Coastal Community Resilience Assessment Framework of Maritime Disasters Management for Saudi Arabia

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Doctor of Philosophy (PhD)

DECLARATION

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

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LIST OF PUBLICATIONS

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- The paper entitled ‘‘A Review of Coastal Community Resilience Frameworks for Disaster Management” (Under review)-Natural Hazards - Springer Journal.
- The paper entitled ‘‘Stakeholder perception of coastal community resilience to maritime disasters” To be submitted to Sustainable Cities and Society- Elsevier Journal.
- The paper entitled ‘‘Identification of Coastal Community Resilience Assessment Factors to Maritime Disasters (The Delphi Technique Consultation)” To be submitted to sustainability- MDPI.

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ABSTRACT

Saudi Arabia, the largest country in the Arabian Peninsula, is home to 33 million people, 50% of whom live within 100 km of the coastline. Due to its geographical location, bathymetric and tectonic profiles, and exposure to vulnerabilities along petroleum export routes, the country faces increasing risks from both natural and human-induced maritime disasters, especially along the coastlines where significant centres of economic activities are located. Limited studies on coastal resilience in the region and the lack of effective disaster risk management in the country inspired this research to identify maritime disaster risks and impacts and develop a structured framework to assess coastal community resilience through stakeholder consultations. The work was accomplished in the following five stages.

First, a systematic literature review identified potential maritime disaster risks at present and in the future. Three types of risks to natural disasters are found: local tsunamis in the Red Sea and Arabian Gulf due to the movements of the Arabian tectonic plate; cyclones and tsunamis originating in the Indian Ocean; and the projected sea level rise and associated impacts because of anthropogenic climate change. Moreover, as the top oil-producing country, the Saudi economy relies on oil export routes, which are prone to human-induced maritime disasters such as oil spills, piracy and terrorism. The review of disaster risk assessment and resilience frameworks revealed that most focused primarily on governance and infrastructure, and their development did not adequately consider stakeholders' views. The review also found gaps in policies and response to disaster risks, some of which were specific to the unique socio-cultural context of Saudi Arabia. Stage two entailed an assessment of stakeholders' perceptions of the previously identified factors of resilience to maritime disasters. Demographic differences in perception were investigated using principal component analysis. Identified factors were examined by a panel of experts using the Delphi technique in stage three. Two rounds of Delphi consultation helped refine the identified factors further and obtain experts' consensus on their relevance for assessing resilience. The outcome was a three-level framework with constituent indicators, split into four interrelated dimensions: infrastructure, society and economy, environment and climate change, and government and institutions. In stage four, analytic hierarchy process was used to assign a level of importance to each group of indicators using pair-wise comparisons. Weights were computed to enable the aggregation of scores from indicators and dimensions into an overall figure. In the final stage, the resulting Coastal Community Resilience to Maritime Disasters (CCRMD) was validated by comparing it to three well-established frameworks (LDRI, CDRI 3 and CRDSA) that were employed in similar contexts and, by engaging the experts to verify the relevance, implementation and adaptation of the framework in Saudi Arabia.

This research developed a framework for assessing coastal community resilience to maritime disasters, which is comprehensive in terms of its constituent criteria and is more contextual than previous works because of the structured engagement with stakeholders in each development stage. As a regional first, the framework is a step forward in the development of well-managed and established protocols and policies governing the management of risks of maritime disasters in Saudi Arabia and potentially the Gulf.

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Chapter 1
Introduction

Chapter 1 opens with a background on the research, outlining the maritime disaster risks faced by coastal communities and the importance of developing effective means to mitigate the risks. The Chapter discusses the research aims, objectives and the research questions posed, thereby underscoring the need for this research both in the context of the Kingdom of Saudi Arabia and globally. It then proceeds to discuss the research plan, ethical considerations and the contributions of this research. Finally, it ends with a brief outline of the following chapters, providing a picture of how the thesis is organised.

1.1 Background

Rapid economic and population growth, along with the increasing technological development, have increased the need for a number of countries to utilise their coastal areas more efficiently (Cicin-Sain and Belfiore, 2005, Costanza and Farley, 2007, McGranahan et al., 2007). For instance, in the Kingdom of Saudi Arabia (KSA), over 50% of the total population currently live within 100 km of the coastlines (Abualnaja, 2011). Disaster risks arising from the geographical, bathymetric, and tectonic profiles of the coastal areas in the KSA are reflected in the numerous disasters that occurred in the area in the recent past (Lam et al., 2015).

There is a growing concern over the rise in disasters and their associated impacts across the globe (EM-DAT, 2015). Figure 1-1 compares the frequency of disasters across four continents from 1990 to 2015, highlighting Asia's vulnerability to disasters. From a general perspective, water-related disasters, including maritime, accounted for nearly 90% of the disasters in the world (UNISDR, 2015) with significant impacts on people, society and economy. 577 disasters occurred around the world in 2015 alone causing 33,445 deaths, affecting more than 103 million people and causing more than US$70 billion worth of damage (EM-DAT, 2015).

Maritime disasters have been defined as "those natural and man-made disasters that occur at the interface between the ocean and the coastline. These frequent disasters include human-caused actions and natural events that threaten the life and stability of coastal communities" (IOTWSP, 2007). In general, there are two types of maritime disasters: natural and man-made. A natural disaster is a complex system, involving a number of interactions, under specific conditions, between natural disaster inducing factors and socio-economic systems (Ahmad et al., 2016). Natural disasters such as tropical cyclones, rising sea levels and tsunamis, typically affect large numbers of people.

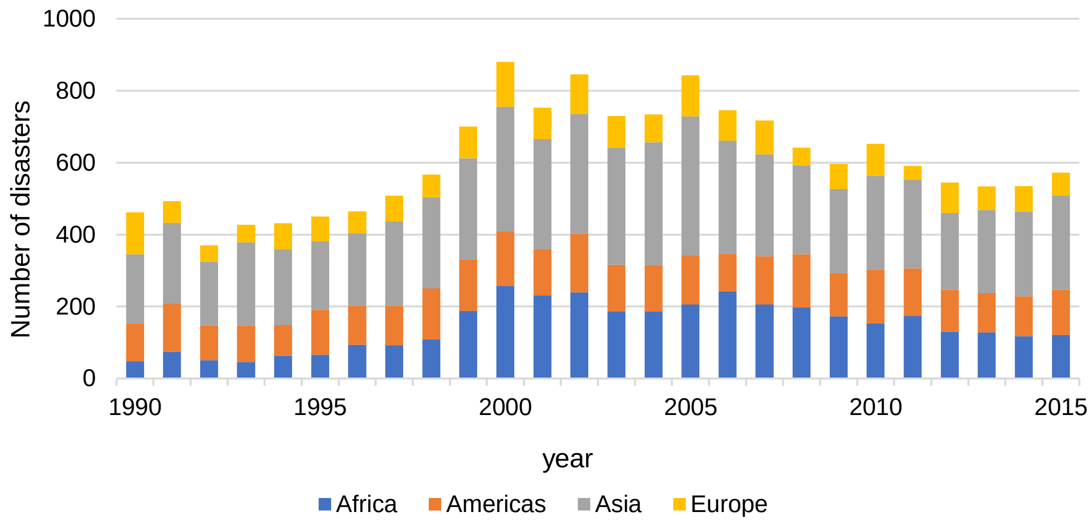

Figure 1-1 Frequency of disasters from 1990 to 2015: A comparison of continents

Roughly every 10 years, the death toll reaches one million, with many more millions of people rendered homeless (Wei et al., 2015). Damage to the global economy caused by natural disasters accounted for US$40 billion in the 1960s, US$70 billion in the 1970s, and US$120 billion in the 1980s (Wei et al., 2015). For example, the Indian Ocean Tsunami of 2004 off the west coast of Indonesia indicates that maritime disasters still continue to cause great loss of human life, environmental damage, major disruption of infrastructure, and economic loss.

On the other hand, man-made disasters take place as a direct result of human action (Shaluf, 2007) and have increased exponentially since the mid-1990s (Coleman, 2006). These disasters can be sudden, resulting in a considerable physical impact. This is exemplified by the 2010 oil spill in the Gulf of Mexico's coastal region, which cost approximately US$6.1 billion (Sawada et al., 2011). Furthermore, maritime terrorism and piracy places global economies and business infrastructures at risk. This is particularly true of the oil industry and only serves to undermine confidence in communication along global sea lines, which has also contributed to increased maritime insurance costs (Shane and Magnuson, 2016). Thus, both types of disasters have the potential to cause severe damage to human life, economic development, the built environment and natural resources, with coastal regions being the most commonly affected (Lam et al., 2015).

