairman of the NCCD
Medical Response and Public Health (MRPH)	Emergency Centre for Health Crisis	Director of emergency centre of health crisis, Health sector coordinator in the NCCD
Relief and Shelter	Ministry of Social Development (MOSD)	Coordinator of relief and shelter in the MOSD with the NCCD
	Ministry of Education (MOE)	Consultant in the minister's office, coordinator between MOE (school building) and Relief and Shelter
	Oman Charitable Organisation (OCO)	Executive President of the authority
	Public Authority for Stores and Food Reserve (PASFR)	Director of commercial affairs department
Media	Oman News Agency (ONA)	Director of Oman News Agency
Search and rescue	Public Authority for Civil Defence and Ambulance (PACDA)	Rescue Officer
	Public Authority of Water and Electricity (PAWE)	Director of the Operation department
Infrastructure	Ministry of Transport (MOT)	Director of Roads Department
	Ministry of Oil and Gas (MOOG)	Coordinator between the oil and gas department and the fuel stations

In the interviews, a list of mixed open and closed questions was used to collect the information, with additional questions for clarifying information. The interviews were conducted in Arabic and then the answers translated into English. The questions were about the power and interest of the stakeholder, the information flow, and the interaction between the stakeholder's organisation and other partners. These questions were designed to cover three areas: the importance of disaster management in the organisation, the information used in the decision making, and the interaction between the organisation and other organisations. The list of questions and scoring system for answers are presented in Table 5.2, and the open-ended questions to collect stakeholders' opinions about different issues related to disaster management are presented in Table 5.3 and Table 5.4.

Schmeer (1999) proposed four key research tools in his study: (1) questionnaires; (2) stakeholder tables; (3) definitions of stakeholder characteristics with instructions for completing the stakeholder table; and (4) scoring scales for quantitative/closed questions. Caniato et al. (2014) applied Schmeer's (1999) method to collect and analyse data from secondary and primary sources to evaluate infectious waste management in Thailand. The method adopted by Caniato et al. (2014) is applied in this study to collect data from the stakeholders.

Table 5.2 Scoring system for stakeholders of the Organisation

Parameter	Value scale
Knowledge of others with regards to roles, functions and duties of all NCCD members	Low knowledge (1-3)
	General knowledge (3-4)
	Complete knowledge (5-10)
The degree of importance of risk management in the organisation's decisions.	Not important
	low (1-3)
	Limited (3-5)
	Highly important (5-10)
Influence of the organisation’s decisions on the work of risk management in the NCCD decisions.	No influence
	Low (1-3)
	Limited (3-5)
	High influence (5-10)
The interest of stakeholder in disaster management and the NCCD	Not interested
	Low interest (1-3)
	Limited interest(3-5)
	High interest (5-10)
Attitude of the stakeholder toward disaster management	Strongly positive
	Positive
	Slightly positive
	Neutral
	Slightly negative
	Negative
	Strongly negative
Power: the power of the stakeholder to influence the decision making in the NCCD, and the power to develop the work in the organisation.	Low (1–3)
	Limited (3 -5)
	High (5 –10)

Section one of the interview focused on the organisation’s functions, the stakeholder's characteristics, and the organisation’s responsibilities in disaster management. It also addressed the process and knowledge of decision making in the organisations. The questions in this section were about the degree of knowledge of decision making in the organisation and how this knowledge influences decision making in the NCCD. Table 5.3 shows examples of the questions applied in the interview. These questions were intended to give a clear focus on the roles and challenges that the organisations faced and views on the best way to development.

Table 5.3 Questions used in part one of the interviews

What is the role of the organisation in risk reduction?
Mitigation (infrastructure, dams)
Preparedness for response (public awareness, preparing the shelters)
Response and emergency (early warning, rescue and evacuation)
Recovery (health and social services, reconstruction, resettlement)
What is the primary responsibility of the organisation within the disaster management cycle?
Are there any challenges during the implementation of the responsibilities?

Table 5.4 shows examples of the questions used in part two of the interview. The second section focused on the required information and experience for disaster management in the organisation. It focuses on data collection resources and the challenges of gathering data, data quality, information flow and sharing experience of disaster management, and how these affect decision making, and what the organisation needs to develop and improve the work. The stakeholders were asked to list the data resources and to classify the quality of the received data. The data quality was categorised from 0 to 5. The classification of the data is based on the availability of the data from the sources, the accuracy of the data, and the speed of collection (the time from data order and source's response).

Table 5.4 Questions used in part two of the interviews

Can you list the sources of the data in the organisation? Classify the data quality based on the (availability, accuracy, the speed of collection). The classification is from low (0) to high (5).
Is sharing information with other organisations important? Why?
Are experts and highly qualified employees available in the organisation? Can they develop the work of disaster management in the organisation? To what extent?
Does the organisation face any challenges in data collection? What are the reasons for difficulty in the data collection?

Part three of the interview focuses on cooperation between organisations. In this part of the interview the stakeholder was asked to make a list of the organisations their organisation interacts with in relation to disaster management, with details about the reason for the interaction, and how often contact occurs (regular, irregular, based on event).

5.3 Data analysis

5.3.1 Stakeholder analysis

Stakeholder analysis is used in many fields from business management to policy, environmental management, and development (Brugha and Varvasovszky, 2000; Mushove and Vogel, 2005; Reed, 2008). Stakeholder analysis is frequently used, and for many reasons. It is a systematic, critical, and sensitive approach (Reed et al., 2009). It is a powerful participatory approach used to understand the nature of the stake claims and their relationship with each other (Mushove and Vogel, 2005; Reed et al., 2009), and for policy analysis and planning (Grimble and Wellard, 1997; Reed et al., 2009).

The application of stakeholder analysis in development and environmental management focuses on understanding power dynamics and improving the transparency and equity of decision making in a development project (Reed et al., 2009). Stakeholder analysis in development and environmental management is an issue of participation, including public participation in decision making (Mushove and Vogel, 2005). It has been used to empower the interests of marginal and less powerful groups to enable them to have greater influence on decision making (Mushove and Vogel, 2005; Reed et al., 2009). However, the agenda of those convening the process can also abuse the stakeholder analysis to empower or marginalise certain groups (Reed et al., 2009).

Our stakeholder analysis aims to evaluate the existing strategy for extreme weather risk reduction (including structural and non-structural measures) and its strengths and weaknesses at all levels. It also identifies the best ways of stakeholder engagement in the decision-making process and determines how they are relevant to the policy and planning strategy (Brugha and Varvasovszky, 2000; Reed, 2008; Reed et al., 2009; Prell et al., 2009).

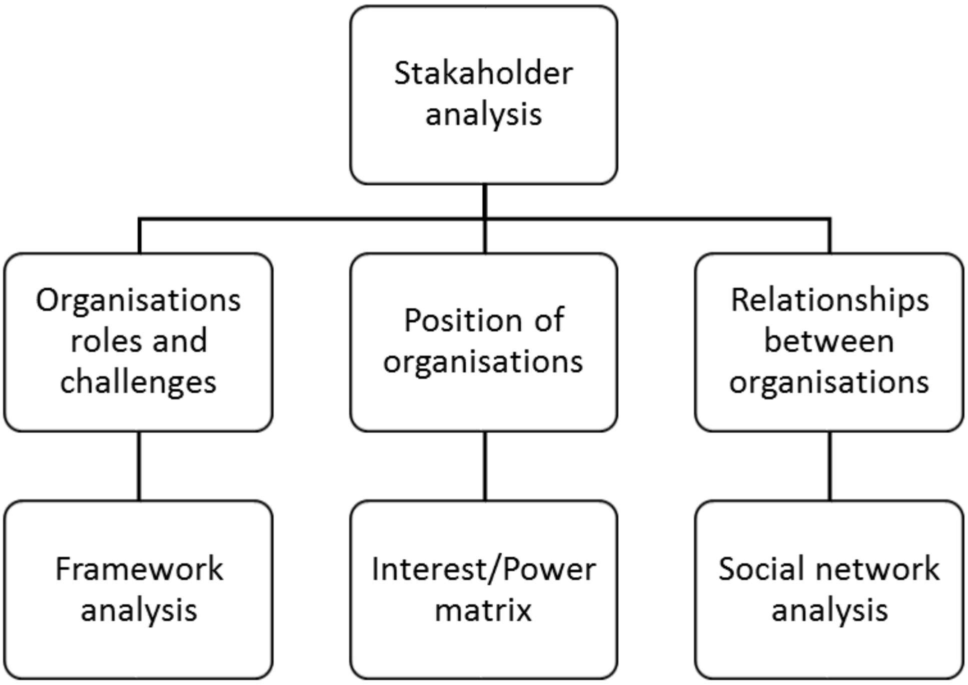

Figure 5.1 Stakeholder analysis typology

In this study, stakeholder analysis is used to identify the roles and challenges of the organisations, categorise the organisations, and to identify the relationship between them. Three different components are analysed: frameworks, power matrices and social networks.

5.3.2 Framework analysis

Framework analysis is a useful method for organising primary data (Lebel et al., 2006), and to understand the text of that primary, qualitative data (Lacity and Janson, 1994). It is a method used to understand the process of analysing the design and performance of an institutional arrangement (Imperial, 1999). It is a useful method to analyse the roles and responsibilities, and the challenges of the organisations (North, 1993; Lebel et al., 2006; Young, 2002; Imperial, 1999).

The framework analysis used in this study focuses on the roles and challenges of the organisations listed in Table 5.1, and the associated interviews with the stakeholders. The framework analysis is used to identify the function of each organisation, how all organisations are connected, and to analyse the roles and challenges of each organisation. Table 5.5 shows how the analysis is organised.

Table 5.5 Form to analyse the role and challenges of organisations

Organisation	Type of participation	Roles and responsibilities	Challenges
Organisation	Mitigation (infrastructure, dams) Preparedness for a response (public awareness, preparing the shelters) Response and emergency (early warning, rescue and evacuation) Recovery (health and social services, reconstruction, resettlement)		

Figure 5.2 illustrates the framework analysis of the organisation's performance and capacity. The framework studies the function, and the roles and challenges of each organisation. The method is used to understand the capacity of each organisation.

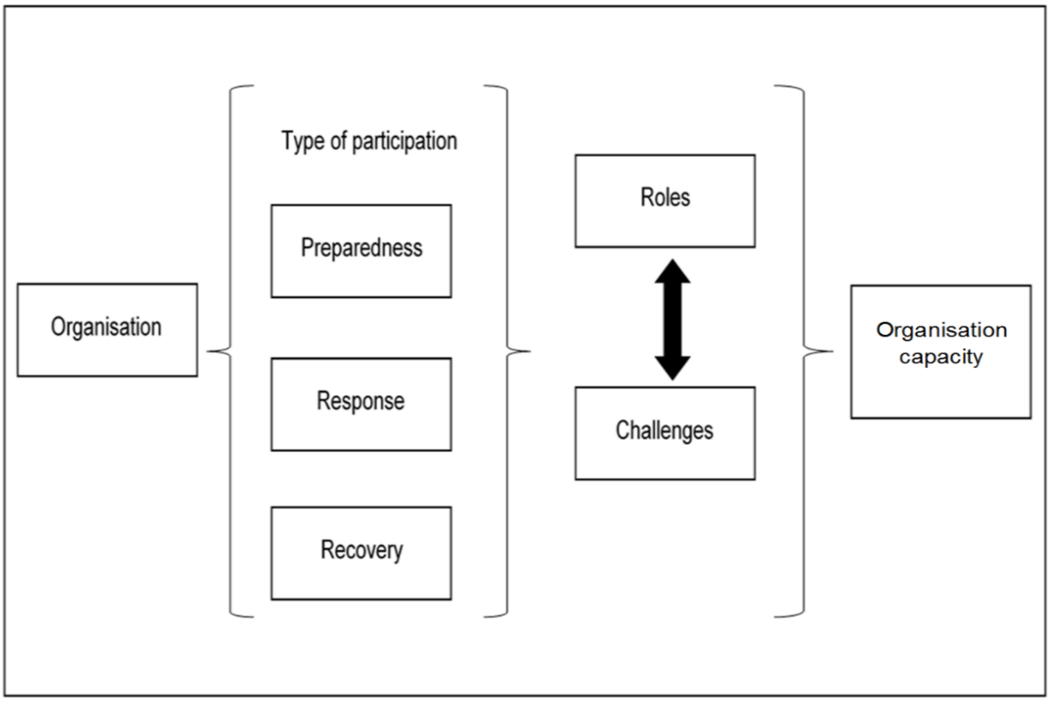

Figure 5.2 Framework analysis of organisational capacity

5.3.3 Power / Interest Matrix

Reed et al. (2009) provide two methods to categorise the stakeholder: 1) analytical categorisation (top-down), and 2) reconstruction (bottom-up). The analytical categorisation is a set of methods in which classification of stakeholders is carried out by those conducting the analysis based on their observations of the phenomenon in question and “embedded in some theoretical perspective on how a system functions” (Reed et al., 2009; Hare and Pahl-Wostl, 2002). Reed et al. (2009) review several examples of using this method of categorising, such as: using level of influence and interest, cooperation and competition, collaboration and threat, urgency, and legitimacy. Reconstructive methods allow stakeholders to categorise themselves in a way reflecting their concern (Reed et al., 2009, Hare and Pahl-Wostl, 2002).

For this study, the analytical category power and interest are used to categorise stakeholders into “Key Player”, “Context Setters”, “Subject” and “Least important” (Reed et al., 2009). This method helps to evaluate how stakeholder involvement will lead to, for example, a pragmatic end (Reed et al., 2009). In this study, this category will contribute to identifying the organisations with high influence in decision-making within the NCCD.

The power and interest matrix is used to classify each stakeholder with respect to their power to influence the National Committee of Civil Defence (NCCD) and the level of interest they have in disaster management in Oman. A “Key Player” is the stakeholder with high power and high level of interest in the disaster management committee, and the stakeholder who has the authority to make major decisions during extreme events. The stakeholders with a small degree of interest and high power are the “Context Setters”. They can affect the work of the committee, although their level of interest is low. The “Subject” is the stakeholder with a high degree of interest and low power in the system and is the stakeholder who needs to be informed about the decisions that have been made by the committee. The last group is the “Least important” stakeholders who have low power and low interest. They are stakeholders with a minimal interest in, or ability to influence, the committee.

5.3.4 Social network analysis

Social network analysis is defined as “a method based on the assumption that relationships among the interacting units are important” (Wasserman and Faust, 1994). It is a method focused on the relationship between actors and on the pattern and implication of these relations (Wasserman and Faust, 1994; Prell, 2011). Researchers apply social network analysis to express the relationship between the interacting units. It is used to understand how actors are positioned in the network, and how the relations are structured into the overall network pattern (Prell et al., 2009, Wasserman and Faust, 1994). It has been applied by Schmeer (1999) to analyse stakeholder characteristics. Schmeer (1999) defined social network analysis as ‘‘a process of systematically gathering and analysing qualitative information to determine whose interests should be taken into account when developing and/or implementing a policy or program’’. Applying this method gives a better understanding of the actor’s roles and actions, and analyses the driving forces and existing coordination between stakeholders, as well as identifying the strength of the communication between the actors that can affect the operation and planning (Caniato et al., 2014). Furthermore, the method encompasses theories, models, and applications regarding relational concepts or processes (Wasserman and Faust, 1994, Lienert et al., 2013). In policy analysis, social network analysis concentrates on the structural patterns between the actors (Lienert et al., 2013). In natural resources management, the method can be used to ensure that the key player in the network is not marginalised, identify a conflict between the actors, and select representatives based on the network structure (Reed et al., 2009).

This method is used in the current study to understand the interaction between organisations working in disaster management. It is capable of identifying the structural pattern of the actors involved in the disaster management process. It is relevant to understanding the different pattern of relational ties and structural characteristics of the networks in this study (Reed et al., 2009; Prell et al., 2009; Lienert et al., 2013). Understanding the structural pattern of the networks can lead to conclusions about the impact of the actors on information transfer and the influence of each actor on other actors (Reed et al. 2009, Prell et al., 2009; Lienert et al., 2013). Actors with strong relationships powerfully influence each other; support each other in times of emergency; have similar ideas and plans; communicate successfully; and highly trust each other (Prell et al., 2009). Social analysis is also used to identify centrality, which indicates the power of the network to connect the different actors (Marin and Wellman, 2011).

In this study social analysis is used to identify the functional level of the organisations during the extreme weather events by identifying the weak and strong relationships between institutions, and by analysing the organisational planning systems and planning regulations. A social network is a network of actors connected to each other through significant relations (Marin and Wellman, 2011). The social network is constructed from nodes and ties. The nodes demonstrate the institutions and the stakeholders (Clark, 2006). The measures used to analyse the network are Density, Cohesion, and Centrality (Brandes, 2001; White and Harary, 2001; Parise, 2007; Yang, 2014).

Density is the proportions of connections between the actors as presented in a graph of the social network (Wasserman and Faust, 1994; Prell, 2011; Yang, 2014; Stark, 2016). Network density is used to measure the strength of the ties and the frequency of interaction between the organisations based on a scale from 0 to 1 (Prell et al., 2009); (0) indicates a highly dispersed network and (1) a network that is very dense. The network ties are thus used to identify weak and strong relationships between institutions (Marin and Wellman, 2011). Therefore, this will help to identify the strength of an institution's network system (Prell et al., 2009). Density is measured by calculating the ratio of the number of connections and the maximum possible number of actors in the network (Wasserman & Faust, 1994);

$$\Delta = \frac{\mathbf{L}}{\frac{\mathbf{g(g-1)}}{\mathbf{2}}} = \frac{\mathbf{2L}}{\mathbf{g(g-1)}}$$

Equation 5.1

Where Δ is the density of the network, (L) is the number of connections between the actors, and g (g-1) is the maximum number of actors in the network.

Centrality is the measurement of the distribution of relations in the network (Yang, 2014; Parise, 2007; Cross et al., 2004). It looks at the number of ties between actors (nodes) and which actor has the most ties in the network (Wasserman and Faust, 1994; Prell, 2011). Centrality is measured in several ways including the degree of centrality, betweenness, and closeness. Here, centrality is calculated to identify organisations with high interaction with other organisations and high influence in the disaster management system (Wasserman and Faust, 1994).

The degree of centrality is represented by the count of the number of the actors directly connecting to a focal actor from both directions of ties (Opsahl et al., 2010; Prell, 2011). The minimum number of degrees is 0 and maximum degree (g-1); if the degree centrality is 0, the network is isolated. The actor with the highest degree of centrality is the most highly connected and influential actor in the network. The degree of centrality is calculated by using the function (Wasserman and Faust, 1994; Koschützki et al., 2005; Prell, 2011),

$$\boldsymbol{Dc} = \sum\nolimits_{\boldsymbol{i=1}}^{\boldsymbol{g}} \boldsymbol{in(Xi)} + \sum\nolimits_{\boldsymbol{i=1}}^{\boldsymbol{g}} \boldsymbol{out(Xi)}$$

Equation 5.2

Where (Dc) is degree of centrality, (Xi) the connection of each actor from both sides, the in degree $(\,in(Xi))$ and the out degree $\big(out(Xi)\big)$.

Closeness reflects how close the actor is to other actors in the network (Wasserman and Faust, 1994). It represents the productive actor that interacts easily with other actors (Wasserman and Faust, 1994; Opsahl et al., 2010). A simple method for measurement of Closeness suggested by Sabidussi (1966) and Wasserman and Faust (1994) is geodesic distance. It is computed by the sum of distances from one node in the network to every other node (Sabidussi, 1966; Opsahl et al., 2010). If the distance increases, the Closeness centrality then decreases. Thus Sabidussi (1966), Wasserman and Faust (1994) estimate the function of actor closeness as:

$$\boldsymbol{Cc(i)} = \left[\sum_{\boldsymbol{j=1}}^{\boldsymbol{g}} \boldsymbol{d(i,j)}\right]^{\boldsymbol{-1}}$$

Equation 5.3

Where Cc is Closeness. The function is the inverse of the distance from actor (i) to all other actors in the network(g).

Closeness centrality is measured by counting the distance between two actors. Therefore the minimum closeness attains the value of 0 if there are no connections. However, the maximum value for any reachable actor and the sum of distance can be infinitely high (Wasserman and Faust, 1994).

Beauchamp (1965) suggest a function to standardise the closeness, so the maximum value equals unity. The standardised function (Beauchamp, 1965) ranges in value from 0 to 1, and the function is:

$$\boldsymbol{C'c(i)} = \frac{\boldsymbol{g-1}}{\left[\sum_{\boldsymbol{j=1}}^{\boldsymbol{g}} \boldsymbol{d(i,j)}\right]} = \boldsymbol{(g-1)Cc(i)}$$

Equation 5.4

Where $\boldsymbol{C'c(i)}$ reflects the closeness centrality. The function is the inverse average of distance between actor i and all other actors. It is equal to 1 if the actor is maximally close to all other actors in the network(g). .

The Betweenness centrality actor is the actor that is between two connected actors. The Betweenness actor has more control over some paths than the actors at the network edges, and so has more influence on the other actors in the network (Freeman, 1977; Wasserman and Faust, 1994; Opsahl et al. 2010). Betweenness Centrality (C_B) represents the actor located between other actors and is calculated by counting all minimum paths which pass through the actor in the network (Wasserman and Faust 1994). Hence, Betweenness stresses the communication between actors (Freeman, 1977; Wasserman and Faust, 1994). Freeman (1977) estimates the probability of the shortest path of communication from one actor to another by using the function:

$$\boldsymbol{C_B(n_i)} = \frac{\boldsymbol{gjk(n_i)}}{\boldsymbol{gik}}$$

Equation 5.5

The term $C_B(n_i)$ reflects the Betweenness centrality. Where gik is the number of the shortest paths between two actors, and $gjk(n_i)$ is the number of paths between two actors including the actor(n_i).

Betweenness has minimum value of 0 and maximum value (g-1) (g-1)/2, which is the number of two actors not including actor (n_i) between them

(Wasserman and Faust, 1994). Therefore Wasserman and Faust (1994) suggest the following function to standardise the betweenness between 0 if there are no connections, and 1 if the actor is linked with all other actors. Therefore, the standardised betweenness can easily be compared to other actors' value (Wasserman and Faust, 1994);

$$\boldsymbol{C'_B(ni)} = \frac{\boldsymbol{C_B(n_i)}}{\left[\frac{\boldsymbol{(g-1)(g-2)}}{\boldsymbol{2}}\right]}$$

Equation 5.6

5.4 Results

The results in this chapter are presented in three ways to examine the capacity of each organisation in the disaster management system. They show the position of the organisation, the source of information, and the interaction between organisations. The results show the organisations that take an important position in the system, and how these organisations influence the performance of other organisations. They also show the roles and challenges of the organisations. These results can be used to develop better plans and policies for disaster management in Oman.

5.4.1 Organisation roles and challenges

Framework analysis is used to analyse the roles and challenges of the NCCD partners. The analysis is done by sector based on the information gathered from the partner organisations. The data analysis shows the participating organisations and the responsibilities of each sector within the disaster management cycle. Figure 5.3 displays the sectors' participation in each part of the disaster management cycle. The figure shows that most sectors act in the response part, with five organisations taking part in the preparedness section and only two sectors involved in disaster recovery.

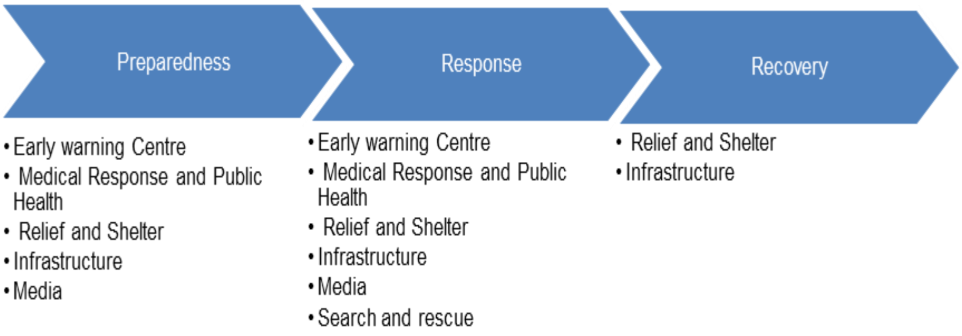

Figure 5.3 Organisations involved in disaster management in Oman.

Figure 5.4 shows the responsibilities of each sector and how it is connected. It shows that the NCCD is the coordinator organisation. It takes the role of managing the work and the communication between the different sectors. The other sectors are responsible for the preparedness for response and recovery. The roles and responsibilities of each organisation are varied.

The result shows that the EWC is responsible for forecasting and monitoring any natural hazards that can cause disaster in the country. They must give the NCCD main members 24 hours warning of any event. They provide information or data to all committee sectors and government agencies to help them make rescue and relief faster based on the available information. The EWC coordinates with the various media organisations to broadcast public warnings. The EWC must ensure that all warnings are issued and continuous to the end of the event, when the EWC issues an end notice which is sent to other sectors as well as all the media organisations.

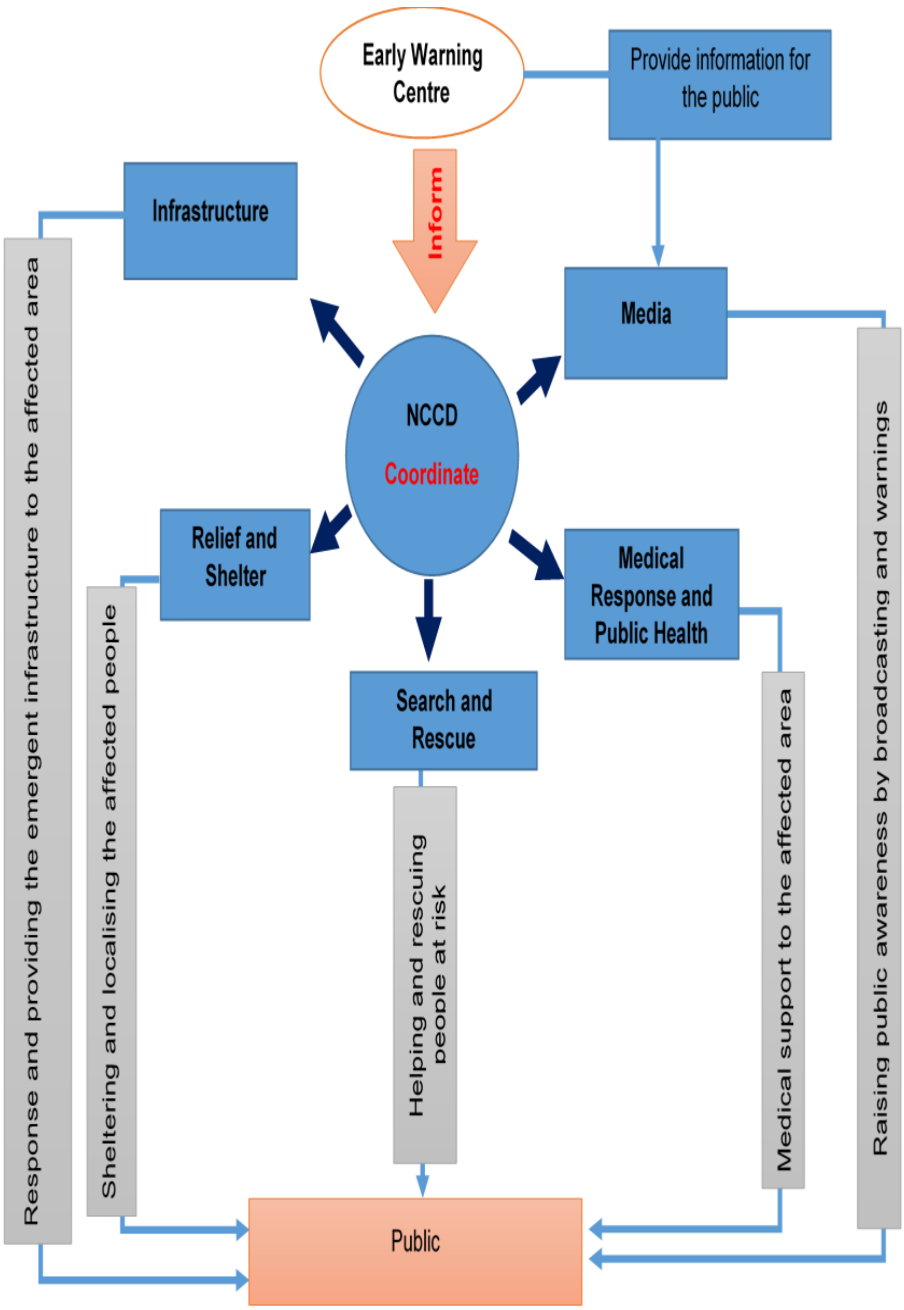

Figure 5.4 The process of disaster management in Oman

Table 5.6 gives more details about the roles and responsibilities for each organisation within the sector. It shows a variety of responsibility within the organisations. However, there is some duplication of responsibility. For example, the responsibilities of MOSD and OAC both include listing the affected people in the disaster area. Likewise, the volunteering groups and NGOs are doing the same thing. Not all these organisations are sharing the collected information and each one is working separately.

Table 5.6 The roles and responsibilities of NCCD partners[7]

Early Warning Centre
A. Informing members of the main committee in the ministry and the heads of other committees before the event (24 hours advanced notice) B. Direct contact with the media during a state of emergency; broadcasting warnings and various weather statements and repeatedly. C. Coordination with the media to broadcast public warnings, and make sure that the centre sends copies of these warnings to the President and the members of the main committee (NCCD), as well as the concerned authorities in the country (Oman Royal Police (ORP), Ministry of Defence) D. Providing any information or data to all relief committees and government agencies that will help them to make the rescue and relief faster based on the available information. E. Developing communication channels and lines between the disaster management committee in the EWC and other sectors' committees that should be used only for the emergency. F. The EWC to issue the end notice once the event is finished and send it to other sectors, as well as all media, for publication.
Medical Response and Public Health
A. Providing medical support to the affected area B. Monitoring the affected area after the event for any abnormal infectious diseases. C. Making sure that the medical centres and the hospitals will not be affected by the disaster. D. Building public awareness about health and safety during disasters. E. Building a database about the expected health disasters that may occur as a result of weather disasters
Infrastructure
A. The sector comprises six subsectors (water, electricity, roads, sewage, oil and gas, communication) B. Provide water and electricity in the affected area C. Repair damaged roads, and remove waste from the affected area D. Provide secure communication lines E. Provide fuel to the affected area

[7] Source: Interviews, and secondary data from each organisation (Handbooks, leaflets, websites...)

Table 5.6 / Cont.

Relief and Shelter
1. Ministry of Social Development A. Planning, preparedness and capacity-building to ensure the readiness and immediate and efficient response to emergencies, ensuring the provision of housing, food and clothing and treatment for those affected B. Set up appropriate mechanisms for receiving donations (in-kind and cash), organising the volunteer work, managing the shelters and the delivery of relief items. C. List the people affected by the disaster and assess their needs
2. Ministry of Education A. Provide shelters (schools)
3. Oman Charitable Organisation A. Provide clothes and blankets to the affected people B. Receive donations from both inside and outside Oman and distribute among the affected people C. List the people affected by the disaster and assess their needs
4. Public Authority for Stores and Food Reserve A. Provide relief food B. Find appropriate places for food storage and delivery centres in all governorates of Oman C. Monitor and control product prices in stores and supermarkets by cooperation with the Consumer Protection Authority
Media and Press A. Raise public awareness through broadcasting alerts and warnings B. Spread awareness messages to citizens C. Reduce rumours

Although the roles and responsibilities of these organisations in disasters are clear, most of the stakeholders believe that they are facing challenges to achieve the aims of their plans, for several reasons. First, the legislation and rules are not clear to some stakeholders, and they think that there is no legal and regulatory framework for action in the committee. Therefore, most stakeholders are relying on using their experience. They believe that the rules should be clarified for each organisation so there will be no overlap and conflict between them. For example, there is some duplication of the responsibilities between some organisations during the recovery period for compensation of the affected people. This duplication causes poor distribution of compensation. Second, cooperation between different sectors is based on personal contacts, and there is no clear formalised system for collaboration and information flow between the sectors. Therefore, the work in these organisations has the potential to become slow and less efficient if personal contacts change or are not upheld. Third, some institutions have little interest in the subject, especially in the pre-and post-disaster phases. Some organisations do not have specific departments for disaster management, and responsibilities are included within the competence of other departments. Fourth, some stakeholders believe that disaster management in Oman is only relevant at the response level, hence there is insufficient planning and mitigation for the disasters, which makes the response inflexible. Lastly, there is a need for capacity building at the national and local level, with more financial and human support needed to achieve this aim. Table 5.7 gives further details about the challenges of each organisation

Table 5.7 Challenges of NCCD partners during severe weather events[8]

Early Warning Centre
A. There are different centres in Oman monitoring different types of hazards, and there is negotiation between them over joining together in a multi-hazards early warning centre. B. Public awareness about disasters in Oman is very low, and although there is a plan to develop this, it will take time C. Capacity building
Media and Press
A. Difficulty of covering some of the cases from the site because of the severity of the conditions
Infrastructure
A. Cooperation between the institutions is insignificant

[8] Source: Interviews, and secondary data from each organisation (Handbooks, leaflets, websites...).

Table 5.7 / Cont.

Medical Response and Public Health
A. There is a national system for disaster management in Oman but without rules and regulations B. The legal and regulatory framework for action is not clear for the stakeholder. C. The disaster management in Oman is only at the response level, and there is no mitigation of disasters, which makes the response inflexible D. The cooperation between different sectors is always in person, and there is no clear system for cooperation and information flow between the sectors E. Financial and human resource changes
Relief and Shelter
1. Ministry of Social Development A. Difficulty of covering some of the cases from the site because of the severity of the conditions B. There are no written plans because of the absence of decision regulations, and there is no responsibility for proper planning C. There is no interest in the subject in some institutions, especially in pre- and post-disaster D. Institutions do not have specialised departments, and the subject is included within the competence of other departments E. There is no appreciation from the decision maker for those working in disaster management
2. Ministry of Education A. Schools are not prepared to be shelters
3. Oman Charitable Organisation A. Provide cooperation and training across different institutions B. Difficulty of interaction between organisations, for any reason, because it takes a long time
4. Public Authority for Stores and Food Reserve A. The cooperation between the institutions is very low. Communication has to be increased between the institutions to provide data to determine the requirements of each institution B. The roles are not clear for some organisations, and there are overlaps and conflicts between them

5.4.2 Power / Interest Matrix

Figure 5.5 shows the position of the stakeholders in the disaster management committee in Oman. The Early Warning Centre (EWC) is a key player in the NCCD, with the highest power and interest of any stakeholder organisation. They are responsible for informing the head office of the NCCD about any severe event. The stakeholders in the EWC are highly qualified in forecasting and monitoring the severe weather phenomena. They have a clear plan for capacity building in an emergency. They have the power to influence and change the level of the national emergency response based on the report they provide during the event. Their interest level in disaster management has increased with time as they have better understood the benefits coming from disaster management to the community. They raise experience in disaster risk management in the organisation and risk reduction in the community.

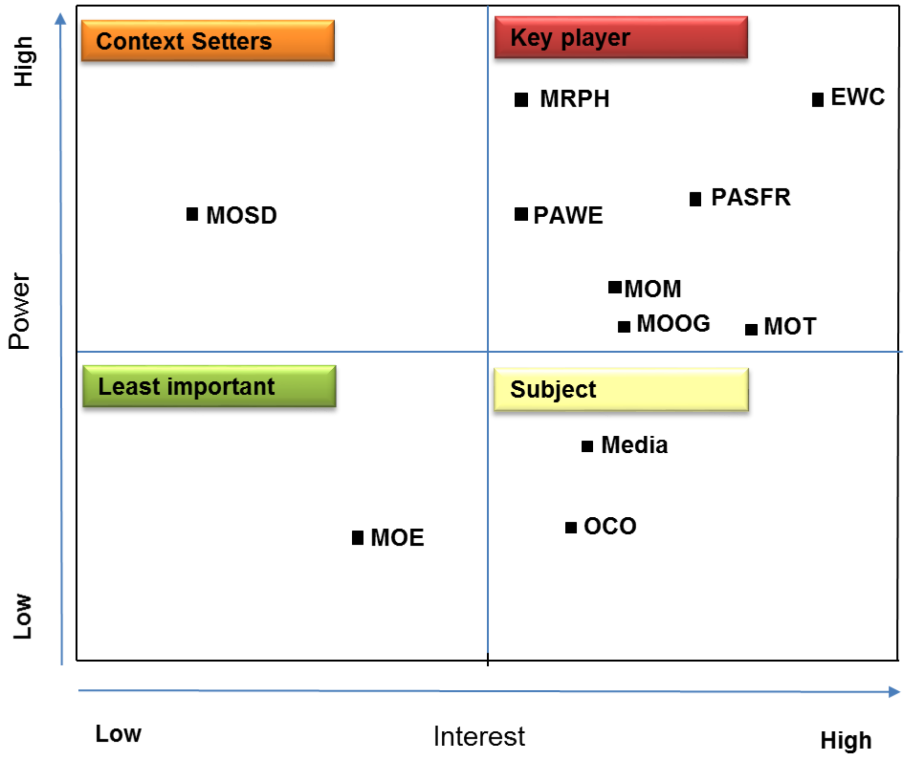

Figure 5.5 Power/Interest matrix for disaster management stakeholders

Medical response and public health (MRPH) is also a key player in the NCCD. MRPH is responsible for providing medical help to affected people, and responsible for monitoring and controlling infectious diseases and epidemics that can spread after the disaster event. The level of their interest is increased by their understanding of how the risks could affect the daily lives of people. They have a high sense of responsibility for the type of risk that the community may face during and after the disaster.

Infrastructure is a sector of key players in the NCCD. The sector is managed by the public authority of water and electricity who have partners from the public authority of electricity and water (PAEW), the Ministry of Oil and Gas (MOOG), the Ministry of Transport (MOT), and municipalities for waste (MOM). The infrastructure stakeholders are key players because they have the power and interest to influence emergency management in Oman. They are responsible for providing the emergency needs of infrastructure in the affected area during the event. The infrastructure is a critical sector in the NCCD because any failure in infrastructure could affect the work of another sector, like the MRPH, and the Public Authority for Stores and Food Reserve (PASFR).

The relief and shelter sector is another important sector in the NCCD. The sector is controlled by the Ministry of Social Development (MOSD) and has partners from the Public Authority for Stores and Food Reserve (PASFR), the Ministry of Education (MOE) for school buildings, and Oman Charitable Organisation (OCO). The social development (SD) sector acts as a context setter in the NCCD. They have the power to influence NCCD decisions but do not have a high level of interest. The stakeholder in the MOSD needs to be informed about any decisions made by the NCCD. The OCO are a subject stakeholder; they have interest in the NCCD, but do not have the power to influence committee decisions, although they can control charity work in their organisations. The Ministry of Education (MOE) holds the position of the least important group in the system. The MOE does not have the power or the interest to influence NCCD decisions. However, it has to provide schools as shelters during any event. The GAFS are key players as stakeholders in the NCCD. They have a high level of interest and ability to affect the NCCD. They are responsible for food security and monitoring food availability in the market during the disaster. They are a critical partner in the NCCD because the absence of food during the disaster could cause famine in the affected area.

The media and press are subject stakeholders in the NCCD. They are responsible for public awareness during the event. They need good communication with other sectors in order to be informed about any new decisions. The sector is also responsible for reducing rumours during the disaster by giving the correct information to the public. The stakeholder in the media organisations believes that the work on disaster management within the organisation has improved, and become more organised through time and experience.

5.4.3 Information flow

This section focuses on the information that is used to develop the work in each organisation, and the data flow between them. The data used to get these results is derived from interviews conducted with the decision makers in the organisations listed in Table 5.1 The information resources are different in each organisation due to the variety of their roles. Figure 5.6 shows the information flow network among the stakeholders. The numbers in the connection reflect the information flow quality, and is scaled from 0 to 5; 0 for low quality and 5 for high quality.

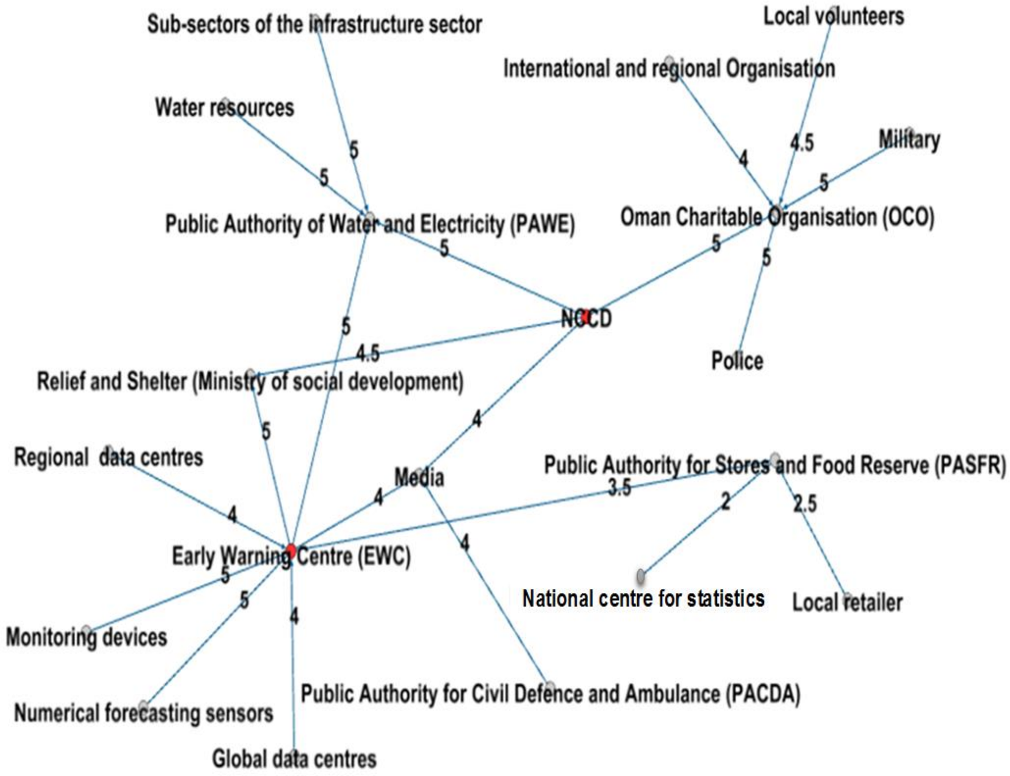

Figure 5.6 The network of information flow between the organisations

The network analysis indicates that most stakeholders get information directly or indirectly about disasters from the early warning centre (EWC) and the NCCD. The NCCD coordinates information flow between different sectors within the committee. They transfer the relevant data from each organisation to the others, and especially to those organisations that don't have direct interaction with the EWC. The network shows that the EWC maintains a high degree of connectivity between the organisations.