According to Huq (2016), disaster risk management can be defined as the organisation and implementation of improvements to deal with any potential risks and impacts of disasters. This includes emergency operations and rebuilding communities after a disaster has occurred. Mikulsen and Diduck (2016) have offered a comprehensive explanation of disaster risk management, defining it as “the sum total of all activities, programs and measures which can be taken before, during and after a disaster with the purpose of avoiding a disaster, reducing its impact or recovering from its losses.” Most studies (e.g. (Mikulsen and Diduck, 2016, Kusumasari et al., 2010, Shaluf, 2008) have grouped disaster risk management into four phases: mitigation, preparedness, response and recovery.

Mitigation comprises all pre-activities that can prevent or reduce the impact of a disaster (Shaluf, 2008) such as the availability of better facilities and the number of physicians. Preparedness, on the other hand, includes planning, public awareness, education, the design and implementation of a warning system, training, risk communication, research identification and community preparation for disaster response (Mat Said et al., 2011). Davis et al. (2012) state that the preparedness phase is an important component of any disaster risk management plan because it helps curb any negative impacts associated with disaster. The involvement of the community is essential in pre-disaster preparedness and disaster response. It must, therefore, form part of any legislation or planning instruments and be supported by local governance to enhance the community’s resilience (Van Aalst et al., 2008).

Response, refers to any activities that follow a disaster whether immediate, short-term or long-term, and constitutes the third phase (Lin Moe and Pathranarakul, 2006). These activities serve to provide victims with emergency assistance by preserving life, property, the environment and any social, economic or political structures in communities. The final phase, recovery, is a long-term plan that must be carried out until all systems return to normal or improve following a disaster. Shaluf (2008) claims that this can be achieved through damage assessment, debris removal and disaster assistance centres.

Overall, disaster risk management can be said to involve a reduction in a community’s vulnerability or an increase in its resilience (Thomalla et al., 2006). Although resilience may appear to be the opposite of vulnerability, Twigg (2007) claims that the terms are related. Numerous researchers such as (Spellman and Whiting, 2006, Arbon, 2014, Ahmad et al., 2016) have emphasised the importance of resilience over vulnerability reduction when facing disasters. Recently, the United Nations International Strategy for Disaster Reduction (UNISDR) proceeded to integrate resilience into its plan (Alshehri et al., 2015b). Therefore, all policies, practices and theories relating to disaster risk management need to be incorporated to achieve disaster-resilient communities (Chang and Shinozuka, 2004).

To be able to develop and integrate resilience into disaster risk management strategies it is crucial that a deep understanding of this concept is gained. The term resilience originates from the Latin word *resilire*, meaning ‘rebounding back’ (Alexander, 2013).

Over time this had progressed to be a description of elasticity and eventually progressing to the definition of being resistant by not being susceptible to an event in this case, the impacts of natural disasters. Resilience is an adaptable conception that can be employed to aid coastal communities in dealing with and overcoming the impacts of disasters. Not all researchers view resilience as a useable concept with some deeming a plethora of definitions as the reason for this (Vale, 2014). This is not a strong argument as the concept of resilience can easily be made useable by developing a deep understanding of the particular situation for which resilience needs to be developed.

The extensive applicability of resilience across different fields of study has led to it being a topic of continual discourse. Some question its wide applicability, which has, however, later shown to be dependent on the type of resilience under study; e.g. whether it is ecological or engineering resilience (Davoudi et al., 2012). Various applications of resilience have also been reported as a response to an emergency, as argued by Davoudi et al., 2012 when discussing the London climate adaptation strategy. Regardless of the semantics, Davoudi et al. had clearly alluded to the four stages or disaster risk management; namely, prevent (mitigation), prepare, response and recovery. Thus, one can argue that resilience in this case was not simply a response to an emergency but also involved preparatory steps prior to the advent of the disaster. Therefore, we see that the definition of resilience has progressed from the definition of ‘rebounding back’ to more of a dynamic concept involving the adaptability to the impacts of disasters and changes in communities.

One study has reflected on resilience as a mechanism of survival that employs a top down approach, although it limits the definition of resilience by only accounting for the response and recovery phases (Valikangas, 2010). Others have viewed resilience as simply an alternative word for planning (for disasters) (Porter and Davoudi, 2012). In fact, resilience encompasses both these concepts as it involves preparatory planning stages as well as stages of response that aid survival. Thus, the definition and scope of resilience are as important as the measures identified to assess and enhance resilience. By encompassing all disaster risk management stages in the definition of resilience and in its application, it becomes evident that resilience is not just a concept but a dynamic way of building frameworks for disaster risk management.

1.2 Research problem

Saudi Arabia (KSA) is no exception in terms of its susceptibility to the risk of maritime disasters. With a population of 32.9 million (World Bank, 2019), KSA is the largest country located on the Arabian Peninsula, and approximately 50% of its population, live within 100km of a coastline (Abualnaja, 2011). These coastal areas are also the focus of a large amount of economic activity. The KSA also has the second largest oil reserves in the world. There are 161 active rigs in the Arabian Gulf, through which 90% of the national oil exports and 55% of global oil exports are transported (ALAli, 2013). In addition, the Red Sea annually accommodates an estimated 33,000 ships and 6,500 tankers and conveys 7% of total global oil consumption (van Ginkel, 2014). The Saudi Port Authority reports that the country's ports receive around 13,000 cargo ships annually (GAS, 2014), while revenues generated from oil account for 70% of the economy (Stats.gov, 2017). These facts demonstrate that the KSA's coastal regions are an important contributor to the country's economy.

KSA's coastlines are increasingly at risk of maritime disasters including tropical storms, tsunamis, rising sea levels and oil pollution. These risks stem from its geological, tectonic profile, climate change and its bathymetrical profile, and cause high losses both financially and in terms of lives. One of the key challenges in managing disaster risks and enhancing resilience is that the country does not have well-defined roles and responsibilities for disaster risk management within its governance structure. The ineffective governance structure has led to the gap in the recording of disaster events and their impacts, which in turn affects the development of effective policies and mitigation measures to deal with current and future disasters. It, therefore, follows that there is a critical need to develop a local framework to assess coastal community resilience for maritime disasters risk management, especially when one does not currently exist for Saudi Arabia.

1.3 Aims and objectives

This research aims to identify maritime disaster risks and their impacts with a view to develop a locally-relevant assessment framework for enhanced community resilience to maritime disasters in the Saudi Arabian context.

The objectives of the research are to:

a) Review the state-of-the-art in disaster risk management and resilience with particular reference to maritime disasters in Saudi Arabia and surrounding regions to identify the indicators that affect community resilience.

b) Engage stakeholders and assess their perceptions of the challenges facing coastal communities' resilience and the priorities concerning maritime disasters.

c) Investigate expert opinions and reach consensus on the relevance of the identified indicators to enhance community resilience in Saudi Arabia through a consultative process.

d) Prioritise and develop a weighting system for local community resilience indicators through expert consultation to enable assessment and benchmarking.

e) Integrated (a) to (d) to develop a framework for assessing coastal community resilience.

f) Validate the developed framework.

1.4 Research questions

As a result of the above discussion, the overarching research question is *how can a local framework be developed to assess coastal community resilience for maritime disasters risk management within a Saudi Arabian context?* To answer this question and achieve the identified aim and objectives, the following sub research questions were formulated.

- RQ1: Which maritime disasters pose a risk to the coastal communities of Saudi Arabia and what are their likely impacts?
- RQ2: Are the well-established coastal community resilience assessment frameworks appropriate for the Saudi Arabian context?
- RQ3: Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?
- RQ4: How can identified resilience factors be incorporated into a local coastal community resilience assessment framework?
- RQ5: What is the most appropriate applicable weighting system to reflect an accurate assessment of community resilience in the context of Saudi Arabia?

1.5 Research plan

This study intends to enhance the resilience of coastal communities in Saudi Arabia to maritime disasters through the development of a coastal community resilience assessment framework. This will be accomplished by adopting a mixed methods approach including the review of the literature, identification of the main maritime disasters (natural and man-made) facing Saudi Arabia and the assessment of the opinions of stakeholders and experts.