The EWC are responsible for monitoring and forecasting hazards. They get their information and data from different resources, for example monitoring devices, global data centres, digital forecasting sensors, and regional data centres. However, satellite data takes time to be received by the EWC because there are no specific satellites for the region and Oman. The stakeholders in the EWC believe that the information from these resources is excellent, but would be even better if more satellites covered the area.

The emergency centre for health crisis represents the medical response and public health sector. The centre is facing the challenge of absence of information for decision making. They do not have enough human resources working in data collection and communication. Their only source of information during disasters is the NCCD. The decision maker in the centre believes that building a clear structure for data collection and communication between the organisations and making clear plans for survey and identification of needs will facilitate data transmission.

The Oman News Agency (ONA) represents the media and press sector in the NCCD. They receive information from the NCCD, EWC, and the Public Authority of Civil Defence and Ambulance (PACDA). They receive the first information about the disaster from the EWC and the NCCD so that they can inform the public. They believe that they receive high-quality information. The ONA has qualified staff that gather information from the affected area during the disaster, and they do not have any problems with sharing information with NCCD members.

The public authority of water and electricity controls the infrastructure sector. The authority coordinates the data flow between subsectors (water, electricity, sewage, transport, waste) and the NCCD. The sector believes that they get high-quality information from the other sectors. However, these results seem implausible because the stakeholder then reported that cooperation with other sectors is weak and they need more training in disaster management. Interviews with some stakeholders in the regional area confirm that collaboration between the subsectors is poor and that there is a lack of cooperative planning and information sharing.

The relief and shelter sector and subsectors (OCO and PASFR) receive high-quality information from other organisations, which they use to guide decisions during the disaster. However, they are facing challenges with data and information gathering. For example, some government organisations do not share all information freely, meaning the relief and sheltering sector has to expend time and effort to get it, while the information that is shared is of deficient quality.

5.4.4 Organisations' interaction

This section discusses the relationships between the organisations playing roles in disaster management in Oman. Social Network Analysis was used to analyse the data obtained from interviews with the stakeholders in the organisations. Figure 5.7 shows the interaction between the disaster management organisations in Oman. Severe weather events are applied in this study as a hypothetical natural disaster risk. The network is classified based on the degree of interaction, based on the events in blue, regular interaction in red, and irregular in green.

The results represented in this section indicate the strengths and weaknesses of the network. The results reveal the density of the network, the degree of centrality, and its cohesion, measured as a function of Betweenness and Closeness.

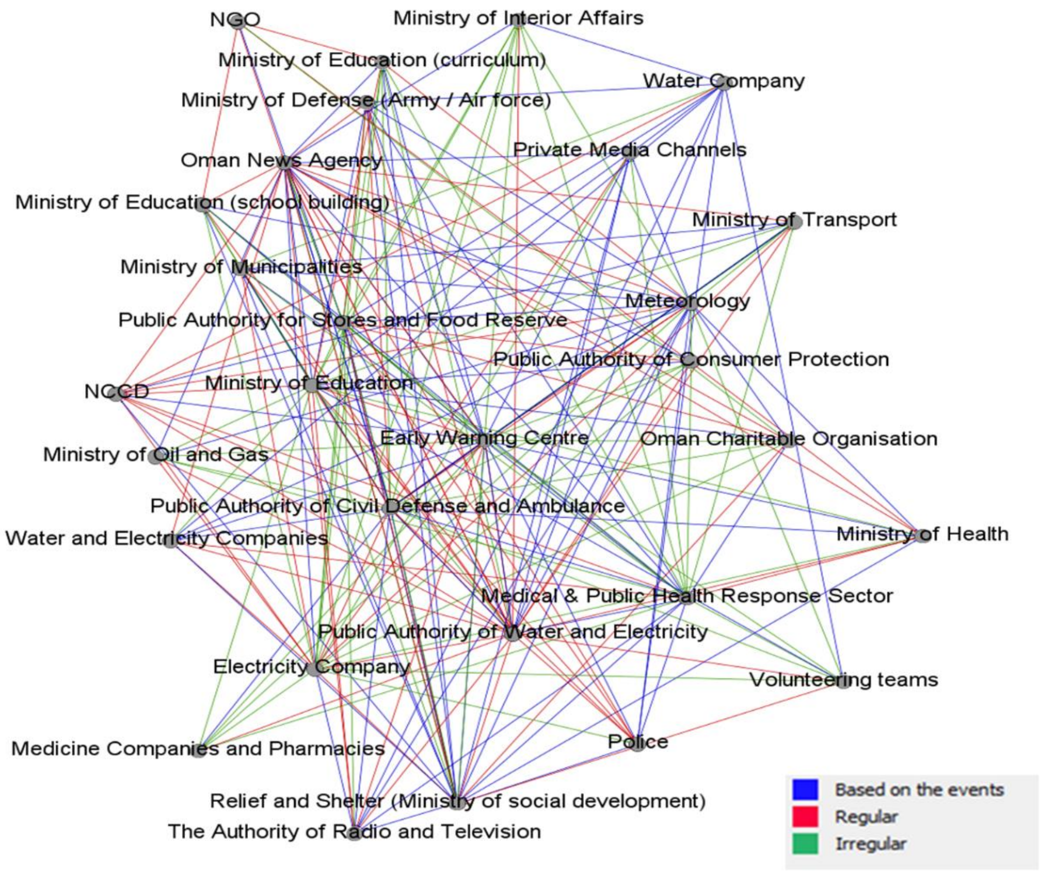

Figure 5.7 Organisation interaction during extreme weather events

5.4.4.1 Density

The density of the Omani disaster management network is 0.3. The density indicated a highly dispersed network. It is a sign that the communication between organisations in the network is very weak. Therefore, the cooperation between organisations will be very slow, affecting the quality of services provided by these sectors to the public during an event. Low density is also shown in an extensive network with a large number of ties. In this network, there are 31 actors (nodes) and 233 interactions (links).

5.4.4.2 Centrality

Figure 5.8 shows a high total degree of centrality in the organisation network; the scale of the network shows the centrality from low (0, blue) to high (1, red). There are actors with a large number of links with other organisations, indicating a significant influence on those organisations in the network. The result shows that the General Authority of Civil Defence and Ambulance (PACDA), and the EWC have the highest degree of centrality, followed by the Oman News Agency (ONA), and the Public Authority of Water and Electricity (PAWE). The result demonstrates that the PACDA and the EWC take controlling roles in the system, and have great ability to influence disaster management in Oman. Both organisations affect disaster management by coordinating all sectors through the PACDA, and by early forecasting and informing the organisations about any severe event in the EWC. Table 5.7 displays the degree of centrality of organisations in the network.

Figure 5.8 Organisations with a high degree of centrality

Table 5.7 Organisations ordered from high to low network centrality

Organisation	Degree	Organisation	Degree
Public Authority of Civil Defence and Ambulance	34	Ministry of Municipalities	11
Early Warning Centre	34	Ministry of Education (school buildings)	11
Oman News Agency	32	Ministry of Education (Curriculum)	11
Public Authority of Water and Electricity	31	Ministry of Defence (Army / Airforce)	11
Relief and Shelter (Ministry of Social Development)	27	Water and Electricity Companies	10
Public Authority for Stores and Food Reserve	26	Private Media Channels	10
Ministry of Education	23	Oman Charitable Organisation	10
Meteorology	23	Ministry of Interior Affairs	10
Medical & Public Health Response Sector	23	Ministry of Health	10
Electricity Company	23	Volunteering teams	9
NCCD	12	Public Authority for Consumer Protection	9
Ministry of Transport	12	Ministry of Oil and Gas	8
Water Company	11	Medicine Companies and Pharmacies	7
The Authority of Radio and Television	11	NGO	6
Police	11		

5.4.4.3 Betweenness Centrality

Figure 5.9 and Table 5.8 show high Betweenness centrality among the actors. The data analysis reveals that the Oman News Agency (ONA) has the highest Betweenness and is the organisation in the system that interacts and collaborates most with other organisations. The Public Authority of Civil Defence and Ambulance (PACDA), the organisation coordinating search and rescue sector, also has high Betweenness centrality. The Early

Warning Centre (EWC) has the same Betweenness centrality as the PACDA, and it is responsible for transferring information about the disaster.

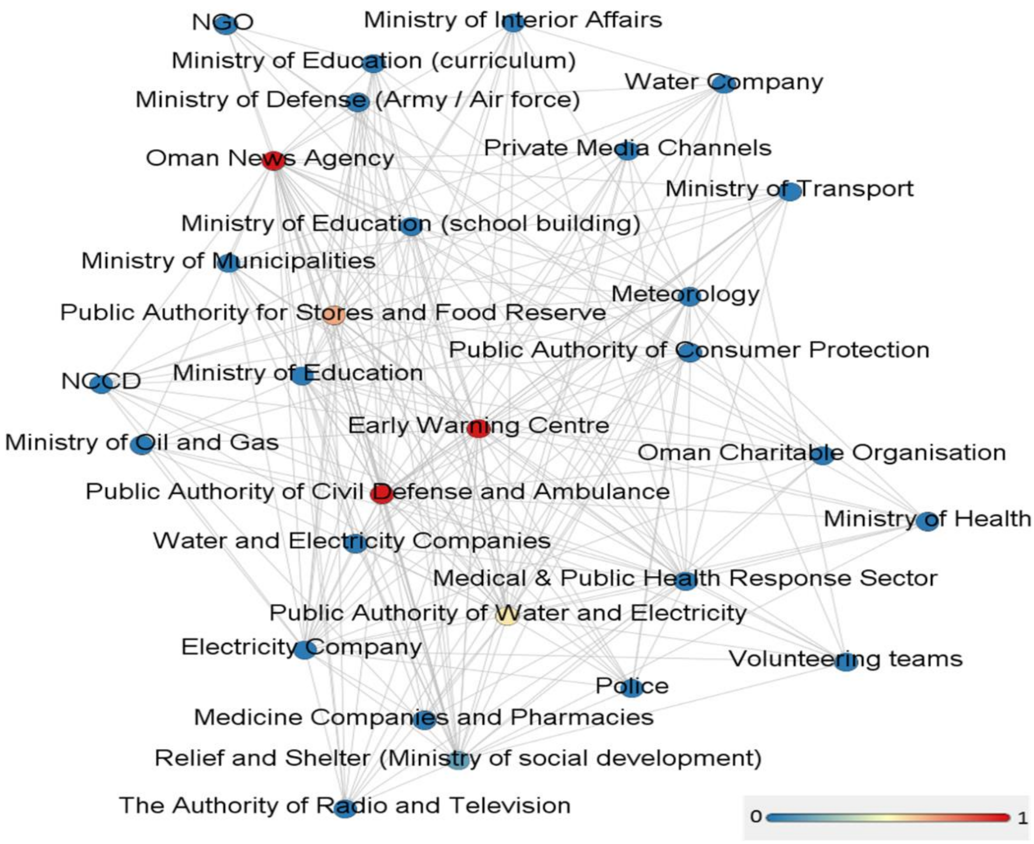

Figure 5.9 Betweenness centrality for disaster management organisations

Table 5.8 Organisations with high Betweenness centrality

Organisation	Betweenness Centrality
Relief and Shelter (Ministry of Social Development)	0.003
Public Authority of Water and Electricity	0.011
Public Authority for Stores and Food Reserve	0.014
Early Warning Centre	0.020
General Authority of Civil Defence and Ambulance	0.020
Oman News Agency	0.020

5.4.4.4 Closeness Centrality

Figure 5.10 and Table 9 demonstrate the closeness centrality of the organisations. The data analysis reveals that the EWC, PACDA, Medical and Public Health Response sector, followed by the Public Authority of Water and Electricity (PAWE), has the highest closeness centrality. Organisations with high closeness centrality are quick to interact with other organisations during the disaster. They are productive organisations with good ability to communicate and transmit information to the other organisations.

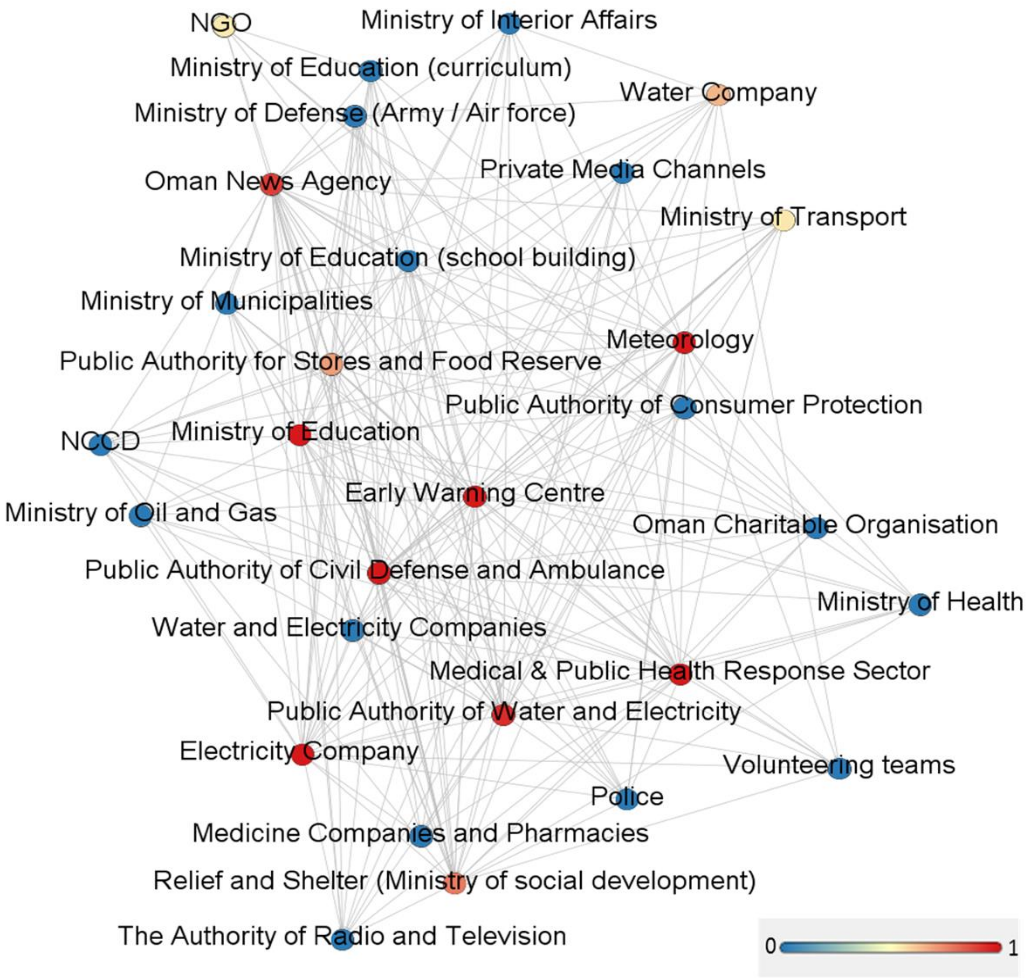

Figure 5.10 Closeness centrality of organisations

Table 5.9 Organisations with high closeness centrality

Organisation	Closeness centrality
NGO	0.55
Ministry of Transport	0.55
Water Company	0.66
Public Authority for Stores and Food Reserve	0.71
Relief and Shelter (Ministry of Social Development)	0.79
Oman News Agency	0.92
Public Authority of Water and Electricity	0.96
Early Warning Centre	1
Electricity Company	1
Public Authority of Civil Defence and Ambulance	1
Medical & Public Health Response Sector	1
Meteorology	1
Ministry of Education	1

5.4.5 Types of cooperation

This section of the interview was concerned with the reason for the collaboration between the organisations. Figure 5.11 shows the network of interaction between organisations based on the kind of collaboration. It shows that organisations are cooperating over information, human resources, financial support, and physical material like equipment used in the evacuation and response, and other aspects that depend on the degree of the disaster.

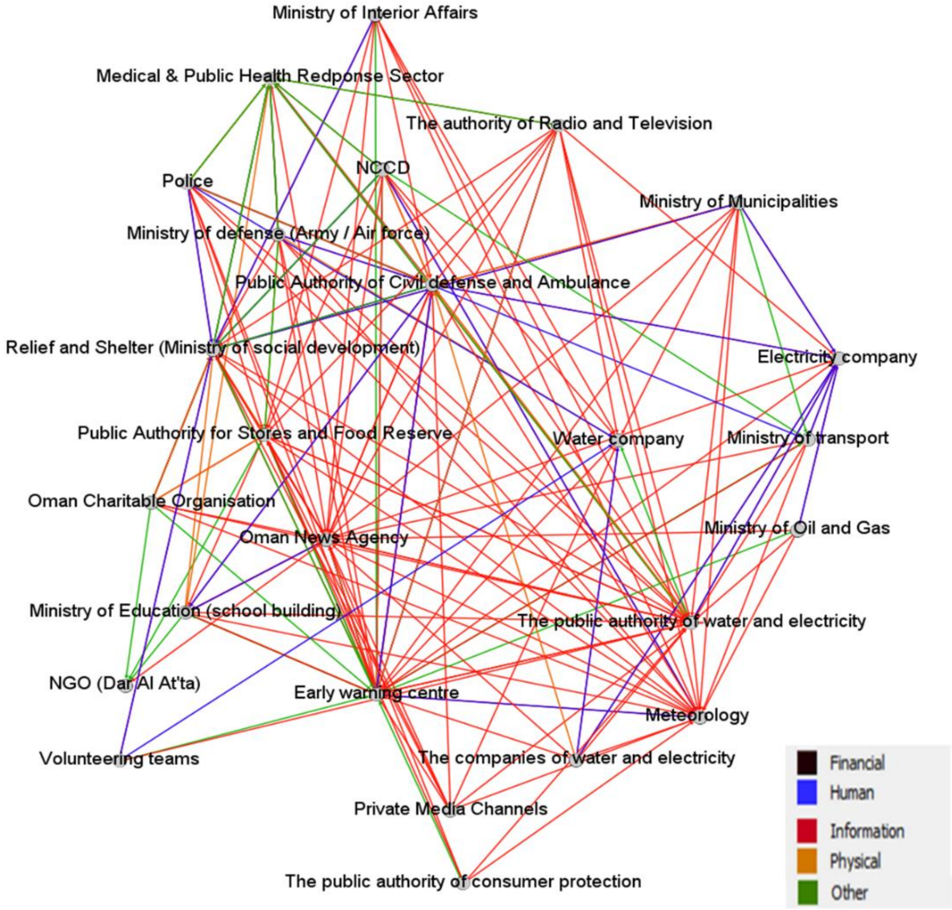

Figure 5.11 The network of organisations by type of cooperation

The number of interactions between organisations is presented in Figure 5.12. The results reveal that the organisations interact most highly with the PACDA, then with the EWC and the NCCD. Also, the results display that there is weak interaction with the volunteering teams and the public authority of consumer protection. The result exposes the high impact of the PACDA, the EWC, and the NCCD in the committee.

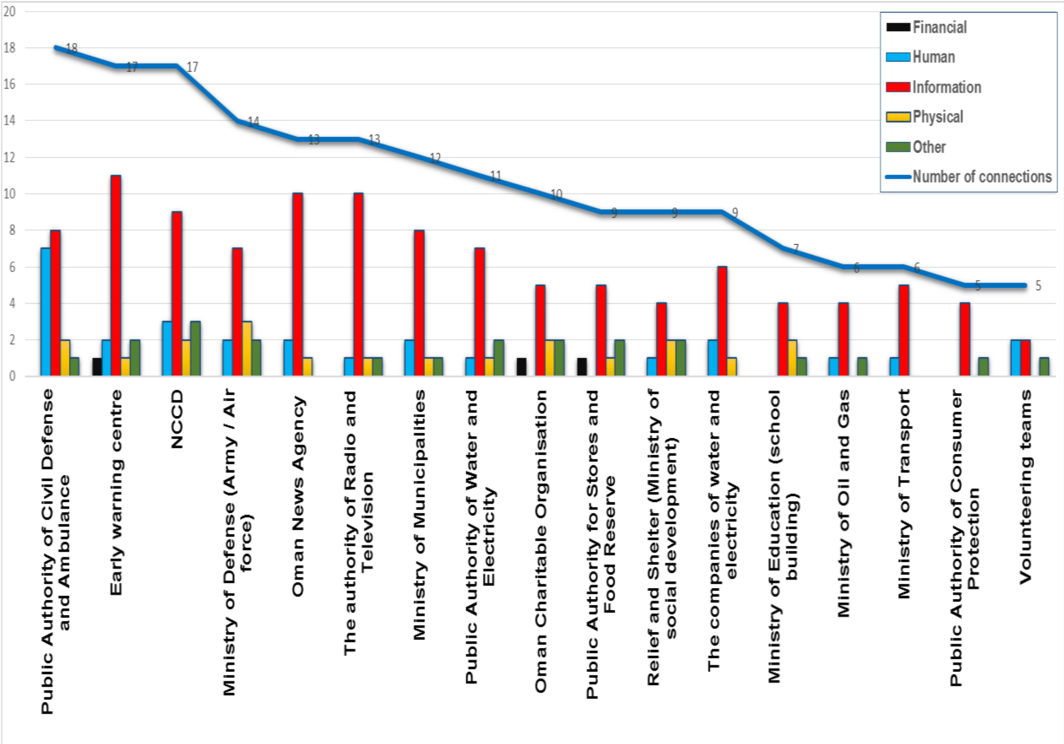

Figure 5.12 Connections between organisations by type

Table 5.10 displays the reasons for interaction between the organisations. The results indicate that most organisations believe the most important reason for interaction is to share information. For example, the analysis shows that 11 organisations cooperate with the EWC for information, followed by ten organisations that interact with the Oman News Agency, and the authority of radio and television, and nine organisations interact with the NCCD for the information. Some of the organisations are shown to be interacting with the general authority of civil defence and ambulance (PACDA) for human resources. For physical resources like equipment used during the events, the organisations interact with the Ministry of Defence, the NCCD, and PACDA. Interaction for financial support is limited to three organisations.

Table 5.10 Frequency of organisational interaction by type

Organisation	Financial	Human	Information	Physical	Other
Early warning centre	1	2	11	1	2
Ministry of Defence (Army / Air force)	0	2	7	3	2
Ministry of Education (school building)	0	0	4	2	1
Ministry of Municipalities	0	2	8	1	1
Ministry of Oil and Gas	0	1	4	0	1
Ministry of Transport	0	1	5	0	0
NCCD	0	3	9	2	3
Oman Charitable Organisation	1	0	5	2	2
Oman News Agency	0	2	10	1	0
Public Authority for Stores and Food Reserve	1	0	5	1	2
Public Authority of Civil Defence and Ambulance	0	7	8	2	1
Public Authority of Consumer Protection	0	0	4	0	1
Public Authority of Water and Electricity	0	1	7	1	2
Relief and Shelter (Ministry of social development)	0	1	4	2	2
The Radio and Television Authority	0	1	10	1	1
The water and electricity companies	0	2	6	1	0
Volunteering teams	0	2	2	0	1

5.5 Conclusion

This chapter evaluated the disaster management system in Oman from an organisational perspective. Relevant organisations were investigated using collected interview and questionnaire data, and organisational capacity in disaster management was assessed using stakeholder analysis and social network analysis. Results indicate the capacity of organisations based on four distinct analyses. First, framework analysis was used to analyse the roles of the organisations and the challenges they face. Then, the power and interest matrix was used to classify organisations and to identify the position of each organisation. Next, information sources available to each organisation, and how important they are to the decision makers, were analysed. Finally, interaction between the organisations was investigated, and those organisations that were ranked highly for communication and cooperation between organisations were identified.

The result of the roles and challenges analysis shows that most organisations are responding to the events. It indicates that the system is reactive more than preventative/proactive. Also, the result shows a variety of responsibilities for each organisation. It reveals that each organisation has different responsibilities during the event based on the roles of each organisation in the NCCD. However, there is duplication of responsibilities among some organisations. For example, the MOSD is responsible for assessing damage and surveying affected people, but at the same time, the OCO and the NGOs are doing the same job. When it comes to recovery and compensation, each organisation has a different system. Duplication in responsibilities causes poor distribution of compensation among the people affected by a disaster. Although there is duplication of some responsibilities, most organisations understand their responsibilities. However, they face difficulties during the implementation. The challenges of the organisations are diverse. In some organisations, the absence of clear rules and plans is the main issue. Thus, the work in these organisations will be disorganised, which will affect their performance. Also, there are challenges of public awareness, capacity of the organisations, and communication between the organisations. Disorganised communication between the organisations, poor public awareness, and the low capacity of some organisations could affect the performance of the NCCD and other organisations.

The power/interest matrix analysed the position of the organisation in the NCCD. The results show that most organisations take part as key players in the NCCD disaster management committee. This is an indicator of the importance of all organisations in the committee. An organisation may impact on decision-making in the committee, and their decisions will be important. Some organisations, like the MOSD, act as context setters in the committee, having the power to make decisions in the committee but having low interest in doing so. Their low interest in disaster management may thus cause a negative impact on the committee decisions.

Organisations responsible for the media are subject stakeholders. They have high interest in disaster management in Oman but don’t have the power to make important decisions in the committee. The MOE are the least important group in the committee – they have little interest in the committee and lack the power of making decisions that impact the work of the committee. These organisations have low power to influence the committee decisions. However, their decisions are important, as they have an important function in disaster management.

The third part of the results shows the information flow within the network of organisations within the committee. It reveals that the EWC and the NCCD Executive Office take the role of conveyors of information between organisations. The information resources for each organisation are diverse. Most organisations collect the information they need from the relevant sources, and that helps them in their decision making.

The interaction and cooperation between organisations are displayed in the third part of the results. The interaction network density indicates weak interaction between the organisations. The degree of centrality is also analysed, and the results show high centrality for the EWC and the PACDA, which indicates their great ability to influence the system, controlling the work of the committee. The organisations with high communication value can take on the role of organiser in the system. It is evident from the secondary data that PAWE is organising the infrastructure sector in the committee. The sector has six partners: water, electricity, sewage, transport, oil and gas, and the municipality.

The results show high betweenness centrality for the EWC and PACDA. The high betweenness result reveals the organisations that are in the middle position between organisations, with a great ability to transfer data and information between them. The results also show that the EWC, PACDA, and the MRPH are highly productive organisations with excellent communication with other organisations. The high closeness centrality indicates this high productivity.

Overall, the result of the network analysis shows that the EWC and PACDA have important positions in the committee. It is clear that both organisations have significant roles and their decisions can influence the committee's decisions. The organisations are highly productive, and they have good communication with the other organisations.

The final part of the analysis shows that information and human resources are the main types of interaction between organisations. High-quality information is very important for all organisations to ensure appropriate decision are made.

In conclusion, this chapter has analysed the organisational system to identify the strengths and weaknesses of the disaster management committee in Oman and help to signpost the parts in the network of organisations that need improvement. The organisations must focus on developing and updating their plans and related rules of implementation. The plans should be shared with other organisations. Hence each organisation will understand the roles and responsibilities of the other organisations, which will reduce the probability of overlapping and duplicating responsibilities. It is essential that all organisations improve their communication systems to enable information to flow clearly, in a well-organised process. The current communication system depends on the NCCD Executive Office, or on personal relations between the organisation's decision makers. Public awareness is very important and may affect the performance of the organisations. Thus it is important to raise awareness at both the institutional and local level.

The next chapter focuses on the effectiveness so far of the organisations' current disaster management capacity in building resilience to disasters in Oman, using the international Hyogo framework for action (HFA) as a reference framework.

Chapter 6 Disaster resilience in Oman: An appraisal with reference to the Hyogo disaster reduction framework

6.1 Introduction

In the previous chapter, Omani organisational capacity in disaster management was assessed through an investigation of the networks of disaster management organisations and their interaction. Chapter six now examines the extent to which Oman, through these organisations, has developed a disaster management system able to build community resilience to major natural hazards. The chapter aims to assess the extent to which organisations in Oman are developing resilience to disasters, as judged by reference to the international Hyogo Framework for Action (HFA) on resilience to natural disasters, discussed in Chapter 3.

Oman's disaster management system is relatively new, and analysis concerning the HFW will help to understand the level of resilience achieved to date, and how this could be enhanced. Also, the United Nations Office for Disaster Risk Reduction, UNISDR (2011) report on the HFA countries' progress in implementing the priorities of HFA does not contain data specific to Oman, although a more recent report (UNISDR, 2015) does include Oman in an aggregate analysis of 15 Arab countries. Thus the study presented in this chapter will more specifically identify the current performance of Oman, and its position relative to other countries in the region and worldwide.

This chapter begins with an overview of the appraisal methodology for data collection (section 6.2) and analysis (section 6.3); followed by presentation of results (section 6.4) in five thematic areas structured according to the Hyogo framework for the institutional survey. This is followed by presentation of local people's perception of Omani disaster management. Then, section 6.4.7 draws together these results as aggregate resilience indexes, which are used to evaluate overall performance and to benchmark against UNISDR evaluations for other territories. Section 6.4.4 discusses the progress of Oman, and comparisons made with the world average and progress of other Arab countries, to identify the level of achievement in Oman relative to other countries.

6.2 Data collection

For the resilience analysis, questionnaires were used to generate the necessary data for the HFA implementation in Oman. They address the resilience components of the disaster resilient community as provided by Twigg (2009), and the five priorities for action in the UNISDR Hyogo Framework for Action (HFA) (UNISDR, 2005). Table 6.1 summarises these priorities and the indicators of progress of HFA.

The questionnaire was targetted at both decision makers working in disaster management organisations in Oman and local people. At the organisational level, out of 30 questionnaires circulated among the stakeholders, 19 completed responses were received. The responders worked in organisations with different roles and positions related to disaster management.

Two questionnaires were designed for the data collection, addressing the organisational level and local level stakeholders. In the first (institutional level stakeholders' assessment) three indicators were used to measure the implementation of each of the five Hyogo thematic areas. Each indicator was measured by two characteristics of a disaster resilient community provided by Twigg (2009).The second form addresses the local people's assessment of an organisation's implementation of resilience. In this case, 14 characteristics were used to address the five priorities for action. The questionnaire used for the local community had fewer measurements and was more focused on their knowledge and priorities for disaster risk reduction in Oman. The questionnaires distributed between local people randomly selected from different area in Oman.

In both forms, stakeholders were asked to assess the degree of implementation of the disaster resilience indicators on a scale from 0 (not-applied) to 3 (strongly applied).

Table 6.1 HFA priority actions and progress indicators used in the study

Priorities for action	Indicators of progress
1. **Governance (HFA1)**: Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	1. Institutional frameworks for DRR policy, planning, priorities, and political commitment, regulatory system 2. Institutional mechanisms, capacities and structures; allocation of responsibilities 3. Community participation
2. **Risk Assessment (HFA2):** Identify, assess and monitor disaster risks and enhance early warning	1. Hazards/risk data and assessment 2. Vulnerability/capacity and impact data and assessment 3. Scientific and technical capacities and innovation
3. **Knowledge and Education** (HFA3): Use knowledge, innovation and education to build a culture of safety and resilience at all levels	1. Public awareness, knowledge and skills Cultures, attitudes, motivation. 2. Information management and sharing strategy 3. Education and training
4. Risk Management and Vulnerability Reduction (HFA4): Reduce the underlying risk factors	1. Environmental and natural resource management 2. Health and well being 3. Physical protection; structural and technical measures
5. **Disaster Preparedness and Response (HFA5):** Strengthen disaster preparedness for effective response at all levels	1. Organisational capacities and co-ordination 2. Early warning systems 3. Emergency preparedness, response and recovery

Table 6.2 shows the responders' organisations and roles. The second questionnaire, circulated among local people, received 35 complete responses. This local questionnaire focused on the knowledge of the responder about disasters and disaster management in Oman. Local people were asked to assess some actions and their implementation by organisations. The result of the local people's questionnaire was used to assess the decision maker result from the first form.

Table 6.2 Organisations and stakeholders in resilience survey.

Organisation	Roles	Category
Medical & Public Health Response Sector	Medical staff	Government
Meteorology department	Director of Forecasting and Early Warning system	Government
Early warning centre	Weather forecast specialist	Government
Ministry of Education	Curriculum editor	Government
Public Authority for Stores and Food Reserve (PASFR)	Authority director	Government
MOSD	IT tech	Government
MOSD	Sector director assistant	Government
Electricity company	Director	Private company
Public authority of civil defence and ambulance	Chief of the national team for search and rescue	Government
Oman News Agency	News editor	Government
NCCD	Disaster management officer	Government
Ministry of Transport	Engineer	Government
Public Authority of Water and Electricity	Director of the operation department	Government
Public Authority of Water and Electricity	Director of the Authority	Government
Transport	Maintenance Manager	Government
NGO	Volunteer people manager assistance	NGO
NGO	Manager	NGO

Secondary data on the Arab countries' progress in the implementation of Hyogo framework for action was collected from the international report published by UNISDR (2015b)[9]. Also, the world average of achievement was derived from UNISDR (2013c). The data used in this study compares

9 National progress report on the implementation of the Hyogo Framework for Action, the reports are derived from 18 Arab countries, excluding Oman, Kuwait, Saudi Arabia, and Libyan Arab Jamahiriya

the progress of Oman with other Arab states' progress and the global average.

6.3 Data analysis

The data collected from the questionnaires was used to calculate the disaster resilience index at both the organisational level and local community level. A resilience index was calculated as the weighted mean index of the priority for action implementation by using the equation;

$$\boldsymbol{WMI = (wi\,fi + w2\,f2 + w3\,f3 + \cdots \ldots\ldots\ldots\ldots\ldots.. + wn\,fn)/(f1 + f2 + f3 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + fn) = \sum wi\,fi / \sum f}$$

Equation 6.1

The script (w) presents the priority for action weight and (f) is the frequency of the answer. The result is then normalised from 0 to 1 to aid comparison between the different indexes. The index 0 reveals low implementation and 1 high implementation of the resilience components. The normalised index is calculated by using the unity-based normalisation function:

$$\boldsymbol{n\,wMI = (WMI - Min\,W)/(Max\,W - Min\,W)}$$

Equation 6.2

Then the overall average for the priority area is normalised to the score of UNISDR (2011) for the HFA implementation. The scale is between 1 (low), and 5 (high). The normalisation makes comparisons with other countries easier. The score "reflects different stages of disaster risk reduction and implementation of the HFA" UNISDR (2011). Equation 6.3 is used to compare the two data set; the study result and the UNISDR (2011) scores.

$$\boldsymbol{x = \frac{a + (x - A)(b - a)}{(B - A)}}$$

Equation 6.3

$\boldsymbol{x}$ represents the rank of the value. While ($\boldsymbol{a}$) is the minimum value and ($\boldsymbol{b}$) is the maximum value in the data set of UNISDR (2011), and ($\boldsymbol{A}$) is the minimum value and ($\boldsymbol{B}$) is the maximum value in the data set of the study.

The UNISDR (2013c) score for HFA implementation progress is obtained using a five-point scale:

1. Minor progress with few signs of forwarding action in plans or policy.

2. Some progress but without systematic policy and/or institutional commitment.

3. Institutional commitment attained, but achievements are neither comprehensive nor substantial.

4. Substantial achievement attained but with recognised limitations in capacities and resources.

5. Comprehensive achievement with sustained commitment and capacities at all levels.

This assessment enables the results for Oman to be compared with the secondary data available in the Global Assessment Report (GAR) on disaster risk reduction (UNISDR, 2011), the (UNISDR) reports which evaluate other countries' progress in implementing the HFA, and the world average (UNISDR, 2013c).

The result from the second questionnaire (local level) is used to assess the effectiveness of disaster management decision makers. This gives an overview of local people's views on, and degree of satisfaction with, disaster management in Oman.

6.4 Results

This section, Section 6.4.1, presents the results of the analysis of data collected from the stakeholders who estimated implementation of the HFA for action at the organisational level. The results are presented by each of the five HFA components, and then an aggregate index is calculated. Section 6.4.2 shows results from the survey of local people's assessment of HFA implementation. The aggregate index is calculated in section 6.4.3

and compared with the indexes of the world countries, and Arab countries in section 6.4.4

6.4.1 Resilience index (decision-makers)

This section presents the results of the analysis of data collected from the stakeholders who estimated the level of implementation of the HFA for action in their organisations.

HFA 1: Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.

The priority for Action (HFA1, Table 6.1) used to ensure that disaster risk reduction is based on a strong institutional system. Table 6.3 shows the six components of the index used to measure HFA1 performance for Oman (there are two components for each of the three indicators under HFA1). The result reveals that the overall implementation index based on UNISDR (2011) score is 2.87 out of 5. The result indicates that institutional commitment is attained, but achievements are neither comprehensive nor substantial.

Two resilience components, (G1) and (G4), are used to understand the achievement in relation to the institutional indicator frameworks for DRR policy, planning, priorities, political commitment, and the regulatory system. The result shows substantial achievement attained in (G1) in the national disaster risk reduction policy, strategy and implementation plan, with limited achievement in the organisation's strategies and plans. However, although institutional commitment is attained in (G4), the achievement is moderate in the routine integration of disaster risk reduction into development planning and sectoral policies. For example, there is some achievement in relation to climate change policy and strategy in some organisations, such as the meteorology department. Overall, the achievement in the institutional frameworks for DRR policy, planning, priorities, and political commitment, and the regulatory system is moderate, neither comprehensive nor substantial.

Regarding achievement of the second indicator, the institutional mechanisms, capacities and structures, allocation of responsibilities is revealed by components (G2), and (G5). The results show moderate progress in the mechanisms for compliance and non-compliance with laws and regulations (G2). Likewise, institutional commitment is attained, but achievements are neither comprehensive nor substantial on progress in allocating human, technical, material and financial resources for disaster risk reduction (G5). For example, no regulations for disaster risk management exist in some organisations, including the Ministry of Education, and enforcement laws are absent at the national level. Overall, achievement in the institutional mechanisms, capacities and structures is moderate and neither comprehensive nor substantial.

Table 6.3 The weighted mean index of disaster governance.

	Resilience components	n WMI	UNISDR equivalent score[10]
G1	National and Local (Disaster Risk Reduction) DRR policy, strategy and implementation plan, with shared vision of the priorities, targets and benchmarks	0.65	3.60
G2	Mechanisms for compliance and enforcement of laws, regulations, codes, etc., and penalties for non-compliance defined in laws and regulations.	0.39	2.54
G3	The community understands relevant legislation, regulations and procedures, and their importance.	0.39	2.54
G4	Routine integration of DRR into development planning and sectoral policies (poverty eradication, social protection, sustainable development, climate change adaptation, desertification, natural resource management, health, education, etc.).	0.42	2.68
G5	Human, technical, material and financial resources for DRR adequate to meet defined institutional roles and responsibilities (including budgetary allocation specifically to DRR at national and local levels).	0.47	2.89
G6	Inclusion/representation of vulnerable groups in the community decision-making and management of DRR	0.49	2.96
	Governance Index (GI)	0.47	2.87

[10] The score is the normalised n WMI by using equation 3

The third indicator is identified through components (G3) and (G6). The result shows that institutional commitment is attained in the representation of vulnerable groups in community decision-making and management of disaster risk reduction (G6), and the achievement is moderate. However, institutional commitment has not been achieved in the community understanding of disaster risk reduction laws and regulations (G3). Overall, achievement in terms of community participation is moderate, but there is no systematic policy.

HFA2: Identify, assess and monitor disaster risks and enhance early warning

Table 6.4 shows the resilience components of the priority for action relating to identification, assessment and monitoring of disaster risks and enhanced early warning. The six components relate to the three indicators in the HFA2 (Table 6.1), namely: hazards and risk data and assessment; vulnerability/capacity and impact data and assessment; and scientific and technical capacities and innovation (there are two components per indicator). The HFA2 index is calculated as 3 out of 5, indicating that is the Institutional commitment is attained but achievements are neither comprehensive nor substantial.

The results show a strong performance in the indicator for implementation of hazards and risk data assessment. Risk assessment is a participatory process (RA2) including representatives of all sections of community and sources of expertise. A risk assessment provides a comprehensive picture of all types of potential risks (RA1). Overall, the progress in risk assessment is substantial, with recognised limitations in capacities and resources.

Indicators for vulnerability/ capacity and impact data and assessment show a moderate level of achievement for institutional commitment. The indicator is identified by the resilience components (RA4), and (RA5). The results show that community vulnerability and capacity assessments are incompletely implemented and do not provide a comprehensive picture of the vulnerabilities and capacities (RA4, RA5).

Table 6.4 The weighted mean index of risk assessment

	Resilience components	n WMI	UNISDR equivalent score[11]
RA1	Community hazard/risk assessments carried out which provide a comprehensive picture of all major hazards and risks facing community (and potential risks).	0.65	3.60
RA2	Hazard/risk assessment is a participatory process including representatives of all sections of community and sources of expertise.	0.70	3.81
RA3	Skills and capacity to carry out community hazard and risk assessments maintained through support and training.	0.42	2.68
RA4	Vulnerability and capacity indicators developed and systematically mapped and recorded (covering all relevant social, economic, physical and environmental, political, cultural factors).	0.44	2.75
RA5	Community vulnerability and capacity assessments (VCAs) carried out which provide a comprehensive picture of vulnerabilities and capacities.	0.39	2.54
RA6	Assessment findings shared, discussed, understood and agreed among all stakeholders and fed into community disaster planning.	0.40	2.61
	Risk Assessment index (RAI)	0.50	3.00

The results also show that the assessment findings are not completely shared, discussed and understood by the stakeholders and the community (RA6), and the achievement is moderate. Likewise, the achievement in capacity building (RA3) is moderate. The result reveals that achievement in the indicator for scientific and technical capacities and innovation is neither comprehensive nor substantial.

(HFA3): Use of knowledge, innovation and education to build a culture of safety and resilience at all levels

Table 6.5 shows the results of the public awareness index, with six components addressing the three indicators of the Hyogo Priority for Action

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11 The score is the normalised n WMI gained by using equation 3

(HFA3, Table 6.1) to measure Knowledge and Education. The total score for the public awareness index is 2.84 out of 5. Institutional commitment is attained, but achievements are neither comprehensive nor substantial.

Table 6.5 The weighted mean index of Knowledge and Education.

	Resilience components	n WMI	UNISDR equivalent score[12]
PA1	Appropriate, high-visibility awareness raising programs designed and implemented at national, regional, local levels by official agencies (e.g. Health education programs include knowledge and skills relevant to crises (e.g. sanitation, hygiene, water treatment)).	0.54	3.18
PA2	All sections of community know about facilities/services/skills available pre-, during and post-emergency, and how to access these (Legislation specifies right of people to be informed and obtain information about risks facing them)	0.42	2.68
PA3	There is inclusion of disaster reduction in relevant primary, secondary and tertiary education courses (curriculum development, provision of educational material, teacher training) nationally.	0.37	2.47
PA4	Appropriate education and training programs for planners and field practitioners in DRR/ Disaster Risk Management (DRM) and development sectors designed and implemented at national, regional, local levels.	0.37	2.48
PA5	Cultural attitudes and values (e.g. expectations of help/self-sufficiency, religious/ideological views) enable communities to adapt to and recover from shocks and stresses.	0.56	3.25
PA6	Public and private information gathering and -sharing systems on hazards, risk, disaster management resources (incl. resource centres, databases, websites, directories and inventories, good practice guidance) exist and are accessible	0.49	2.96
	Public Awareness index (PAI)	0.46	2.84

The indicator for public awareness, knowledge and skills, culture, attitudes, and motivation is measured by the resilience components (PA1) and (PA5).

[12] The score is the normalised n WMI by using equation 3

The results show that the design and implementation of the awareness raising program are moderate (PA1). It shows that the cultural attitudes and values help the communities to adapt to the risks and recover from shocks and stresses (PA5). Overall the progress level indicates attainment of institutional commitment, but achievements are neither comprehensive nor substantial.

The information management and sharing strategy achievement is measured by the resilience components (PA2) and (PA6). The result shows that there is an accessible system for gathering information and resources on hazards, risk, and disaster management resources including resource centres, databases, websites, directories and inventories, good practice guidance (PA6). It also shows some progress, but without systematic policy and/or institutional commitment, in the inclusion of disaster reduction in primary and secondary education courses, such as curriculum and teacher training (PA3). The achievement in this indicator is moderate, neither comprehensive nor substantial. Progress in education and training is measured by the resilience components (PA3) and (PA4). The result shows some progress in the inclusion of disaster risk reduction in relevant primary, secondary and tertiary education courses. Likewise, the achievement level in the appropriate education and training programs is low (PA4). Overall, it is indicated that progress in education and training is moderate, neither comprehensive nor substantial.

(HFA4): Reduce the underlying risk factors

The risk management index is calculated using the six components presented in Table 6.6, which address the three components of the Hyogo risk management priority for action HFA4. The components are used to measure three indicators: environmental and natural resource management; health and wellbeing; and physical protection plus structural and technical measures. The achievement score is 3.29, which indicates substantial achievement attained but with recognised limitations in capacities and resources.

The results show substantial achievement in environmental and natural resources management. They show that there are appropriate structures and systems for food security (RM1), and moderate achievement in structural mitigation measures (embankments, flood diversion channels, water harvesting tanks, etc.) (RM3). Overall, institutional commitment is attained, but achievement is neither comprehensive nor substantial.

Table 6.6 The weighted mean index of risk management

	Resilience components	n WMI	UNISDR equivalent score13
RM1	Policy, legislative and institutional commitment to ensuring food security through the market and non-market interventions, with appropriate structures and systems.	0.60	3.39
RM2	Engagement of government, the private sector and civil society organisations in plans for mitigation and management of food and health crises.	0.61	3.46
RM3	Structural mitigation measures (embankments, flood diversion channels, water harvesting tanks, etc.) in place to protect against major hazard threats, built using skills, materials and appropriate technologies as far as possible.	0.49	2.96
RM4	Infrastructure and public facilities to support emergency management needs (e.g. shelters, secure evacuation and emergency supply routes).	0.56	3.25
RM5	Resilient and accessible critical facilities (e.g. health centres, hospitals, police and fire stations – regarding structural resilience, backup systems, etc.)	0.68	3.74
RM6	Resilient transport/service infrastructure and connections (roads, paths, bridges, water supplies, sanitation, power lines, communications, etc.).	0.49	2.96
	Risk Management and Vulnerability Reduction index (RMI)	0.57	3.29

The result shows effective engagement between the government, private sector and civil society organisations in preparing plans for mitigation and management of food and health crises (RM2). It appears that critical

[13] The score is the normalised n WMI by using equation 3

facilities, such as hospitals, are resilient and accessible (RM5). The result indicates achievement of substantial progress, with recognised limitations in capacities and resources in health and wellbeing.

Likewise, progress in physical protection and structural and technical measures is substantial, with recognised limitations in capacities and resources. The result shows substantial achievement for structural mitigation measures, and infrastructure and public facilities (RM4), with some limitations in the achievement of resilient transport/service infrastructure and connections (RM6).

(HFA5): Strengthen disaster preparedness for effective response at all levels

Hyogo Priority for action HFA5 on Disaster Preparedness and Response was addressed via three indicators (Table 6.1), and the six components are displayed in Table 6.7. The overall index of 3.7 from 5 indicates that Oman is relatively well prepared for, and able to respond to, a disaster event. The achievement level is substantial, with recognised limitations in capacities and resources.

The first indicator is organisational capacities and coordination, which are measured through the components (PA1) and (PA2). The results show that the value of local and community disaster preparedness is well recognised by the national and local policy and institutional frameworks as an important part of the national preparedness and response system (PR1). Emergency facilities are available to some extent and these are managed by the responsible organisations (PA2). Overall, the achievement level for this indicator is moderate, with achievement in institutional commitment.

Table 6.7 Components of the preparedness and response index.

	Resilience components	n WMI	UNISDR equivalent score[14]
PR1	National and local policy and institutional frameworks recognise and value local and community (Disaster Preparedness) DP as an integral part of the national preparedness and response system.	0.74	3.95
PR2	Emergency facilities (communications equipment, shelters, control centres, etc.) available and managed by the community or its organisations on behalf of all community members.	0.56	3.25
PR3	Efficient national and regional Early Warning System (EWS) in place, involving all levels of government and civil society, based on sound scientific information, risk knowledge, communicating and warning dissemination and community response capacity.	0.68	3.74
PR4	EWS capable of reaching whole community (via radio, TV, telephone and other communications technologies, and via community EW mechanisms such as volunteer networks).	0.81	4.23
PR5	Training, simulation and review exercises carried out with the participation of all relevant government and non-government agencies.	0.63	3.53
PR6	Civil protection and defence organisations, NGOs and volunteer networks capable of responding to events in effective and timely manner, by agreed plans of coordination with local and community organisations.	0.67	3.67
	Preparedness and Response index (PRI)	0.68	3.73

The achievement level in the early warning system is substantial, with recognised limitations in capacities and resources. It is clear that the Early Warning System (EWS) is efficient and involves all levels of government and non-government organisations based on their responsibilities (PR3). The EWS is capable of reaching the whole community via different

[14] The score is the normalised n WMI gained by using equation 3

communication technologies like radio, TV, telephone and social media (PR4).

Progress in emergency preparedness, response and recovery is also substantial, with recognised limitations in capacities and resources. The results show that government organisations, NGOs and volunteer teams are capable of responding to events (PR6). Also, some participants in the system are having training and exercises on emergency response (PR5), and the achievement level is substantial.

6.4.2 Local resilience survey results

This section discusses the analysis of the implementation of the HFA as expressed by the local community (n=35). Table 6.8 displays the component of resilience in the five thematic areas of the UNISDR Hyogo Framework for Action (HFA). The table presents the 14 components of resilience applied in the local people questionnaire to assess the performance of the organisations and to indicate the level of satisfaction among the local people.

The overall average result of the assessment is 2.83 out of 5, revealing that the organisation's performance is medium. This indicates moderate public satisfaction with the organisation's progress.

Three components were used to assess local people’s opinions about the performance of the governance priority (HFA1). They think that the performance in governance is good. The result shows that the people are not fully aware of the crisis plans, but their satisfaction with community participation in disaster risk reduction is moderate.

In the second priority for action (HFA2), the local people believe that the sharing of assessment findings is below average, and the skills and capacity building training are moderate. Overall their assessment of the performance of risk assessment is moderate.

In the third priority for action (HFA3), local people are not happy about the training and institutional support to raise public knowledge of disaster risk reduction; they believe that the support is weak. They also think that the level of inclusion of disaster risk reduction in the relevant primary, secondary and tertiary education courses is moderate. They also consider that the media plays an active role in raising the awareness to reduce disaster risk.

The overall assessment of the priority for action (HFA4) is moderate. The resilience index of transport/service infrastructure and connections (roads, paths, bridges, water supplies, sanitation, power lines, and communications) is weak. However, the resilience index of emergency facilities like shelters and hospitals is greater than the average.

The resilience index for the priority for action (HFA5) is high. Local people believe that early warning systems can reach the entire community via radio, television, telephone, other communication technology, and through civil society units such as voluntary teams. They also think that the civil defence organisations and non-governmental organisations such as voluntary teams can respond to events in an effective and timely manner, using plans agreed with local institutions.

Table 6.8 HFA components and their implementation in the local community

	Component of resilience	n WMI	UNISDR score[15]
GI1	There are clear crisis management plans in the relevant institutions, and the community is fully aware of the mechanisms used to manage the crisis in each institution	0.44	2.8
GI2	The community understands relevant legislation, regulations and procedures, and their importance.	0.43	2.7
GI3	Inclusion/representation of vulnerable groups in community decision making and management of DRR	0.38	2.5
	Governance index (GI)	0.42	2.67
RA1	Assessment findings shared, discussed, understood and agreed among all stakeholders and fed into community disaster planning.	0.34	2.4
RA2	Skills and capacity to carry out community hazard and risk assessments maintained through support and training.	0.43	2.7
	Risk Assessment index (RAI)	0.39	2.54

[15] The score is the normalised n WMI by using equation 3

Table 6.8 Cont./

	Component of resilience	n WMI	UNISDR score[16]
PA1	There is support and training from institutions to raise community skills and capacities to reduce the risk of natural disasters	0.36	2.4
PA2	The inclusion of disaster reduction in relevant primary, secondary and tertiary education courses (curriculum development, provision of educational material, teacher training) nationally.	0.37	2.5
PA3	The media plays an active role in raising awareness about natural disasters and how to deal with them to reduce their risks and negative consequences on society	0.64	3.6
	Public Awareness index (PAI)	0.46	2.8
RM1	Infrastructure and public facilities to support emergency management needs (e.g. shelters, secure evacuation and emergency supply routes).	0.42	2.7
RM2	Resilient transport/service infrastructure and connections (roads, paths, bridges, water supplies, sanitation, power lines, communications, etc.).	0.3	2.2
RM3	Resilient and accessible critical facilities (e.g. health centres, hospitals, police and fire stations – regarding structural resilience, backup systems, etc.)	0.48	2.9
	Risk Management and Vulnerability Reduction index (RMI)	0.40	2.6
PR1	Early warning systems can reach the entire community via radio, television, telephone, other communication technology, and through civil society such as voluntary teams.	0.65	3.6
PR2	Emergency facilities (communications equipment, shelters, control centres, etc.) available and managed by the community or its organisations on behalf of all community members.	0.56	3.2
PR3	Civil protection and defence organisations and non-governmental organisations such as voluntary teams can respond to events in an effective and timely manner, by agreed plans with local institutions	0.59	3.4
	Preparedness and Response index (PRI)	0.60	3.40
	Overall index	0.46	2.83

[16] The score is the normalised n WMI by using equation 3

6.4.3 Resilience Index

The above results, from both the institutional and local people surveys, are drawn together in this section and also compared to disaster management performance evaluations of other countries. Figure 6.1 and Table 6.9 illustrate the five resilience indexes in the institutional survey and the overall (averaged) resilience index. The result shows the aggregate resilience is 0.5, indicating that the implementation of resilience in Oman is at a moderate level and so could be developed to a better level.

The result shows that the public awareness index scores are lowest in relation to the implementation of HFA priorities for action, followed by the governance index. The scores are moderate and below the total average of the indexes, indicating minor progress in these areas. Thus, the community resilience index can be negatively impacted by the governance and public awareness indexes because they are responsible for developing the rules, regulations, DRR plans, and the public's knowledge and awareness about the risks. On the other hand, the preparedness and response and risk management and vulnerability reduction indexes score are higher. This is an indication that these components are of a substantial resilience level in Oman.

Table 6.9 Institutional performance against Hyogo priority action areas

Priority area	nWMI	UNISDR score
Governance Index (GI)	0.50	2.5
Risk Assessment index (RAI)	0.50	2.5
Public Awareness index (PAI)	0.46	2.5
Risk Management & Vulnerability Reduction index (RMI)	0.57	3.2
Preparedness and Response index (PRI)	0.68	3.7
Overall average	0.54	2.9

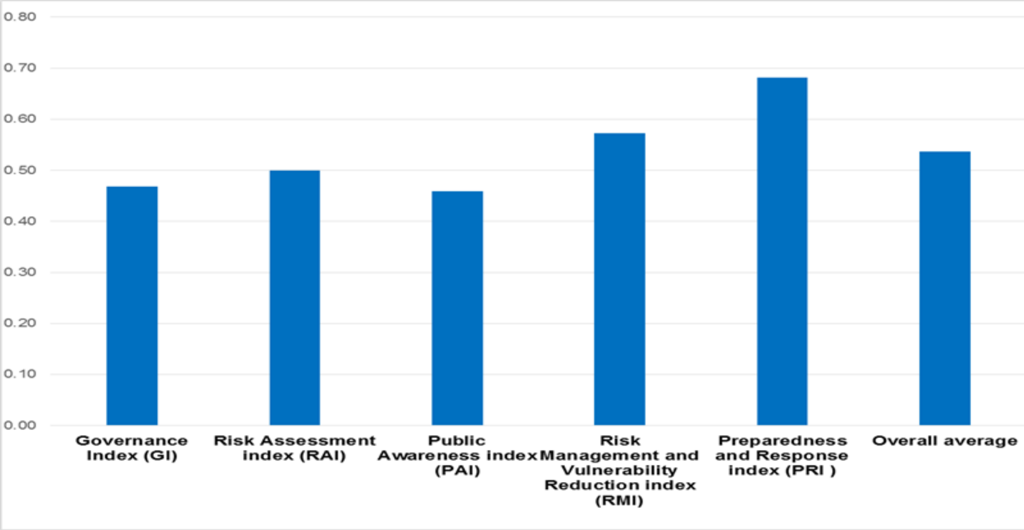

Figure 6.1 Total resilience index of HFA resilience components in Oman

Figure 6.2 and Table 6.10 display the analysis of HFA implementation as determined by the local community. The total index based on the local community response is 0.47. The index is lower than the value estimated by the decision makers in the organisations (Figure 6.3). The result indicates that the public are less satisfied with the disaster management system in Oman than the disaster management organisations.

Table 6.10 Indices of implementation of each area in local level assessment

Priority area	nWMI	UNISDR score
Governance Index (GI)	0.42	2.67
Risk Assessment index (RAI)	0.39	2.54
Public Awareness index (PAI)	0.40	2.60
Risk Management & Vulnerability Reduction index (RMI)	0.46	2.83
Preparedness and Response index (PRI)	0.60	3.40
Overall average	0.45	2.81

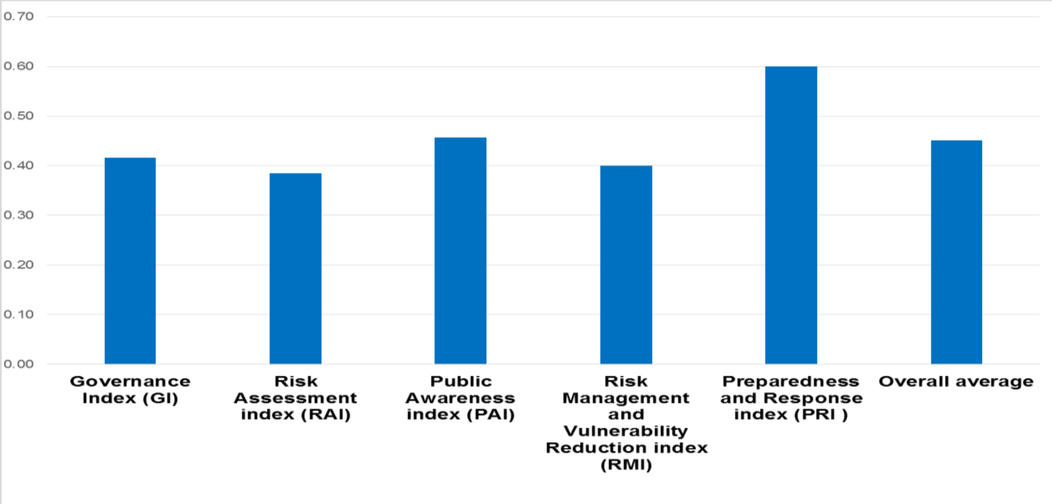

Figure 6.2 Resilience of HAF implementation as judged by local community

The results show a high resilience index for preparedness and response. The result indicates that the local community is satisfied with the action of the organisations and believes that they are well prepared for the response (Figure 6.3). The results in section (6.4.1) show similarity between the public and the decision makers in the indexes of some components. For example, the resilience index of preparedness and response at the institutional and local level scores the same (0.6), as is the index of knowledge and education (0.46). This indicates that the local people agree that the preparedness and response are at a reasonable level of implementation in Oman, but they are not satisfied with the level of knowledge and education implementation.

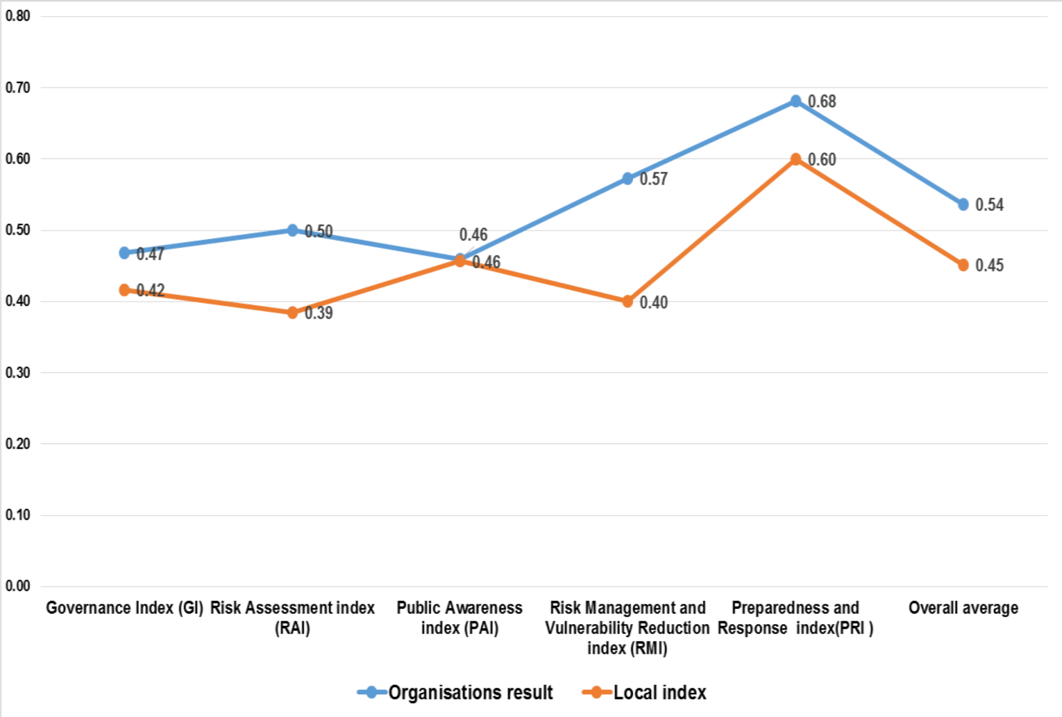

Figure 6.3 Comparison of organisation resilience index and community perception of organisation resilience

The results also show that the local community is less satisfied with risk governance, risk assessment, and risk management in Oman than the organisations responsible for disaster management. The indexes of these components are lower than the indexes expressed by the decision makers in Section (6.4.1). The results indicate that the local community believes that these components are not at the appropriate level. Nevertheless, they do not have sufficient information about the system in Oman, and how it works.

6.4.4 Oman's progress relative to Global / Arab country progress

In this section, the result of the study is compared with the world average for achieving an appropriate level of disaster management and the data on the progress of Arab countries. Comparing the progress of Oman with that of the other Arab countries and the world is important to identify the position of Oman, and the level of the performance in building resilience to natural disasters. The level of Arab country progress is then compared with some events (risk) and wealth (GDP / capita) to understand possible correlation with factors that influence the performance of building resilience.

6.4.4.1 Comparison of Oman to Global average

Figure 6.4 shows the world average for HFA progress compared to that of Oman. According to the UNISDR (2013c), there is significant progress in the world in making disaster risk reduction a priority at national and local level. This strong progress is especially apparent in establishing national policy frameworks, decentralised responsibilities and capacity, and an increase in the interest in establishing a national platform for disaster risk reduction (UNISDR, 2013c). Comparing the world average with the Oman average in HFA1, the results show that Oman’s average for ensuring that disaster risk reduction is a national and a local priority is lower than the global average. The result shows some progress but without systematic policy and institutional commitment. This indicates some weakness in the policies and/or the organisation's commitment. For the priority HFA2, which focuses on identifying and monitoring the risk and enhancing the early warning system, the average progress of Oman is also lower than the global average. Although institutional commitment is attained, the achievements are neither comprehensive nor substantial. For the priority HFA3, using knowledge and education to build public awareness, Oman also scores lower than the world average. Again, although institutional commitment is attained, the achievements are neither comprehensive nor substantial. This indicates some progress in building a culture of safety and resilience at all levels, but the progress is not significant. The average achievement in Oman for the priority HFA4 for reducing the underlying risk factors is higher than the world average. The result shows that a good level of institutional commitment has been attained, but achievements are neither comprehensive nor substantial. This indicates that Oman has made significant progress in increasing the levels of mitigation and building a resilient infrastructure in Oman to reduce risks. The average achievement in Oman for the priority HFA5 of strengthening disaster preparedness is higher than the world average. The result reveals substantial achievement, but with recognised limitations in capacities and resources. This indicates an effective response system to the disaster at all levels. Organisations in Oman are also participating with local people in evacuation training, and in volunteering during the disaster. The overall average of achievement of Oman is lower than the world average, but the difference is small. Oman's progress shows institutional commitment has been achieved, but the achievements are not comprehensive and need more development.

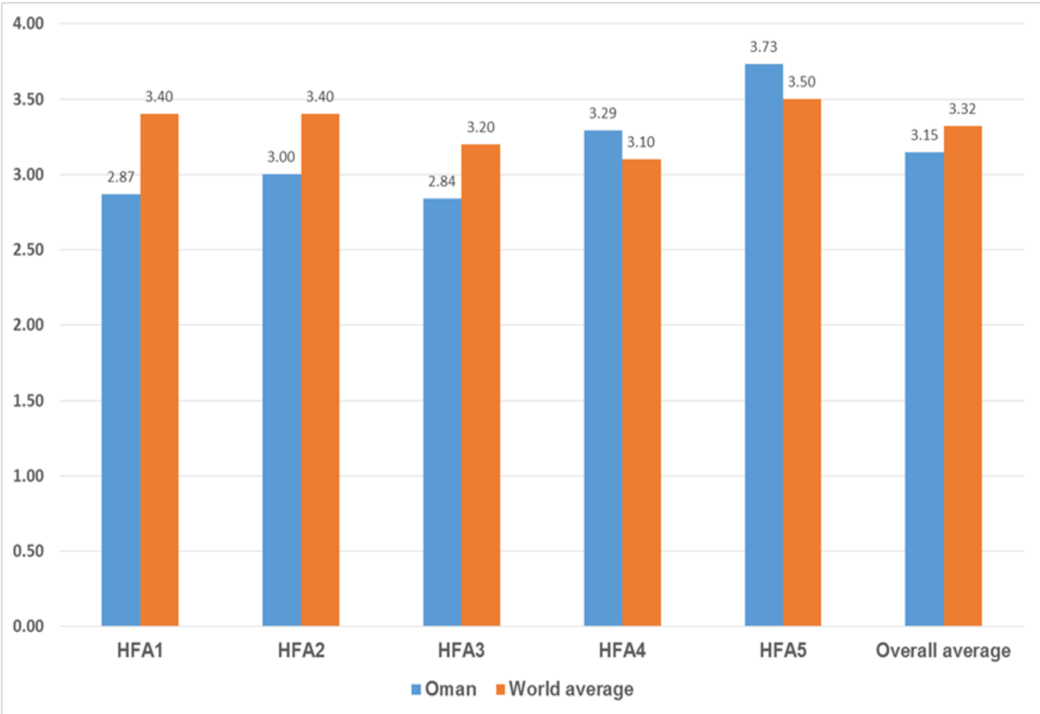

Figure 6.4 The world progress average of HFA implementation and the average progress of Oman's HFA implementation.

6.4.4.2 Comparison of Oman to other Arab countries

At the regional level, according to the UNISDR (2015a) report, progress of the Arab countries in disaster management has increased consistently during the period 2005-2015. Table 6.11 shows the progress of Arab countries in different periods. The data for Oman derives from this study because there are no UNISDR data of progress for Oman. Oman is only included in the aggregated report UNISDR (2015a). The progress of Oman is compared with the Arab countries' progress in the five HFA priorities for action. The comparison with the Arab countries is important to understanding the progress of Oman. The comparison of Oman's progress with that of countries that may have similar criteria based on the number of events (hazards) and wealth (GDP/capita) will give a clear vision of the progress made in Oman and the expected progress.

Table 6.11 Progress of Arab countries in HFA implementation

Country	Year	HFA1	HFA2	HFA3	HFA4	HFA5
Algeria	2011-2013	3.25	3.25	2.75	4.17	4.25
Bahrain	2011-2013	3.50	3.75	3.00	3.17	4.00
Comoros	2009-2011	1.75	2.50	2.25	1.50	1.50
Djibouti	2011-2013	2.25	3.00	3.25	3.00	2.50
Egypt	2013-2015	3.50	3.25	3.00	3.33	3.50
Iraq	2013-2015	1.75	2.25	1.50	1.17	1.50
Jordan	2011-2013	2.25	2.75	2.25	2.50	3.00
Kuwait		No data	No data	No data	No data	No data
Lebanon	2013-2015	2.75	3.50	3.25	2.83	3.25
Libyan Arab Jamahiriya		No data	No data	No data	No data	No data
Mauritania	2011-2013	3.00	3.00	3.00	3.33	3.00
Morocco	2011-2013	3.00	3.00	3.80	3.50	2.50
Oman	2017	2.87	3.00	2.84	3.29	3.73
Qatar	2013-2015	3.25	3.25	2.75	3.17	3.25
Saudi Arabia		No data	No data	No data	No data	No data
Sudan	2011-2013	0.75	2.5	3.5	3.00	2.00
Syrian Arab Republic	2009-2011	3.50	3.00	3.00	3.00	3.30
Tunisia	2013-2015	2.25	2.75	2.25	2.67	2.75
United Arab Emirates	2013-2015	4.50	3.50	4.00	5.00	3.75
Yemen	2013-2015	1.75	1.50	1.75	2.00	1.00

HFA 1: Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.

Figure 6.5 shows the progress of the Arab countries for the HFA priority for Action 1. The Arab region UNISDR (2015a) report indicated some progress in the national platforms in some countries. However, there are challenges in the allocation of resources and development of implementation mechanisms (UNISDR, 2015a). The result for Oman shows that progress for institutional commitment is attained, but achievements are neither comprehensive nor substantial. This is better than the progress of Sudan, Comoros, Iraq, Yemen, Djibouti, Jordon, Tunisia, and Lebanon. On the other hand, the United Arab Emirates (UAE), Egypt, and Algeria all attained better progress than Oman. For example, progress in governance is lower in Oman than in Algeria. Algeria has shown strong institutional commitment i through the passing of Law 04-20 of December 25, 2004, on the prevention of major risks and disaster management in the context of sustainable development, which constitutes a global and coherent framework for planning, programming and implementation of the national disaster risk reduction policy (UNISDR, 2015b)[17]. At the policy level, resource allocation for disaster risk reduction programs follows a different path. The Algerian government allocates annual grants to specialised agencies for operating and equipment in these areas within the framework of the State's annual budget (UNISDR, 2015b). Also, the UAE has comprehensive achievements, commitment and sustainable capacities at all levels. The key indicator of the achievement in the UAE is the availability of resources dedicated to disaster risk reduction (DRR). There is no higher limit for the disaster risk reduction budget at either the national or local level[18]. Meanwhile the DRR budget is a considerable challenge in many countries; for example, Yemen (2011) reported a lack of DRR budgetary allocation[19] (UNISDR, 2015b). The challenge in Oman is that while there is some progress, systematic policy and/ or institutional commitment is lacking in some organisations. The policies have mostly focused on relief and

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17 National progress report on the implementation of the Hyogo Framework for Action of Algeria (2011-2013) published by the UNISDR

18 National progress report on the implementation of the Hyogo Framework for Action of the UAE (2013 - 2015) published by the UNISDR.

19 National progress report on the implementation of the Hyogo Framework for Action of Yemen (2013-2015) published by the UNISDR

response rather than prevention and recovery. However, there are high achievements in the indicator for national platform or committee establishment. In Oman, the National Committee for Civil Defence has been established to take on coordination of all organisations in national level disaster management. A royal decree is in place, and there are regulations and rules for the NCCD's roles and responsibilities.

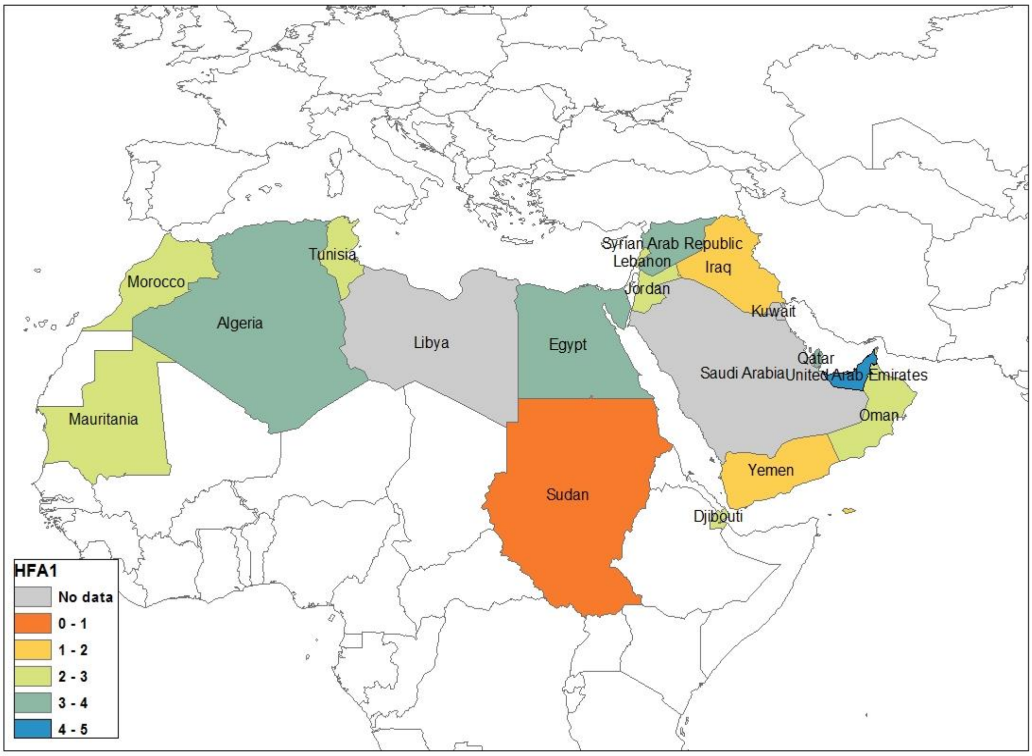

Figure 6.5 The progress of HFA1 in the Arab region[20]

HFA 2: Identify, assess and monitor disaster risks and enhance early warning

Figure 6.6 shows the progress of the Arab courtiers in the HFA priority for action 2. According to the UNISDR (2015a), there is a need to make further efforts to develop a risk assessment program that identifies the social, economic, physical, physical and institutional factors contributing to vulnerability and risk accumulation. The result shows that Oman has made

[20] All maps of the HFA progress in this research produced by the researcher

some progress in this priority. However, it also shows that some countries have made better progress than Oman, such as the UAE, Bahrain, Egypt, and Algeria. Bahrain has substantial achievement regarding this priority; risk assessment is carried out, and a full hazard profile produced (UNISDR, 2015b)[21]. Bahrain has reported that 100% of its schools and hospitals have undertaken multi-hazard risk assessments (UNISDR, 2013). In Oman, risk assessment for tsunami and storm surges is carried out by the early warning centre (DGMAN, 2014b). This assessment identified the social, economic, physical, physical and institutional factors contributing to vulnerability and risk. However, there is no multi-hazard risk assessment for schools and hospitals in Oman. The progress of Bahrain is higher than that of Oman because Bahrain has a small population and geographically is not a highly vulnerable country, while Oman has more population and geographically is a country vulnerable to multi-hazards, including tsunami, cyclones, and other hazards. For example, according to the numbers of extreme hazards recorded on the EM-DAT database, five occurred in Oman and zero in Bahrain in the period (1982-2011)(UNISDR, 2015b). The result shows that the UAE has the best progress in this priority, exceeding that of Oman, because the organisation has a high budget to carry out risk assessment, and the country is small compared with Oman, and geographically it is less vulnerable than Oman.

[21] National progress report on the implementation of the Hyogo Framework for Action of Bahrain (2011-2013) published in the UNISDR

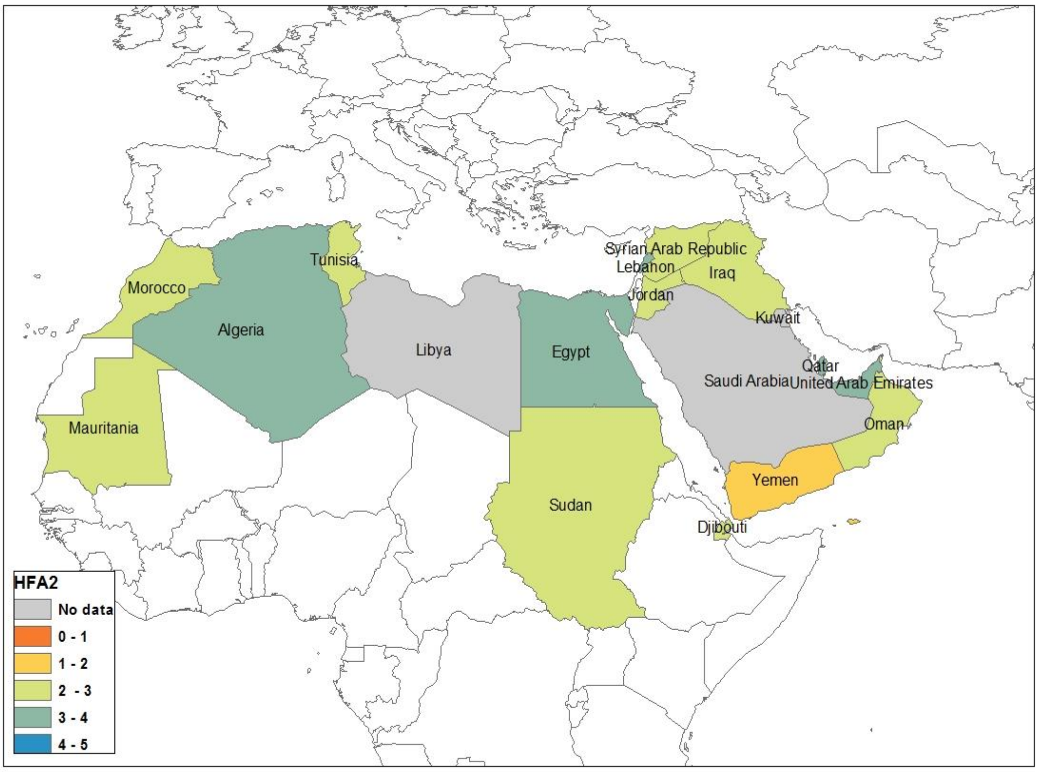

Figure 6.6 The progress of HFA2 in the Arab region

HFA 3: Use knowledge, innovation and education to build a culture of safety and resilience at all levels

Figure 6.7 shows the progress of the Arab courtiers in the HFA priority for action 3. According to the UNISDR (2015a), there is some progress in this priority. The result shows that Oman has made moderate progress in this priority compared with other Arab countries. The result shows that the UAE, Bahrain, Lebanon, Sudan, Djibouti, and Morocco have made better progress than Oman. For example, Lebanon implemented some training programs to increase the awareness, preparedness, and emergency management of public and private institutions, involving the efforts of the Lebanese national government with the support of the UNDP on DRR (UNISDR, 2015b)[22]. Bahrain has established a program of community

[22] National progress report on the implementation of the Hyogo Framework for Action of Lebanon (2013-2015) published by in the UNISDR

participation. This program mainly relates to fire disasters; the schools are visited by fire officers who conduct evacuation exercises (UNISDR)[23]. Likewise, the same program of fire evacuation exercises is conducted in the schools in Oman by the Civil Defence. However, the progress of Oman in this priority is lower than that of Bahrain, and this is because Oman is more affected by multi-hazards than Bahrain, and has a higher population. In Oman, also, on 7/9/2016, the Early Warning Centre, the Civil Defence, and the Ministry of Education conducted training on tsunami evacuation in some schools in the coastal area, and the students were happy with this exercise because it introduced them to new knowledge about this disaster[24]. Recently (2018), the Early Warning Centre and the Meteorology Department in Oman published translated books and some studies about tsunami and offered it to the public[25].

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[23] National progress report on the implementation of the Hyogo Framework for Action of Bahrain (2011-2013) published in the UNISDR

[24] The information about this training was published in the social media by one of the participated schools (Najia bint Amer).The published material is a video of the training

[25] According to the director of the Meteorology (2018), the department published four translated books about tsunami, 1) Where the first wave arrives in minutes, Oman-ICO UNESCO Project, 2) Tsunami Glossary, Oman_ICO UNISCO Project, 3) Great Wave, Oman-ICO UNISCO UNESCO, and 4) Remembering the 1945 Makran Tsunami, IOTIC-Project.