Overall, the study was structured into theoretical and empirical stages, to ensure that the research questions are examined comprehensively and effectively. The initial theoretical assessment involved the following:

a) A critical systematic review of existing coastal resilience assessment frameworks, globally; and

b) The elucidation of applicable assessment criteria determined through a comparative analysis of the selected frameworks to identify differences and similarities in the criteria; thus, assembling a list of criteria that are relevant for the Saudi context.

The empirical stage involved the following:

a) The examination of both public and expert opinions on the identified assessment criteria to define a list of relevant resilience indicators and sub-indicators;

b) Experts were consulted on the relevance of the identified list of indicators and sub-indicators by developing a consensus through a Delphi exercise, resulting in a refined list of indicators and sub-indicators;

c) The refined list is then utilised to rank indicators and sub-indicators and a weighting system was developed by employing analytic hierarchy process (AHP). This weighting scale allowed the prioritisation of the various assessment factors in terms of their relevance to establishing the resilience of the coastal communities in the KSA; and

d) Finally, the framework was validated by comparing it to the well-established frameworks and, by engaging the experts to verify the relevance, implementation and adaptation of the framework in Saudi Arabia.

The systematic adoption of the theoretical assessments into an assessment framework has also led to the development of a methodology that can be generally applied in future investigations on the resilience of different communities and in different contexts.

1.6 Contributions of this study

The key contributions of this thesis are as follows.

a) **Insights into maritime disaster risk and exposure in KSA**: The most frequently occurring natural disasters within the context of Saudi Arabia are tropical cyclones and tsunamis, while man-made disasters are related to oil spills, piracy, terrorism and vessel disasters. In particular, this study highlights that due to being located on the Arabian Tectonic Plate, the Arabian Gulf is vulnerable to natural disasters, while the Red Sea, a key location for the export and transportation of oil to Europe, is most commonly affected by man-made natural disasters. This study also recognises the potential long-term impact of sea level rises on Saudi Arabia's lowland areas due to anthropogenic climate change. The projected sea level rise is mostly likely to result in the loss of land, and a deterioration in water quality, with a particularly detrimental impact on the economy and the inhabitants. Saudi Arabia's exposure and risk to maritime disasters are different from disasters experienced in regions across the globe for which resilience frameworks have been developed. This is understandable as the different regions are likely to have varying contributing factors.

b) **Identification of resilience criteria and their importance**: Stakeholder consultations with experts and the public revealed the influence of prior experience and knowledge on perception of risk. While the public regarded tackling oil spills[1] as the most notable challenge in Saudi Arabia, the experts opined on the importance of environmental factors including climate change. The systematic review of existing coastal community resilience frameworks for disaster risk management investigated their content, structure, and assessment method. Sixty-four critical resilience criteria under four dimensions were identified by analyzing the convergence and divergence of the consideration of assessment indicators in the reviewed frameworks.

c) **Global frameworks are inadequate for assessing local/regional resilience**: Existing frameworks focus mostly on governance and institutions, infrastructure, and society and the economy. Despite significant risks, the impacts on the environment and potential risks of climate change are not prioritized as much. The reduced emphasis of environment and climate change factors in existing frameworks was regarded as a shortcoming. Only 22% of the frameworks consider future risks, rendering the remainder inadequate for assessing projected risks from climate change. 56% of the frameworks considered a single disaster type. Community resilience is inherently multi-dimensional and often multi-disaster. Therefore, the interrelationships between multiple disaster should be adequately addressed in any assessment framework.

d) **Prioritisation of enviornmental factors in resilience assessment**: The reduced emphasis of environment and climate change factors was regarded as a shortcoming of the nine frameworks assessed through the literature review that was adjusted and corrected in the CCRMD framework. The CCRMD framework, however, does concentrate a greater proportion of resilience criteria on environmental and climate change factors. This would therefore ensure reduced effects on the ecology and climate which would not exacerbate issues such as climate change which in turn could lead to further increases in the frequency of

[1] Media exposure of maritime disaster incidents such as terrorism and oil spills may have contributed to the collective public perception of their importance. Long term gradual environmental impacts, despite causing more damage overall do not necessarily register as being more important than sudden-onset disasters.

maritime disasters. Some methodologies involved include the prevention of ecological destruction and reduction of water waste.

e) **Stakeholder involvement is critical to the development of resilience assessment frameworks**: None of the reviewed frameworks consulted the full spectrum of stakeholders (public, government and experts) during the development process, which compromised their applicability, acceptability and effectiveness. This study has also resulted in the identification of a methodology for the development of a framework that incorporates the opinion of the public and field experts and that enables the elucidation of resilience factors in coastal communities. Previous frameworks did not seek public opinion a factor that this study shows can serve to highlight issues that are at risk that are only likely to be identified by the communities living in risk regions. Thus, this is a highly efficient approach to identification of such factors which can include factors such as the impact disasters would have on livelihood in the region as well as the level of awareness and training of the community. Overall, public perception led to the better targeting of essential factors affecting resilience and formed an ideal initial foundation for the expert analysis that followed in the form of the Delphi technique and the Analytical Hierarchy Process.

f) **Systematic method for ranking and weighting of indicators**: Primarily, this study has also led to the development of an evaluation system through the development of the framework and the use of the AHP. This is significant in that it allows for all criteria including the dimensions, indicators and sub-indicators as well as the framework as a whole to be evaluated through weighting. This weighting can therefore also be applied to similar examinations of resilience indicators in future covering maritime and other forms of disasters that can endanger a community.

1.7 Organisation of the thesis

This thesis is divided into nine chapters. The contents of each chapter are summarised below to give an overview of the organisation of the thesis. The relationship between study objectives, questions, methods and chapters are given in Table 1-1.

Chapter 1: Introduction. This chapter covers the background of maritime disasters and their risk to coastal communities with regard to the Kingdom of Saudi Arabia. It details the study aims, objectives and research questions. It also outlines the contribution to knowledge that this study offers.

Chapter 2: Maritime disasters in Saudi Arabia. The second chapter covers relevant literature on the various types of maritime disasters both man-made and natural and their impact on coastal regions of the KSA. The types of disasters are detailed together with their impact. Therefore, this chapter will answer the first research questions as detailed above in section 1.4.

- RQ1: Which maritime disasters pose a risk to the coastal communities of Saudi Arabia and what are their likely impacts?

Chapter 3: Coastal community resilience frameworks. The second chapter covers relevant literature on coastal community resilience frameworks. A review of the literature is outlined, and a critical comparison of well-established global frameworks applied in the assessment of coastal community resilience is conducted, thereby aiding in the specification of relevant indicators and sub-indicators that are used in the development of the target framework. Therefore, this chapter will answer the second research question as detailed above in section 1.4.

- RQ2: Are the well-established coastal community resilience assessment frameworks appropriate for the Saudi Arabian context?

Chapter 4: Methodology. This chapter is a review of the methodology used in this study. It provides an explanation of the methodology and supporting software. Moreover, it provides justification for the methodology selected, the approach used and the philosophy behind it. More specifically this chapter provides a background for the public perception on the research topic as well as the two techniques the Delphi technique and the Analytical Hierarchy Process as well as software employed, namely Expert Choice. Furthermore, it details the mathematical formulae applied throughout the development and in the application of the final framework.

Chapter 5: Stakeholder perception of resilience to maritime Disasters. This chapter set to define the public's perception to resilience indicators for maritime disasters. It details the composition of a questionnaire used to examine public perception and to record the publics' demographics and characteristics. This allows for the data to be better defined for analysis. Analysis of the data collected was conducted using Principal Component Analysis. The results generated helped prioritise the indicators according to public opinion, their demographic and characteristics. This chapter therefore responds to the third research questions which ask:

- RQ3: Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?

Chapter 6: Identification resilience assessment factors. This chapter opens by presenting the assessment criteria (indicators and sub-indicators) indicated from the literature review and the publics' perception in the context of Saudi Arabian coastal communities. It follows on to provide the outcomes of the Delphi consultation and discusses these in detail. Thus, it results in the refinement of the proposed assessment criteria specifically in the context of the Kingdom of Saudi Arabia. In so doing it attains a response to the third and fourth research questions which ask:

- RQ3: Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?
- RQ4: How can identified resilience factors be incorporated into a local coastal community resilience assessment framework?