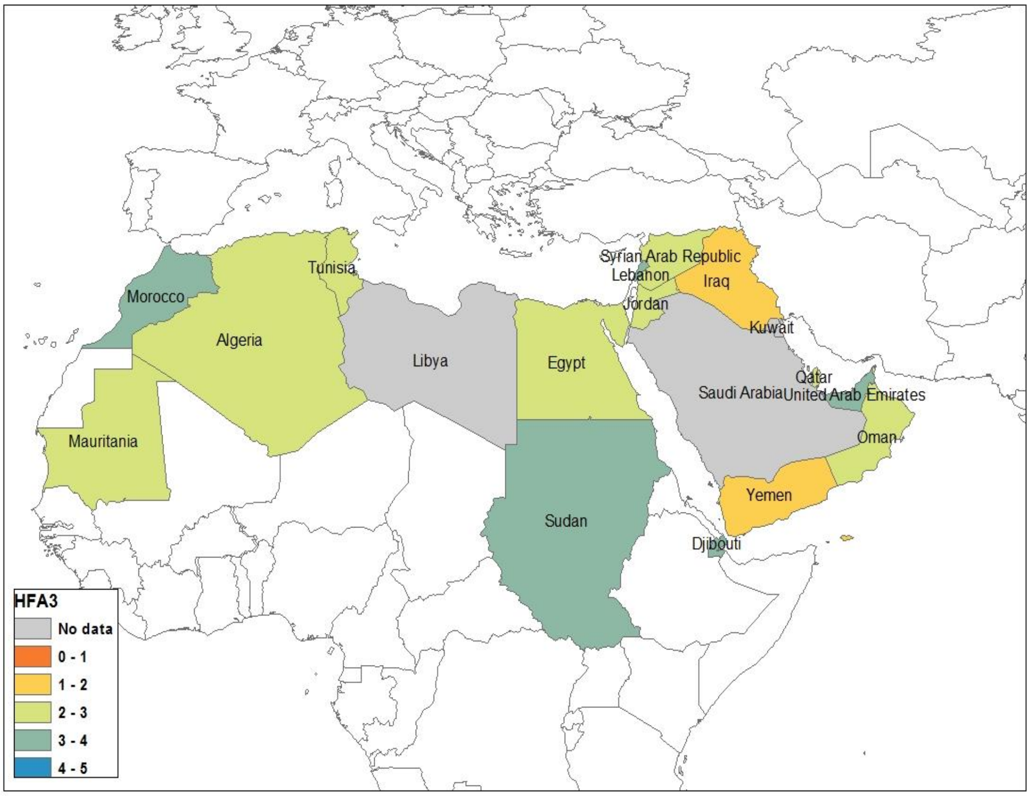

Figure 6.7 The progress of HFA3 in the Arab region

HFA 4: Reduce the underlying risk factors

Figure 6.8 shows the progress of the Arab countries in priority HFA4. The implementation report of the Arab region UNISDR (2015a) indicated the need for the Arab countries to develop national risk management programs at the organisational level in such as schools and hospitals. Oman has achieved substantial progress in this priority, but with recognised limitations in capacities and resources. In comparisons with other countries, the UAE and Algeria have achieved better progress than Oman. The UAE has some programs of risk reduction and sustainability; for example, the Shams1 (Sun1) energy project, which aims to reduce carbon emissions by taking about 15,000 vehicles off the streets. The UAE has clear laws and legislation binding developers through urban planning, and municipalities. The UAE also conducts the most risk assessments of hazards and crisis at the national, local, and institutional level.

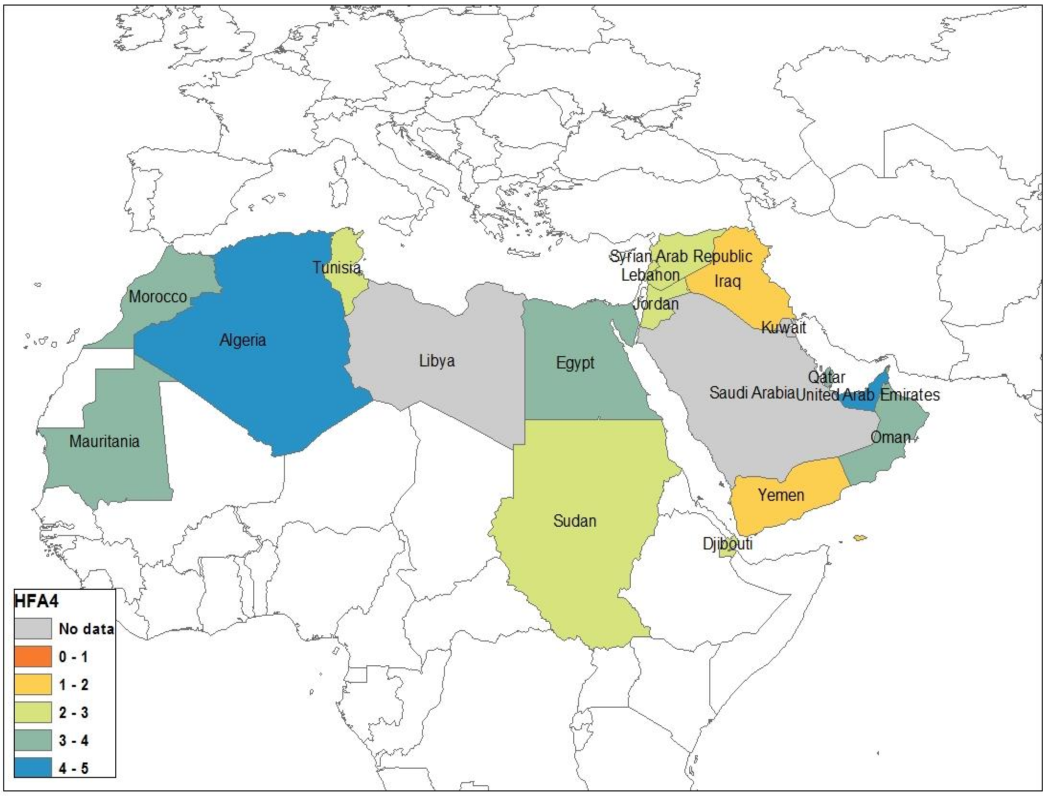

Figure 6.8 The progress of HFA4 in the Arab region

In Oman, the infrastructure is becoming more resilient, and the country is connected by a resilient transport network. However, some challenges still remain in terms of urban planning policies. The policies do not take sufficient account of flood areas, and there are many new settlements in areas of flood risk. For example, during storm Ashobaa (2014), interviews were conducted with some of the affected families in Wadi Tiwi, Oman. One affected house is located in a very low area about 4 meters from the flood area, and near the sea. So, during severe events, it is affected by flash floods. The householder said: *“This house has been built by social housing. I have a piece of land in the upper residential area, but they refused to build on that land because it is in my name and the house belongs to the heirs. "I* *told them that I do not mind changing the ownership of the land to the heirs so that my house is in a safer place, but they refused,"*[26]

This family has been affected before by cyclone Guno (2007) and cyclone Phet (2011)[27]. It was one of four families still living in the area after cyclone Guno and cyclone Phet because they did not get compensation for their houses and they cannot build a new house in another place. The other problem is that when the Ministry of Housing gave compensation to other people affected during Guno it did not take from them the ownership certificate for the old house. When the area was then hit again, by cyclone Phet, they asked for new houses, and some of them are now viewed as having two houses. The main problem, in this case, is the absence of systematic laws and legislation on compensation after the crisis.

HFA 5: Strengthen disaster preparedness for effective response at all levels

Figure 6.9 shows the progress of the Arab countries in HFA5. The UNISDR (2015a) report stated that there is a need for basic disaster preparedness and contingency plans, and there is a need to describe response and recovery efforts to develop separate recovery plans. Oman has achieved substantial progress in this priority but with recognised limitations in capacities and resources. Among the Arab countries, Algeria has made higher progress in this priority. In Algeria, a national disaster management system operates through contingency planning and interventions as well as structural measures for disaster management (UNISDR, 2015b). Emergency plans exist and are implemented at different levels (National, Wilaya and local); they are governed by Decree 85-231 on the organisation of interventions and disaster relief (UNISDR, 2015b). Algeria has significant achievements with sustained capacities and commitments in place at all levels in the procedures for information exchange during hazards and for post-disaster analysis (UNISDR, 2015b). In Oman, there is a significant

[26] Interview with householder, Wadi Tiwi, 10/06/2014.

[27] The director of social housing department in the ministry of housing refused a meeting with the researcher twice.

achievement in response and evacuation during disasters. The Public Authority of Civil Defence and Ambulance (PACDA) has a good system of response to all type of disasters. The PACDA has highly trained rescue officers, and is also licensed for international rescue, enabling it to serve in any affected area in the world. The PACDA runs training programs for the public, and conducts frequent fire evacuation exercises in schools and hospitals.

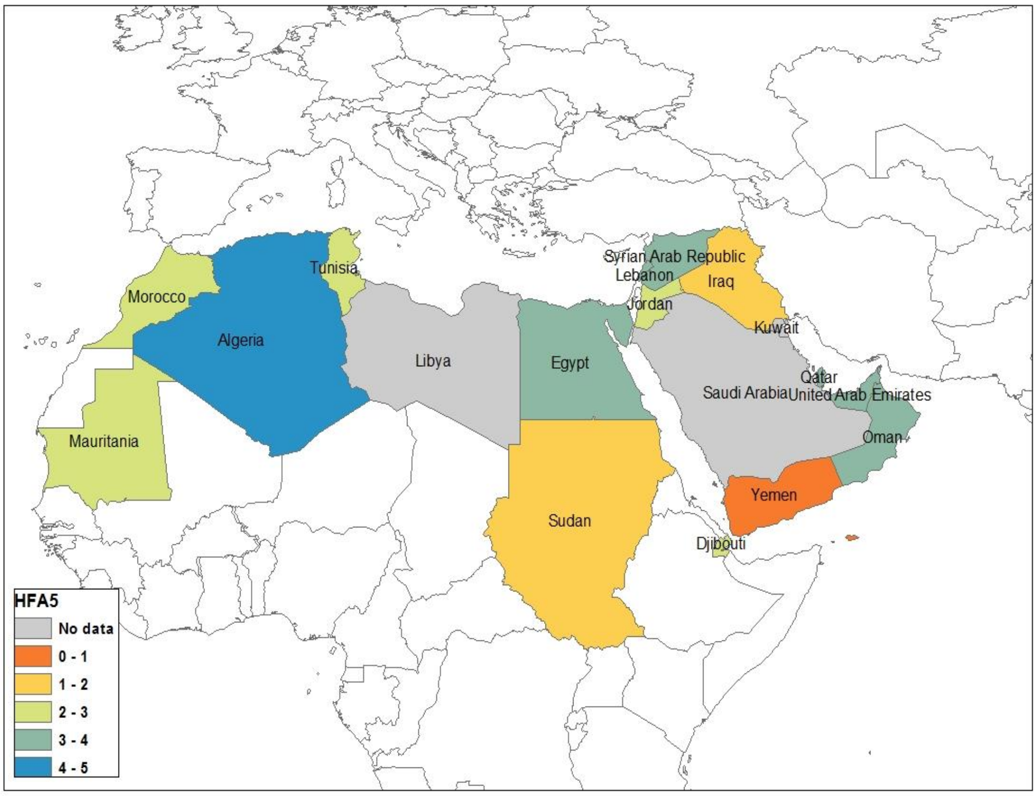

Figure 6.9 The progress of HFA5 in the Arab region

Overall average of HFA for action in the Arab countries

Figure 6.10 shows the overall progress of HFA for action in the Arab countries. UNISDR (2015a) discloses that at the national level, the strategic objective and future forecast data show increased awareness of the need to move from a culture of response to a culture of prevention and mitigation, thus improving resilience. The result shows that overall Oman has substantial achievement but with recognised limitations in capacities and resources. In comparison with other countries, the UAE has made higher progress in the implementation of HFA for action. The UAE has made this high progress because it has a comprehensive approach to multiple risks in disaster risk reduction and development (UNISDR, 2015b). The UAE makes effective efforts using strong strategy, knowledge and participation from the concerned parties to identify and enhance risk reduction and recovery capacities (UNISDR, 2015b). The UAE also integrates social justice and security interventions into disaster risk reduction and recovery activities (UNISDR, 2015b). It makes effective efforts using a strong strategy of strengthening partnerships with non-governmental actors, civil society and the private sector at all levels (UNISDR, 2015b)[28]. Oman, meanwhile, in this priority has substantial achievements in terms of national and local policy and institutional frameworks that recognise and value local people and communities as an integral part of the national preparedness and response system. Oman has comprehensive achievement in the establishment of a capable early warning centre involving all levels of government and non-government organisations. The Public Authority of Civil Defence and Ambulance is capable of responding to events in an effective manner, and integrates the community into the evacuation training.

[28] National progress report on the implementation of the Hyogo Framework for Action of the UAE (2013 - 2015) published in the UNISDR.

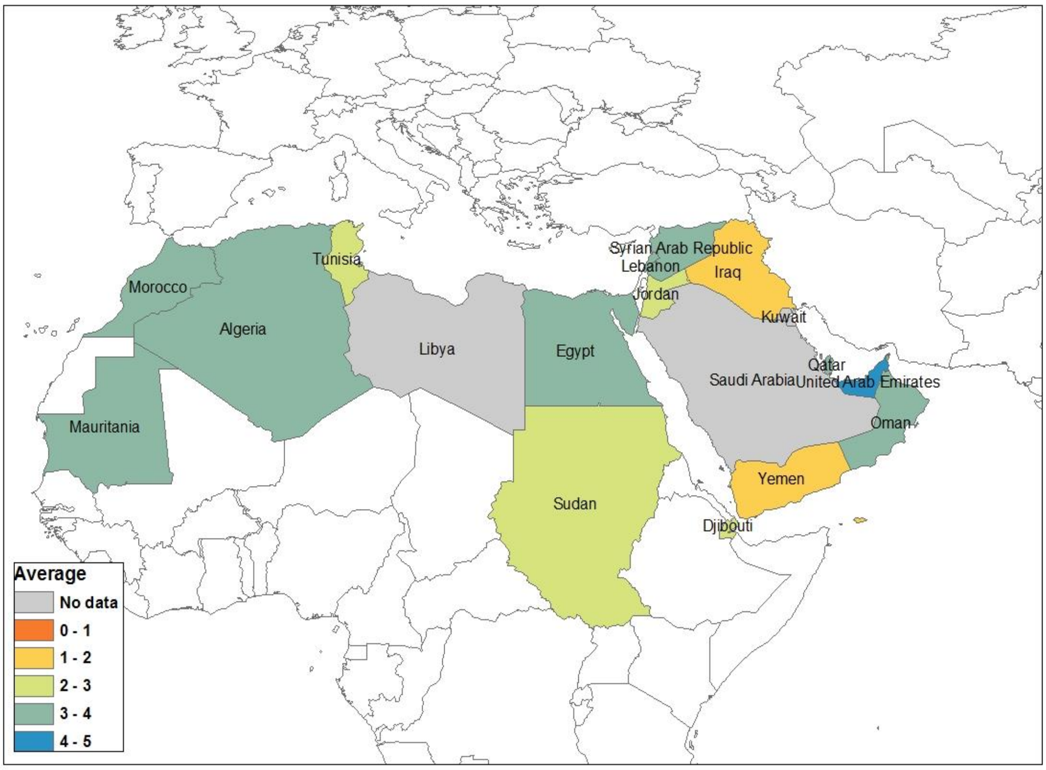

Figure 6.10 Overall average of HFA progress in the Arab region

Hazard and wealth are assumed to influence disaster resilience. It is expected that countries that experience more hazard events give disaster resilience more attention, and that wealthier countries are better able to build more resilient communities. Comparing the achievements on the HFAs for action in the Arab countries with the data on the hazards and wealth in these countries (GDP/Capita) will enable an assessment of the relationship between these variables.

Table 6.12 presents a summary of events in the Arab countries from 1982 to 2011 using the data from the Emergency Events Database (EM-DAT). The number of events in Oman is modified by adding data from the Indian Meteorology Department. GDP per capita of the Arab countries in 2009 is derived from the international monetary fund (IMF) database[29]. Pearson correlation is used to identify the relationship between the achievements of

[29] data source : http://www.imf.org/en/data &
http://www.sacmeq.org/interactivemaps/statplanet/StatPlanet.html

HFA for Action in the Arab countries and hazard frequency and national wealth, shown in Table 6.13.

Table 6.12 Summary of disaster events in the Arab countries from 1982 to 2011, and GDP per capita (PPP current int. $) (2009)

Country	GDP per capita	Events
Algeria	6,801	58
Bahrain	35,145	0
Comoros	1,151	10
Djibouti	2,476	13
Egypt	6,044	21
Iraq	3,655	8
Jordan	5,401	10
Kuwait	13,374	1
Lebanon	2,070	6
Libyan Arab Jamahiriya	4,519	1
Mauritania	24,874	22
Morocco	92,121	28
Oman	2,357	9
Qatar	4,820	0
Saudi Arabia	8,220	12
Sudan	37,820	42
Syrian Arab Republic	2,543	6
Tunisia	6,801	9
United Arab Emirates	35,145	0
Yemen	1,151	29

Table 6.13 displays the result of Pearson correlation between progress on achievement of the Hyogo framework for action, number of hazards, and national wealth (GDP/Capita) in the Arab countries. The result of the correlation with wealth is 0.41, indicating a minor positive impact of wealth on progress in HFA implementation, but the correlation is not statistically significant. The correlation for hazard events is -0.13, indicating a minor negative impact of the number of events on the overall average progress of HFA, but again this is not statistically significant.

Table 6.13 Pearson correlation of the progress of achievement of HFA for Action with hazard frequency and wealth (GDP/Capita)

Pearson correlation	HFA1	HFA2	HFA3	HFA4	HFA5	average
GDP/ Capita	0.44	0.43	0.17	0.32	0.39	0.41
Events (Hazards)	-0.31	-0.28	0.05	0.15	-0.10	-0.13

The correlations between the progress of the five priorities of HFA for action with wealth (GDP/Capita), and with number of events suggest a medium or minor positive impact for wealth, a minor negative or positive impact for number of hazards in terms of progress in all priorities. However, there are differences in the correlation results in respect of the individual HFA priorities. The correlation between wealth and the progress of HFA1 is 0.44, which is the highest figure found in comparing the correlation with other priorities. However, this correlation is not significant. The lowest wealth correlation is with progress of HFA3, at 0.17. The result possibly suggests that although wealthier countries are building institutional platforms for disaster management, they are not investing in public awareness or building knowledge about risk. Correlation between progress in the priorities and number of hazards shows a small positive impact in HFA 3 (0.05), and HFA4 (0.15). It shows a small negative impact in HFA1 (-0.31), HFA2 (-0.28), and HFA5 (-0.10), but the relationship is not significant. The results indicate that the number of events slightly increases the knowledge of the risk in the communities. There also appears to be a minor negative association between number of events and progress in institutional platform of disaster management (HFA1), risk assessment (HFA2), and preparedness for the response (HFA5).

The result shows that the countries with high GDP and a low number of events achieved comprehensive or substantial progress in HFA implementation, for example, the UAE and Bahrain. Countries with a high number of events and low GDP achieved limited progress in the HFA. However, in some countries, for example, Algeria, the results indicate that high number of events and low GDP are associated with substantial achievement in the HFA priorities for action. Algeria[30] has made significant efforts to meet the commitments through implementation of a coherent strategy and identified and committed actors in many aspects. Some related indicators of progress include: 1) the impact of the legislative and regulatory mechanisms induced by the last disasters that the country has experienced has helped develop the resilience capacity of the population. This scheme is mainly directed by the law 04-20 on the prevention of natural disasters, the law 03-12 on the obligation for insurance, the law 04-05 of August 14th, 2004 modifying and completing the code of town planning, the new version of the seismic code. 2) The school curriculum has a component on natural and environmental materials. 3) Incorporating insurers into risk reduction and managing disaster effects is an innovative approach that will, with development, act as an indicator of significant progress in the future. 4) The establishment of the "National Delegation to Major Hazards" in 2011.

Oman’s progress in terms of HFA increased after cyclone Guno, and cyclone Phet. The country started to realise the importance of investment in building resilience to disaster in all priorities. However, while the achievement is not the same in all priorities, it is of significance. The progress can be indicated by the royal decrees[31] (NCCD, 2010) which were enacted after cyclones Guno and Phet to reform the National Committee for Civil Defence to make it more active, and to improve the regulations and the plans for disaster management at national and local level in Oman. Significant progress has been made in terms of the early warning system. The early warning centres have expertise in monitoring, forecasting, and analysing multi-hazards, such as tropical cyclones. The early warning centre has made significant efforts in multi-hazard risk assessment and vulnerability assessment of tsunami and storm surges (DGMAN, 2014c; DGMAN, 2014b).

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[30] National progress report on the implementation of the Hyogo Framework for Action of Algeria (2011-2013) ,published in the UNISDR

[31] The royal decrees has been reviewed in chapter 3

The result reveals that national wealth and number of hazard events are not significantly associated with the resilience index or its components. Therefore, more investigations are needed to understand what is influencing resilience and the performance of the disaster management in Oman.

6.5 Conclusion

Chapter five assessed the network of Omani disaster management organisations and their interaction. Chapter six builds on this analysis and examines the extent to which Oman, through these organisations, has developed a disaster management system able to build community resilience to major natural hazards. The chapter has applied a community resilience index approach, using surveys applied to both institutions and the local community, based on measurements of the implementation of a series of specific actions in five thematic areas as determined by the international Hyogo framework. The results of this analysis address resilience in each thematic area, the overall resilience of the disaster management organisation system, and resilience of that system, as perceived by local people. The result is then compared with national progress reports on the implementation of the Hyogo Framework for Action worldwide and in the Arab countries.

The results show that disaster preparedness and response is better developed than the other resilience themes, as judged by both organisational replies and the local community. The results indicate that preparedness and response to emergencies are well established and that local people are satisfied. Risk management and vulnerability reduction indices are also higher than the average according to the decision makers, while the index is lower than the average based on the evaluation by the local community. This is a sign that local people are not satisfied with the risk management and mitigation used to reduce the risk of disasters in Oman. The public believes that the country needs more resilient infrastructures facilities and the available services are not appropriate.

The index for risk assessment as perceived by the decision makers is at an average level. However, the risk assessment index at the local level is very low. The result indicates that the public do not have enough information about risk assessment in Oman. The local community believes that the findings of risk assessments are not shared with the community.

The results for both the decision makers and the local community indicate low resilience indexes in governance and the knowledge and education about disasters. This outcome is an indication of weakness in the rules, regulations, disaster management plans and the enforcement of laws in Oman. Likewise, public awareness about the disaster is not at the appropriate level. Comparing the overall progress with other countries shows that although progress has been made in Oman, the level is relatively low. The result indicates low performance in the implementation of the HFA priorities for action in Oman compared with the world average.

The comparisons between the results obtained for Oman and the worldwide average show that the progress for Oman in HFA1, HFA2, and HFA3 is below the world average, but progress in HFA4 and HFA5 is above average. This indicates there is very likely scope in Oman for improving the governance platform through developing systematic and clear policies. Also, there is a need for more attention from all organisations to risk assessment and public awareness programs. The comparison with Arab countries shows that some countries have achieved better levels of progress than Oman. However, these countries have better resources for disaster management, with low vulnerability to hazards, relative to Oman. Overall the achievement of Oman is close to the world average, with some minor differences, which derive from the world average including some countries with a high capacity for achievement and low vulnerability to disasters. Furthermore, significant efforts have been made to implement coherent strategy with identified and committed actors; for example, the royal decree to restructure the disaster management scheme in Oman, and the progress made with the early warning system. However, there has been some delay in terms of the related organisations meeting the commitments on the implementation of national strategy. The individual organisations need to monitor and discuss their organisation’s progress continuously, to understand progress in disaster resilience in the five areas introduced by Twigg (2009).

The result of Pearson correlations between resilience index, wealth and number of events show that these correlations are not significant. The hypotheses are rejected, and wealth and number of events are not the only reasons influencing the disaster management system or the resilience and performance of the disaster management system in the Arab countries, including Oman.

Chapter five explored Oman’s organisational capacity in disaster management through an investigation of the network of disaster management organisations and their interaction. Chapter six has built on that analysis, by seeking to understand and critically evaluate the extent to which that capacity produces disaster resilience in Oman. The next chapter extends the analysis further, by seeking to understand the institutional factors that influence the performance of organisations, and in terms of which responsibilities, to develop disaster resilience. Chapter seven will focus on the variables affecting the resilience and performance of the disaster management system in Oman.

Chapter 7 Factors affecting disaster resilience in Oman: Integrating Stakeholder Analysis & Fuzzy Cognitive Mapping

7.1 Introduction

Chapter seven aims to answer the research question about the factors that influence the capacity of organisations to manage the risk from extreme weather events. The chapter will clarify the weakest and strongest parts in the disaster management thematic area provided by the Hyogo Framework (HFW). Also, the chapter will examine how each part of the system can influence the performance of the other part, negatively or positively.

The organisations working in Oman in the disaster management field are used as a case study in this research. Oman is a good example through which to understand organisational performance because the system in Oman is new, and the government is working hard to improve it. The government aims to achieve the global goals in disaster management and to build community resilience.

Section 7.2 presents the analysis approach of the Fuzzy Cognitive Mapping which has been explained in chapter four. Section 7.3 presents the results of analysis of the interviews and focus group discussions undertaken during the fieldwork in Oman. The result examines the factors influencing the institution's performance. It shows the weakest and strongest aspects of disaster management in Oman’s system. The chapter analyses the relations between each part and the influence of each one.

7.2 Materials and methods

7.2.1 Fuzzy cognitive mapping

For a better understanding of the factors that are affecting organisational performance during extreme weather events, Fuzzy Cognitive Maps (FCMs) were derived from analysis of the interactions between stakeholder groups involved in disaster management in Oman. FCM was selected as the principal research tool for this workshop as:

A. It provides an effective means for participants to contribute knowledge on the processes of interest that can subsequently be structured for a wider understanding of the system.
B. Participants build their mental models to find the best common scenario for building community resilience. The model limits the researcher's introduction of personal bias into policy analysis and scenario development.
C. It is an effective way of controlling for partiality and bias amongst participants.

The FCM results from three stakeholder groups were merged to create an aggregate model combining the different stakeholder perspectives. This model can then be used by policy-makers to inform decisions on organisation and investment for improving disaster response and resilience in Oman.

7.2.2 The FCM map

FCM is a graphical presentation of knowledge or a perception of a given system (Kontogianni et al., 2012; Michael, 2009). FCM has nodes that represent factors and edges that represent the relationship between nodes. The graph (map) is used to analyse the complex system of stakeholder relationships by using matrix algebra, which provides a way to explain the FCM structure (Özesmi and Özesmi, 2004). Examining the structure can help to determine stakeholder opinions about the disaster management system and clarify the strongest and the weakest parts of the system.

In the FCM the strength of the connection is classified to out-degree and in-degree. Out-degree is the cumulative strength of the relationship between the factors, and the in-degree is the cumulative strength of the connection entering the factors (Gray et al., 2012; Abbas, 2014). The out-degree is calculated by adding the values of the edges coming out from each factor, and the in-degree is the outcome of adding the values of the edges entering each factor (Özesmi and Özesmi, 2004).

Factors are categorised as a transmitter, receiver, or ordinary. Transmitters are factors with positive out-degree and no in-degree and are not affected by any other factors. Receivers are factors with positive in-degree and no out-degree and do influence other variables in the FCM. The ordinary factors are the nodes in between receivers and transmitters and are determined by positive in-degree and positive out-degree (Gray et al., 2012; Abbas, 2014). Figure 7.1 shows the different types of factors based on the in-degree and the out-degree.

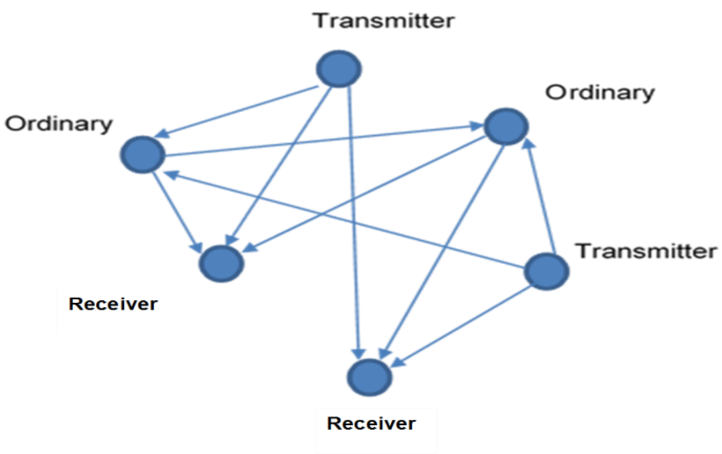

Figure 7.1 Graph structure in the FCM

The immediate centrality domain is the total out-degree and the in-degree in each variable (Özesmi and Özesmi, 2004). It is used to understand the contribution of the factors, and to identify the degree of connection between the variable and other factors (Özesmi and Özesmi, 2004). However, the variable can be more central with a smaller number of edges if the edges have larger weights (Kosko, 1986; Özesmi and Özesmi, 2004). The edge weight is the value in between the factors and is between -1 and 1.

The density is the index of connectivity and is calculated by the number of factors (N) and the number of connections (C) (Gray et al., 2012; Hage and Harary, 1983).

$$\mathbf{D} = \frac{\boldsymbol{C}}{\boldsymbol{N}^2} \boldsymbol{or} \quad \boldsymbol{D} = \frac{\boldsymbol{C}}{[\boldsymbol{N}\,(\boldsymbol{N}-\mathbf{1})]}$$

Equation 7.1

The density indicates whether the factors in the system are well connected (democratic system) or if some forcing factors are affecting the system (hierarchical system) (Gray et al., 2012; Özesmi and Özesmi, 2004). A high-density score indicates a flexible system with more opportunity for change, while a low-density score represents a more rigid system with less room for change (Özesmi and Özesmi, 2004).

The complex nature of the FCM is determined by calculating the ratio of receiver factors to the transmitter factors (R: T) (Gray et al., 2012). A complex map is indicated by a high ratio between the receivers and the transmitters and reflects a system with many outcomes and implications (Gray et al., 2012; Eden et al., 1979). Moreover, maps with a higher number of transmitter factors indicate top-down thinking and represent maps with more forcing functions (Gray et al., 2012; Eden et al., 1979). However, the consequences of these functions are not well articulated (Gray et al., 2012; Eden et al., 1979).

Another way to measure the hierarchy index (h) of the FCM (MacDonald, 1983; Özesmi and Özesmi, 2004) is by using the equation:

$$\boldsymbol{h} = \frac{\mathbf{12}}{(\boldsymbol{N}-\mathbf{1})\boldsymbol{N}(\boldsymbol{N}+\mathbf{1})} \sum_{\boldsymbol{i}} \left[\frac{\boldsymbol{od}(\boldsymbol{vi}) - \sum \boldsymbol{od}(\boldsymbol{vi})}{\boldsymbol{N}}\right]^{\mathbf{2}}$$

Equation 7.2

The system is fully hierarchical when the h index is equal to 0, and more democratic when the h index equals 1. The democratic system is usually more adaptable to the environment, and the system can be changed (Özesmi and Özesmi, 2004)

7.2.3 Simplifying the system (FCM)

A complex system with high numbers of factors and connections can make the system function analysis unclear and potentially counterproductive. Therefore, the best way to analyse and understand the complex system is by simplifying it. An aggregated map is a merged FCM from some component FCMs (Gray et al., 2012; Abbas 2014). Aggregation of stakeholder maps is used to simplify the analysis of several FCMs by standardising and reducing the FCM data set. Qualitative and quantitative methods can be used to merge the stakeholder maps (Gray et al., 2012; Özesmi and Özesmi, 2004). In the quantitative aggregation, one draws a subgraph and visually identifies the active component in the cognitive map (Harary et al., 1965; Özesmi and Özesmi, 2004). In the qualitative aggregation, factors are clustered by category. In this study, qualitative aggregation is used to simplify and merge the factors into five groups: Disaster preparedness and response, Governance, Knowledge and Education, Risk Assessment, and Risk Management. Each group contains a number of factors.

The weight of edges between each cluster is calculated by the average of the weights of the connection between the factors in each cluster. Also, the value of each cluster is obtained by calculating the average values of the factors in each group. Then the change in the cluster value is calculated by the equation:

$$\boldsymbol{new\ value}(\boldsymbol{xi}) = \boldsymbol{Tanh}\left(\sum_{\substack{\boldsymbol{j=1} \\ \boldsymbol{j\neq 1}}} \boldsymbol{X}(\boldsymbol{t}-\mathbf{1})\boldsymbol{wij}\right)$$

Equation 7.3

Tanh(x/2) is used to normalise the data between (-1 & 1). The calculation is used to understand how each cluster can impact the other cluster positively or negatively, and to identify the strongest and weakest cluster in the system. The outcome will help the decision makers in development of the disaster management process in Oman.

7.3 Data collection

Two workshops were conducted in Oman to develop FCM factors of the organisations' disaster management performance. The first workshop was on 3 August 2015, and it was used to collect primary data for planning the main workshop. The main workshop was conducted on 14 April 2016. Four

FCMs were developed during the workshop. Each FCM indicates different factors affecting the system from five different thematic areas provided by the HFW.

7.3.1 Pilot workshop

The pilot seminar was conducted in Oman with stakeholders from different organisations with disaster management interests. The pilot study was used to identify factors affecting the performance of organisations from the stakeholder perspective and build preliminary FCMs. In the case of the pilot workshop, 15 stakeholders were invited to attend. The stakeholders were from five organisations: General Authority of Civil Defence and Ambulance, Early Warning Centre, Emergency Centre of the Health Crisis, Ministry of Municipalities (Department of flood dams), and the National Committee of Civil Defence (NCCD). The stakeholders were divided into three teams, within each team there were five representatives, each from a different organisation. The stakeholders were asked to identify the primary factors affecting the performance of the organisations during extreme weather events (cyclones and floods) and then develop an FCM for these factors. The stakeholders identified a total of 23 factors in the workshop which were used to develop the FCMs. Each team used the 23 factors to create four different FCMs. The FCMs created were based on different participant perspectives, so each had a different outcome (FCM). The outcome shows how the related factors could have a different impact on the performance of the institutions in a variety of ways according to the stakeholder's perspective. The outcome was also used to build the plan of the subsequent main workshop.

7.3.2 Community resilience workshop

A total of 16 stakeholders from these organisations attended the main workshop (see details in Appendix C), which was conducted on 14 April 2016. Stakeholders from different organisations associated with the disaster management system in Oman were invited to the workshop. Participants represented the six sectors of the disaster management committee in Oman and two non-government organisations. The non-government organisations were selected because of their roles in the community, especially those with relationships to households and poor people. Table 7.1 shows the participating organisations in the workshop. This workshop was used to confirm the results of the pilot study and make them more clear and detailed, and it was better organised. The participating stakeholders were clustered into three groups: the disaster (cyclones) group, the organisation group, and the local community group, based on the result of the pilot study. The factors in the pilot study focused on how the organisations, disaster and the public community affected the organisation's performance, and these factors were used to create the group theme for the factors in the main workshop. This grouping helped the participants to be more specific about the factors affecting the organisation's performance based on the particular theme. The group discussions helped to classify the factors and make them more comprehensive; for example, by discussing what factors related to cyclones could have an impact on disaster management in Oman.

Table 7.1 Organisations participating in the main FCM workshop.

Sector	Organisation	Number of participants
National Committee of civil defence (NCCD)	-	2
General Authority of Civil Defence and Ambulance	-	1
Relief and shelter	Oman Authority of food security	1
Early warning centre	General Authority of Civil Aviation and Meteorology	3
Infrastructure	The public authority of water and electricity	1
	Electricity company	1
	Transport	1
Public Awareness	Media	1
	Ministry of Education (Curriculum Development Directorate)	1
NGO	Dar Al Atta'a (charity organisation)	2
	Omani Women's Association	2
Total		16

Participants in each group were asked to identify the factors in their cluster by using five thematic areas provided by the Hyogo Framework (HFW)[32]: Governance, Risk assessment, Knowledge and Education, Risk management and vulnerability reduction, and Disaster preparedness and response (UNISDR, 2005). The stakeholders in each group identified a list of factors. The thematic areas of the factors were then used (by the researcher) to merge and simplify the central FCM. The final compiled FCM was created by combining the three FCMs made by the different groups of stakeholders into one FCM representing the disaster management system in Oman.

Participants were asked to make a subjective judgment to score the factors into negative and positive on a scale ranging from -3 to +3. Then participants were asked to find the relationship between the factors by drawing edges between the factors. The edges show the relationship between the relevant factors and the strength of influence of the factors. Finally, the participants provided a quantitative value for the connection between the components (ranging from -1 for a strong negative correlation and +1 for a strong positive correlation) (Gray, 2012). The variable value and edge weights were then used to calculate the contribution change in each variable, positively or negatively.

7.4 Results

The results of this chapter are divided into two sections: the outcome from the pilot workshop, and the outcome from the main workshop. The pilot study identified general factors affecting the organisation's performance. The factors in the pilot study focused on the organisations, the public, and the disaster. The main workshop result gives more details on the factors affecting the performance based on the three themes: organisations, the public, and the disaster.

[32] HFW was explained previously in the literature chapter

7.4.1 Pilot study workshop

This section presents the outcome of the pilot workshop which was used to collect the main factors affecting the organisation's performance, and to build the plan of the main workshop. It displays four different FCMs formed in the pilot workshop from 21 factors. The elements were identified and discussed by the groups in the seminar. Table 7.2 shows the outcome of each of the FCMs deriving from the pilot workshop groups.

Table 7.2 Results of FCM formation by the pilot workshop teams

FCM parameter	Team 1	Team 2	Team 3	Team 4
Num of Factors	21	21	21	21
Num of Transmitters	2	4	0	8
Num of Receivers	2	11	12	2
Num of Ordinary	17	6	9	10
Num of Connections	36	22	65	27
C/N	0.58	0.95	0.32	0.78
Complexity (R:T)	1	2.75	0	0.25
Density	0.081	0.49	0.15	0.067
Ct	Cooperation (6.75)	Meteorology Statement (6.25)	Comprehensive emergency plan (9.75)	Public Awareness (5.75)

The results are different for each team. The first team considered a more connected system with a high number of connections between factors with a low-density score. The system has a large number of ordinary, and a similar number of transmitters and receivers. The results show a more flexible system, with less potential for change. However, the second team, considered a complex system with a large number of receivers and a low number of transmitters. This team also developed the FCM with the highest density, allowing more room for change within the system. The third team's FCM has a large number of receivers and no transmitters. Their FCM indicates a high number of factors not affecting the other factors in the system. The complexity ratio is zero, and the density is low. The FCM reveals a floppy system with a low chance of change. The fourth team developed a flexible system with no chance of development, shown by a significant number of transmitters with a low number of receivers, which suggests a system with a broad range of forcing functions, which cannot be controlled by other factors in the system. Also, the system has a low score for complexity and low density, which indicates less room for change within the system.

The outcomes for the high centrality variable in the four teams' FCMs are respectively: cooperation, meteorology statement, comprehensive emergency plan, and public awareness. These outcomes give a general view of the essential factors affecting the system in Oman. They show different results for the same 23 factors because of the different views of the stakeholders.

Each team's FCM gives different results. This shows how individuals' background and experience can affect disaster management in the NCCD. It also confirms the importance of having a disaster management plan within each organisation.

7.4.2 Main workshop results

7.4.2.1 Fuzzy cognitive map structures and functions

Data collected from the main workshop resulted in four FCMs; three maps were focused on the thematic areas of the different groups, and the fourth was a merged map, created by the researcher, and used to understand how the three different systems are working together and affecting each other. This FCM expresses the factors that influence the whole disaster management system from various interpretation. Table 7.3 summarises the structural and functional measurements of each FCM. The values reflect the change in each map which allows for comparison of the different FCM models, and which factors are affecting the system.

Table 7.3 Summary of the structure and function of each FCM

FCM Parameter	Community	Hazard	Organisations
Number of factors	33	20	25
Number of connections	43	36	47
Number of transmitters	9	5	7
Number of receivers	7	2	0
Number of ordinary	17	13	18
C/N	1.3	1.8	1.88
Complexity (R:T)	0.77	0.4	0
Density	0.039	0.09	0.075

7.4.2.2 Community

Figure 7.2 displays the FCM for the community group model. The model represents a very complex system. The complexity is indicated by both the high number of transmitter and receiver factors and the low-density index. Low-density shows a rigid system with less room for change. Table 7.4shows the transmitters and the receivers for the community FCM, and the centrality of each variable. The FCM has many transmitters which show the outside forces affecting the function of the system, and a large number of receivers which consider the many possible outcomes of the system and make it more dynamic. The transmitter factors seen as driving the system are financial support for organisations and quality of the community, transport, sewage, and communication. The receivers include evacuation and relief, shelter preparedness, bank services, and public awareness about hazards. These values indicate important influences on the system.

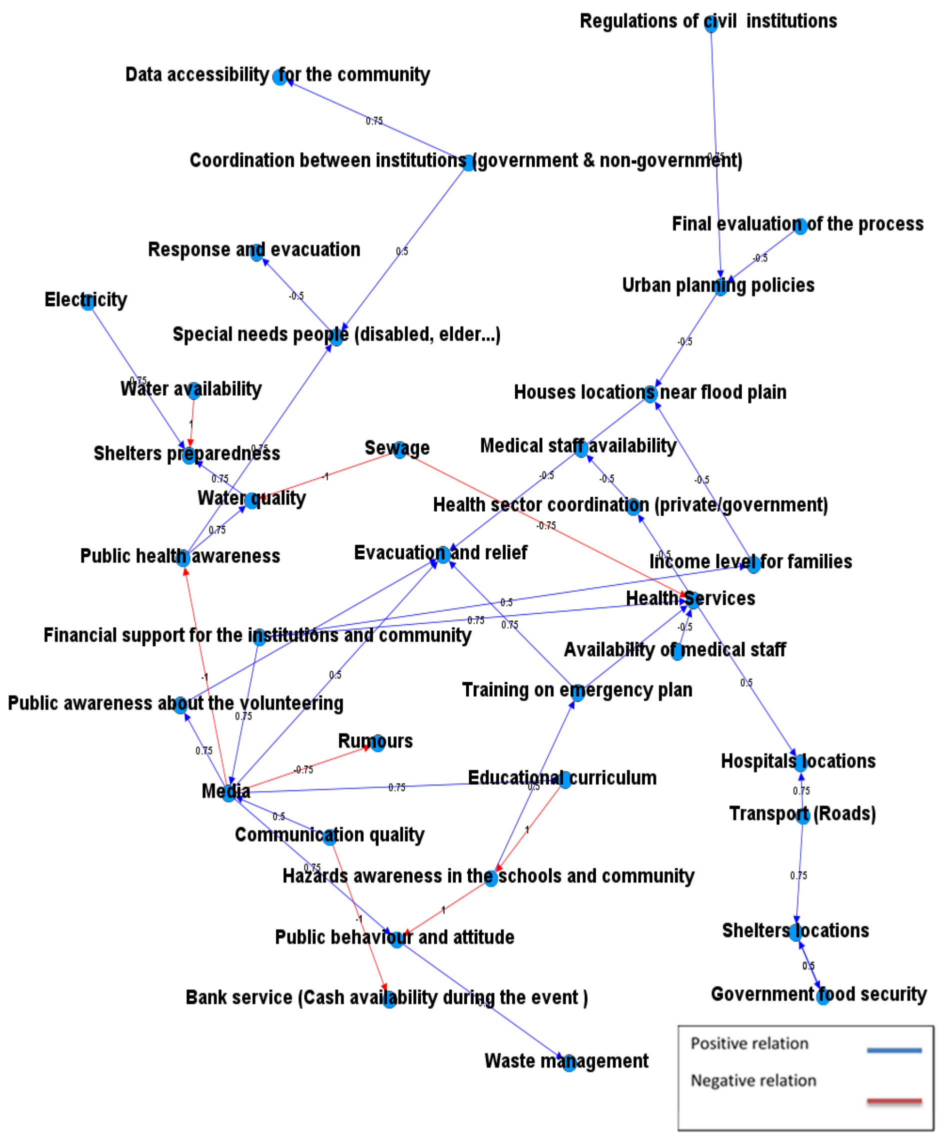

Figure 7.2 FCM for the community group

Table 7.4 Transmitters and receivers in the Community FCM

Transmitter	Out-degree	Centrality
Final evaluation of the process	0.5	0.5
Electricity	0.75	0.75
Regulations of civil institutions	0.75	0.75
Water availability	1	1
Coordination between institutions (government & non-government)	1.25	1.25
Communication quality	1.5	1.5
Sewage	1.75	1.75
Transport (Roads)	2	2
Financial support for the institutions and community	2	2
Receiver	**In-degree**	**Centrality**
Waste management	0.5	0.5
Data accessibility for the community	0.75	0.75
Hospital location	0.75	0.75
Rumours	0.75	0.75
Hazards awareness in the schools and community	1	1
Bank service (Cash availability during the event)	1	1
Shelters preparedness	2.5	2.5
Evacuation and relief	3.25	3.25

7.4.2.3 Hazards

Figure 7.3 shows the hazard group FCM. The map analysis reveals that the system is a top-down thinking system with high chances of change, a low-density index and low complexity. Hazards indicate a high number of transmitter factors, with a lower number of receiving factors. Therefore, the outside forces of the transmitter affect the function of the system. Financial support, early warning, private institutions training, central data system, and speed of data sharing are the transmitters driving the system, while two receiver factors averaged in the hazards map were emergency and evacuation plan, and food security. Table 7.5 presents the transmitter and receiver values for the hazards FCM in Figure 7.3

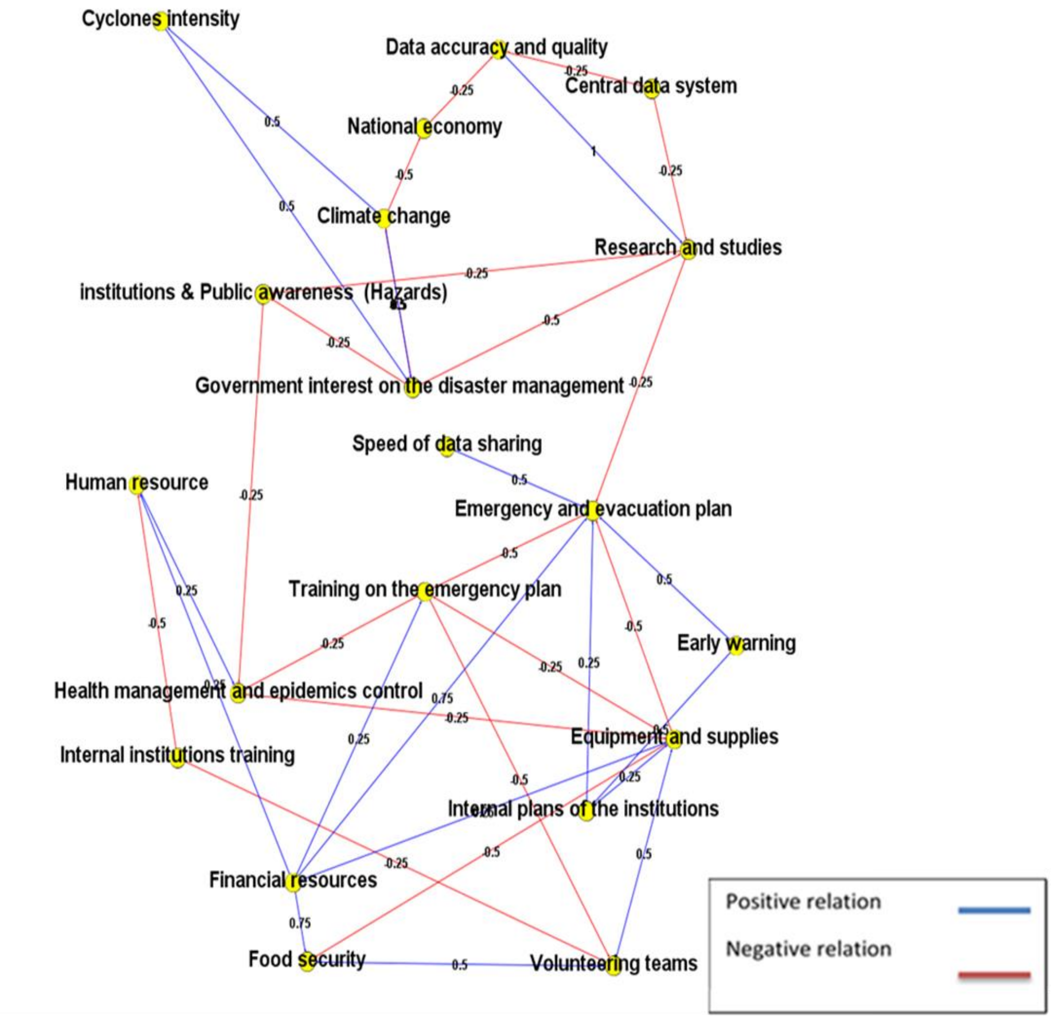

Figure 7.3 FCM for the hazards group

Table 7.5 Transmitters and receivers in the hazards FCM

Transmitter (5)	out-degree	Centrality
Speed of data sharing	0.50	0.50
central data system	0.50	0.50
Internal institutions training	0.75	0.75
Early warning	1.00	1.00
Financial resources	2.25	2.25
Receiver (2)	**in-degree**	**Centrality**
Food security	1.75	1.75
Emergency and evacuation plan	3.25	3.25

7.4.2.4 Organisations

Analysis of the organisations FCM (Figure 7.4) provides a similar result to the hazards FCM. It indicates a high number of transmitters with no receiver factors (Table 7.6). This suggests that the system functions under outside forces, with no influence. Transmitters are seen as forcing factors related to risk assessment and risk management include the absence of financial plans for disaster management and absence of the final evaluation of the committee work

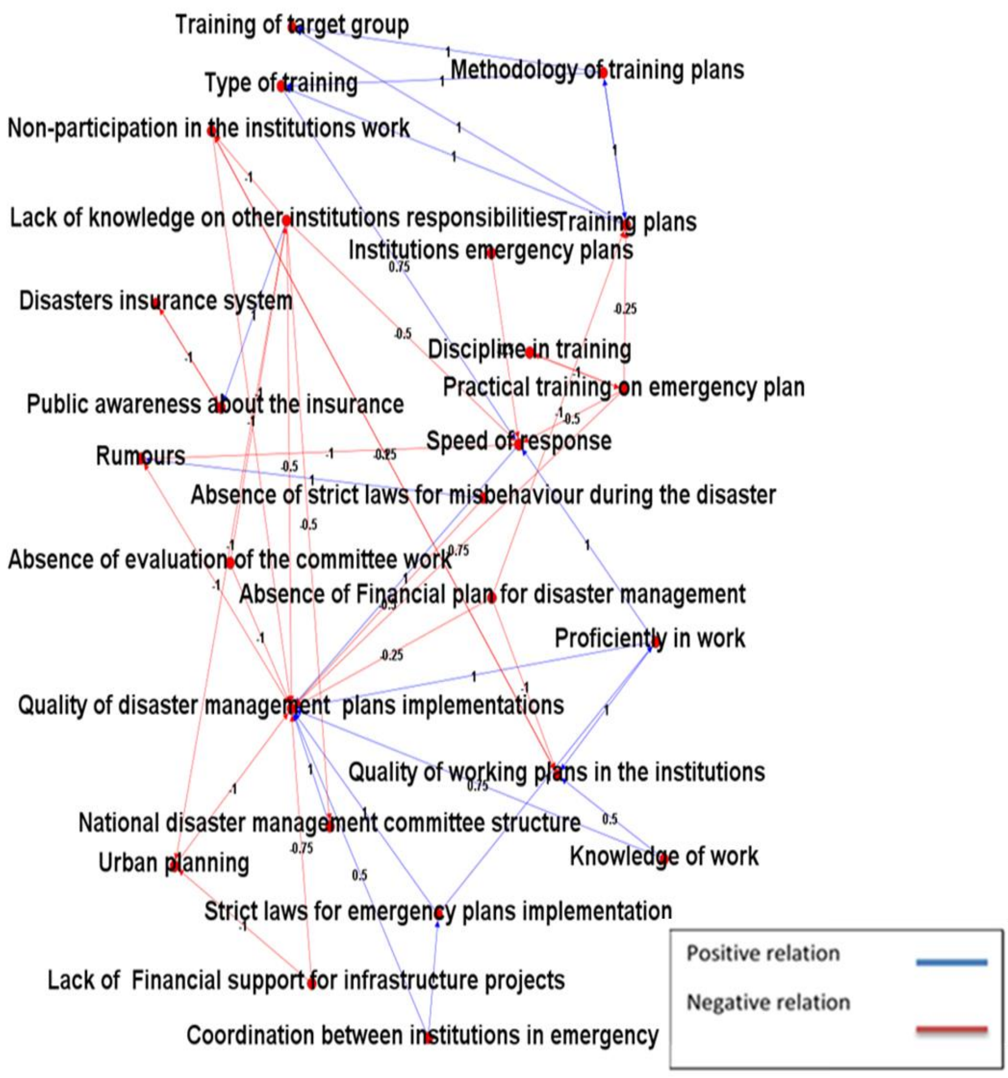

Figure 7.4 FCM for the organisations group

Table 7.6 Transmitters and receivers in the organisations FCM

Transmitter	out-degree	Centrality
Institutions’ emergency plans	0.50	0.50
Knowledge of work	1.25	1.25
Absence of strict laws for misbehaviour during the disaster	1.50	1.50
Coordination between institutions during the emergency	1.50	1.50
Absence of final evaluation of the committee work	2.00	2.00
Absence of Financial plan for disaster management	2.25	2.25
Receiver (0)	in-degree	Centrality

7.4.3 Merged FCM (Disaster Management System in Oman)

The merged map is the outcome of merging the three FCMs developed by the stakeholders in the workshop. In this FCM, a judgment was made to join some of the variables from the three maps based on similarity and use them as linking factors between the three FCMs. Figure 7.5 displays the merged map. It shows that the community accounts for 34.9 % of the factors, organisations 25.4%, hazards 20.6%, and the merged factors 19%. It also shows that the community factors have a wide-ranging influence on the system. The thickness of the connections is related to the weight of the edge, and the colour of the type of the relation; red for negative, and blue for positive). Furthermore, the figure show that the system is influenced by high number of negative and positive factors. For example, the coordination between organisations, and the transport network has a positive impact on the system and they can have a positive change in other factors, which can improve the system. On the other hand, the planning polices, and the intensity of cyclones can have a negative impact on the system and reduce system capacity. Therefore, the comprehensive analysis of the factors affecting the system is important to develop it and make it more resilient. However, analysing the impact of each factor makes the system complex and difficult to improve.

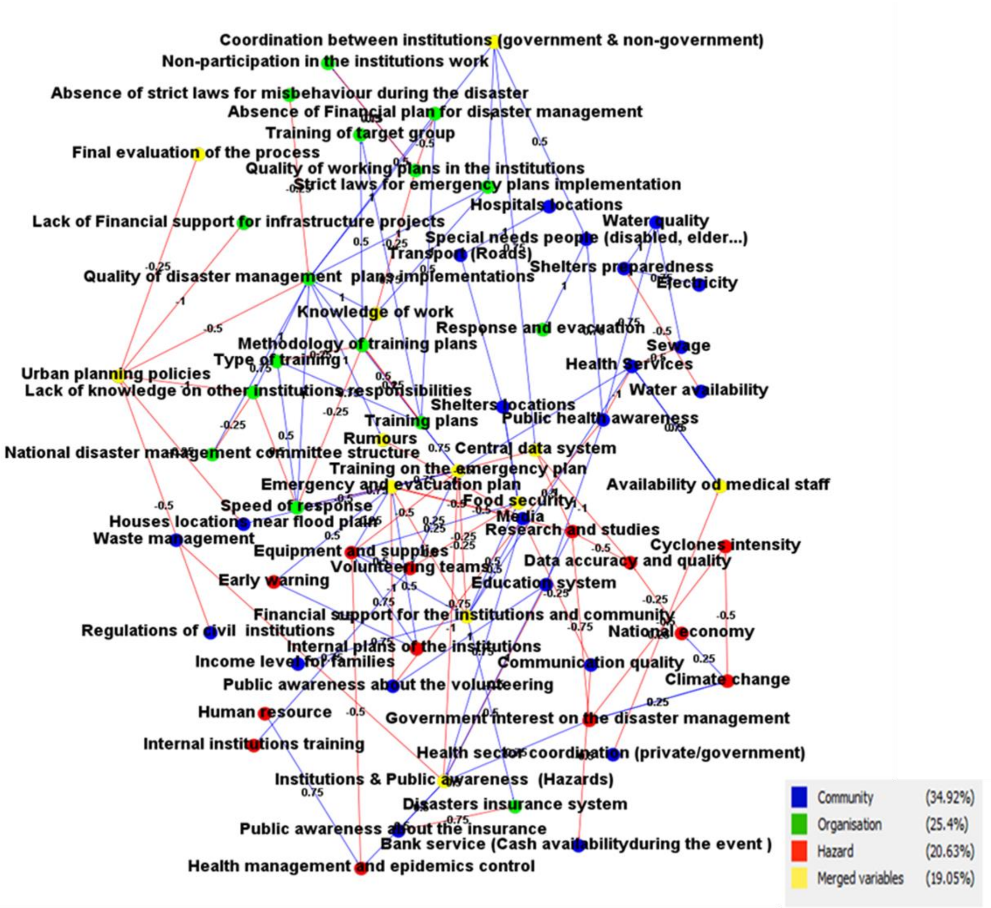

Figure 7.5 Merged FCM (Disaster management system in Oman)

Table 7.7 shows the FCM function analysis results. It shows that the density index is small, indicating a rigid system with less room for change. The transmitters are higher than the receivers, which reflects that outside factors are influencing the function of the system and making it complex and inflexible. However, the hierarchy index is zero, which reveals a fully democratic system.

Table 7.7 The FCM function parameters in the merged map

FCM Parameters	Values
Number of factors	62
Number of Connections	116
Number of Transmitters	15
Number of Receivers	6
Number of Ordinary	41
C/N	1.85
Density =C/(N)2	0.03
Complexity Index (R: T)	0.4
Hierarchy Index, h	0

Table 7.8 shows the transmitters and receivers on the map. Financial support for institutions and the community has a high centrality amongst transmitter factors. The positive value of this financial support for the institutions and community can increase the value of other factors, like the health system and food security. The next highest centrality transmitters are the lack of knowledge on other organisations' responsibilities, coordination between institutions (government & non-government), and the absence of a financial plan for disaster management. Five receivers are included in the map, and it considers the factors affected by other factors in the system. Shelter preparedness has the highest centrality, which shows the degree of collaborative effort required to improve the shelters.

Table 7.8 Transmitters and receivers in the merged FCM

Transmitters	Out-degree	Centrality	Variable value
Financial support for the institutions and community	4.25	4.25	1
Lack of knowledge on other institutions responsibilities	3.5	3.5	-1
Coordination between institutions (government & non-government)	2.75	2.75	2
Absence of financial plan for disaster management	2.25	2.25	-1
Lack of financial support for infrastructure projects	1.75	1.75	1
Sewage	1.75	1.75	-2
Absence of strict laws for misbehaviour during the disaster	1.5	1.5	-3
Communication quality	1.5	1.5	-1
Final evaluation of the process	1.5	1.5	1
Transport (roads)	1.5	1.5	1
Early warning	1	1	2
Water availability	1	1	2
Electricity	0.75	0.75	2
Internal institutions training	0.75	0.75	-1
Regulations of civil institutions	0.75	0.75	1

Receivers	In-degree	Centrality	Variable value
Shelter preparedness	2.5	2.5	2
Training of target group	2	2	1
Bank service (cash availability during the event)	1	1	-1
Hospital location	0.75	0.75	2
Response and evacuation	0.5	0.5	2
Waste management	0.5	0.5	1

7.4.4 Clustering the FCM variables

This section presents the outcome of the clustered FCM used to simplify the complex system. Figure 7.6 illustrates the five clusters of factors in the clustered FCM. The factors are clustered based on the thematic area, and the researcher judgement. The graph present a model of disaster risk reduction based on HFA thematic area. The graph shows two thematic areas with negative impact on other thematic areas. It show that Governance can have a negative impact on risk assessment, and that risk management and risk reduction can also have a negative impact on Governance. On the other hand, other thematic areas have positive impacts on other areas.

The graph analysis (Table 7.9) reveals that the system is flexible and well connected. The factors are all ordinary[33], while disaster preparedness and response is the high centrality cluster, and risk management and vulnerability reduction, followed by knowledge and education are the least central clusters. The result shows that disaster preparedness and response are the strongest clusters in the system, while risk management and vulnerability reduction is the weakest. The outcome will help the decision makers in the process of developing disaster management policies and plans. The density index is high, and the complexity index is zero, which makes the system flexible with more space for development to achieve the goals. The hierarchy index is 0.45, which makes the system both more democratic and more adaptive to the environment.

Overall, the analysis reveals that clustering the factors influencing the system makes the system more flexible and easy to analyse. Therefore, improving the weakest cluster will be easier.

[33] Factors that influence and are influenced by the other factors

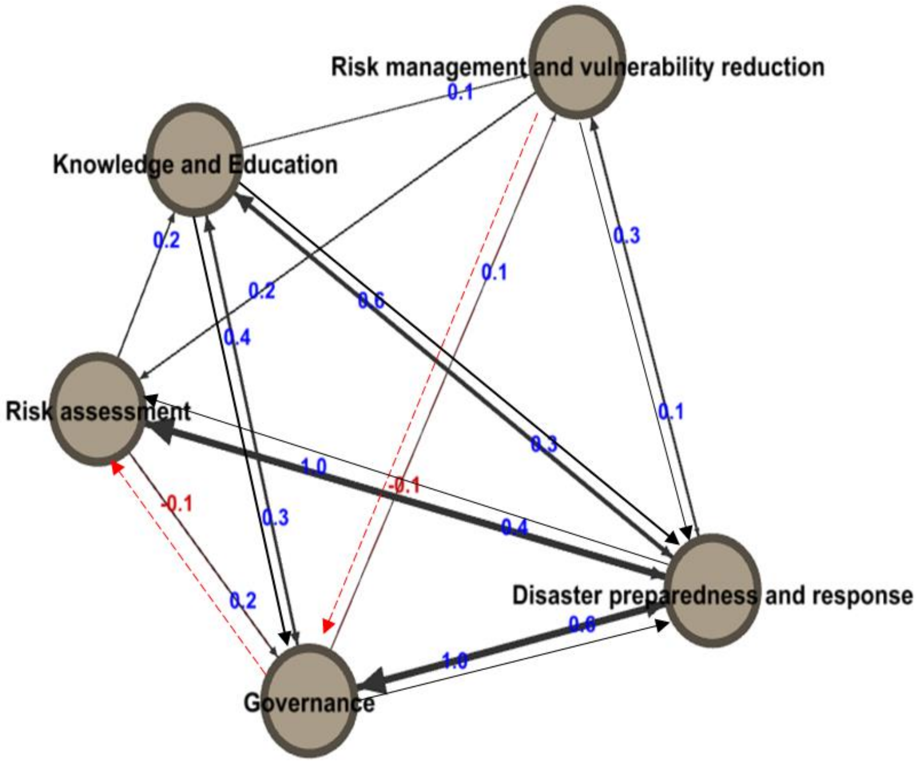

Figure 7.6 The clustered map graph

Table 7.9 Graph indices for the clustered map

	Disaster preparedness and response	Governance	Knowledge and Education	Risk assessment	Risk management and vulnerability reduction
Disaster preparedness and response	0.00	1.00	0.56	1.00	0.31
Governance	0.56	0.00	0.44	0.13	0.13
Knowledge and Education	0.31	0.31	0.00	0.00	0.00
Risk assessment	0.38	0.19	0.19	0.00	0.00
Risk management and vulnerability reduction	0.06	0.06	0.00	0.19	0.00
Total in degree	1.31	1.56	1.19	1.31	0.44
Total out-degree	2.88	1.00	0.63	0.75	0.19
Centrality (id+od)	4.19	2.56	1.82	2.06	0.63
Transmitters	0	0	0	0	0
Receivers	0	0	0	0	0
Ordinary	1	1	1	1	1
No. of factors	5				
No. of connections	16				
No. of Transmitters	0				
No. of Receivers	0				
No. of Ordinary	5				
Connection/Factors	3.2				
Density	0.64				
Complexity	0				
Hierarchy Index, h	0.45				

7.4.5 Calculating the change

Figure 7.7 illustrates the factors in the merged FCM. It shows the values of each variable based on the scoring done by participants in the workshop, and the average value for the merged factors. The factors are scored from -3 to 3 based on the degree of their influence and importance in the system. The factor scores show the degree of factor importance from the stakeholder perspective. The score is used to calculate the degree of influence by using Equation 3 as the function for calculating the change of factor value.

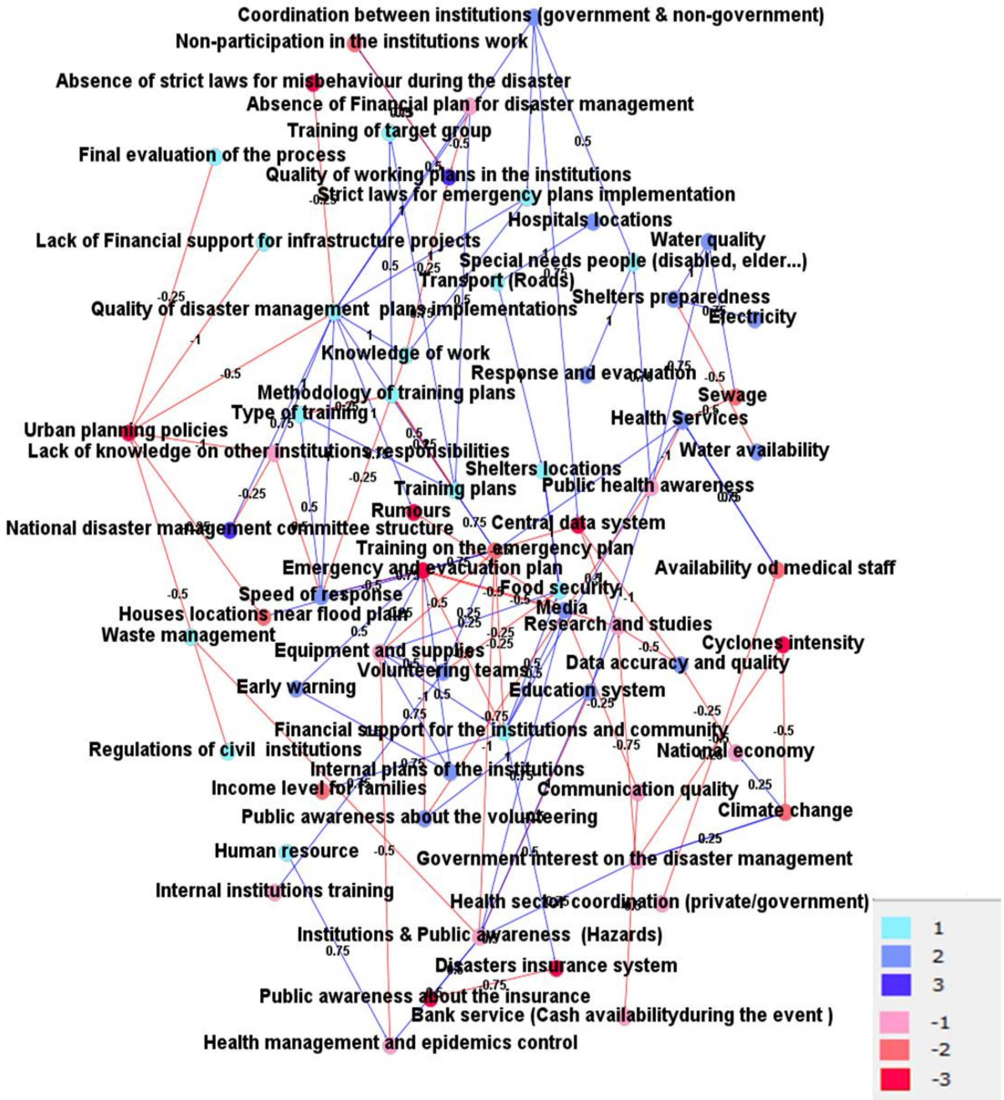

Figure 7.7 The factor values in the merged FCM

Figure 7.8 shows how the factors changed because of the influence of other factors in the merged FCM The figure shows the negative and positive change in the factors. Furthermore, there are some factors negatively changed in the system, for example, the urban planning polices, and the quality of disaster management plans implementation. Meanwhile, there are other factors positively changed including emergency and evacuation plans, the availability of medical staff, and shelters preparedness.

Table 7.10 display the value (x), the new value (xi) of the factors and the total edge weights (∑Wij) from the impacted factors. The result reveals that some factors changed negatively or positively because of the effect of another variable. The degree of change in the variable value is due to the number of factors connected with the affected variable and their value and the edge weight. For example, the availability of medical staff value changed positively from -2 to -1.5. The variable was impacted by two factors with total edge weights 0.5. Meanwhile, shelter preparedness changed positively from 2 to 4.5 by total edge weight 2.5. Some factors changed negatively, for example, non-participation in the institution's work, which changed from -2 to -4, and urban planning policies changed from -3 to -4.75. Positive changes in the factors reveal that the system moved towards improved performance, while negative changes mean that more effort is needed to improve the system

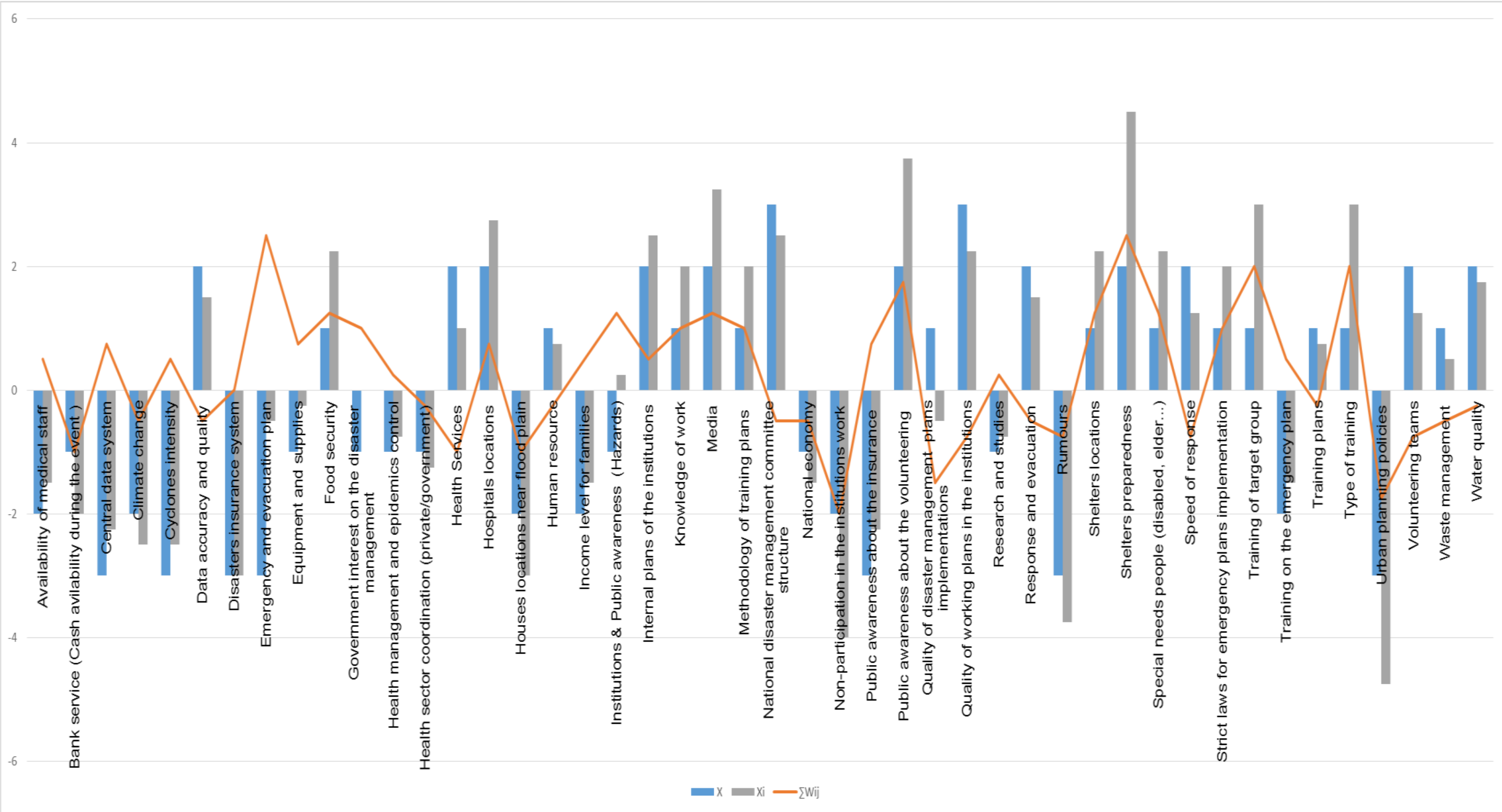

Figure 7.8 Negative and positive change in factors: X is the factor value, Xi is the new value after the change, and ∑Wij is the total edges weights affecting the factor

Table 7.10 The factor values and the total influence of edge weights

Variable	X	∑Wij	Xi
Non-participation in the institution’s work	-2	-2	-4
Urban planning policies	-3	-1.75	-4.75
Quality of disaster management plans implementations	1	-1.5	-0.5
Bank service (Cash availability during the event)	-1	-1	-2
Health Services	2	-1	1
House location near flood plain	-2	-1	-3
Quality of working plans in the institutions	3	-0.75	2.25
Rumours	-3	-0.75	-3.75
Speed of response	2	-0.75	1.25
Volunteering teams	2	-0.75	1.25
Climate change	-2	-0.5	-2.5
Data accuracy and quality	2	-0.5	1.5
National disaster management committee structure	3	-0.5	2.5
National economy	-1	-0.5	-1.5
Response and evacuation	2	-0.5	1.5
Waste management	1	-0.5	0.5
Health sector coordination (private/government)	-1	-0.25	-1.25
Human resource	1	-0.25	0.75
Training plans	1	-0.25	0.75
Water quality	2	-0.25	1.75
Health management and epidemic control	-1	0.25	-0.75
Research and studies	-1	0.25	-0.75
Availability of medical staff	-2	0.5	-1.5
Cyclone intensity	-3	0.5	-2.5
Income level for families	-2	0.5	-1.5
Internal plans of the institutions	2	0.5	2.5
Training on the emergency plan	-2	0.5	-1.5
Central data system	-3	0.75	-2.25
Equipment and supplies	-1	0.75	-0.25

Table 7.10 Cont./

Variable	X	∑Wij	Xi
Hospital location	2	0.75	2.75
Public awareness about insurance	-3	0.75	-2.25
Government interest in disaster management	-1	1	0
Knowledge of work	1	1	2
Methodology of training plans	1	1	2
Strict laws for emergency plans implementation	1	1	2
Food security	1	1.25	2.25
Institutions & public awareness (hazards)	-1	1.25	0.25
Media	2	1.25	3.25
Shelter locations	1	1.25	2.25
Special needs people (disabled, elderly)	1	1.25	2.25
Public awareness about volunteering	2	1.75	3.75
Training of target group	1	2	3
Type of training	1	2	3
Emergency and evacuation plan	-3	2.5	-0.5
Shelter preparedness	2	2.5	4.5

In the clustered map the average value of the factors in each cluster is calculated. Table 7.11 shows the value of each group and the total weight of the edges between the groups. The value of the group and the weight of the edges between each cluster is used to calculate the change in the value. Table 7.11 and Figure 7.9 display the variation in the value of each group. A positive change from 1.2 to 3.46 is shown in the value of disaster preparedness and response, while risk assessment shows a negative change from -0.83 to -1.35.

Table 7.11 The indices of change in the cluster values

Cluster	X	Wij	New value
Disaster preparedness and response	1.20	5.25	3.46
Governance	0.50	5.75	1.53
Knowledge and education	0.14	4.75	0.35
Risk assessment	-0.83	4.25	-1.35
Risk management and vulnerability reduction	-0.73	1.75	-0.36

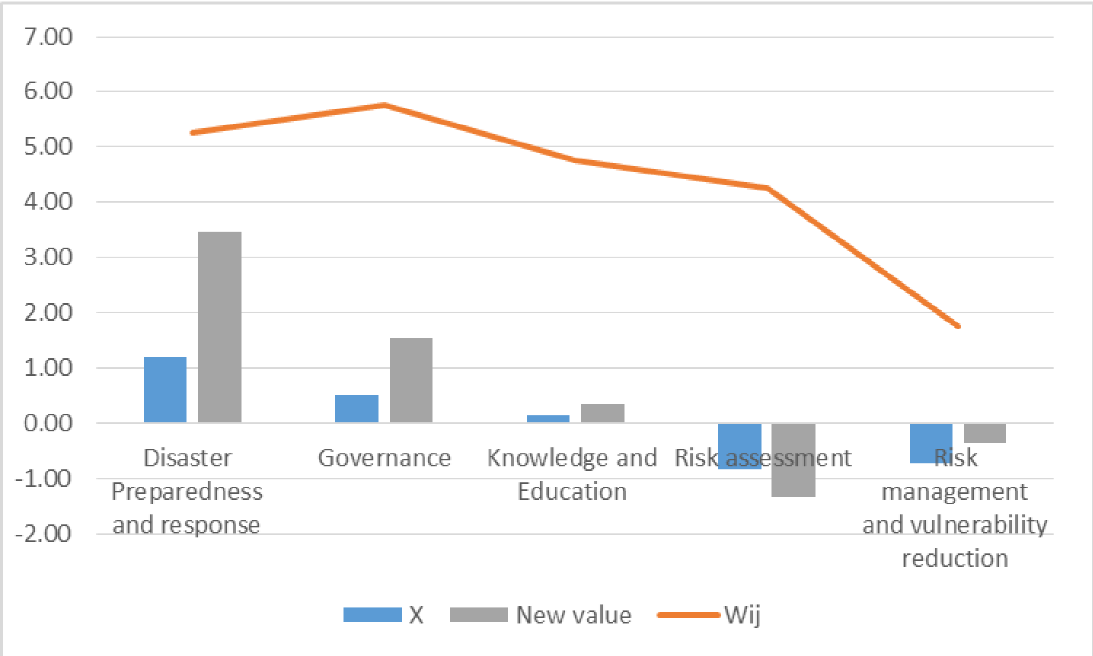

Figure 7.9 Cluster value change

7.5 Conclusions

The results in this chapter indicate that many external factors affect the disaster management system in Oman. These factors were identified and assessed using FCMs from two workshops: the pilot study workshop, and the main workshop.

The pilot workshop produced four FCMs showing different opinions of organisational performance in Oman, created by the four groups of stakeholders. The stakeholders considered four different systems based on 23 factors. The four different perspectives of the FCMs display four important factors impacting system performance: cooperation between the organisation, meteorology statement, comprehensive emergency plan, and public awareness. All these factors can influence the system negatively or positively.

The result from the pilot workshop shows that the stakeholders, with their different knowledge and experiences, and in the absence of clear disaster management plan and policies, may affect an organisation's performance in disaster management. In Oman, it was evident from the secondary data collected from different organisations that in some sectors organisations do not have plans and strategies for disaster management, and they depend on the experience of the decision maker. The absence of plans could negatively influence the organisation's decision making in the future if the type of risk changes. It is important that each organisation has a clear risk management plan to avoid any serious consequences in the future.

The result of the main workshop was analysed in steps. First, the FCMs from the different stakeholder groups were examined individually. The outcome from these FCMs shows a different perspective of the factors that can impact the organisation's performance based on the particular theme.

The first FCM presented the factors affecting an organisation's performance from the local community aspect. It reveals that the system is exposed to outside forces. For example, it shows that decrease in communication quality during the disaster will result in a decrease in the media’s performance and their ability to send broadcasts and warnings to people in the risk area. Also, availability of clean water can improve shelter preparedness through preventing diseases caused by dirty water. In Oman, the water for the shelters is provided by water tankers rather than pipelines, which can be affected by the hazards, but water tankers can also be affected by the accessibility of roads. The result in the first group shows that the system is complex and rigid.

The second FCM assesses the factors affecting the system from the hazard aspect. The analysis indicates that the system is hierarchical and top-down, with outside forces affecting the function of the scheme. Outside forcing factors and the low level of influence of the system increase the complexity of the system. The results show that an increase in financial support will improve food security, and the emergency and evacuation plan. For example, the government allocated funds for food security to protect the country from risks because of potential famine. After Guno, funding for the NCCD and EWC was increased to improve the emergency system in these organisations.

The third FCM examines performance from the organisations' perspective. It shows that the system is completely under external forces, with no income factors influencing the system. The system is inflexible, and there is no room for change. However, improving factors such as training plans will help to improve human resources in the organisations, and this will improve performance.

The analyses of the three FCMs show that the community FCM has the lowest density score, while the hazard FCM has the highest. This signifies that compared to the other groups the community group views the system as more inflexible, with less opportunity for change within the system. The centrality analysis shows that the community FCM represents a highly complex system with a broad range of receivers. The organisations and hazards FCMs reveal top-down systems with more outside forcing factors and fewer factors controlling the function.

The merged map of the three FCMs is used to understand the combined system for disaster management in Oman, integrating the perceptions of community, hazard and organisation teams. The maps were linked together by the factors present in more than one map and used to analyse how each FCM can affect the other FCM in a single system. The outcome shows that the system in Oman is complex, with a high number of the driving factors and a low-density index, which reduces the chance of change. However, the hierarchy index ratio was zero, indicating the system is fully democratic. A democratic system is more adaptable to the environment and can be developed (Özesmi and Özesmi, 2004).

A complex system is difficult to analyse and can give complicated outcomes making decision-making difficult. The clustered map is used in this study to simplify the system by clustering the factors into five groups. The result creates a model system that is simpler and more stable and flexible, with more chances of change. The system is more democratic than hierarchical, and this increases the probability of improvement. However, this model also depends on the system of the organisations and the decision makers. Nevertheless, the result shows that the model can help the decision makers in the process of developing disaster management policies and plans.

In the clustered map, the change in the factor values is also calculated to identify the factors that can modify the system positively or negatively. The result shows the weakest and the strongest parts of the system. Examining the weakest and strongest parts will help to focus on those parts that need to be changed or improved to increase the system performance. Also, changes in values show the impact of one cluster on any other cluster. For example, in the clustered map the result shows that the risk assessment value changed negatively due to the effect of the other clusters.

Finally, it was clear from the pilot and the main workshops that a range of factors are affecting organisational performance, for example, clear plans and policies within the organisations. It was clear from the secondary data, and the interviews with the decision maker that some organisations do not have clear policies and plans and they depend on the experience of the stakeholders. Also, cooperation and direct communication between some organisations are weak. It was clear that the NCCD is leading the organisations during joint events, and after the event, the communication between most organisations stops. Weak communication between the organisations affects other parts of the disaster management process, such as mitigation. It is important that the organisations focus on development and improvement of all factors that may reduce the organisation's performance before, during, and after the event.

There was some progress in some organisations in such as the early warning system, in knowledge and education, and risk assessment. However, the organisations need to improve their work in risk management and vulnerability reduction, governance of the regulations and policies within the organisations and across the whole system. The absence of improvement in one part of the system can reduce the performance in another part.