Chapter 7: Prioritisation of resilience assessment factors. This chapter details the background and methods used in AHP. The outcome of the AHP and the analysis of these are detailed. Thus, this chapter completes chapter six by prioritising the dimensions, indicators and sub-indicators that had been indicated according to their weighted outcomes and using Express Choice software. It also details mathematical formulae applied in the framework being developed. Ultimately, the last two research questions (questions four and five) are covered by this chapter.

- RQ4: How can these identified resilience factors be incorporated into a local coastal community resilience framework?
- RQ5: What is the most appropriate applicable weighting system to reflect an accurate assessment of community resilience in the context of Saudi Arabia?

Chapter 8: Development and validation of the framework. This chapter details how the framework for measurement of the resilience of coastal communities in the context of the KSA was developed. It also seeks to verify the developed framework by assessing the suitability of the framework for the coastal communities in the KSA. It achieves this through a comparison of this framework to various frameworks identified through the literature review.

Chapter 9: Conclusion. This chapter offers a summation of the study. It summarises the research finding and provides answers for each research question posed. It highlights the contributions to knowledge and the study limitations and builds on all these by recommending future areas of research. Furthermore, this chapter concludes by offering suggestions for the management of risks of maritime disasters and the construction of community resilience in the KSA.

Table 1-1 Relationship between study objectives, questions, methods and chapters.

Objective	Research Questions	Method	Chapter
To establish the maritime disasters that pose a risk to the Kingdom of Saudi Arabia To identify criteria that are important for the measurement of coastal community resilience and determine their applicability to the Saudi Arabian context	RQ1- Which maritime disasters pose a risk to the coastal communities of Saudi Arabia and what are their likely impacts? RQ2- Are the well-established coastal community resilience assessment frameworks appropriate for the Saudi Arabian context?	Literature Review	Two & Three
To engage stakeholders and assess their perceptions of the challenges facing coastal communities' resilience and the priorities concerning maritime disasters	RQ3- Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?	Survey (Questionnaire)	Five
To **investigate** expert opinions and reach consensus on the relevance of the identified indicators to enhance community resilience in Saudi Arabia through a consultative process To prioritise and develop a weighting system for local community resilience indicators through expert consultation to enable assessment and benchmarking	RQ3- Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context? RQ4. How can identified resilience factors be incorporated into a local coastal community resilience assessment framework?	Consensus (Delphi)	Six
	RQ4. How can identified resilience factors be incorporated into a local coastal community resilience assessment framework? RQ5- What is the most appropriate applicable weighting system to reflect an accurate assessment of community resilience in the context of Saudi Arabia?	AHP	Seven
To develop a framework for assessing coastal community resilience To **validate** the developed framework		validation	Eight

Chapter 2

Maritime disasters in Saudi Arabia

This chapter reviews previous studies on maritime disasters and coastal community resilience frameworks. It details a systematic review of the literature covering the subject of maritime disasters that face the KSA and provides a visual illustration of these disasters and how they approach the Kingdom. It explains the impact of these disasters and the need for clear leadership and effective policies on disaster risk management for the KSA.

2.1 Overview

Coastal zones are more densely populated than non-coastal areas (Neumann et al., 2015) and there is a global ongoing trend of coastal migration associated with demographic changes (Hugo, 2011). Urbanisation rates and population growth in coastal areas are higher than the hinterland, driven by coastward migration and rapid economic growth (Smith, 2011). The Kingdom of Saudi Arabia (KSA), the largest country in the Arabian Peninsula, is no exception. As of 2017, It has a population of 32.9 million (World Bank, 2019), spread across thirteen administrative regions. Around 50% of its population live within 100 km of the coastline (Abualnaja, 2011) where major centres of economic activities are located. In addition, KSA has the second[2] largest oil reserve in the world with 161 active rigs in the Arabian Gulf. Most of the national (90%) and more than half of the global oil exports (55%) are transported through the Arabian Gulf (ALAli, 2013). Besides, around 33,000 ships and 6,500 tankers carrying about 7% of the oil consumed globally pass through the Red Sea every year (van Ginkel, 2014). According to the Saudi Port Authority, around 13,000 cargo ships arrive in its ports every year (GaStat, 2014). Revenues generated from the oil industries account for 70% of the total economy (GaStat, 2017). Saudi coastlines, therefore, play a significant role in its economy.

Due to its geographical, tectonic and bathymetric profiles, coastal areas of Saudi Arabian have been subjected to numerous maritime disasters, particularly during the last two decades (Abualnaja, 2011, Lam et al., 2015, Ewing and Synolakis, 2011). Over one thousand people lost their lives between 1991 and 2015 from maritime disasters, which were responsible for economic losses amounting to billions of US dollars (USD). Despite being highly vulnerable to a wide range of natural and man-made disasters, attempts to systematically record and analyse the historic disasters in KSA, and their associated impacts have been limited (Pararas-Carayannis, 2013), which is of vital significance for

[2] As of 2017, Venezuela has the largest reported oil reserve of 302,250 MMbbl (million barrels). KSA has the second largest reported oil reserve of 266,208 MMbbl. However, KSA is the top producer of oil in the World with a daily production of 4.4 times that of Venezuela in 2016. Data source: (OPEC, 2017).

designing effective policies and interventions to reduce their impact on the society, economy, and environment.

Maritime disasters are defined as “natural and man-made disasters that occur at the interface between the ocean and the coastline. These frequent disasters include human-caused actions and natural events that threaten the life and stability of coastal communities” (IOTWSP, 2007). The Indian Ocean tsunami in 2004 caused great loss of human life, environmental damage, major disruption of infrastructure and economic losses, exposing the maritime disaster vulnerability of coastal regions across several countries of South and Southeast Asia. Even though a maritime disaster has a low probability, it has serious consequences (Yan et al., 2009). Natural maritime disasters, such as tropical cyclones, rising sea levels and tsunamis, are an inevitable aspect of the maritime environment and can lead to death, economic decline and ecological damage. Moreover, the risk from natural disasters are projected to increase around the coastal communities as a consequence of climate change (Kantamaneni et al., 2018).

In contrast, most man-made maritime disasters are the result of grounding, explosions, fire or collision, many of which can lead to sea water being polluted with oil, contaminated water and other harmful substances (Akyuz et al., 2017). Furthermore, maritime terrorism and piracy results in considerable risk for global economies and business structures, especially the oil industry, which undermines confidence in communication along global sea lines and has also contributed to increased maritime insurance costs (Shane and Magnuson, 2016).

The lack of understanding of the source of the threat or disaster is a major concern. The breakdown of information gathering and communication also play an important role. Unfortunately, there is currently no official central database that lists historic disasters to have affected Saudi Arabia in the past (Pararas-Carayannis, 2013). This is due to a lack of clearly-defined leadership and a failure to act decisively. Lack of leadership vision can be defined as the failure to classify an incident as a disaster, which shows a general poor understanding of the system and situational awareness. The failure to act is a result of the overlapping of responsibilities of agencies. There is little coordination between the different parties that provide infrastructural services (Altalhi, 2013). All of these factors have contributed to the delay in founding a national centre for disaster risk management.

2.2 Type and characteristics of maritime disasters

This study provides an insight into the maritime disasters affecting the KSA coastlines over the last two decades and their associated impacts based on a review of existing literature and data sources on maritime disasters. Table 2-1 illustrates the classification of the included papers according to five different categories: (a) disaster type; (b) number and year of occurrences; (c) economic impact; (d) mortality; and (e) location. The data collected on these disasters are illustrated on a map of KSA in Figure 2-1, illustrating their clustered location and frequency of occurrence. The detailed findings related to each disaster extracted from the systematic review are discussed in the following sub-sections.

2.2.1 Natural maritime disasters

The natural maritime disasters facing the globe are varied and are completely dependent on a coastal communities location and climatic conditions. In the case of the KSA, natural maritime disasters that can face it come in the form of tsunamis, tropical cyclones and sea level rises.

Tsunamis form a potential danger for large areas of the globe, but the risks are higher in those areas with high seismic activity in marine and coastal regions (Villholth and Neupane, 2011). The literature review reveals that the largest source of tsunamis in the Eastern Hemisphere consists of the Sumatra subduction zone on the eastern side of the Indian Ocean (Jaffe et al., 2005). The height of a tsunami is governed by water depth; i.e. the deeper the water, the larger the potential size of the tsunami. The depth of the Indian Ocean would then allow such waves to travel long distances with little loss of energy (Jordan, 2008). Thus, the Indian Ocean is considered as the main source of tsunamis capable of impacting on the coastline of eastern KSA (Kumar and Alam, 2010, Pararas-Carayannis, 2013).

The subduction of the Indian Plate by the Burma Plate resulted in a megathrust earthquake under the Indian Ocean with the epicentre off the west coast of Sumatra, Indonesia on 26 December 2004 (Jaffe et al., 2005). The earthquake triggered a series of devastating tsunamis along the coasts of fourteen countries bordering the Indian Ocean (i.e. south-east Arabian Peninsula) and killed 250,000 people. It was the first event since the 1964 Alaska earthquake to cause death and destruction across an oceanic basin and is regarded as one of the deadliest disasters in recorded history (Okal et al., 2006). As illustrated in Table 2-1 and Figure 2-1, waves of one metre in amplitude from the tsunami reached the south-eastern coast of the Arabian Peninsula within seven hours, the Gulf of Oman within eight hours, and Dammam, a coastal city of KSA on the Arabian Gulf, in twelve hours[3].

[3] The nearest locations to KSA's coastline (Dammam) from which the travel time of the tsunami has been calculated are: Doha and Dukhan in Qatar; and Kuwait City in Kuwait (Kumar and Alam, 2010).

Table 2-1: Disasters affecting Saudi coastlines between 1991 and 2015

Data source	Year of disaster	Type of disaster	Classification of disaster	Frequency	Economic Impact	Mortality	Location of disaster
Tawfiq and Olsen (1993), Bejarano and Michel (2010), Joydas et al. (2012), Jones et al. (1998), Danish (2010) Readman et al. (1996)	1991	Oil spill	Man-made	1	$55 million	N/A	Arabian Gulf
Langworthy et al. (2004), Hong and Ng (2010), Winner et al. (2012), Raymond (2006), Elentably (2013)	2000	Terrorism	Man-made	1	$250 million	17	Arabian Sea (Aden Harbour)
Jordan (2008), Kumar and Alam (2010), Kumar (2013), Pararas-Carayannis (2013)	2004	Tsunami	Natural	1	N/A	N/A	Arabian Sea (the South-East Arabian Peninsula) and Arabian Gulf
Soliman (2013), Bjornstig and Forsberg (2016), Ashour (2015), El-Ladan and Turan (2012)	2006	Vessel disasters	Man-made	1	N/A	1161	Red Sea
Wang et al. (2012), Anisetty et al. (2013), Mashhadi et al. (2013)	2007	Cyclone Gonu	Natural	1	$4 billion	49	Arabian Sea (The south-east Arabian Peninsula)
Ploch et al. (2011), Bryant et al. (2014), UNITAR (2014), ICC–IMB (2015), Townsley et al. (2015)	2010	Piracy	Man-made	17	N/A	N/A	Red Sea, Arabian Sea
	2011	Piracy	Man-made	13	N/A	N/A	Red Sea, Arabian Sea
	2012	Piracy	Man-made	15	N/A	N/A	Red Sea, Arabian Sea
	2013	Piracy	Man-made	2	N/A	N/A	Red Sea, Arabian Sea
	2014	Piracy	Man-made	3	N/A	N/A	Red Sea, Arabian Sea
ESSO (2015b), ESSO (2015a), Kumar (2016)	2015	Cyclone Chapala	Natural	1	N/A	8	Arabian Sea (the South Arabian Peninsula)
	2015	Cyclone Megh	Natural	1	N/A	18	Arabian Sea (the South Arabian Peninsula)
El-Raey (2010), Hereher (2016), Babu et al. (2012)		Sea level rise	Natural	Continuous	N/A	N/A	The metropolitan area along the eastern coastline comprising Dammam, Dhahran, Al Khobar are more vulnerable

Notes: N/A: Not Available; ESSO: Earth System Science Organisation; ICC IMB: International Chamber of Commerce International Maritime Bureau; UNITAR: United Nation Institute for Training and Research

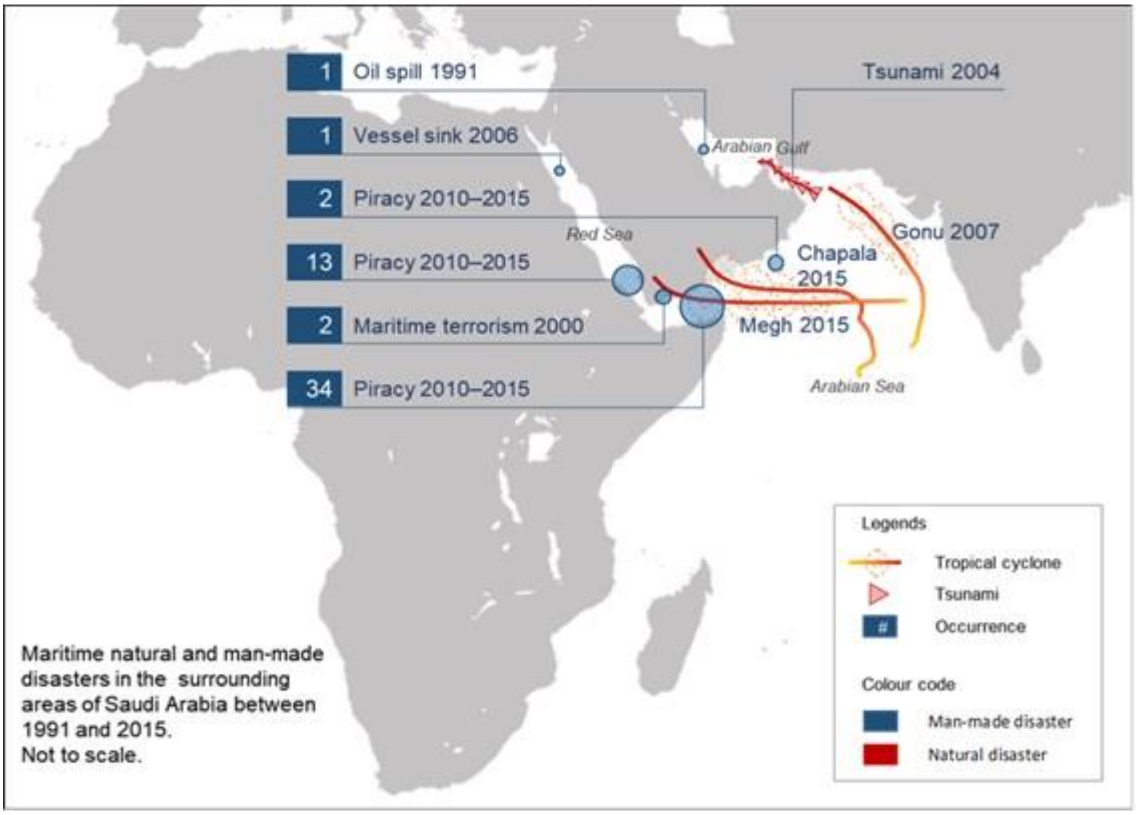

Figure 2-1 Number of reviewed sources according to type of maritime disaster

KSA is located on the Arabian Tectonic Plate that runs the length of the sea floor beneath the Red Sea; as a result, a large number of earthquakes have occurred in this region (Jordan, 2008). Several studies suggest that earthquakes could occur along the Red Sea and in the southern regions of Iran, and trigger tsunamis along the coastline of KSA on the Arabian Gulf and the Red Sea (Pararas-Carayannis, 2013, Kumar, 2013, Jordan, 2008).