In Oman, the organisations are improving disaster preparedness and responses. However, the development process needs to focus on all parts of the system because each part is linked to the other and can influence it both positively and negatively. The organisations need clear plans and policies for disaster and risk management. Clear and appropriate plans will help them avoid conflicts when working with each other and create greater efficiency of investments and running costs. Moreover, it will reduce the risk of plans failing during a disaster event if all parts of the system are strong in each organisation.

Chapter 8 Summary discussion and conclusions

8.1 Introduction

Community resilience to disaster is receiving significant attention from national and international organisations. Building resilience to disaster is essential for every country, especially highly vulnerable countries exposed to major natural hazards. The purpose of this thesis was to develop a deeper understanding of community resilience to disaster arising from extreme weather events in Oman, and the implications for building resilience in the related organisations so as to better cope with potential disasters. This final chapter summarises the findings from Chapters 4 – 7 in Section 8.2.1, synthesises the findings of the thesis in Section 8.2.2 and develops recommendations arising from the research in Section 8.4.

8.2 Summary of chapters and synthesis of findings

8.2.1 Chapter summaries

This section summarises the work done in the analysis chapters in this thesis. These chapters build on the research overview (Chapter one), the development of the theoretical approach to the research and associated research framework (Chapter two), and review of the literature on disaster management in the study area (Chapter three) which collectively identify gaps in knowledge, which then form the foundation for the thesis research.

Chapter 5 evaluated the disaster management system in Oman from an organisational perspective. Organisational capacity and stakeholder involvement in disaster management were analysed to understand the capacity and performance of disaster management organisations in Oman. The methods applied in this chapter were stakeholder analysis and social network analysis. Stakeholder analysis was used to understand the performance and capacity of organisations, while social network analysis was used to understand the relationship and interaction between organisations. The chapter analysed the roles and challenges of the organisations, the information flow within and between them, and the interaction between organisations. The chapter recognises high and low capacity organisations in Oman.

Chapter 6 analysed the level of resilience of the organisations. The chapter investigated the implementation of the Hyogo Framework for Action (HFA) in Oman based on the thematic area and resilience index components proposed by Twigg (2009). The chapter identifies the level of resilience in Oman relative to the world average, as well as in comparison to Arab states, for each index component. The comparison was based on wealth (GDP/Capita), and the prevalence of disasters in each country. Resilience was measured using a weighted mean index and normalised between 0 and 1 to simplify the result. The index was subsequently scored between 1 and 5 to permit a direct comparison with the UNISDR resilience index which employs a 1-5 scale.

Chapter 7 investigated the factors affecting disaster management resilience in Oman, by applying Fuzzy Cognitive Mapping (FCM) with organisational stakeholders. The chapter identifies how these factors affect the performance either negatively or positively. Relevant factors were identified through a participatory research process and categorised according to the thematic areas of HFA and Twigg (2009).

8.2.2 Synthesis of results

The total population in Oman is about 4.6 million people (4,638,602)[34]. Nearly 80% of the population live in low-lying coastal and flood areas, and more than 60% [35]of the population live in urban areas (large cities, and centre of wilayat[36]). Urbanisation and development in Oman have concentrated the population in the large cities because of the better opportunities for jobs and education (Al-Awadhi, 2007). Urbanisation has

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[34] National Centre for Statistical information; https://data.gov.om/#signup=complete accessed December 2017

[35] The percentages are estimated based on the population of each region and the location of the region.

[36] Wilayat are small towns

also increased the number of immigrants from other countries (Al-Shaqsi, 2015). Different parts of Oman are exposed to natural hazards such as storms[37] and floods. The disasters in the affected places occur when natural hazards are coupled with high exposure and vulnerability, which are linked to the level of development of the disaster management system (UNISDR, 2015). The ability of the disaster management system to prepare, manage, and recover from disasters is in turn linked to the national and local management and governance system (UNISDR, 2015). The literature review indicated relatively little progress in research about the disaster management system in Oman, while international reports such as the UNISDR reports include Oman only in the synthesis reports on the world or the Arab countries. There is no clear assessment of disaster management and the progress of the organisations in Oman.

This thesis provides an assessment of organisational capacity and resilience with respect to disaster risk reduction in Oman. It fits within a wide range of research that seeks to understand and build community resilience to disasters associated with natural hazards. The analysis was developed with reference to the Hyogo Framework for Action: Building community resilience to disasters. The literature on the Hyogo framework as applied in the Arab region indicated a need to review the disaster management system in Oman, which is new and had not previously been assessed. The framework of this thesis is developed to assess the capacity of the disaster management system in Oman, its resilience to natural hazards, and the factors affecting organisational performance in building community resilience to extreme weather events (specifically, tropical cyclones). The main finding of the thesis is reviewed in the context of the three analytical chapters (Chapters 5-7).

1. Capacity of Disaster Management System

The results reveal that the disaster management system in Oman is a hierarchical system centred on the National Committee for Civil Defence

[37] See Appendix 3 Spatio-temporal analysis for the tropical cyclones in Oman.

(NCCD). The NCCD, like many organisations in this hierarchy, acts in a reactive manner rather than being preventive/proactive. Some of the organisations in the disaster management system, such as those involved in the provision of basic services, the infrastructure sector, relief and sheltering sector, and the media and public awareness sector, have significant roles and responsibilities, but they are facing a. number of challenges. The main issue with these organisations was the absence of definite plans and enforcement rules. Disaster resilience work is disorganised in these organisations, which has a negative effect on the performance of the NCCD, and the organisations that have made better progress, like the Early Warning Centre (EWC). Weakness in public awareness is also an important issue affecting NCCD performance.

The information resources analysis shows that most organisations collect information from other relevant organisations to support their decision making. This information is transferred to other organisations within the NCCD and the Early Warning Centre (EWC) who hold the position of conveyor of information. However, the interaction between the relevant organisations is weak, which is seen in the weak interaction between human resources and the passing of information. However, there is potential for the EWC and the Public Authority for Civil Defence and Ambulance (PACDA) to influence the interaction between Organisations, as they play a central role in the NCCD. The Public Authority of Water and Electricity (PAWE), which is responsible for infrastructure across six subsectors, is in a position of high responsibility, and is the most effective communicator organisation in the system. The EWC, PACDA, and the Medical Response and Public Health (MRPH) organisations are all highly productive, with excellent communication with other organisations.

2. Resilience

To better understand the resilience level in Oman it is necessary to have a good grasp of the performance of processes represented by the HFA, which was achieved through the analysis of performance with respect to the HFA resilience index components. HFA commitments have been attained, but the achievements remain modest. The analysis shows that the institutional platform is not stable as there is a weakness in the enforcement of disaster management related laws and regulations. Progress has been made in this area, but the implementation of HFA resilience components remains insufficient. Whilst decision makers report satisfaction with the level of resilience achieved; local people are not satisfied because they lack sufficient information about the risks they face (the finding of risk assessments conducted by decision makers). It is clear that public awareness of the risks faced needs to be enhanced. People are also not satisfied with the training of local people (e.g. evacuation procedures) and the wider programs designed to raise public awareness and develop appropriate responses. The public believe that support from the relevant organisations here is weak. The disaster management and vulnerability implementation are moderate, with weakness in risk mitigation and development of resilient infrastructure, which does not satisfy local people. The results show that disaster preparedness and response at the organisation level are however better developed than the other resilience themes. Preparedness and response to the emergency events are significant, and local people are satisfied with the organisation's response .to the severe weather events.

Comparing the results for Oman with those for Arab countries and the world average shows that the resilience position of Oman is similar to the world average with small differences in all resilience themes. The resilience progress in Oman is at a good level compared with other countries. For example, comparing Oman with the United Arab Emirates (UAE) shows that the resilience index of the UAE is higher than that of Oman in all Hyogo priorities for action. However, the UAE’s vulnerability to disaster is lower than that of Oman, and it has higher GDP than Oman, which means the UAE has more financial resources for disaster management. These differences in vulnerability and wealth between Oman and the UAE put Oman in a good position regarding resilience to disasters. However, there is a need for development in some relevant organisations in Oman so as to build a community more fully resilient to disasters. Organisations need to be more connected and better able to communicate and discuss the progress of each organisation respectfully to understand the strengths and weaknesses in the system.

Understanding the factors that influence disaster management resilience, both negatively and positively, is essential. The main finding from the analysis of factors is that the system is a responsive system, with weakness in the mitigation and proactive actions. The main factors signposted by the stakeholders, which can have a negative impact on the performance, were those in the risk management and vulnerability reduction theme, and the governance theme. For example, disaster management plans have not been completed in all relative organisations. There is also a lack of integration of disaster management into planning policies. This has caused the problem of location of many residential and urban areas near to flood risk areas.

The factors involved in disaster preparedness and response, risk assessment, and knowledge and education are better developed. The influence of the aggregated factors in these themes is slightly positive. For example, there is good progress in tsunami risk assessment in Oman. However, there is a need for more development to raise the positive impact of these factors; for example, by improving the material and methods of public awareness about natural hazards in Oman. The weaknesses in relation to the risk management and vulnerability reduction theme and the governance theme are significant. The significant weaknesses in these areas constrain performance of building community resilience. For example, the weaknesses in structural mitigation aspects such as the absence of resilient roads could negatively affect the progress of rescue and evacuation during extreme weather events like floods. In addition, the lack of full awareness of the procedures for evacuation of the population may increase their vulnerability.

8.3 Review of Thesis Aims

8.3.1.1 To what extent can Oman manage disaster?

The capacity of the disaster management system in Oman was indicated based on four different analyses. First, the framework analysis was used to analyse the roles and challenges of organisations. The result reveals that each organisation in the system has different responsibilities and there is a variety of responsibilities in the system. However, the organisations face some difficulties during the implementation of disaster management plans because the rules and regulations are not clear for some organisations. Second, the position of the organisations in the system was analysed by the power/interest matrix. The result shows that most organisations take part as key players in the NCCD. The result is an indicator of the importance of all organisations in the committee. It is reveals that the decisions of all organisations are important in the NCCD.

The third part of the analysis reveals the availability of information in each organisation and the information flow between organisations. The NCCD Executive office, and the EWC take the role of conveyors of information between organisations. However, the information for each organisation is collected from different resources and for their specific decision making needs.

Finally, the interaction between organisations was analysed to investigate the strength of cooperation between the organisations. The interaction network density indicates weak interaction between organisations. The result shows that the EWC and the PACDA have great ability to influence the system and control the work of the committee. The organisations with high communication value can take on the role of organiser in the system. Furthermore, the betweenness result of the system reveals that the EWC and PACDA take a middle position between organisations, with great ability to transfer data and information between them. The closeness centrality result shows that the EWC, PACDA, and the MRPH are highly productive organisations with excellent communication with other organisations.

From the results, it was clear that there is a well-developed disaster management system in Oman. The institutional platform is achieved in the National Committee for Civil Defence (NCCD), with explicit royal decrees and regulation for forming and structuring the emergency system in Oman. However, the system is more responsive to disaster than proactive/ preventive, which is significant as responsive systems have a higher chance of failure during extreme events than proactive/preventive systems (Al-Shaqsi 2015). However, a few organisations are more proactive, including the Early Warning Centre, Medical Response and Public Health, and the Public Authority for Civil Defence. These organisations are highly productive, and have good communication with the other organisations.

The system is a hierarchical (Top-down) system coordinated by the NCCD. The system is also a democratic one which gives the opportunity for more adaptation to changes in the environment. However, some organisations need to develop their own emergency system more fully and integrate that more precisely within the organisational structure as a whole.

Overall, the system has the potential, with some development in the related organisations, to manage the disaster risk in Oman. The system is precise, with some organising rules and regulations. However, there is a need for more explicit written plans in the related organisations to achieve the desired goals.

8.3.1.2 To what extent are organisations in Oman implementing HFA resilience components?

The five thematic areas of the Hyogo framework (UNISDR, 2005a), along with the resilience components developed by Twigg (2009) were used to investigate the organisations resilience in Oman. The index of implementation of disaster resilience components was calculated to answer this question, and the result compared with results from other Arab states and the world average.

The result show that the disaster preparedness and response is better developed than other resilience themes as judged by both organisational replies and the local community. The preparedness and response to emergency is well established and the local people are satisfied. The result indicates that the risk management and vulnerability indices is higher than average according to the organisations, while the local peoples' evaluation is lower than the average. The people believes that there is a need for more resilient infrastructure and they are not satisfied with the available risk management and mitigation services. The index for risk assessment perceived by the organisations is average and very low according to the local peoples' assessment. The public do not have enough information about risk assessment in Oman, and the finding on risk assessment are not shared with the community. The results of the governance and knowledge and education indices are below average as judged by both the organisations and the local people's assessment. The result show that public awareness about disaster is not at the appropriate level. The result indicates weakness in the rules, regulations, disaster management plans and enforcement of laws.

It was clear from the result that the achievement of Oman is at the world average with only minor differences; this indicates moderate progress because the world average includes countries with a high capacity for achievement, and low vulnerability to disasters, which is a rather dissimilar context to Oman. Furthermore, comparison with other countries in the Arab region is a more useful comparison of performance. The comparison made with countries in the same region but with differences in vulnerability and wealth (GPD/Capita) shows the worthy performance of Oman compared with other Arab states. For example, United Arab Emirates (UAE) has better progress in the resilience components. It has better financial funding of disaster management than Oman. However, Oman is more vulnerable to natural disasters than the UAE. The progress of Oman in response to previous natural events like Gonu show the appropriate level of resilience to disaster. Oman has sustainable achievement in the progress of preparedness and response to the disaster, and the good progress was demonstrated during cyclone Guno. Progress in public awareness about disaster management has improved since Guno. However, there is a need for more improvement in raising public awareness by the related organisations, like the media, and the Ministry of Education. Comparing the progress of Oman and the UAE in disaster management shows that Oman has made less progress than the UAE. The big land area of Oman, along with diversity in the geomorphological landscape, requires more funds for development of structural measures to mitigate the effects of disasters. Meanwhile, the UAE is wealthier than Oman, and it has less land area than Oman, with fewer types of geomorphological landscapes. However, the progress of the organisations related to the disaster management system needs more development to reach the appropriate level.

8.3.1.3 What institutional factors affect the capacity of organisations to respond to disasters, and how can we improve performance to build community resilience?

The participating stakeholders from the relevant organisations answered this question. The factors affecting the capacity of organisations were identified and assessed using FCMS from two workshops: the pilot study workshop, and the main workshop.

The pilot workshop produced four FCM’s and the stakeholders considered four different systems based on 23 factors. The four different perspectives offered by the FCM display four important factors impacting system performance: cooperation between organisations, meteorology statement, comprehensive emergency plan, and public awareness. The factors can influence the system either negatively or positively.

In the main workshop three different FCM’s were produced based on three themes: the system from the local community aspect, from the hazards aspect, and from the organisations aspect. The results show that the system viewed from the community aspect is complex and rigid, and exposed to outside forces. From the hazard aspect the system is affected by outside forces affecting the function of the system and increasing its complexity. The analysis of the system from the organisations aspect show that the system is completely under external forces, and the system is inflexible with no room for change.

These three perspectives were then merged to analyse the mutual influence of the three aspects in the system. The outcome shows that the system in Oman is complex, with a high number of driving factors and a low-density index, which reduces the chance of change. However, the hierarchy index ratio was zero, indicating a fully democratic system and hence that a system more adaptable to the environment can be developed.

The factors in the merged FCM, were clustered in five thematic area of the Hyogo Framework for Action. This clustered map is used to simplify the system and make decision making easier. The result creates a model system that is simpler, more stable and flexible. The system in this model is more democratic than hierarchical, and this increases the probability of improvement. The change in the factors value in the clustered map identifies the factors that can modify the system positively or negatively. The result shows the weakest and strongest part in the system. Examining the weakest and strongest part will help to focus on areas that need to be changed or improved to increase system performance.

Overall, the stakeholders identified factors influencing the system positively or negatively. The most influential factors with negative impact are in the governance and disaster management and vulnerability reduction clusters. For example, the location of houses near the flood area can have a negative impact on evacuation plans during an emergency. The location of housing is also negatively affected by the urban planning policies. Likewise, the absence of a comprehensive emergency and evacuation plan negatively impacts on the emergency system.

Factors with positive impact on the system are those in the areas of risk assessment, and knowledge and education, and the main signposted positive factors are in the preparedness and response cluster. For example, the availability of prepared shelters has a positive impact on the evacuation plan. The media also has a positive impact on public awareness and the emergency system.

8.4 Recommendations for building disaster resilience in Oman

This study provides some recommendations for an effective governance platform for disaster management at all levels and community resilience. Four recommendations can be drawn from this study so as to accelerate and improve the development of community resilience to disaster in Oman.

1. Strengthen the institutional system

Strengthen the institutional system to ensure that disaster management has a substantial basis, focusing on the gaps and challenges of the institutional system that affect the planning, management, and implementation of disaster risk reduction. The mechanism of implementation (rules and regulation, plans, enforcement of laws) needs to be improved in each organisation and shared with other organisations. For example, rapid urbanisation, with weak land use planning policies, and building settlements near flood risk zones increase the risk from extreme weather events in Oman. Improving land use policies to reduce the vulnerability and reduce the disaster risk is important. This recommendation on disaster risk governance is consistent with the second priority for action of the Sendai framework for disaster risk reduction (UNISDR, 2015d). This priority focuses on developing and strengthening governance for prevention, mitigation, preparedness, response, recovery and rehabilitation (UNISDR, 2015d). The Sendai framework encourages collaboration and partnership across mechanisms and institutions to implement instruments relevant to disaster risk reduction and sustainable development (UNISDR, 2015d).

It is essential to improve systems of communication and interaction between the organisations to enhance the performance of the disaster management system. For instance, increasing the interaction between government, non-government, and private sectors organisations to formulate policies that improve decision making for disaster risk reduction. This can be achieved in Oman by empowering the local authorities, through regulatory and financial means, to work and coordinate with local communities, indigenous people and migrants, in disaster risk management at the local level. In addition, cooperation should be strengthened across global and regional mechanisms and institutions to better implement instruments and tools in other domains that have clear relevance to disaster risk reduction. These domain include climate change mitigation and adaptation, biodiversity, sustainable development, poverty eradication, environment, agriculture, health, food and nutrition (UNISDR, 2015d).

2. Improve the participation of all relevant organisations and stakeholders in risk assessment

The second recommendation is to improve the participation of all relevant organisation and stakeholders in risk assessment. Better tools and statistical information about hazards and risk need to be made available. Some information in international reports is based on estimation (UNISDR, 2015b) and Oman-specific information is often lacking. Having a complete database about risk from natural hazards in Oman is essential. The availability of comprehensive data can improve disaster risk assessment, evaluation and management.

The Sendai framework first priority for action focuses on understanding disaster risk in all its dimensions: vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment (UNISDR, 2015d). This understanding of risk is needed to develop better disaster risk reduction policies and practices. Risk assessment for infrastructure and basic services is important to identify the potential risk. For example, there is very little risk assessment for schools, health centres and hospitals in Oman. It is important to develop risk assessment for the schools, to build better safety programs to protect the students from multi-hazards risk. Risk assessment of the hospitals is provided for the hazards of diseases, and epidemics; however, there is no risk assessment for natural hazards like floods.

The resilience of roads and communication networks is important during a disaster. The Ministry of Transport is working to develop better roads and bridges. However, more work is still needed on the roads to improve the drainage system and reduce flooding during the rainy days. Providing a comprehensive risk assessment for flooding of the roads and urban areas is important to reduce the potential risk of floods.

3. Further develop public awareness of disasters

The third recommendation is to increase the range of knowledge and education of disaster and risk. It is essential to provide better information about the disaster and type of risk to the public, and they need to learn the best way of prevention. The country needs to develop an active program of public awareness. The program must have the support of all organisations, and be adequately financed to support information collection, analyses and dissemination, along with the necessary human resources such as technical and communication experts, and other stakeholders. The public awareness programs should include information on the type of risk, risk assessment of any potential risks, and the best ways to prevent and minimise such risks. The media and the education system should work to develop a better public awareness system for multiple hazards and disaster risks and provide programs on an ongoing basis, not only during the event.

Developing better programs about the natural hazards in Oman, and presenting them to the public through the media and education system is important to increase the knowledge of natural disaster in the community. Building the knowledge of disaster and the disaster risk reduction is important to enhance the performance of other organisations during the disaster. The absence of public awareness has caused many negative consequences in the past; for instance, citizens have attempted to use the roads during floods, causing cars to be washed away, and some fatalities.

4. Build a stable system to reduce the disaster risk

The fourth recommendation is to build a stable system to reduce risk in the community, through building better public facilities and improving housing building codes, and land use policies. Other at-risk countries, like Japan, have well-prepared programs against earthquake and most people across the country regularly participate in emergency training (UNISDR 2005). A similar situation needs to be developed in Oman, with a program of emergency training involving all people in the country, so as to reduce risk and build resilience to natural disaster.

The Sendai third priority for action focuses on investment in disaster risk reduction for resilience (UNISDR, 2015d). “Public and private investment in disaster risk prevention and reduction through structural and non-structural measures is to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment”(UNISDR, 2015d,p.18). Designing coherent disaster risk reduction and sustainable development policies, plans, practices and mechanisms is important across all levels and sectors in the country. Strengthening the design and implementation of inclusive polices and social safety mechanisms is essential in the communities, countries and, the environment (UNISDR, 2015d). This will help to enhance the social, health, and cultural resilience of communities and individuals to disasters in Oman. For example, focusing on the social aspects of the community, such as health and well-being, education, and the housing system, is important to reduce social vulnerability to natural hazards. For example, reducing the implications of poverty, and enhancing lifestyle by improving the economic system, and the resources distribution in the community.

It is essential to provide appropriate financial support for disaster management through such as developing a clear financial system to support disaster management in all related organisations, with clear rules for the budget, financial management, and accountability. This will enhance the disaster preparedness for effective response, and recovery - “build back better” rehabilitation and reconstruction (UNISDR, 2015d).

8.5 Conclusion

This thesis has achieved its initial aims and objectives, has addressed some of the gaps in the previous studies. The research has some limitations. First, regarding cooperation of the relevant organisations, some organisations refused to cooperate with the researcher, leading to the limitation of information and data. Second, there were difficulties in obtaining secondary data, as there is a lack of data about the natural hazards and disaster management system in Oman, which affected the quality of the research. An attempt was made to compensate for the data limitation through the primary data. The primary data depends on stakeholder interviews and questionnaires, which introduced the implications of data accuracy and quality, and the psychological perspective of the stakeholder.

There is a persistent need for building a comprehensive database of the natural hazards in Oman and making it ready for use in future research. There is also a need for more studies about the vulnerability to multi natural hazards in Oman. The impact of the natural hazards in the economic system and the development in Oman also need more focus from the relevant organisations. It is important to focus on the relation between the economic system and the potential risk in order to build a more stable economic system in the country and reduce the economic vulnerability to disaster.

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Appendices

Appendix A: Spatio-temporal patterns of Tropical Cyclones in the Arabian Sea

A.1 Introduction

This appendix reviews the tropical cyclones that hit Oman in the period (1880-2014), with a spatiotemporal analysis. The tropical cyclones analysis in this appendix assesses the need of Oman to build resilience to severe weather events, and to identify risk areas in Oman. The result will help to build a better background about cyclones risk in Oman.

The data on Tropical cyclones tracks are analysed spatially and temporally to gain better classification of season and direction.

Section 2 reviews the regional background, focusing on the history of the tropical cyclone, and the major climate phenomena in the North Indian Ocean, and Arab Sea. Section 3 discusses the data and the method applied in this study. Section 4 presents the result, and section 5 the result discussion and conclusion.

A.2 Regional background

Tropical cyclones and storms are common in Oman. They affect the coastal area from Muscat in the north to Salalah in the south, with occasional cyclones in the Gulf of Oman, at the southern extreme of the Persian Gulf (see Figure 1 for a region map). They are associated with extreme winds, storm surges and major flash floods that have caused loss of life and substantial damage to infrastructure. For example, in 2007, tropical cyclone Guno, the most powerful cyclone recorded in the Arabian Sea for the last 100 years, struck the coast of Oman (IMD, 1999). Guno caused an estimated $4 billion in damage, and 100 people lost their lives (Evan and Camargo, 2010). Guno was followed by cyclone Phet in 2010, which like Guno also made landfall in North Oman.

Tropical storms, less intense than cyclones, are common, and some that have hit the Omani coastline over the last century or so have also resulted in major losses. For instance, in 2002 a tropical storm hit Salalah in the south of Oman. The storm caused massive damage in the area due to the unusually high rainfall, estimated at 58.6 mm in the city and about 250.6 mm in the mountains (Al-Habsi et al., 2014). Historically many severe storms have hit Oman and caused considerable damage. Another example, from 1890, is a severe cyclonic storm that entered the sea of Oman and then moved to northern Oman, an unusual track for cyclones in the Oman region (Membery, 2001). The storm killed 734 people and had an economic cost equivalent to billions of dollars in today's terms (Membery, 2001)

Figure 1 the Arabian Sea region and the location of Oman

Table 1 The Indian Metrological Department cyclones classification.

Name	Wind speed	Approx. Atlantic equivalent	Description
1. Deep Depression	28-33 knots (52 - 61 km/h)	Tropical depression	A system causing cyclonic disturbance in which the maximum sustained wind speed lies in the range 28 knots (52 km/h) to 33 knots (61 km/h) may be called a "deep depression".
2. Cyclonic storm	34 - 47 knots (62 - 88 km/h)	Named tropical storm	Generic term for a non-frontal synoptic scale cyclone originating over tropical or subtropical waters with organised convection and definite cyclonic surface wind circulation. The term is also used for a storm in the north Indian Ocean with maximum sustained wind speed over 33 knots.)
3. Severe cyclonic storm	48 - 63 knots (89 - 118 km/h)	Named tropical storm	A cyclonic disturbance in which the maximum average surface winds speed is in the range of 48 to 63 knots (89 to 118 km/h).
4. Very severe cyclonic storm	64 - 119 knots (119 - 221 km/h)	Hurricane categories 1-3	A cyclonic disturbance in which maximum wind average is 64 knots to 119 knots (119 to 221 km/h).
5. Super cyclonic storm	> 120 knots > 221 km/h	Hurricane categories 4-5	A cyclonic disturbance in which maximum wind speed is 120 knots and above (222 km/h and above).

[Source: (IMD, 2015)]

Table 1 displays the Indian Metrological Department cyclones classification, which indicates wind speed as a key criterion in the typology. In the Arabian Sea region, all these cyclone types, and indeed the majority of cyclones themselves, form near the Laccadive Islands (~11° N, 73° E) in two seasons; the pre-monsoon and the post-monsoon (Galvin, 2008b). However, cyclones have been recorded that form in the Bay of Bengal and then move across India to then re-form in the Arabian Sea. For example, a November 1966 cyclone started in the Bay of Bengal before eventually hitting the southeast coastline of Oman at Salalah (IMD, 1979). Figure 2 shows the seasonal distribution of the Arabian Sea tracks and illustrates that while some form in the Bay of Bengal, the majority originate in the Arabian Sea Itself.

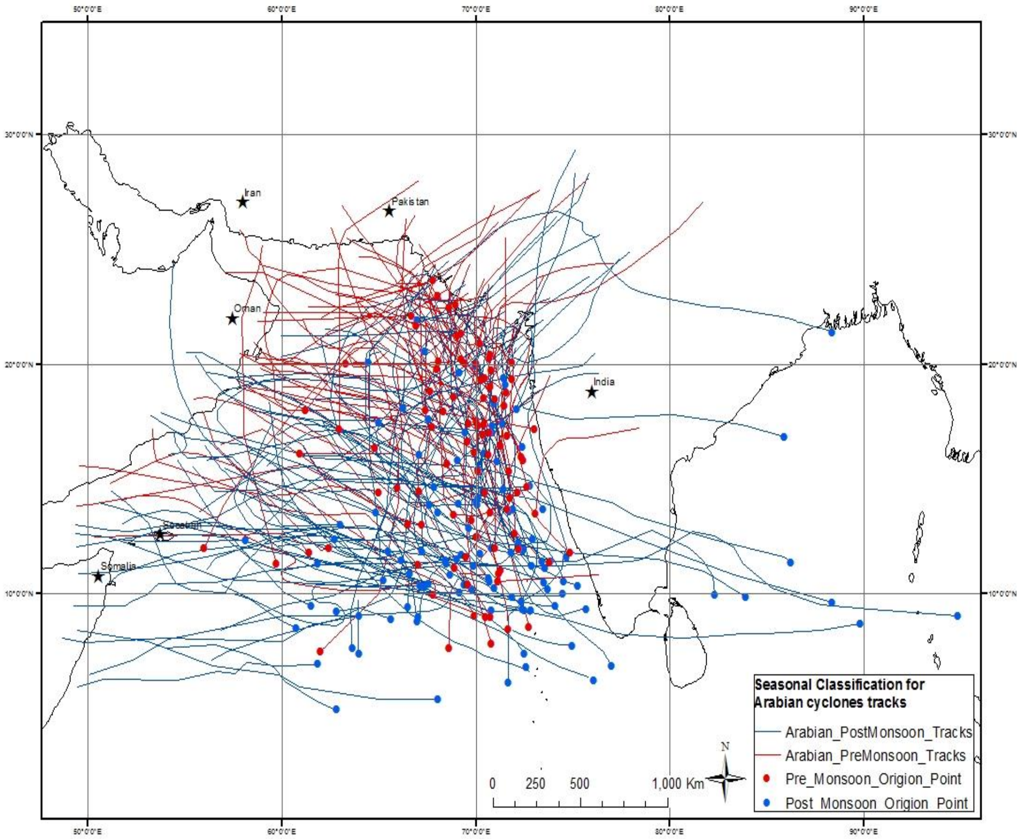

Figure 2 the seasonal distribution of Arabian Sea cyclone tracks

The pre-monsoon season lasts from the end of April to June, when a south-westerly wind rises, and the sea surface becomes very warm (Galvin, 2008a). The post-monsoon season lasts from September to December when the south-westerly wind decreases and a north-easterly wind develops over the Arabian Sea (Galvin, 2008a). Table 2 summarises the monsoons seasons over the Arabian Sea.

During the pre-monsoon, the strength of the south-westerly winds increases the conditions of cyclones formation in the Arabian Sea (Calvin, 2008b; Membery, 1998). Membery (1998), analysed the frequency of tropical storms and cyclones affecting the coast of Oman from 1890 to 1996 and found that nearly half of the Arabian Sea cyclones formed between 14 May and 16 June, with the rest of the tropical cyclones formed during the post-monsoon (Calvin, 2008b). Evan and Camargo (2010), reviewed the Joint Typhoon Warning Centre (JTWC) best-track data for tropical cyclones and storms in the Arabian Sea, 1979-2008. Their analysis shows that of 41 cyclonic storms that formed in the Arabian Sea, 23 made landfall with an intensity equivalent to a tropical depression or stronger. Of these, there were eight severe cyclonic storms, seven very severe storms, and one super cyclonic storm. The study found that, on average, 1-2 cyclones formed in the Arabian Sea per year.

Table 2 The monsoon seasons in the Arabian Sea

Months	Monsoon
January – March	The winter monsoon transition period
	The peak of the winter monsoon in January with strong north-easterly wind over India and the Arabian sea
May- June	Pre-Monsoon
	The south-westerly wind rises, and the sea surface temperature becomes very warm in the Arabian sea. During this period the tropical system is expected in the Arabian sea
July-September	The summer monsoon transition period
	The peak of the summer monsoon in August with strong south-westerly wind across the Arabian Sea and Bay of Bengal
October – December	Post-monsoon
	The tropical system is expected in this period when the southwesterly wind decreases, and the north-easterly wind rises over the Arabian sea

[Source: (Galvin, 2008a)]

Although severe cyclones and storms have hit the southern and eastern Arabian Peninsula for many years, relatively little research has been conducted on tropical cyclones in the Arabian Sea, whilst there is a specific lack of research into cyclones affecting the coastlines of Oman and Yemen. Most cyclone research relevant to the Arabian Sea has been conducted as part of research into storms elsewhere in the Indian Ocean, particularly the Bay of Bengal (Singh et al., 2000; Chaudhry, 2013). These studies show increases in the intensity trend over the North Indian Ocean (Arabian Sea and Bay of Bengal). However, the trend in the Arabian Sea is not significant. Evan and Camargo (2010) conclude that this finding is uncertain because historical data is of variable quality and has not been sufficiently validated in the Arabian Sea. Sumesh and Kumar (2013), studied the variability of tropical cyclones over the North Indian Ocean (NIO)[38] during the normal El-Nino[39], El-Nino Modoki[40] and the Indian Ocean Dipole (IOD). They showed that the frequency of the tropical cyclone over the Arabian Sea is lower during the normal El-Nino, but that the Positive IOD and the El-Nino Modoki can significantly alter the cyclones activity in the Arabian Sea. Furthermore, the IOD index from the National Oceanic and Atmospheric Administration (NOAA) shows positive IOD mode in the Indian Ocean in 2015 (see Figure 3). During 2015,one tropical system formed in the pre-monsoon (June), including storm “Ashobaa”, and hit Ras-Al Had, Oman, and three tropical systems formed in the post-monsoon (November), including the very severe cyclonic storm “Chapala” (cyclone category 5), and very severe cyclonic storm “Meg” (cyclone category 4); both of these hit Socotra and Yemen, whilst a tropical depression also developed, but died in the sea. Figure 3 shows the IOD period in the Arab Sea and the north Indian Ocean, the positive IOD is in the blue, and the negative in red.

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[38] Indian Ocean Dipole (IOD) is a unique and inherent air-sea interaction process in the Indian Ocean, and is independent of the El Nino/ Southern Oscillation (ENSO). It is characterised by cooler than normal sea surface temperatures (SST) in the eastern Indian Ocean equatorial region near Sumatra, and warmer than normal SST in the western Indian Ocean equatorial region near Africa. The phenomenon causes heavy rain in Africa and drought in Indonesia (Saji et al., 1999).

[39] El Nino (Normal) is a phenomenon in the Pacific Ocean characterised by warmer than usual SST in the east of the Pacific equatorial region (Weng et al., 2007; Weng et al., 2008).

[40] El Nino Modoki is a phenomenon in the Pacific Ocean characterised by warm SST in the central Pacific equatorial region and cooler SST in the east and west (Weng et al., 2007;Weng et al., 2008).

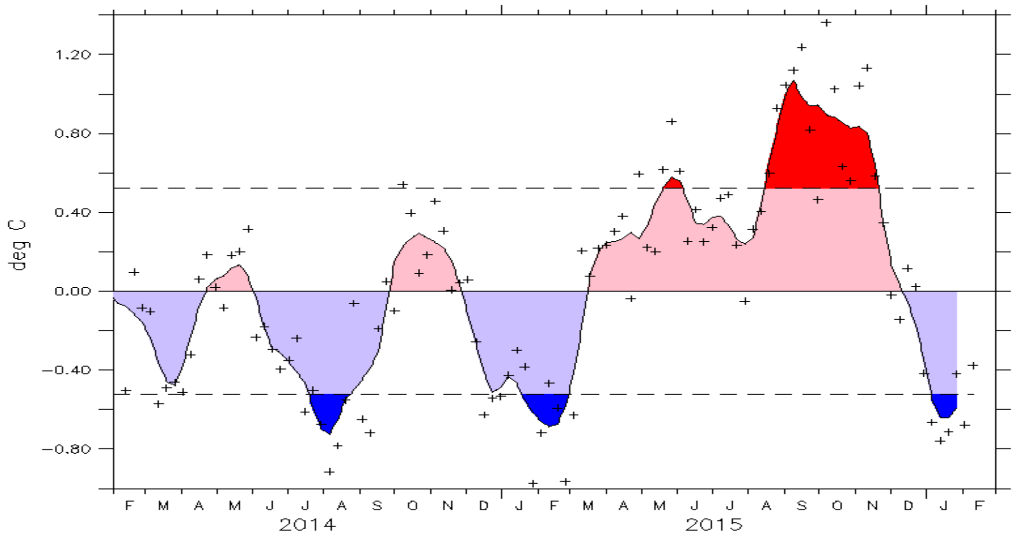

Figure 3 IOD mode index from NOAA, 2014-2015

The impact of Madden-Julian Oscillation (MJO) in cyclone formation has been studied by Krishna Mohan et al. (2012). The study found that about 82% of cyclones formed during the positive Madden-Julian oscillation (MJO)[41]. Krishna Mohan et al. (2012) stated that cyclone formation over the NIO is a complex phenomenon as it is affected by multiple Ocean atmospheric phenomena including El Nino, El Nino Modoki, IOD and MJO (Krishna Mohan et al., 2012; Sumesh and Kumar, 2013).

A.3 Data and Methods

A spatial database of tropical cyclones was created based on tracks obtained from the Indian Metrological Department Atlas for the period 1881-1999 (IMD, 1979; IMD 1999) and the IMD e-Atlas for the tracks of storms and depressions over the north Indian Ocean for the period 1891-2014 (IMD, 2014). The data used in this study are thus for the tropical systems in the Arabian Sea, 1881-2014. The tracks show tropical system categories and the origin point for each tropical system with the data organised based

[41] Madden-Julian Oscillation (MJO); "is the dominant component of the intra seasonal (30-90 days) variability in the tropical atmosphere. It consists of large-scale coupled patterns in atmospheric circulation and deep convection, with coherent signals in many other variables" (Zhang 2005)

on the seasonal and monthly distribution of cyclone tracks and their origin points. The tracks that made landfall in Oman have been extracted from the total tracks to be analysed separately.

ArcGIS 10.2 is used to map the cyclones' tracks (shapefiles) by season (pre-monsoon and post-monsoon) and month. GIS is then used in kernel density estimation (KDE) by season and month for the total Arabian sea cyclones and for the cyclones that made landfall in Oman, in a similar manner to that used by Joyner and Rohil (2010) to calculate the density distribution of Atlantic tropical cyclones 1944-2009. The cyclones are categorised based on the Sampson scale and the bandwidth 6-hour interval (Joyner and Rohil, 2010).

The method of Linear Direction Mean (LDM) is used to identify the linear trend of the tracks (i.e. the mean angular direction of the storm). The LDM is calculated for the tracks clustered, both seasonally and monthly, to reveal track trends over time. GIS is used to calculate the LDM for different angles using trigonometry. The GIS is then used to measure the angle of each line from the coordinates of the beginning and end points. Then the sine and cosine of each angle are calculated. LDM is calculated by dividing the sum of sines by the sum of cosines (Mitchell, 2005, p 56);

$$\boldsymbol{\theta_i} = \arctan\frac{\sum_i \sin\theta i}{\sum_i \cos\theta i}$$

Equation1

θ_i Is the angle of the directional mean of the lines (LDM), $\sum_i \sin\theta i$ is the sum of the sines of the angle of the lines, and $\sum_i \cos\theta i$ is sum of the cosines of the angle of the lines. The output of the calculation is given as: the directional mean angle (clock wise from due East), compass angle (clock wise from due north), circular variance (i.e. how much the direction deviates from the directional mean), mean track length in decimal degree (DD) and then converted to kilometres (1 DD = 111.3 km), and the mean of the origin (X, Y co-ordinate) of the track.

A.4 Results

A.4.1 Arabian Sea tropical cyclones frequency

Table 3 gives summary statistics for the tropical cyclones that formed in the Arabian Sea, 1881-2014. In total, 223 tropical systems formed in the Arabian Sea of which 124 made landfall, and 99 died in the Arabian Sea and the Gulf of Aden. The data show that India is exposed to the highest frequency of cyclones making landfall, with 27.4% of the total.

Overall 41 tropical systems made landfall in Oman, 18.4% of the total, and another 16 entered Omani coastal waters but died in the sea (between 60 - 64 ° E). Of the 41 that made landfall in Oman, 18 were tropical depressions, and 11 were storms, with 12 classified as a severe storm or stronger.

Table 3 Distribution of tropical systems in the Arabian Sea, 1881 to 2014

Country	Frequency	%
The Gulf of Aden	6	2.7
India	61	27.4
Oman	41	18.4
Pakistan	10	4.5
Sea	93	41.7
Socotra	5	2.2
Somalia	6	2.7
Total	223	

The formation of tropical cyclones (TC) in the Arabian Sea occurs in two seasons; pre- and post-monsoon. Figure 4 shows the monthly distribution of TC in the Arabian Sea, and also specifically those that made landfall in Oman, for both seasons, from 1881-2014, and reveals that there is a high frequency of cyclones formation in May and June in the pre-monsoon, and in October and November in the post-monsoon.