The second form of natural disaster are the **tropical cyclones**. These can typically reach a width of several hundred kilometres, and cause destructive high winds, torrential rain and storm surges (NASA, 2014). Tropical cyclones are relatively rare in the Arabian Peninsula; most storms that occur in this area are relatively small tornadoes (FAO, 2015a). As illustrated in Figure 2-2, only six category 3 or stronger tropical cyclones occurred over the Arabian Sea during the study period between 1991 and 2015. The map[4] in Figure 2-2 also shows that tropical storms and depressions are active mostly in the Arabian Sea. Of the six category 3 and above tropical cyclones, Gonu, Chapala, and Megh are notable in terms of their impact (Henson, 2015). This is attributed to several factors, including the relatively small size of the Arabian Sea (i.e. spans a total area of 3,861,672 km2), the short length of the tropical cyclone seasons (i.e. May to early June,

[4] The map is produced using the Historical Hurricane Tracks tool, developed and maintained by the National Oceanic and Atmospheric Administration (NOAA) in the United States. https://coast.noaa.gov/hurricanes/

and late October to November) due to southwest monsoons and the presence of a large amount of dry air over the Arabian Peninsula (FAO, 2015a). Saudi Arabia suffered from tropical cyclones comprising large rotating tropical storms with wind of at least 119 km to severe cyclones reaching over 250 km.

Gonu is the most powerful cyclone to have formed in the Arabian Sea (Fritz et al., 2010, Wang et al., 2012, Anisetty et al., 2013). As illustrated in Figure 2-2, Gonu originated in the north-west and crossed the Omani and Makaran coasts before hitting the south-east coastline of KSA on 7 June 2007(Anisetty et al., 2013). It is reported to have caused severe damages, and accounted for economic losses of around USD 4.216 billion (Anisetty et al., 2013).

Chapala is recorded as the second strongest cyclone to form in the Arabian Sea (Henson, 2015, FAO, 2015a). As illustrated in Figure 2-2, It originated from a low-pressure area in the Eastern Arabian Sea on 28 October 2015, making a landfall on Yemen's southern coast, and flooding the port city of Mukalla as a result (ESSO, 2015b). During the cyclone, a combination of strong winds and flooding severely damaged the port city, resulting in the loss of five lives and injuring over one hundred people (Kumar, 2016, UNISDR, 2015). Following the dissipation of Chapala, Megh was formed in the central Arabian Sea on 8 November 2015, as shown in Figure 2-2, (ESSO, 2015a). It passed directly over the Island of Socotra before hitting the southern coast of Yemen causing more extensive devastation than Chapala (FAO, 2015b).

The literature also shows that all the recorded tropical cyclones along the Arabian Peninsula have occurred on its southern edges. This has led the Indian Ocean to be recognised as the potential source of future destructive tropical cyclones, including those with the capacity to impact on the coastline of eastern Saudi Arabia. According to Kumar (2013), it is also possible that global warming will intensify atmospheric disasters; i.e. greater frequency and higher intensity tropical storms in the Arabian region, which will result in the increased threats to the current infrastructure of coastal communities across the Arabian Gulf.

The third of the natural disasters facing the KSA come in the form of rises in **sea levels**. Due to anthropogenic global warming, sea levels have been steadily rising and are expected to continue to rise over the next centuries (Church and White, 2011). The Intergovernmental Panel on Climate Change (IPCC) projected that the sea level will rise between 23 and 96 cm from 1990 to 2100 (Nicholls, 2002). However, more recent studies have suggested that the rate of sea level rise may be greater than previously thought. Thus, many sea levels will rise by over one meter by 2100, although the exact increase will vary from region to region (Loucks et al., 2010, Alothman et al., 2014).

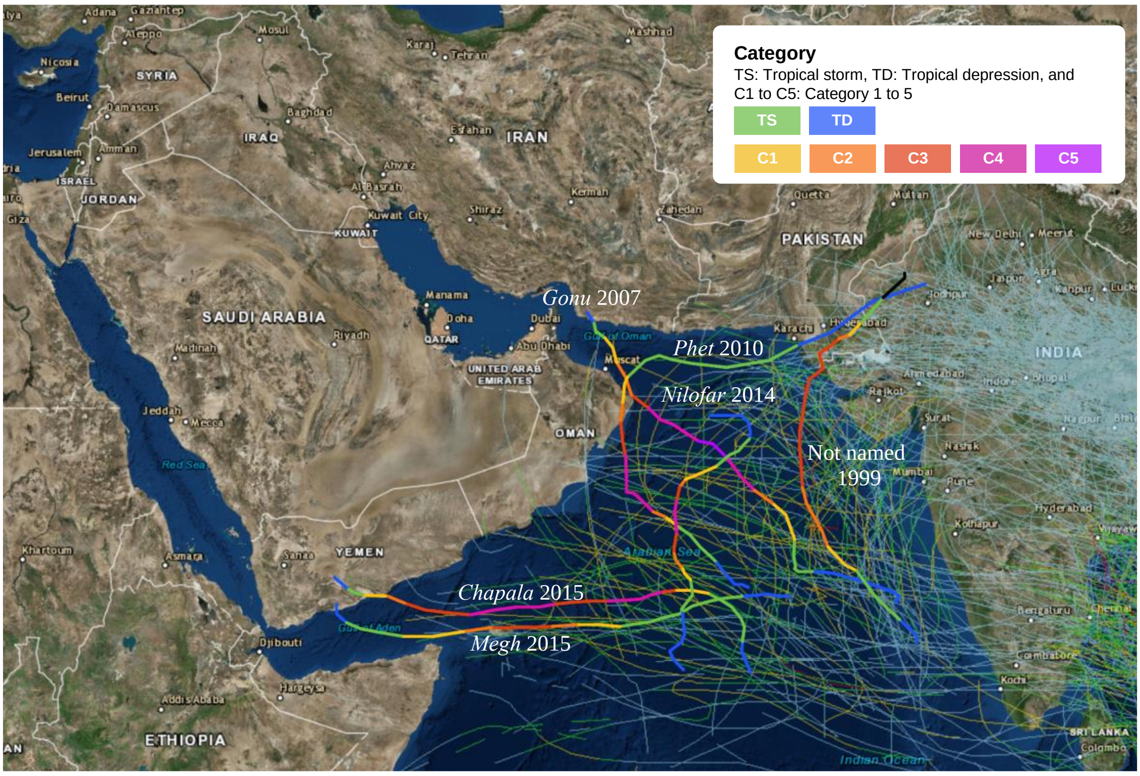

Figure 2-2 Category 3 and above cyclones and their tracks in the Arabian Sea between 1991 and 2015. Tropical storms and depressions are seen in the background to demonstrate the storm activities in the area.

As over 50% of the population of KSA currently live within 100 km of the coastline (Abualnaja, 2011, Lam et al., 2015), major consequences of a rise in sea level could include the following (Nicholls, 2002):

- coastal erosion and land loss;
- deterioration of fresh water; and
- considerable socio-economic impact.

The western coast of KSA has consolidated and raised beaches, which serve as stable barriers against waves and storm surges; however, any rise in sea level could lead to such lowlands being easily flooded (Parry, 2007). Digital Elevation Model (DEM) data indicate that lowlands; i.e. 1 m level, cover an area of 890 km2 along the entire coast. A sea level rise of 2 m could inundate an area of 2075 km2, representing a coastal strip with a maximum width of approximately 6 km from the shoreline (Hereher, 2016).

According to Kadhim et al. (2016), rapid and unplanned urbanization on flat lands across the coastline has significantly increased the risk of a potential maritime disaster. Previous research suggested that Saudi port cities such as Yanbu, Jeddah and Jazan on the coastline along the Red Sea, and El Khafji, Al Jobail, Al Dhahran, and El Khobar along the Arabian Gulf are vulnerable to sea level rises due to high population growth, socio-economic activities and their historical importance (El-Raey, 2010, Hereher, 2016). Our analysis of vulnerability to the sea level rise is presented in Figure 2-3. The coastal cities extending along the south Red Sea coast and the south Arabian Gulf coast are the locations most vulnerable to sea level rises. Dammam metropolitan area comprising the cities, Dammam, Dhahran and Al Khobar lies in the most vulnerable coastal area in KSA, as shown in the inset of Figure 2-3. Dhahran is home to the KSA oil industry and plays an important role in Saudi economy.

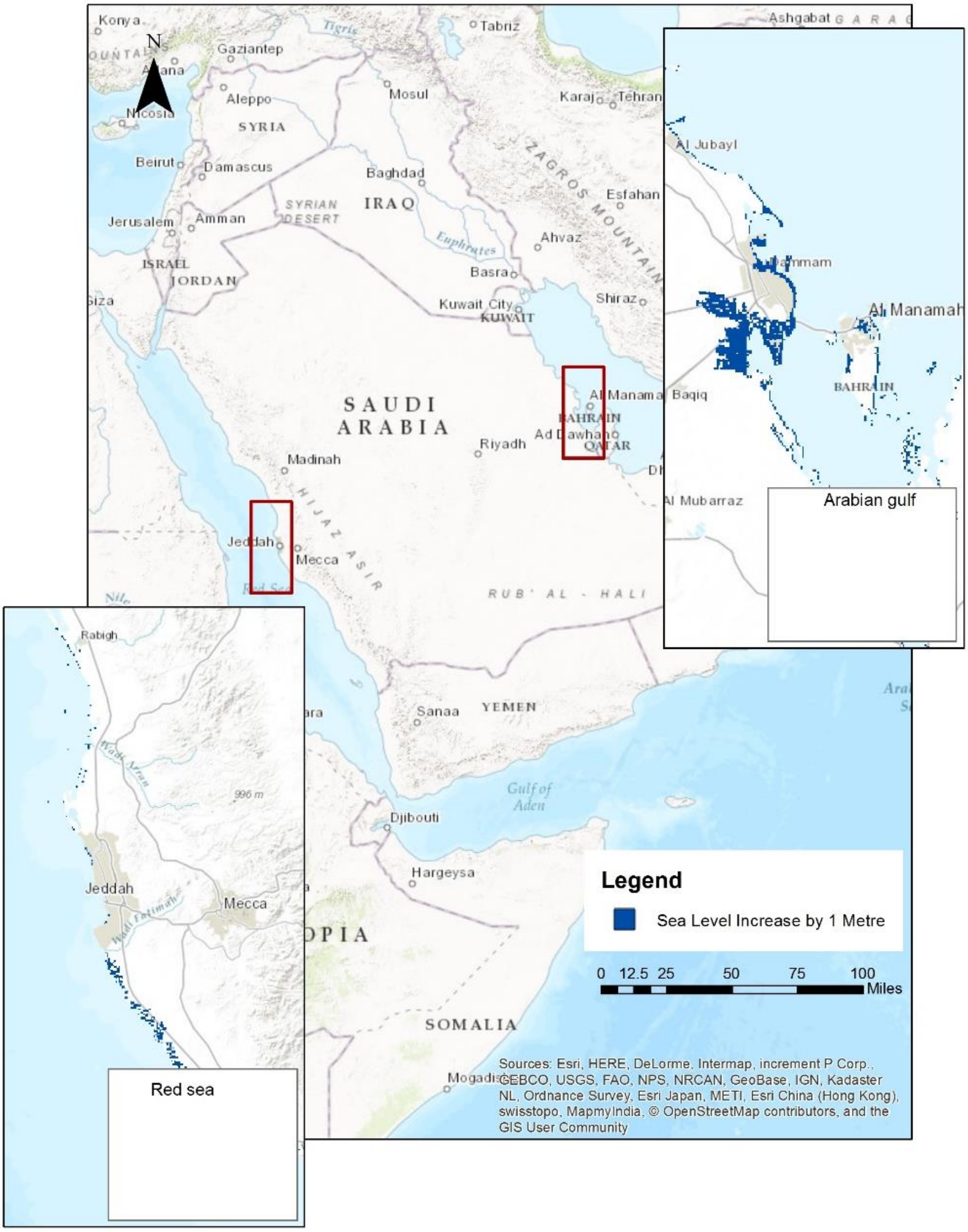

Figure 2-3 Coastal vulnerability map of Saudi Arabia (sea level increase by 1m)

2.2.2 Man-made maritime disasters

Man-made maritime disasters also come in various forms. These, however, are not only a consequence of the geographical location of the KSA, but rather, they are also due to the KSA's main export petroleum. Man-made disasters that are likely to face the KSA include vessel disasters, oil spills, maritime piracy and maritime terrorism.

Being one of the busiest maritime regions in the world, Saudi Arabia is highly vulnerable to **oil spillage**. Estimates suggest that between 0.5 and 10.8 million barrels of crude oil was intentionally released into the Arabian Gulf during the 1991 Gulf War (Bejarano and Michel, 2010). The Gulf oil spill extensively contaminated the water along the coastal areas of the Arabian Gulf. Tawfiq and Olsen et al. (1993) reported the catastrophic impacts of this human-induced maritime disaster on coastal habitats and environmental resources over 640 km of Saudi Arabia's coastline. The oil travelled to the south by north-westerly winds and regional circulation patterns, affecting virtually the shoreline, from the Saudi-Kuwait border to Abu Ali Island equivalent to a distance of nearly 800 km (Bejarano and Michel, 2010). The residual oil formed surface sediments in several locations in the affected coastal region for up to fourteen years following the oil spill. The total damage caused accounted for more than USD 340 million (Joydas et al., 2012, Tawfiq and Olsen, 1993).

The Arabian Gulf is prone to marine pollution. The United Nations Educational, Scientific and Cultural Organization (UNESCO) noted that 75% of global oil spills take place in the Arabian Gulf area, resulting in environmental disasters costing billions of dollars (Alamri, 2010, Bjornstig and Forsberg, 2016). When an extensive oil spill takes place, it is likely to spread for hundreds of nautical miles from the source of incident, resulting in severe damage to the maritime environment of the coastline (Akyuz et al., 2017).

Besides, the Iranian coast is at a higher risk of experiencing tsunamis triggered by earthquakes originated in the Arabian Tectonic Plate and subsequently, makes the coastline of Saudi Arabia more prone to maritime pollution due to oil spillage.

The next form of disaster is maritime **terrorism** which is defined by The Council for Security Cooperation in the Asia Pacific (CSCAP) as: "the undertaking of terrorist acts and activities within the maritime environment, using or against vessels or fixed platforms at sea or in port, or against any one of their passengers or personnel, against coastal facilities or settlements, including tourist resorts, port areas and port towns or cities" (Hong and Ng, 2010). In order to combat maritime terrorism, the International Ship and Port Facility Security (ISPS) Code has been developed by the International Maritime Organization (IMO). According to Hong and Ng (2010), "the ISPS Code is a comprehensive set of measures to enhance the security of ships and port facilities, developed in response to the perceived threats of terrorist attacks and piracy to ships and port facilities in the wake of the 9/11 attacks in the US". Since the 9/11 terrorist attack in New York, maritime communities are increasingly concerned about the potential of a terrorist attack against ships or other infrastructure targets, such as port facilities.

Our review and subsequent analysis reveal that the commercial and passenger ships entering and leaving the Red Sea through the Gulf of Aden are at a higher risk of experiencing piracy, armed robbery, and maritime terrorism. The Arabian Sea and the Indian Ocean have recently experienced a series of attacks resulting in a general increase in maritime terrorism (Hong and Ng, 2010). The USS Cole bombing in 2000 is regarded as one of the deadliest terrorist attacks at sea. The USS Cole (DDG-67), an Arleigh Burke-class guided-missile destroyer of the United States Navy was attacked by terrorists while refuelling at Yemen's Aden harbour, killing seventeen and injuring 47 (Langworthy et al., 2004, Johnson, 2012). The repairing cost of the extensive internal damage amounted to USD 250 million. Despite being at a high risk of terrorist attacks, ships entering the region are covered by insurance only if the risk of such attacks is specified in the policy (Lewins and Merkin, 2011).

The third of the man-made maritime disasters facing the region comes from **vessel disasters**. The propensity of using large ships for transporting goods and materials has increased the risk of accidents occurring along the congested coasts and in narrow channels (Gao and Shiotani, 2013). The key reasons behind the accidents include sinking in storms; fire and explosion; and collision with other vessels (Bjornstig and Forsberg, 2016). The application of advanced technology, such as radar and global positioning system (GPS) have reduced the risk of collision and minimised navigation errors. However, reducing accidents due to sinking and fire remain a challenge for Saudi Arabia.

Soliman (2013) provided an insight into one of the most catastrophic man-made maritime disasters in recent decades - the sinking of the Al-Salam Boccaccio 98 ferry in the Red Sea as a result of fire in the cargo area. Only 350 out of 1,415 passengers survived and were left fighting for their lives in the open sea. This tragic event took place while the ferry was only 87 km (i.e. 54 miles) away from its destination, Safaga Port, Egypt (Soliman, 2013). Despite having clear weather conditions and a calm sea, the search-and-rescue operation was delayed, and a passing vessel rescued some passengers. The other passengers had to wait more than twenty hours to be rescued, whereas, the International Convention for the Safety of Life At Sea (SOLAS) recommends that all passengers should be evacuated from a shop within thirty minutes (Winskog, 2012). This is attributed to poor disaster risk management preparedness and action. The Red Sea connects the East and West marine transportation, which has led to an increase in congestion at sea and along main maritime routes, making it highly vulnerable to vessel disasters.