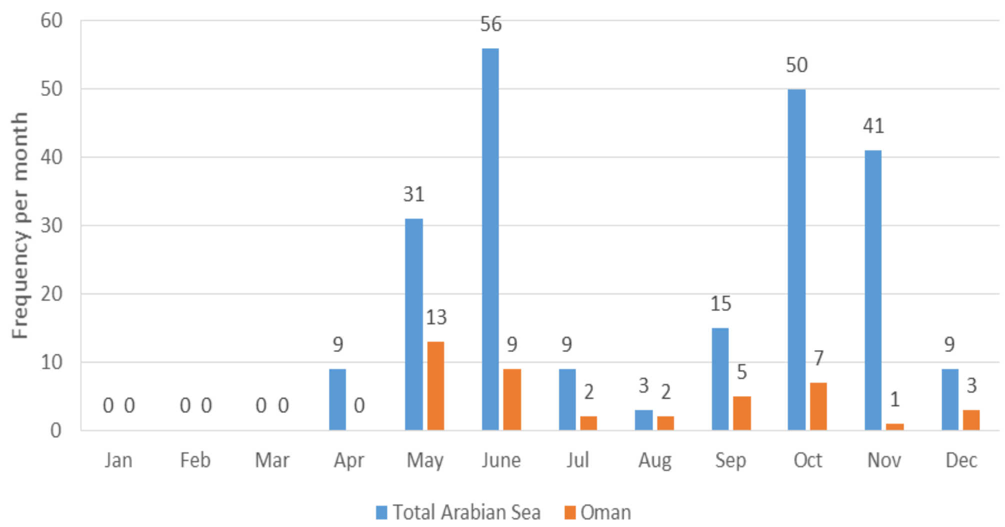

Figure 4 Distribution of tropical systems in the Arabian Sea, 1881-2014

Table 4 Tropical events that made landfall in Oman, 1881 to 2014

Month	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
1880-1894	0	0	0	0	1	2	0	0	0	0	0	0	3	7.1
1895-1909	0	0	0	0	2	1	0	0	0	1	0	0	4	9.5
1910-1924	0	0	0	0	3	0	0	0	0	1	0	0	4	9.5
1925-1939	0	0	0	0	1	0	0	0	1	0	0	0	2	4.8
1940-1954	0	0	0	0	0	1	0	0	1	1	0	0	3	7.1
1955-1969	0	0	0	0	3	0	1	0	1	2	1	1	8	19.0
1970-1984	0	0	0	0	1	2	1	2	1	0	0	1	7	16.7
1985-1999	0	0	0	0	0	1	0	0	1	1	0	1	3	7.1
2000-2014	0	0	0	0	2	2	0	0	0	1	0	0	5	11.9
Total	0	0	0	0	13	9	2	2	5	7	1	3	39	92.9
%	0	0	0	0	31.0	21.4	4.8	4.8	11.9	16.7	2.4	7.1		

Table 4 also shows the monthly frequency distribution, in roughly equal (15 years) bands, for TC that made landfall in Oman since 1881**.** Overall 24 events made landfall in the pre-monsoon; 13 were in May and 9 in June, a period that accounts for about 50% of all TC in the record. In the post-monsoon 12 events made landfall in Oman, six in October, five in September and one in November (IMD 1979, 1999), a pattern that remains consistent with the shorter 1881-1998 record of Membery (1998).

A.4.2 Arabian Sea storm track analysis

A.4.2.1 Arabian Sea tracks classification.

The tracks analysis reveals a distinct difference between the pre- and post-monsoon. Figure 5 displays the distribution of the cyclone’s origin point and track in the pre-monsoon, based on the monthly analysis. All the cyclone origin points in the pre-monsoon were in the Arabian Sea, being south-east in the Arabian Sea in May, and moving slightly to the northeast in June, then to the north in July. The tracks vary in direction each month, but a clear pattern of track movement is to the southwest Arabian Sea in May, and to the northwest in June and July, although there are numerous cases in June when the track curves north east towards India.

Figure 5 shows the distribution of tracks and origin points in the post-monsoon, where the origin points are distributed over a large area. Most post-monsoon storms originate in the northeast Arabian Sea in September and move gradually to the south-east and the south Arabian Sea in October, November and December. However, several storms formed in the Bay of Bengal and track west over India before arriving in the Arabian Sea. The tracks analysis shows that usually the post-monsoon tracks moved to the west of the Arabian Sea in September and gradually to the southwest in October, November and December toward the Gulf of Aden and the Horn of Africa. However, there are recorded tracks in November that recurve to India in the east of the Arabian Sea.

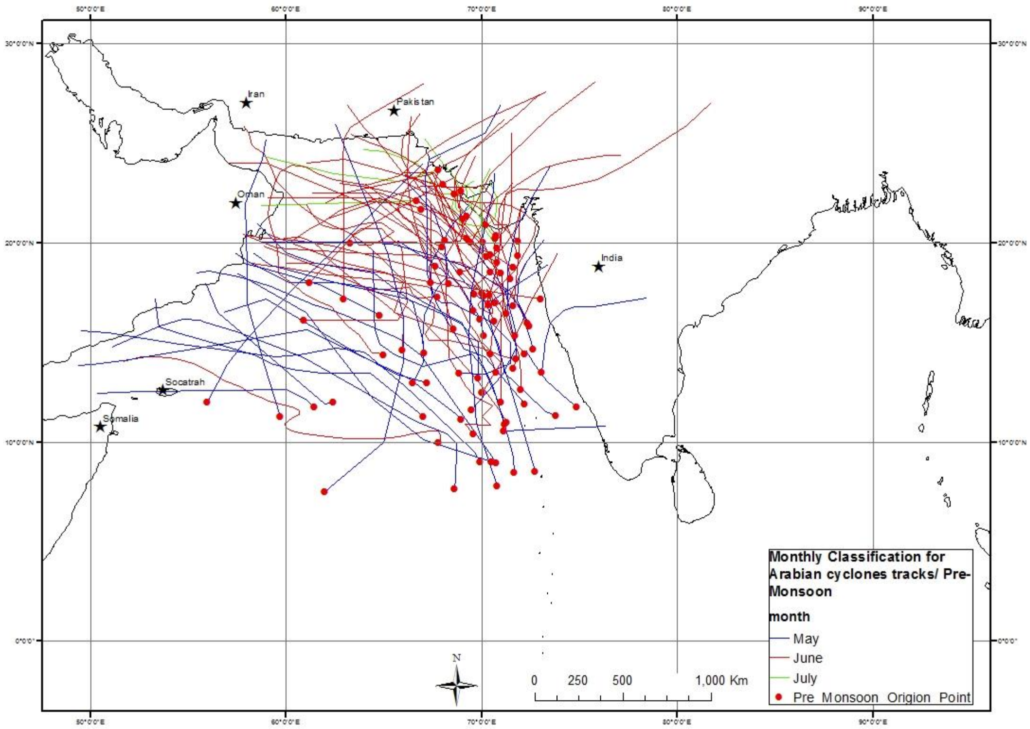

Figure 5 Monthly distribution of the tracks in the pre-monsoon

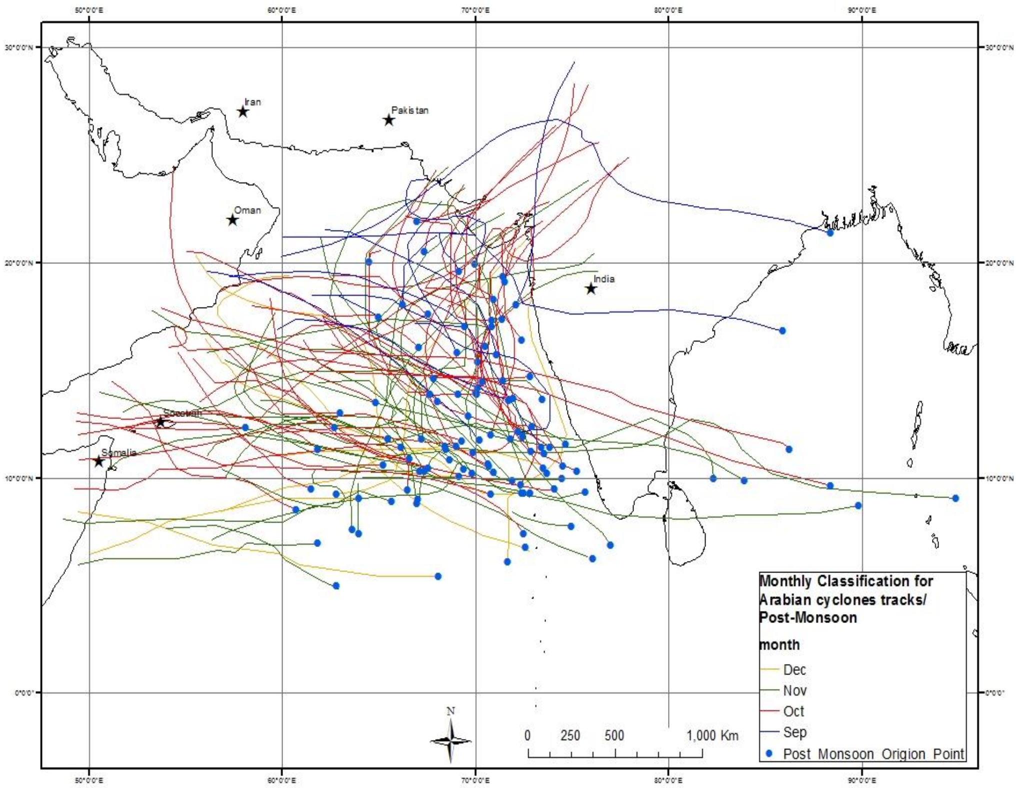

Figure 6 Monthly distribution of the tracks in the post-monsoon

The origins and tracks of the tropical systems that made landfall in Oman show different patterns by season and month of cyclone formation. Figure 7 displays the origins and tracks in the pre-monsoon, revealing a distinct difference in tracks within this period. In May, tropical systems frequently travel to the coastline between Masirah Island in central Oman and Salalah in south-west Oman. In June the track direction moves to central and north-east Oman, such that tropical systems arrive at the coast from Masirah island to Ras Al Had and beyond in the Oman sea. Note, however, that historical records indicate that on occasion, storms may deviate from this general pattern. The storm of June 1885 is known to have moved to the southeast coast and entered the Gulf of Aden in Yemen (Membery 2002) whilst a strong storm recorded in May 1898 is known to have crossed Oman from Ras Madrakah and moved to north Oman (IMD,1979).

Figure 8 shows the origins and tracks in the post-monsoon, which similarly reveals a distinct tracks pattern within this period. In September the tracks travel to the central of Oman from Masirah to Ras Madrakah and then move progressively to south-east Oman, toward Salalah in October and December.

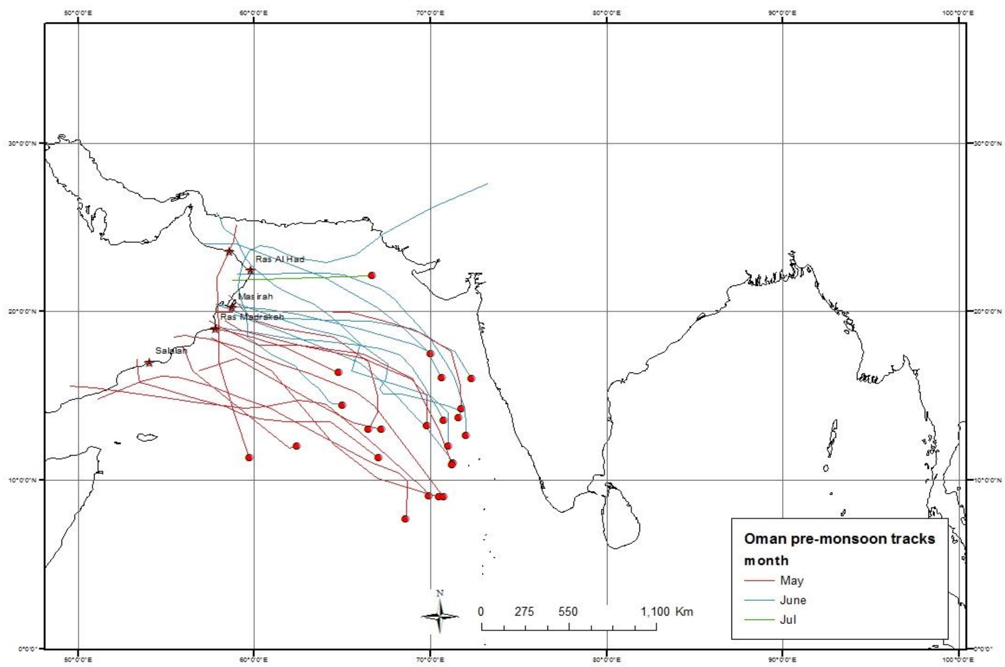

Figure 7 Monthly distribution of pre-monsoon tracks making landfall in Oman

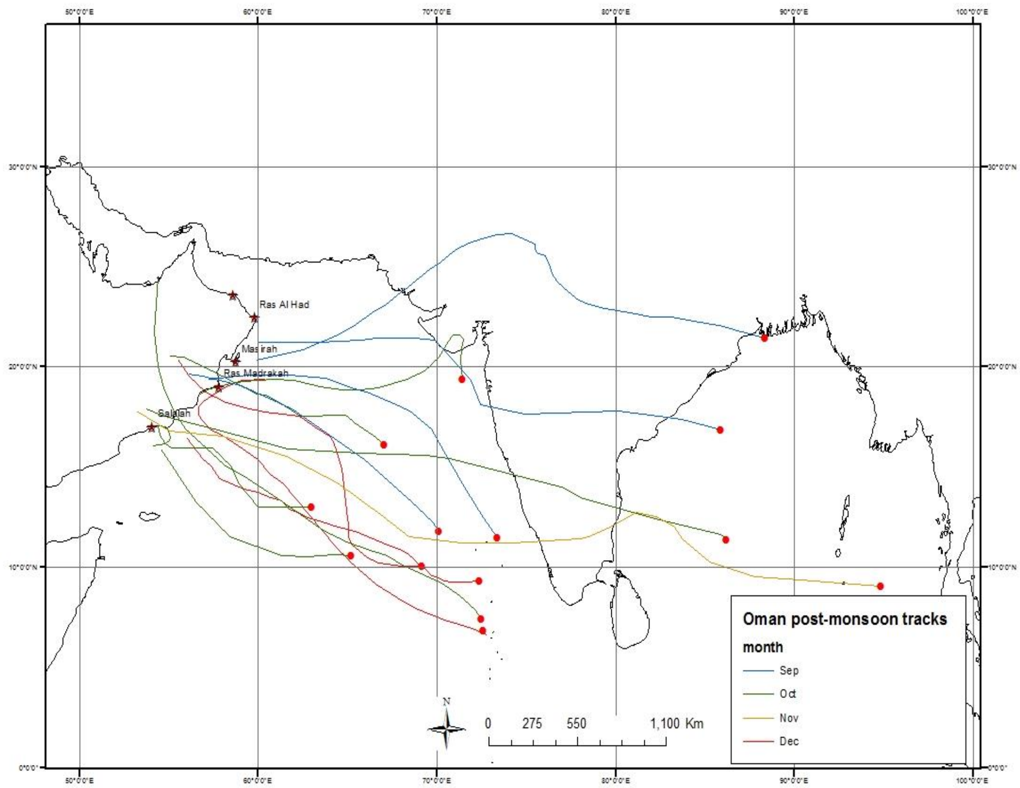

Figure 7 Monthly distribution of post-monsoon tracks making landfall in Oman

A.4.2.2 Arabian Sea seasonal and monthly distribution of the tracks KDE

Kernel Density Estimation is used to analyse the distribution of the cyclones tracks, to identify the high-density area of the cyclones in the Arab Sea.

Figure 9 displays the KDE of all the tracks in the Arabian Sea. KDE shows a high-density area of tracks movement to the north-east, near the north-west coastline of India (Gujrat). KDE of the pre-monsoon tracks shows a high density of track movement over a large area of the Arabian Sea, from 15–25° N and 60- 73° E. The high-density KDE in the post-monsoon is exposed in the southeast to the south of the Arabian Sea.

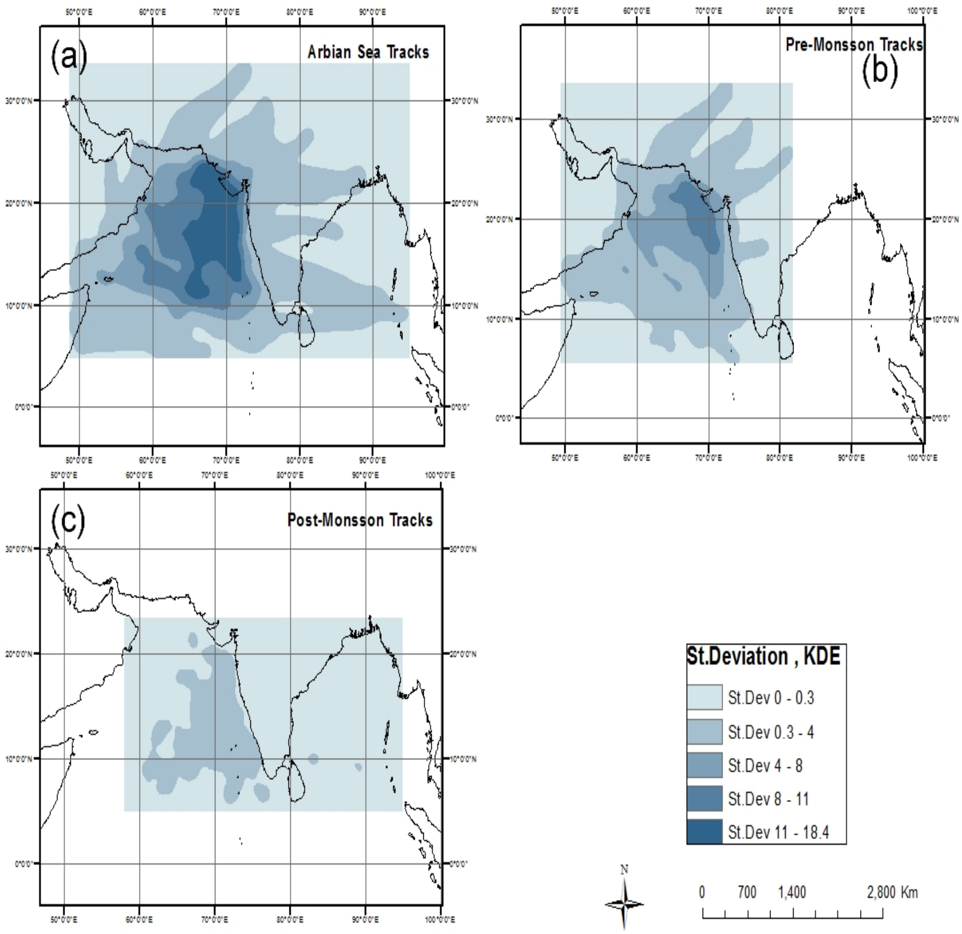

Figure 9 KDE of the Arabian Sea tracks. a) KDE of total Arabian Sea tracks, b) KDE of the pre-monsoon tracks, c) KDE of the post-monsoon tracks

Figure 10 shows the KDE of the monthly distribution of tracks in the Arabian Sea. The KDE show that there is a high density of tracks in the middle of the Arabian Sea in May, with the highest density of the KDE in June in the north-east Arabian Sea**,** and in October in the south Arabian Sea. The high density of the KDE in November is located in the east of the Arabian Sea in the 65° -70° E and 10°-15° N.

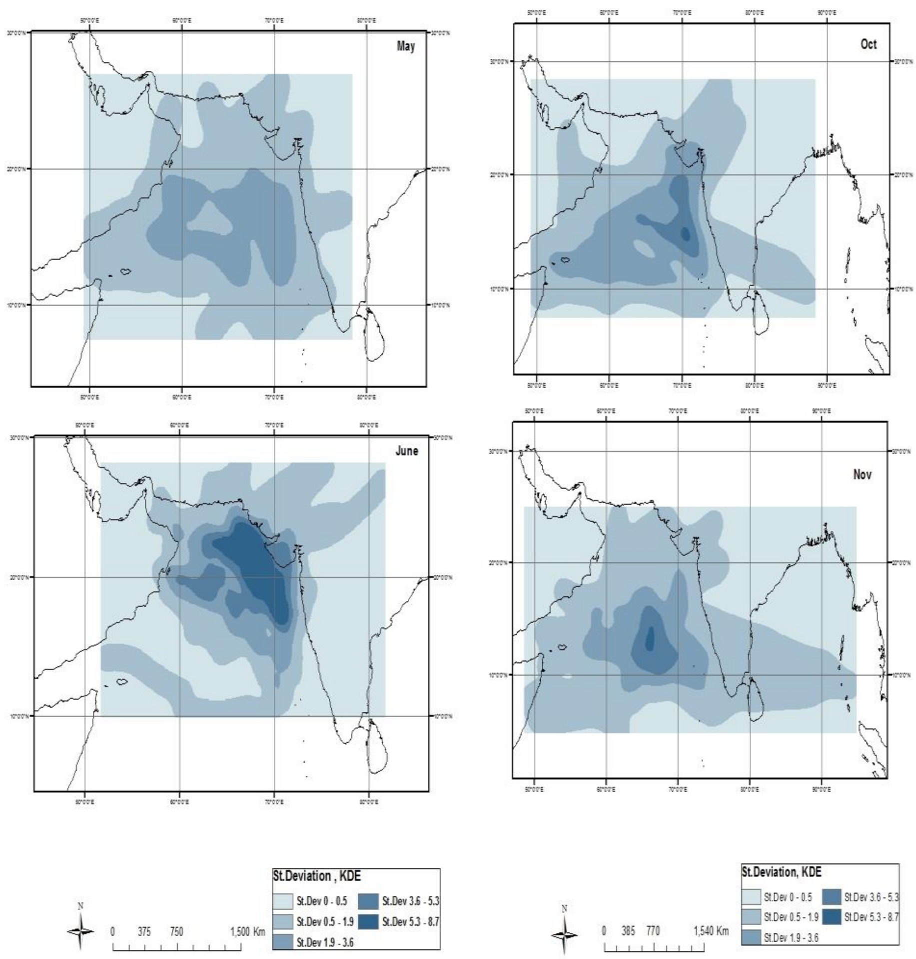

Figure 10 Monthly distribution of tracks KDE in the Arabian Sea

Figure 11 shows the KDE of tracks that made landfall in Oman and Figure 11(a) shows the KDE of all tracks. There is a high density of tracks in the Middle East coastline of Oman near Ras Madrakah, whilst the pre-monsoon KDE in figure 11(b) shows a high density in the Ras Madrakah area. A high density of tracks in the post-monsoon period in figure 11(c) is found toward the southeast coastline of Oman, near Salalah.

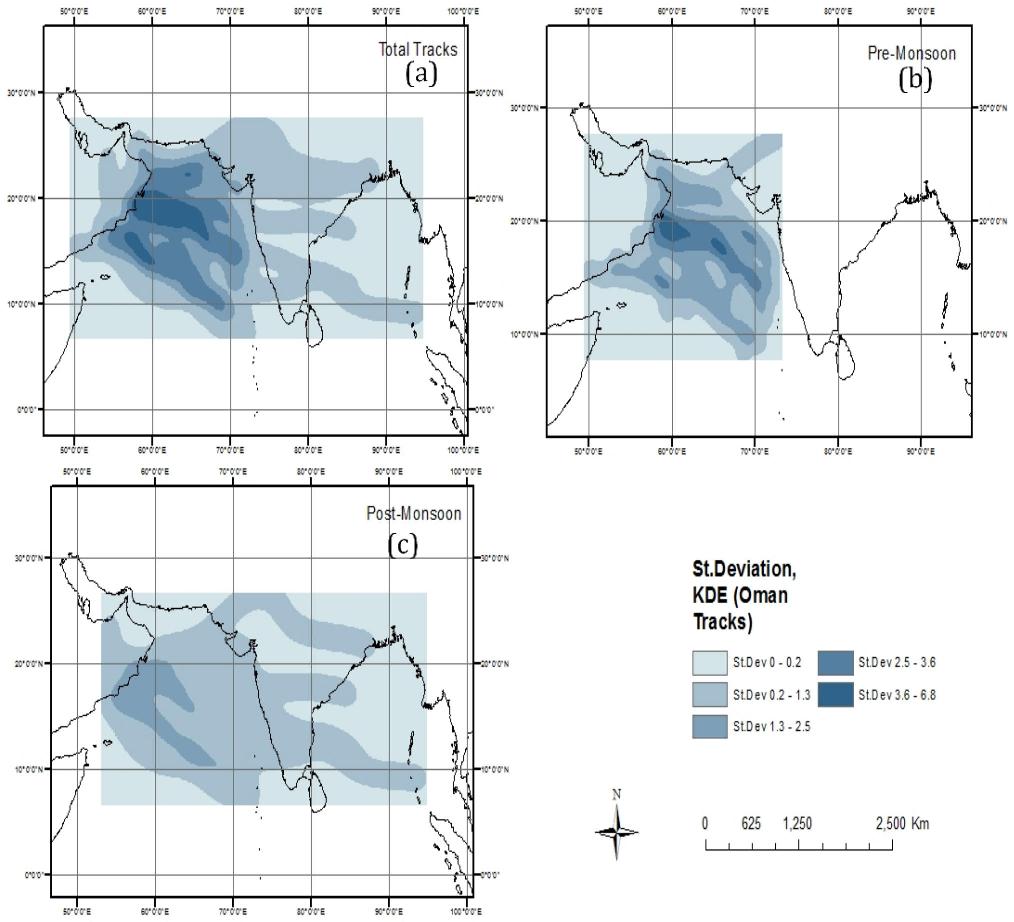

Figure 11 KDE of the tracks making landfall in Oman; a) KDE of the total tracks, b) KDE of the pre-monsoon tracks, c) the KDE of the post-monsoon tracks.

Figure 12 shows the monthly distribution of tracks KDE for Oman. The KDE show that the highest density of the tracks in May is in the middle of Oman near Ras Madrakah, with some density in the south near Salalah. In June the KDE reveal the highest density is again in the middle of Oman, with high density to the north of Oman near Ras Al Had. In May and June the highest density of the tracks KDE is still in the middle of Oman near Ras Madrakah in Sep and Oct, with the high density spreading to the south near Salalah in Oct.

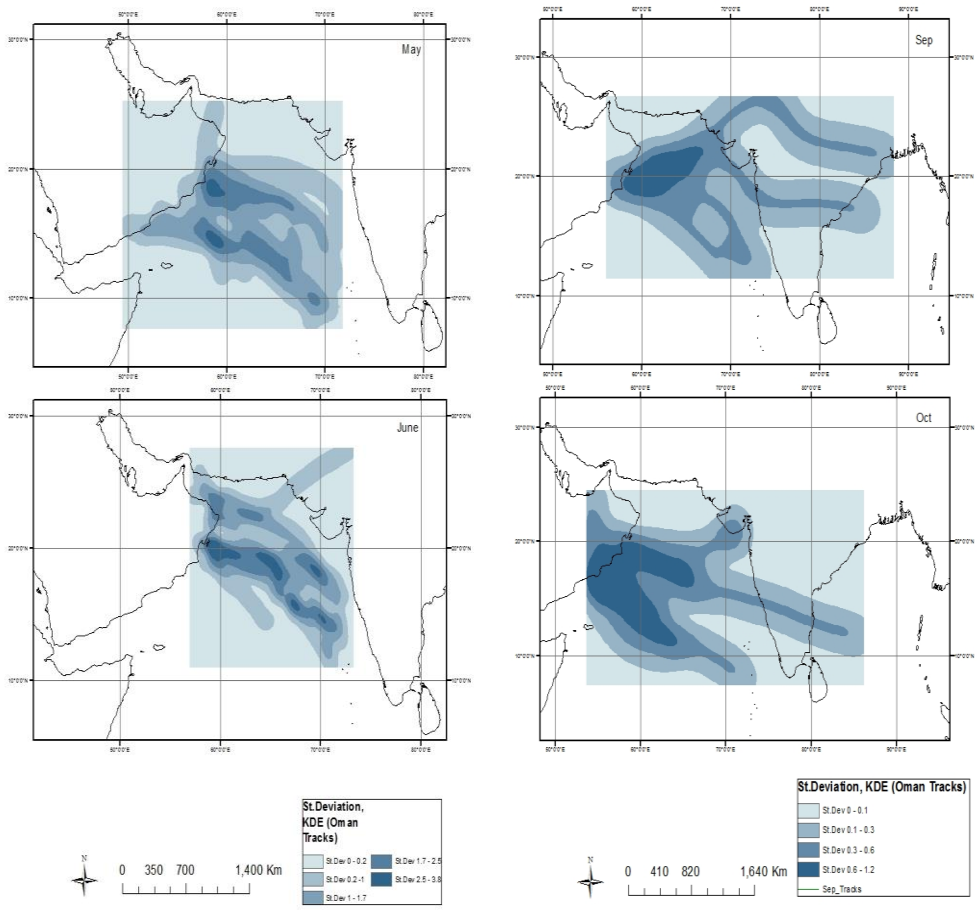

Figure 12 Monthly distribution of Oman tracks KDE

A.4.2.3Linear Direction Mean (LDM)

The linear directional mean is a statistical-spatial analysis used to identify the mean direction of lines, like cyclone tracks. In this study, the LDM is used to identify the mean direction of Arabian Sea cyclone tracks, 1880-2014, with results presented in Table 5 and Figure 13 for all tracks in the Arabian Sea. For these data, the LDM is to the north-west towards Oman and Iran, with the directional mean angle, 127.8° (clockwise from due east). The average length of the tracks in the Arabian Sea is 1479.4 km.

Figure 13 shows the LMD in the pre- and post-Monsoon periods. The LDM is to the north, to the coastal line of Pakistan in the pre-monsoon, with mean directional angle 120.4°, whilst the LDM in the post-monsoon is to the northwest Arabian Sea toward Oman’s north-east coastline, with mean directional angle 136.4°.

Table 5 The LDM parameters of the total Arabian Sea tracks

Tracks	Compass[42] Angle	Direction Mean angle[43]	Circular Variance[44]	Ave X	Ave Y	Ave Length (DD)	Ave Length (Km)
Arabian Sea	322.25	127.75	0.28	66.72	16.82	13.29	1479.40
Pre-Monsoon	329.59	120.41	0.24	67.04	18.96	10.97	1221.05
Post-Monsoon	313.63	136.37	0.30	66.27	14.91	14.10	1569.08

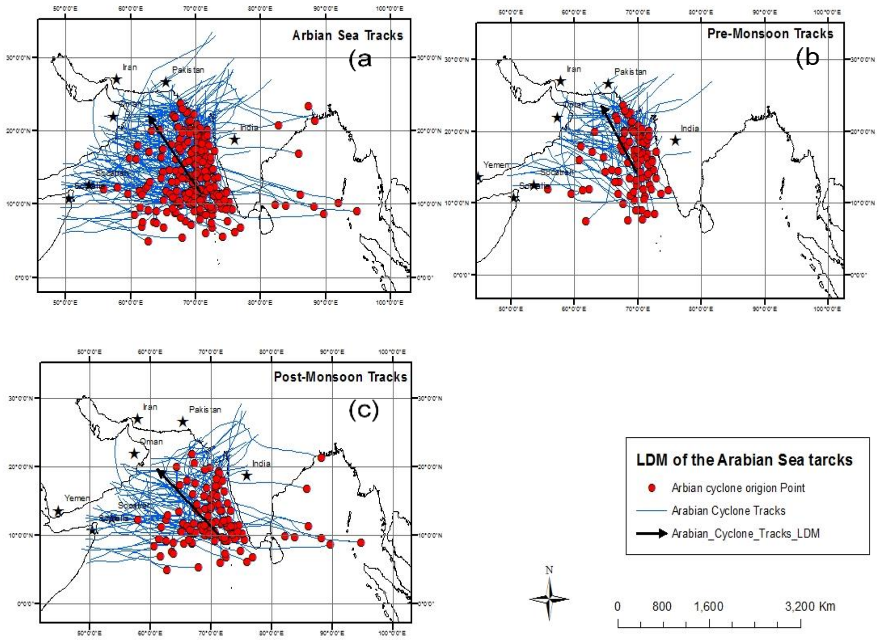

Figure 13 LDM direction of Arabian Sea tracks, a) total tracks, b) pre-monsoon tracks, c) post-monsoon tracks

[42] (clock wise from due north)

[43] (clock wise from due East)

[44] (i.e. how much the direction deviates from directional mean

Figure 14 shows the LDM of all tracks that made landfall in Oman. The mean directional angle for the total track is 157.75° to the Middle East Oman coastline in the south of Masirah Island, with mean length 2169 km. The LDM of the pre-monsoon tracks, as shown in figure 14(b), moved slightly to the north of the LDM of the total tracks to the middle of Masirah Island, with mean directional angle 146°, and mean length 1827 km. Figure 14(c) displays the LDM of tracks that made landfall in Oman in the post-monsoon period. The mean directional angle is about 158 ° to Ras Madrakah, with mean length 2361 km. Table 6 shows the parameters of the LDM for the seasonal tracks that made landfall in Oman, 1881-2014.

Table 6 LDM parameters for the seasonal tracks that made landfall in Oman

Tracks	Compass Angle	Direction Mean angle	Circular Variance	Ave X	Ave Y	Ave Length (DD)	Ave Length (Km)
Oman tracks	298.25	151.75	0.11	64.54	17.09	19.48	2168.96
Pre-Monsoon	304.02	145.98	0.08	63.47	17.11	16.41	1827.00
Post-Monsoon	292.07	157.93	0.03	64.71	16.25	21.21	2361.04

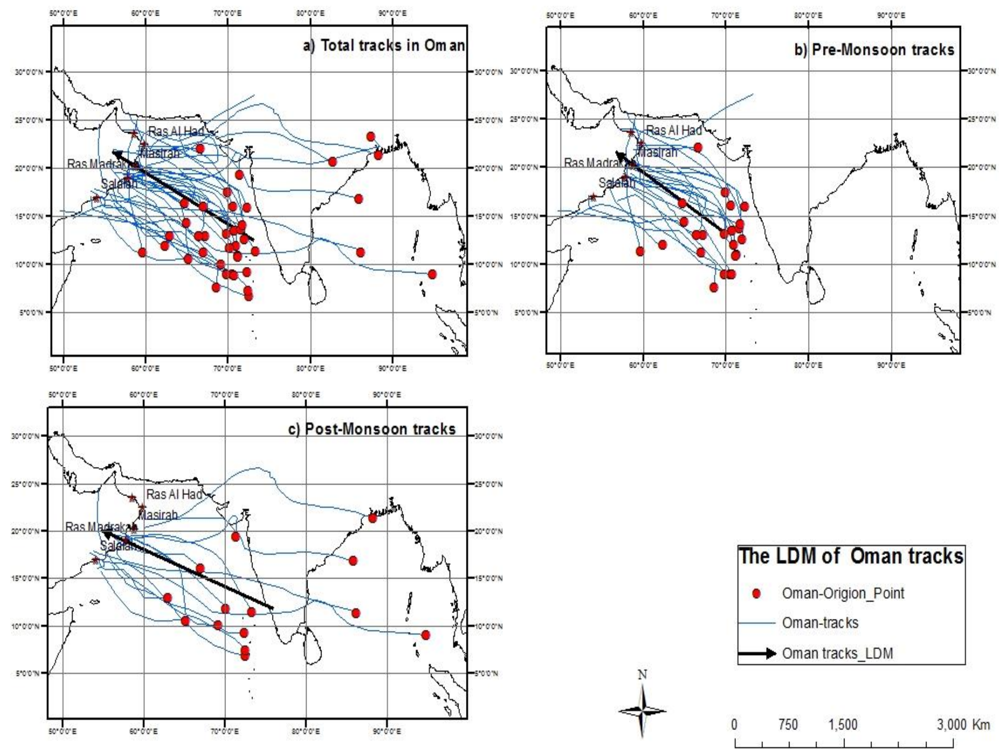

Figure 14 LDM direction of tracks that made landfall in Oman; a) total tracks, b) pre-monsoon tracks, and c) post-monsoon tracks.

Figure 15 (a) displays the Monthly LDM of the tracks that made landfall in Oman. May and June are the high frequency, pre-monsoon months. The LDM shows a different direction between May and June, The direction in May is to the Middle East coastline of Oman; directly to Ras Madrakah. In June the LDM direction moves to the north-west Arabian Sea, and towards Muscat, the capital of Oman. Figure 15 (b) shows the LDM of the post-monsoon tracks that made landfall in Oman. The high-frequency TC occurs in September and October. The LDM of the September track moves to Masirah Island on the eastern coastline of Oman. By October, the LDM has moved to the south-east coastline to Salalah, the main southern city in Oman. Table 7 shows the parameters of the LDM in the pre-monsoon months and in the post-monsoon months.

Table 7 LDM in pre- and post-monsoon months.

Tracks	Compass Angle	Direction Mean	Circular Variance	Ave X	Ave Y	Ave Length (DD)	Ave Length (Km)
May	302.59	147.41	0.05	62.30	15.71	15.71	1748.75
June	306.30	143.70	0.12	65.35	18.91	17.83	1984.31
Sep	287.63	162.37	0.02	67.99	18.92	21.78	2424.18
Oct	289.22	160.78	0.03	65.87	15.45	25.92	2885.40

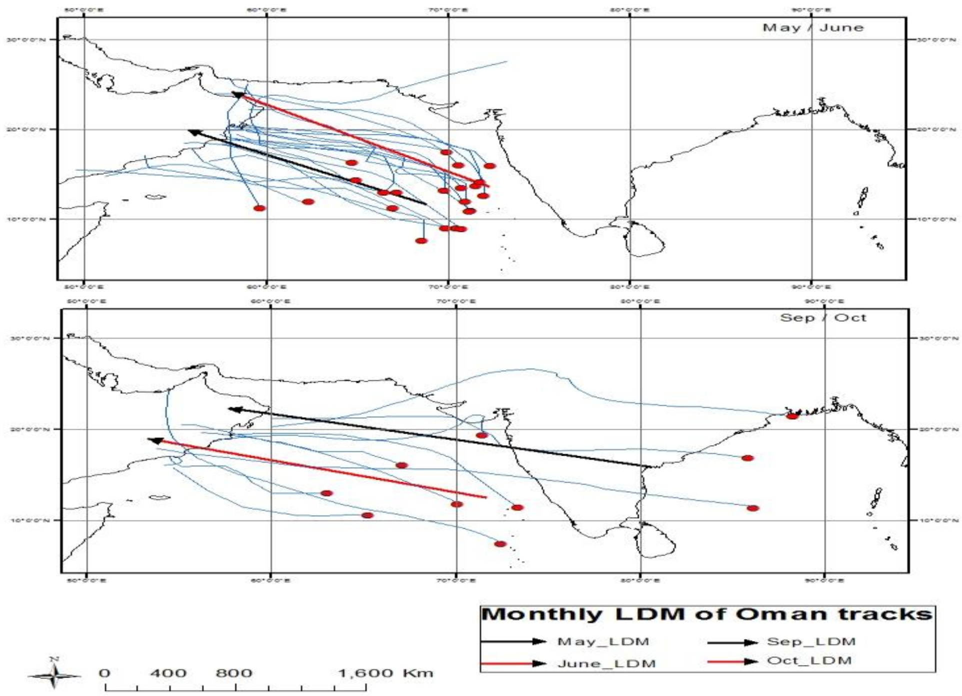

Figure 15 Monthly LDM of tracks making landfall in Oman

A.5 Discussion and conclusion

Tropical cyclones in the Arabian Sea form in two seasons: the pre-monsoon and the post-monsoon (Membery, 2001). The analysis presented here is of all recorded cyclones that occur in the Arabian Sea, and those that made landfall in Oman. The analysis shows that cyclone tracks vary seasonally and by month. Cyclones tend to travel to the north of the Arabian Sea, as indicated by the total tracks KDE which shows a high density in the northeast Arabian Sea and an LDM to the northwest Arabian Sea. In the pre-monsoon, high density of tracks is found in the northeast Arabian Sea, and the LDM moves to the north Arabian Sea. High density of tracks in the post-monsoon is in the southeast Arabian Sea, with the LDM moving to the west.

This spatiotemporal pattern of cyclones can be explained by a combination of southern summer Asian monsoon, northern winter monsoon and the distribution of warm water in the Arabian Sea (Qasim, 1982). The summer monsoon starts at the end of April or the beginning of May when the sea surface is very warm (>29° C) (Galvin, 2008). As the summer monsoon moves northward from the sea to the land, the sea surface temperatures rise from south to north (Qasim, 1982; Shetye et al., 1994). This change in temperature explains the change in the origin of cyclones from the south of the region in May, moving northward in June. Post-monsoon, the movement of the winter monsoon and warm water in the Arabian Sea reverses, so the origins and tracks of cyclones move progressively southward from September to November. Thadathil and Gosh (1992) found that the surface water mass in the north Indian Ocean moves south in the post-monsoon, which Shetye et al. (1994) explain as a product of the cool wind that veers from the land to the sea at this time, making the sea surface cooler in the north Arabian Sea than the south.

Figure 16 shows the average SST in the same period of the tracks data, 1880-2014. In the pre-monsoon, the high SST water moved from the southern to the northern part of the Arabian Sea. This is due to the direction of the summer monsoon from the southwest to the north-east. In the post-monsoon, the high SST water moved from the north-east to the south-west as the winter monsoon moved from the northeast to the south-west (Galvin, 2008a).

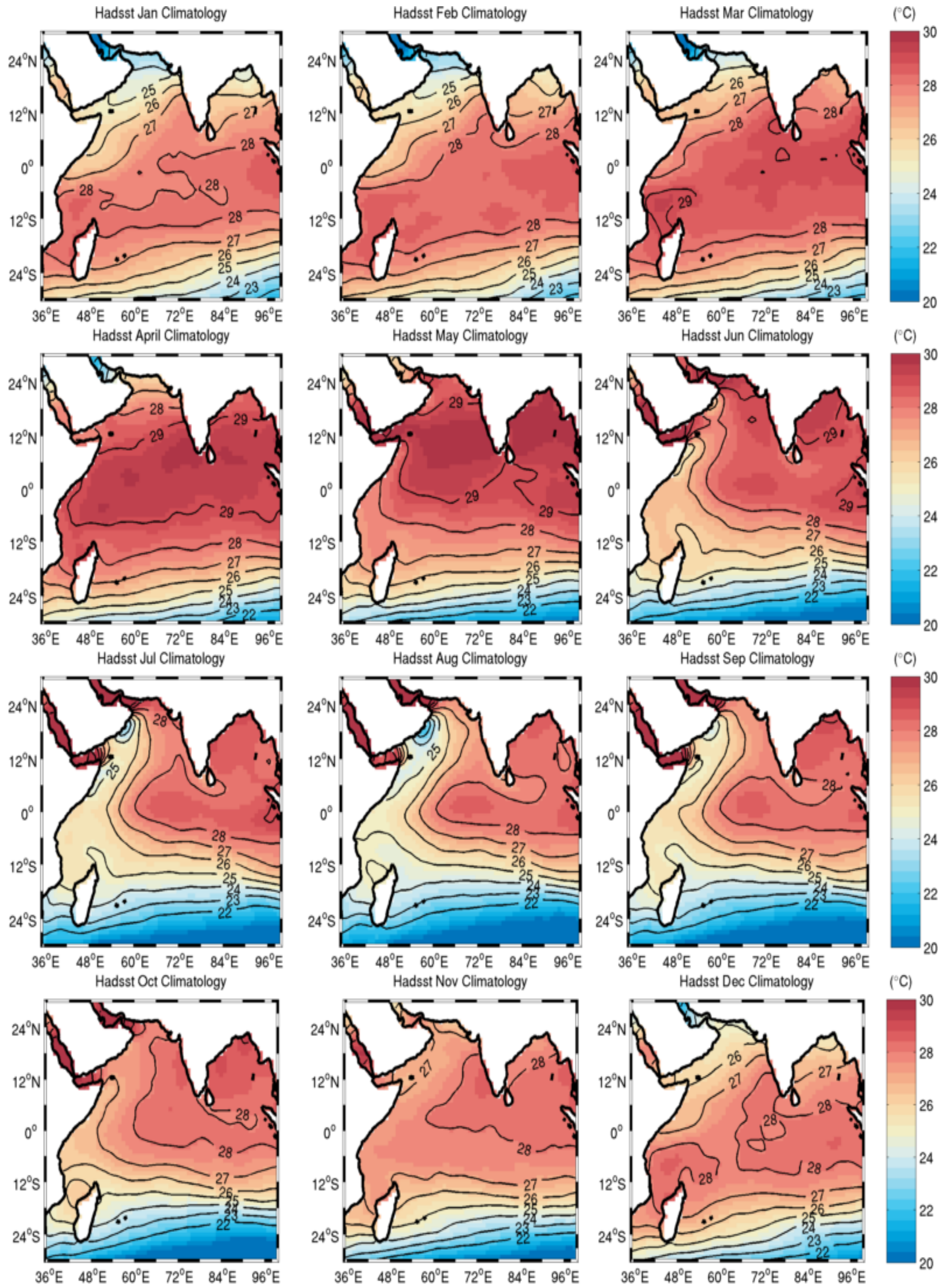

Figure 16 Average SST in the Arabian Sea, 1880-2014

Turning to the cyclones that made landfall in Oman, we find that in the pre-monsoon, cyclones tend to originate in the south of the region in May and move northward in June. Recently, tropical storm Ashobaa developed in June 2015. This cyclone was too recent to be included in the storm track analysis, but given its month of origin, the analysis suggests that this cyclone would strike Oman in the northern region. This is indeed what happened, with the storm travelling to the northeastern coast, hitting Oman near Ras-Al Had. In the post-monsoon, cyclones tend to originate in the north in September, moving progressively southward in October and November. For instance, tropical cyclone Chapala and tropical cyclone Meg that formed in the Arabian Sea in November 2015 both took a direction to the southwest Arabian Sea toward Socotra.

These results reveal a series of general and broadly predictable spatiotemporal patterns. Whilst individual events may deviate from these trends, the general patterns are useful in informing natural hazard risk assessment and management in the region, including Oman which has suffered extensive damage in the past due to a tropical cyclone. The results could, for example, assist with more targeted cyclone preparation and deployment of emergency response resources, based upon areas most at risk to cyclones overall (strategic planning), and to specific storm events when these are first identified (tactical planning). For example, knowing that cyclones that develop in June are more likely to make landfall in the northern part of Oman is valuable emergency planning intelligence.

This chapter is a pilot analysis of the main thesis question. The result of the cyclones analysis in this chapter gives better understanding and background about the cyclones risk in Oman. However, the analysis is not completed, and there is a need for more analysis and risk assessment.

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Appendix B: **Case study of community resilience during extreme weather events (Cyclone Guno in Oman)**

B.1 Introduction

A case study approach with quantitative methods for collecting and analysing data was implemented to explore the socio-economic system and evaluate community resilience during extreme weather events. The case study approach can be used in any area of social science, environmental studies, education and business studies (Johansson 2007) (Johansson 2007). The case study is “an ideal methodology when a holistic, in-depth investigation is needed” (Tellis 1997), and it is used to understand real-life cases in more detail in contextual condition (Yin 2009). The logical design of a case study is important to finding the variables that relate to the research study (Yin 2009). Tellis (1997) outlines four stages for case study methodology: "1) Design the case study, 2) Conduct the case study, 3) Analyse the case study evidence, and 4) Develop the conclusions, recommendations and implication”. Critical design of the case study inquiry is needed in order to manage the particular situation with many different variables, by relying on the use of multiple sources of evidence and understanding the benefits of drawing on previously developed theoretical approaches to guide data collection and analysis (Yin, 2009). Figure 1 shows a design of case study methodology provided by Yin (2009);

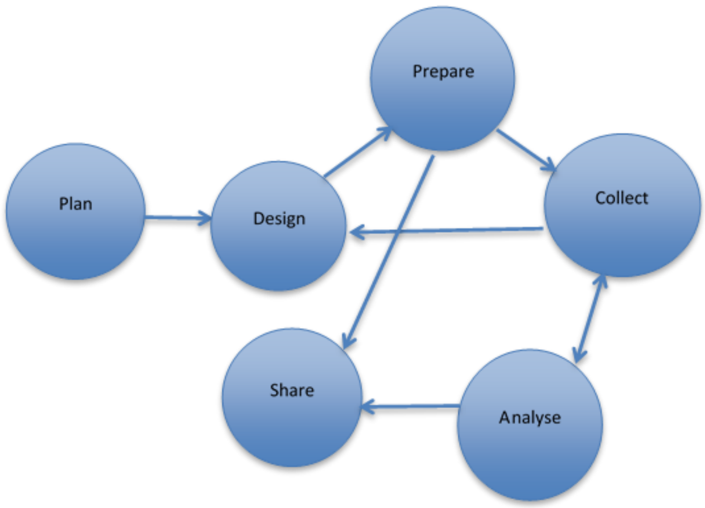

Figure 1 Paradigm of case study methodology provided by Yin

B.2 Case Study location: Quariyat / Oman

Quariyat, a state in the Muscat government area, is the area selected for studying the impacts of tropical cyclone Guno. This study area was selected because of its location near Wadi Dayqah bank and the Sea of Oman coastline. This state’s location in the Makran subduction zone puts the city at risk of flash flood, tropical cyclone and tsunami.

Oman is wide open to the Arabian Sea and is frequently exposed to tropical cyclones (Membery 2001). Historical records of cyclones that have hit Oman’s coastline indicate that hundreds of people have died because of cyclone floods (JWTC 1975-2012, EM-DAT 2014).For instance, 727 were killed during the cyclone that hit Muscat and Al-batina in 1890 and 100 more died subsequently because of cholera (Membery 2002). Table 1 presents a historical record of the high number of people who have died due to tropical cyclones in Oman

Table 1 Deaths due to tropical cyclones in Oman

Year	Location	Number of dead
1890	Muscat and North Oman	727
1959	Salalah (south Oman)	141
2002	Salalah (South Oman)	9
2007	Muscat and North Oman	100
2010	Muscat and North Oman	24

Source: (Membery, 2002; DGMAN, 2014)

B.3.1 Cyclone Guno

Cyclone Guno was the strongest cyclone recorded in the Arabian Sea in the last 100 years (Evan and Camargo 2010, Al-Awadhi 2010). In June 2007 Guno developed from an area of persistent convection in the eastern Arabian Sea (Al-Najar and Salvekar 2009, Dibajinia et al. 2009), and made landfall in north Oman (Al Awadhi 2010). North Oman is affected by cyclones once every 50-100 years and one cyclone every five years has made landfall in southern Oman (Ice 1975, Evan and Camargo 2010). However, it still difficult to recognise if there is any change in the frequency of the cyclones in northern Oman as there are few studies about cyclones in Oman.

Guno was the most powerful cyclone to hit Oman and was categorised as a super cyclone, which is equal to a hurricane in the 5th degree (Al-Kalbani 2011, Al Awadhi 2010). On the first day of its landfall in Oman (5th June), the maximum-recorded wind was 180Km/h, and the maximum rainfall was 900 mm, which is nine times more than the normal annual rainfall in Oman (DGMAN 2014). The huge amount of rain in the mountains caused extreme flash floods, which was the main reason for the massive damage in many places in the affected area such as Muscat (Al-Awadhi 2010).

Table 2 Wind speed readings in Oman Meteorology station during Guno landfall

Station Name	Wind speed (Km/h)/Jnue5th	Wind speed (Km/h)/Jnue6th
Qalhat	105	180
Sur	95	0
Seeb	32	86
Mina Qaboos	44	93
Masirah	65	72
Sohar	29	63
Libra	59	72
Adam	59	49
Bahla	68	84
Buraimi	49	51
Nizwa	59	67
Saiq	123	0
Rustaq	36	74
Samael	70	95

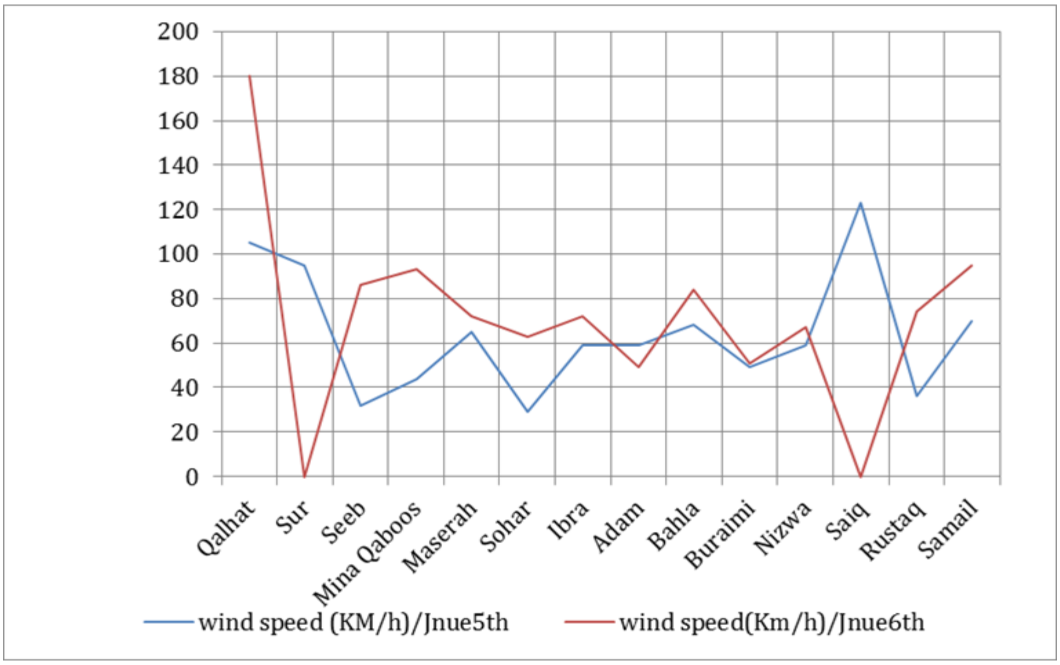

Figure 2 Change in wind speed during the two days of Guno landfall in Oman, from Meteorology station in Oman 45

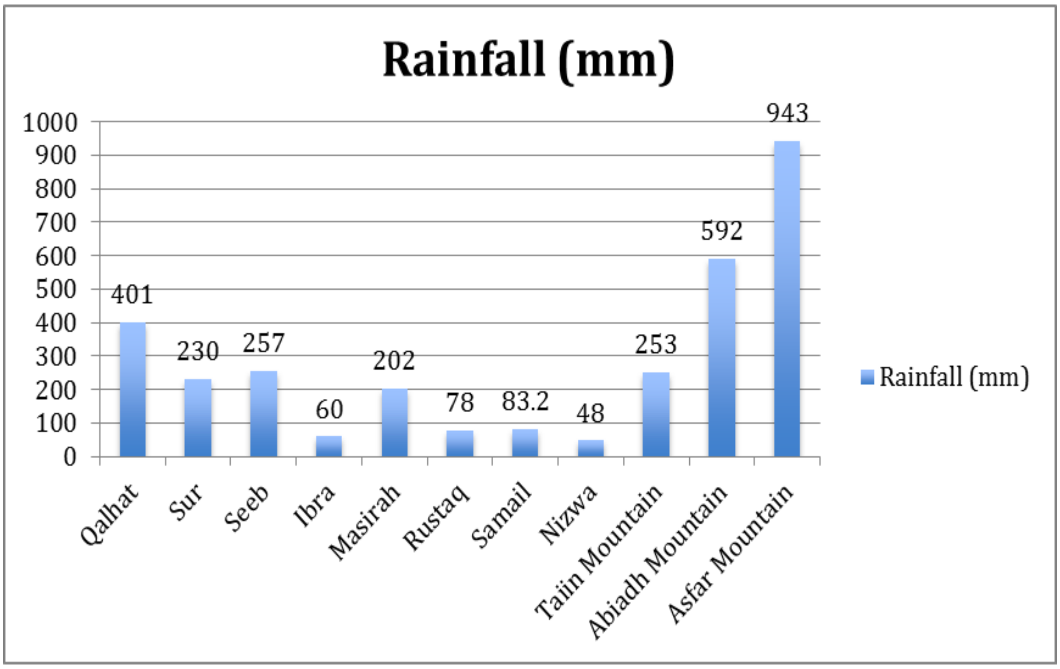

Figure 3 Rainfall during Guno (source: GDMAN, 2014)

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45 Note: the red line drops in Sur and Saiq because of missing data that day

B.3.1 Damage caused by Guno

1. Wadi floods (flash flood)

Cyclone floods usually cause massive damage and destruction (Brody et al. 2009, Al-Awadhi 2010). For example, in 2005, the Hurricane Katrina floods devastated New Orleans, USA (Brody et al., 2009). On the day that cyclone Guno hit, a huge amount of rainfall was recorded in north Oman, with 900 mm of rainfall recorded in Jabal Asfar (Yellow Mountain) (DGMAN 2014b) Massive floods caused huge damage to property and infrastructure estimated at 4 billion dollars and 100 people died (Al-Awadhi 2010) .Table 3 displays the losses of cyclone Guno in Oman; the table is based on the survey conducted by the government after the cyclone to evaluate the losses in Oman. The survey covered 6000 units; 85% of which were in Muscat, the capital, and it was estimated to account for 77% of the total damage (Al-Awadhi 2010)

2. Coastal flood (storm surge)

Storm surge is “an abnormal rise of water generated by the storm, over and above predicted astronomical tide” (NOAA 2014). Storm Surge is caused by a strong wind during the hurricane and raises the sea wave to approximately 15 M, which is more than the sea level average (NOAA 2014). Storm surge leads to enormous damage along the coastlines of the affected area (NOAA 2014). For instance, the storm surge of hurricane Dennis was 7-9 ft and produced significant damage, estimated at $2.23 billion around St. Marks, Florida (NOAA 2014).

A field study conducted along the north coastline by Fritz et al. (2010) found that the highest water marks were recorded at Ras al-Had, with a 5 m surge and in Muscat a surge of about 2 m. Storm surge during Guno led to huge damage to infrastructure and property (Fritz et al. 2010). For instance, roads and buildings near the coastline in Muscat collapsed because of the height and strength of the wave (Al-Awadhi 2010; Fritz et al. 2010). As well as causing socio-economic losses, Guno also affected the coastline ecosystem (Al-Awadhi 2010, Fritz et al. 2010).

Table 3 Estimated losses to property caused by cyclone Guno

Wilayah	Houses Surveyed	Houses Affected	Damaged Houses	Furniture	Household Equipment	Personal Belongings	Transportation/ Vehicles
Muttrah	4273	1135	888	718	730	542	428
Bosher	7179	3894	2776	2680	2721	2310	4065
A'Seeb	30498	12239	9035	7614	7888	6311	5676
Al-Amerat	5968	3468	3089	2013	2044	1419	397
Muscat	607	500	470	387	359	369	144
Quriyat	3512	3115	2891	2470	2478	2436	944
Barka	828	20	552	404	414	318	188
Dbai Al-Bayah	68	68	56	54	39	44	3
Bidbid	95	95	86	73	61	73	5
Sur	5984	4825	4294	3494	3132	2764	386
Al-Qabil	7	7	7	0	1	0	0
Dema	160	159	153	76	90	88	10
Al-Kamil	141	134	121	15	29	33	2
Galan Bani Bo Ali	1396	936	759	599	394	511	6
Galan Bani Bo Hasain	213	135	117	78	17	56	1
Wadi Bani Khalid	130	129	125	15	21	14	0
Total	61059	30859	25419	20690	20418	17288	12255

Source: Al-Awadhi (2009b)

B.4 Quariyat

Quariyat is one of six states in the Muscat government area. It is a fishery port state in northeast Oman, surrounded by AL-Hajar Mountains from the south (Al-Awadhi 2010). Based on Oman Census 2003 this state had a population of about 38,647 inhabitants, a number that rose to 44,911 in

2010 and 46,562 in 2012[46]. Most of the population are vulnerable to natural disaster in different ways.

In 2007 tropical cyclone Guno made landfall in northern Oman, and Quariyat was one of the most affected areas due to the massive flash flood from Wadi Dayqah and storm surges. Wadi Dayqah is one of the biggest wadis in north Oman, collecting rainfall water from the Al-Hajar Chain Mountains and moving it to the sea through Quariyat (MRMWR 2014). During Guno the highest amount of rainfall was estimated in Gabal Asfar (Yellow Mountain), with more than 900mm of rainfall from this mountain going into Wadi Dayqah and the surrounding wadis in Al-Hajar Mountains (DGMN 2014). The wadi, therefore, caused massive damage in Quariyat. For example, according to the Guno damage statistics, Quariyat lost about 2891 houses and 944 vehicles, most of which were not covered by comprehensive insurance for natural disasters (Al-Awadhi 2010).

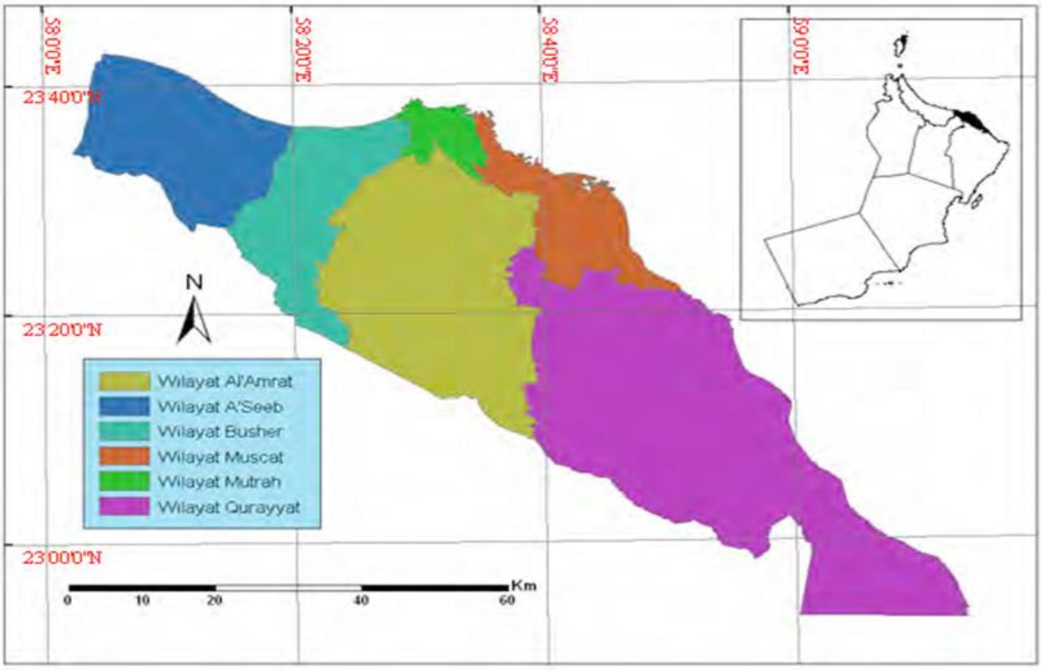

Figure 4 Muscat map; Quriyat in Purple (Source; (Al-Awadhi 2010)

[46] Source of the data is: National Centre for Statistics and Information, Oman

B.5 Data

To fulfil this study's aim to evaluate the community resilience during extreme weather events a survey was implemented of the residents in Quariyat. The survey was conducted to collect information about specific indicators before, during and after Guno. The indicators in the survey focus on the ability of the locals to absorb the disaster socially and economically and the evacuating strategy at all levels. The first survey indicator, the ability to absorb the disaster, focuses on selected factors such as property insurance, socio-economic life level, and risk awareness. The evacuating strategies focus on shelters, warning systems and communication.

A total of 100 survey forms were sent to the residents in Quariyat and just 67 forms were returned. About 10 of these forms had missing data: gender, age, and the average of monthly income. The participants were drawn from local people who were in Quariyat during Guno.

The survey focused on: Evacuation satisfaction during Guno, public awareness, life style level, and insurance. The questions on satisfaction with evacuation asked about: the speed of warning, media role, evacuation requirement, and shelters. The awareness questions asked about the level of experience they gained from Guno, their level of awareness about hazards in the area, and their level of awareness about other cyclones. The life style questions asked about the property they had lost because of Guno, the level of impact of Guno on their current living standard and the government's role in the recovery. The insurance questions asked about catastrophe insurance and the insurance companies' honesty in paying for their losses. The answers to the survey question were rated on a scale from 1 to 5, with three open ended questions provided for the participants to give general views about the evacuation and insurance.

B.6 Result

1. Evacuation satisfaction during Guno

Guno was the first case of evacuation in northern Oman. The military took charge of the evacuation during that time, and most people thought that they did a good job.

Data analysis shows that about 33.3% of the respondents in the study area were satisfied with the evacuation during Guno. On the other hand, 26.7% of the respondents were not. Those who were not happy with the evacuation realised that at the time of the evacuation there was a lack of knowledge about the evacuation and shelter requirements. They said that the shelters were not clean and had not been properly prepared for use as shelters.

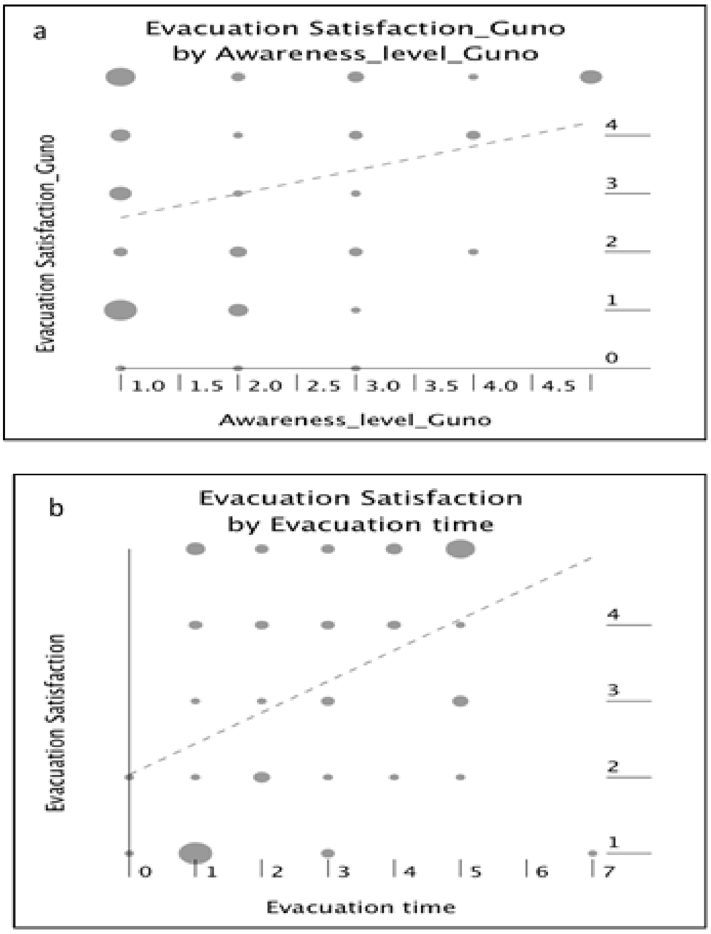

Figure 5 a) correlation between evacuation satisfaction and the awareness level during Guno, b) correlation between evacuation satisfaction and evacuation time.

The people who were satisfied with evacuation were more aware about the situation. They followed the orders which were issued to them by the police and military, so they did not face problems in terms of evacuation time. The statistical analysis shows that the correlation between the evacuation satisfaction and evacuation time is positive and the P-value is < 0.001 which is highly significant. The correlation between evacuation satisfaction and awareness level during Guno is also positive and the P-value < 0.016.

2. Public awareness

Public awareness has developed since Guno. The statistical analyses show that public awareness about natural hazards during Guno was about 50.8%, which is a low score, but this percentage then reduced to about 30.2%. Most people realise the change in public awareness was due to Guno; about 47.6 % of the participants feel that Guno was a very hard experience and made them more aware about weather hazards, and about 54% believe that they are ready for another cyclone such as Guno.

3. Insurance

Catastrophe insurance is important to risk transfer in the vulnerable area (Warner 2009). It is important to manage the economic risks associated with disaster which can affect living standards and lead to poverty in many cases (Warner 2009). Public awareness about catastrophe insurance is important, as well as improving insurance policies and regulation (Warner 2009). The data analysis for the case study shows lack of public awareness about catastrophe insurance.

About 58.7 % of the respondents do not have catastrophe insurance because they think it is not important. They believe that even if they take out insurance, the insurance company will not pay up. They derive their negative outlook from Guno; about 30.2 % said that the insurance companies started to raise catastrophe insurance prices after Guno because there are no policies for monitoring the insurance companies. Most of the respondents agreed with the idea of paying taxes to the government as catastrophe insurance rather than paying private companies.

B.7 Lessons from the case study

There are some valuable lessons to be learned from this case study that help to provide a clear view of the situation in the risk area. The case study will be used as a base for the future research to understand the factors affecting community resilience and institutions' capacity to manage disaster in Oman.

The survey used a range of variables to provide a complete overview about community knowledge at the local level. However, focusing on particular variables will give a more precise result, such as by studying insurance and evacuation individually.

The case study is not complete, and there is a need to conduct a survey in another vulnerable place for contrast. This will demonstrate more clearly whether or not community resilience is at a healthy level.

In conclusion, community resilience to natural hazards is important for risk reduction. In the study area, public awareness has improved since Guno. The result can provide a good expression of the situation in the study area, but it cannot be used in another area in Oman due to the differences in the people's knowledge and experience. Also, the case study did not give a good indication of the level of community resilience in other aspects such as infrastructure and important facilities such as health and education.

Appendix C: Fuzzy Cognitive Mapping Workshop

C.1 Introduction

The workshop forms part of this PhD research that aims to support planning to build community resilience to extreme weather events in Oma. This is the second workshop on the topic and follows a pilot workshop used to scope factors affecting the performance of institutions with respect to extreme events. This workshop seeks to identify the factors that affect community resilience to extreme weather events in Oman and how important each factor is. It will also seek to uncover how these factors are related, and the strength of these relationships. The workshop aims to identify factors from three domains: the disaster (Cyclones), the institutions, and the people.

In this workshop we will use five thematic areas of building community resilience:

1. Governance
2. Risk assessment
3. Knowledge and education
4. Risk management and variability reduction
5. Disaster preparedness and response

The workshop will take place during one day as shown in the schedule.

C.2 The workshop methodology

The Fuzzy Cognitive Mapping method will be used to identify and analyse the factors that are related to community resilience to cyclones. FCM derives points (factors) classified according to the direction (Negative or Positive) and strength of association. A seven-point scale is used in this exercise, with factor relationships measured on a scale of -1 to +1.

Degree of relation	0	1	2	3
Negative		-	--	---
Positive		+	++	+++

FCM is selected as the principal research tool for this workshop as:

1. It provides an effective means for participants to contribute knowledge on the processes of interest that can subsequently be structured for a wider understanding of the system.
2. Participants build their own mental models and then find the best collective model for building community resilience. This avoids the researcher introducing personal bias in system analysis and model development.
3. It is an effective way of controlling for partiality and bias amongst participants.

C.3 Workshop format

1. *Introduction* (15-30 Min). The aims of the workshop and the FCM methodology will be introduced.
    - Participants will develop cognitive maps to reveal mental models that link community resilience to cyclones, people, and institutions.
    - The workshop will give participants a chance for open debate about the factors that contribute to resilience to cyclones.
2. Brainstorming (45 Min)

Each participant will have 5 minutes to reflect on relevant factors; then group brainstorming will run for 20 minutes. The last 20 minutes will be used to discuss the factors, to identify the most effective.

3. Factor classification (45 Min)

In this stage, participants will classify the factors. This classification is intended to identify factor effect (negative/positive) and degree of impact.

4. Linking factors using Fuzzy Cognitive Mapping (60 Min)

In this stage, participants will draw cognitive maps using the different factors and their classification. The process aims to link the factors to find the degree of relationship between them, and so help to identify the key and fundamental factors with high influence on community resilience to cyclones.

5. Results discussion

Participants have the chance to discuss the different Cognitive maps (models) and to identify the best model for building community resilience

C.4 Workshop timetable

Activity	Time
Introduction to the workshop	09:30 – 10.00
Brainstorming	10.00 – 11.30
Break	11:30 – 12:00
Factor classification	12.00 - 12.30
The link between the different factors	12:30 – 13:00
(Break)	1:00 – 1.30
Discussion about the different models (FCM)	1.30- 2:30

C.5 Key words to start the workshop

	Governance	Risk Assessment	Knowledge and Education	Risk management and vulnerability reduction	Disaster preparedness and response
1	Policies and planning priorities	Hazard/ risk data	Public awareness, Knowledge and skills	Environmental and natural resource management	Organisational capacities and coordination
2	Accountability and community participation	Hazard/ risk assessment	Information management and sharing	Health and well-being (including human capital)	Early warning systems
3	Legal and regulatory system	Vulnerability / Capacity and impact data	Education and training	Sustainable livelihoods	Preparedness and contingency planning
4	Integration with development policies and planning	Vulnerability / Capacity and impact assessment	Culture, attitudes, and motivation	Financial instruments (including financial capital)	Emergency resources and infrastructure
5	Institutional mechanisms capacities and structures; allocation of responsibilities	Scientific and technical capacities and innovation	Learning and research	Physical protection, structural and technical measures	Emergency response and recovery
6	Integration with emergency response and recovery			Social protection (including social capital)	Participation voluntarism, accountability
7	Partnership			Planning regimes	
8	Political commitment				

Appendix D: Interview and Assessment form

1- Interview

The interview is part of research about planning for community resilience to extreme weather events in Oman. The aim of this interview is to collect primary data and information in order to estimate the ability of the institutions that work in disaster risk reduction in Oman, by using stakeholder analysis, and by identifying the factors that affect the institutions work.

We promise that the information from this interview will only be used for the research purpose and will not be used for any another purpose.

- Name (optional)………………………….
- Age ………………..
- Education level: high school, undergraduate, postgraduate
- Occupation: ………………….
- Place of work: …………………..

The interview questions:

Part one: is disaster management important in the institution?

1- How are decisions about disaster risk reduction made in the institution? Are there clear structure or team works in the institution? Is it qualified?
2- What is the role of the institution in disaster risk reduction;
- The mitigation (infrastructure, dams)
- Preparedness for a response (public awareness, early warning, shelters)
- Preparedness for emergency and response (early warning, evacuation and help)
- Recovery after disaster (health and social services, replacement, insurance)
3- What is the primary responsibility of the organisation within the disaster management cycle? Are there any challenges during implementation of responsibilities?
4- Is the panel or teamwork clear to you? How well do you think you understand it? Please rank your Knowledge:
- 10 = the panel work is very clear and precise with regard to established procedures, membership and importance
- 5= my knowledge is fairly good in terms of mechanism and members
- 3= my knowledge is very simple and not exceed the members
- 1= I don’t know anything about the panel
5- To what extent is the issue of risk reduction important in the decision making in the organisation
- 10 = highly important and it played a key role in the decision for disaster management in Oman.
- 5 = play a limited role in the disaster management in Oman.

- 3= very simple importance and does not exceed the organisation.
- 1= it is not important

6- To what extent does the organisation decision impact on the decision of the national committee for disaster management?

- 10 = highly affects the decision and not taking it will increase the risk
- 5 = high impact and can improve the committee performance
- 3= limited impact and not important
- 1= there is no importance or effect to the decision of the organisation

7- In general are you interested in disaster risk reduction in Oman?

- 10 = very interested and I am ready to help at any time
- 5 = fair interest and I cooperate if it is necessary
- 3 = limited interest and my cooperation is weak
- 1 = not interested

8- Does your interest change by time? How and why?

9- What is your interest level in disaster management?

- Positive (Strongly- Medium- Slightly)
- Neutral (very neutral - average between negative and positive)
- Negative (Strongly- Medium- Slightly)

10- What are the benefits of disaster risk management for your organisation, community and for you?

Part two: Information and expertise required in risk management at the institution

11- Does the organisation have the necessary information for decision making? How does the organisation get the required information?

Can you list the sources of the data in the organisation? Classify the data quality based on the (availability, accuracy, speed of collection). The classification is from low (0) to high (5).

From	To	Availability	Quality and accuracy	speed of delivery	homogeneity	important

12- Does the organisation face any challenges in data collection? Determine the amount of effort involved in collecting information

- 10 = high effort is made to collect data, often having difficulty collecting information
- 5 = an acceptable effort is made to collect fairly simple and acceptable information
- 3= limited effort and gathers good and useful information
- 1= no effort is made, and the information is available
- What are the reasons for difficulty in the data collection

13- Is sharing information with other organisations important? Why?

14- How important is sharing information with others? Categorize this importance by the effort to publish and provide the necessary information

- 10= a great effort is made to prepare the sources with great accuracy and quality, and it is readily available to other members
- 5 = a good effort is made to provide information, and there is a fair share with others
- 3= your effort is limited to providing data for people you know only
- 1= no effort is made to cooperate or to share information with others

15- Does your opinion about disaster management change over time? How and why?

16- Do you think you can influence the committee decisions in any way? How can you do that?

17- What tools and methods will you follow? Evaluate these methods

- 10 = you have unlimited sources and methods of influence
- 5 = you have a good amount of sources and methods
- 3 = you have a limited amount of sources and methods
- 1= you don't have any idea for influence.

18- Does it take a long time to develop the system and mechanism of work in the committee? Select the amount of change that you can take, taking into account the different variables

- 10 = you directly change the system and in cooperation with other members
- 5 = you made some changes and motivate other members to cooperate with you
- 3 = you seek the change, but you need more time to not cooperate with you
- 1 = you cannot change anything because it is impossible

19- Are experts and highly qualified employees available in the organisation? Can they develop the work of disaster management in the organisation? To what extent?

20- In your opinion, what are the required experiences for members of the risk management committee?

Part three cooperation with other sectors

21- Does the organisation cooperate with other organisation in the decision-making related to the issue of reducing the risk of natural disasters? List the organisation, the type of cooperation and the cooperation degree.

			type of cooperation	type of communication		level of responsibility
From	To	(government (G) / Private (P))	(information / human / financial /physical/ other)	(regular / based on the events / not regular)	important/ Not important in the risk management	(very positive/ positive/ natural / negative / very negative)

22- In your opinion, what factors increase the level of partnership and cooperation between organisations? How can this be developed?

23- Any other comments?

2- Assessment Form (Implementation of resilience components in the Organisation)

Sector: …………………..

Assessed by: ………….

Position: ……………….

Introduction

Planning for community resilience is a process for the community and from the community, and building a resilient community needs cooperation from different systems and institutions (UNISDR 2006, 2012). Planning for resilience is essential to improve capacity to manage disasters. For example, knowing which road infrastructure to make more resilient will make transportation during a hazard event more effective, where it is needed most (Government 2011). Building institutional capacity and commitment is an essential element of this process (Brody et al. 2009) which can be supported by explicit policies and regulations that control the work of relevant institutions (UNISDR 2012, 2013). Thus Algeria, for example, expresses a political will to cope with earthquake disaster through "strengthening institutional capacities for preparedness, response and recovery; and improving institutional capacities and technologies for seismic research, monitoring, assessment and communication" (UNISDR 2013). However, high institutional capacity will not be achieved without institutional and sectoral engagement and participation (UNISDR 2012).

The aim of this form is to aid analysis of planning for natural hazard resilience in the disaster management institutions of Oman. The assessment uses resilience components provided by Twigg (2009) and the five thematic areas of the UNISDR Hyogo framework for Action (HFA);

1. Governance
2. Risk Assessment
3. Knowledge and Education
4. Risk Management and Vulnerability Reduction
5. Disaster Preparedness and Response

In this part assess the degree of implementation (0=Not-Applicable, 1= applied, 2= accepted, 3= strongly applied

No.	Component of resilience				
A	Governance	0	1	2	3
1	National and Local (Disaster Risk Reduction) DRR policy, strategy and implementation plan, with clear vision, priorities, targets and benchmarks				
2	Mechanisms for compliance and enforcement of laws, regulations, codes, etc., and penalties for non-compliance defined in laws and regulations.				
3	Community understands relevant legislation, regulations and procedures, and their importance.				
4	Routine integration of DRR into development planning and sectoral policies (poverty eradication, social protection, sustainable development, climate change adaptation, desertification, natural resource management, health, education, etc.).				
5	Human, technical, material and financial resources for DRR adequate to meet defined institutional roles and responsibilities (including budgetary allocation specifically to DRR at national and local levels).				
6	Inclusion/representation of vulnerable groups in community decision making and management of DRR				
B	Risk Assessment				
1	Community hazard/risk assessments carried out which provide comprehensive picture of all major hazards and risks facing community (and potential risks).				
2	Hazard/risk assessment is participatory process including representatives of all sections of community and sources of expertise.				
3	Skills and capacity to carry out community hazard and risk assessments maintained through support and training.				
4	Vulnerability and capacity indicators developed and systematically mapped and recorded (covering all relevant social, economic, physical and environmental, political, cultural factors).				
5	Community vulnerability and capacity assessments (VCAs) carried out which provide comprehensive picture of vulnerabilities and capacities.				
6	Assessment findings shared, discussed, understood and agreed among all stakeholders and feed into community disaster planning.				
C	Knowledge and Education				
1	Appropriate, high-visibility awareness raising programs designed and implemented at national, regional, local levels by official agencies (e.g. Health education programs include knowledge and skills relevant to crises (e.g. sanitation, hygiene, water treatment)).				
2	All sections of community know about facilities/services/skills available pre-, during and post-emergency, and how to access these (Legislation specifies right of people to be informed and obtain information about risks facing them)				

3	Inclusion of disaster reduction in relevant primary, secondary and tertiary education courses (curriculum development, provision of educational material, teacher training) nationally.				
4	Appropriate education and training programs for planners and field practitioners in DRR/ Disaster Risk Management (DRM) and development sectors designed and implemented at national, regional, local levels.				
5	Cultural attitudes and values (e.g. expectations of help/self-sufficiency, religious/ideological views) enable communities to adapt to and recover from shocks and stresses.				
6	Public and private information gathering and -sharing systems on hazards, risk, disaster management resources (incl. resource centres, databases, websites, directories and inventories, good practice guidance) exist and are accessible				
D	Risk Management and Vulnerability Reduction				
1	Policy, legislative and institutional commitment to ensuring food security through market and non-market interventions, with appropriate structures and systems.				
2	Engagement of government, private sector and civil society organisations in plans for mitigation and management of food and health crises.				
3	Structural mitigation measures (embankments, flood diversion channels, water harvesting tanks, etc.) in place to protect against major hazard threats, built using local labour, skills, materials and appropriate technologies as far as possible.				
4	Infrastructure and public facilities to support emergency management needs (e.g. shelters, secure evacuation and emergency supply routes).				
5	Resilient and accessible critical facilities (e.g. health centres, hospitals, police and fire stations – in terms of structural resilience, back-up systems, etc.),				
6	Resilient transport/service infrastructure and connections (roads, paths, bridges, water supplies, sanitation, power lines, communications, etc.).				
E	Disaster Preparedness and Response				
1	National and local policy and institutional frameworks recognise and value local and community (Disaster Preparedness) DP as integral part of the national preparedness and response system.				
2	Emergency facilities (communications equipment, shelters, control centers, etc.) available and managed by community or its organisations on behalf of all community members.				
3	Efficient national and regional Early Warning System (EWS) in place, involving all levels of government and civil society, based on sound scientific information, risk knowledge, communicating and warning dissemination and community response capacity.				
4	EWS capable of reaching whole community (via radio, TV, telephone and other communications technologies, and via community EW mechanisms such as volunteer networks).				
5	Training, simulation and review exercises carried out with the participation of all relevant government and non-government agencies.				
6	Civil protection and defense organisations, NGOs and volunteer networks capable of responding to events in effective and timely manner, in accordance with agreed plans of co-ordination with local and community organisations.				