The last of the man-made maritime disasters facing the KSA comes in the form of maritime **piracy** which is defined by Article 101 of the United Nations Convention on the Law of the Sea (UNCLOS) as any criminal action or behaviour committed by the passengers or crew of a private ship on the high seas that are self-serving and involve detention, depredation, or violence towards people or property on the ship in question, or another ship at sea. Maritime piracy is not a new phenomenon; however, it has not been regarded as a major disaster until recently (Hong and Ng, 2010). A study by Ploch et al. (2011) suggests that the increasing number of incidents involving maritime piracy may cost the global economy USD 7 billion annually (Ploch et al., 2011).

Maritime piracy continues to pose a significant threat to the world's interests, including international commerce (oil in particular), undermining confidence in communication along global trade routes, thus also resulting in an increase in maritime insurance rates (Shane and Magnuson, 2016).

The increasing number of incidents involving high-profile kidnapping and pirate attacks in the busiest shipping lanes of the Gulf of Aden and the Red Sea has become a major national and international concern (Bryant et al., 2014). Pirates often target maritime traffic crossing areas that are less secure (UNITAR, 2014). Figure 2-1 shows the clustered location of attacks attributed to Somali pirates that took place in the Red Sea, the Gulf of Aden, and the Arabian Sea between 2010 and 2015. However, International Maritime Bureau (IMB) noted an annual decline in the number of attacks in this area in recent years (ICC-IMB, 2015).

Two significant measures have been introduced in a bid to reduce maritime piracy in this location. The first involved the deployment of three independent and coordinated joint navies in the high-risk areas, requiring the operation of over 40 vessels (Bowden et al., 2010). The annual running cost of this measure accounted for more than USD 2 billion (Townsley et al., 2015). The second measure involved the establishment of the Internationally Recommended Transit Corridor (IRTC) underpinning all joint naval operations; i.e. vessels enter IRTC at scheduled times, determined by the speed of each ship, which subsequently travel in appropriate groups (Townsley et al., 2015). This study reveals that, despite the decrease in the number of attacks by Somali pirates, traffic crossing the southern Red Sea at Bab el Mandeb, the Gulf of Aden and the Arabian sea remain at a higher risk of maritime piracy.

2.1.2 Impact of maritime disasters

Our study has found that KSA has experienced a series of devastating natural and human-induced maritime disasters over the last three decades. Transporting more than half of the crude oil consumed globally by the Red and Arabian Sea makes it highly vulnerable to human-induced disasters in particular. The following subsections discuss the potential causes and impacts of both forms of disaster.

2.1.2.1 Natural maritime disasters

The findings of this review suggest that tsunamis do not currently present a significant or recurrent threat to the KSA coastlines. However, the risks are higher in areas with high seismic activity in marine and coastal regions (Villholth and Neupane, 2011). There is potential for local tsunamis on Saudi Arabia's coastline along the Red Sea impacting on major cities and ports, in particular, due to small magnitude earthquakes resulting from movements of the Arabian plate (Pararas-Carayannis, 2013, Kumar, 2013). In addition, the Arabian Gulf coastline is the second main area exposed to tsunamis resulting from earthquakes occurring on the shores of Iran and within the Indian Ocean. The height of a tsunami is governed by water depth, i.e. the deeper the water, the larger the potential size of the tsunami. Therefore, the coastal cities on the Red Sea are exposed to a higher risk of tsunamis than those situated along the Arabian Gulf coastline.

The second form of natural maritime disaster that can potentially impact KSA coastlines is tropical cyclones, which are generally formed within the southeast Arabian Sea, in close proximity to the entrance of the Arabian Gulf. This form of disaster results in destructive high winds and torrential rain, leading to the potential destruction of oil shipping facilities in the Arabian Gulf due to the area being unprepared for such events (Pararas-Carayannis, 2013), as has been demonstrated by the tropical cyclone Gonu.

We found that the KSA coastline is likely to be vulnerable to another additional main natural maritime disaster: rising sea levels. This is currently considered as one of the key impacts of global anthropogenic climate change (IPCC 2014) and forms a significant threat to coastal lowland areas around the world. The rapid urbanisation of the low-lying lands along the KSA coastline has resulted in over 50% of the KSA population currently living within 100 km of the coast (Abualnaja, 2011), which has significantly increased the vulnerability of the coastline to this form of natural maritime disaster (Kadhim et al., 2016). There is also a need to consider the unprecedented global increase in the frequency and severity of natural maritime disasters over the previous two decades, alongside further impacts of climate change.

Air and land surface temperatures in Saudi Arabia are some of the highest in the world (Ahmad et al., 2016), and are projected to increase further as a result of anthropogenic climate change. This implies that if destructive maritime natural disasters take place during hotter seasons and if key infrastructures along the coast such as power and energy are impacted, it may lead to significant cascading downstream effects on both the economy, livelihoods and human health.

2.1.2.2 Man-made maritime disasters

The location of KSA and its oil reserves have played a significant role in rendering KSA vulnerable to man-made disasters. Saudi Arabia has approximately 161 large oil deposits located along the Arabian Gulf, leading the KSA's coastline along the Arabian Gulf to be the area most exposed to an oil spill disaster in the world. Although the International Maritime Organization (IMO) has issued a set of regulations and conventions (e.g. MARPOL 73/78) with the aim of preventing pollution caused by shipping, particularly during the transportation of oil and petroleum products (Akyuz et al., 2017), a UNESCO report has stated that 75% of global oil spills take place in the area of the Arabian Gulf, resulting in environmental disasters that cost several billion US dollars (Alamri, 2010, Bjornstig and Forsberg, 2016).

The Red Sea with its important location for oil export and transportation between Asia and Europe, is the area most vulnerable to maritime piracy. Pirates tend to target areas in which maritime traffic crosses countries with relatively less well-structured governance or are destabilised. Thus, this form of man-made disaster poses a threat to maritime traffic crossing this area, in particular in the southern area of the Red Sea, in which pirates are known to operate. Compliance with the International Ship and Port Facility Security (ISPS) Code should decrease the vulnerability of port facilities and ships in terms of terrorist attacks and piracy. However, maritime piracy continues to pose a significant threat to the world's interests, including international commerce, and oil in particular. As a result, man-made maritime disasters resulting from piracy has the potential to impact on the revenues from KSA oil industries which account for approximately 70% of its economy.

Moreover, as noted above, the coastal areas of the Arabian Gulf remain the world's largest single source of crude oil and its related industries, resulting in this area being one of the busiest global maritime regions, while the Red Sea forms a strategic connection between the East and West. These factors result in a significant risk from maritime terrorism and disasters impacting on commercial and passenger ships entering and leaving the Red Sea and the Arabian Gulf. This is particularly important for business and industry, as entering this region is a known risk, which is not covered by standard maritime insurance policies (Lewins and Merkin, 2011). Moreover, Hong & Ng (2010) noted that a recent maritime security conference established that both the Arabian Sea and the Indian Ocean have experienced increased levels of terrorism, which corroborates the experience of a general increase in maritime terrorism, as demonstrated in the series of attacks carried out in recent years.

A deeper understanding of the context-specific issues associated with each maritime disaster is vital to design effective measures to prevent and reduce the impact of both natural and human-induced maritime disasters.

2.1.3 The need for leadership and effective DRM policies in KSA

The responsibilities for managing disaster risks in KSA are entrusted to several organisations and entities, which makes integrated policies and actions challenging. The needs-based ad-hoc development of disaster risk management capabilities can be attributed as the reason for fragmentation in roles and responsibilities. The need to rescue pilgrims visiting the city of Makkah in the events of emergency led the formation of the first fire brigade in 1927. Following its set-up, fire brigades were established in a number of other cities in the country including Medina, Jiddah, Riyadh, Qasim and Dammam (Alharbi, 2013). However, a major step towards managing disasters took place in 1965 when the fire brigades were replaced by the General Directorate of Civil Defence (GDCD). The GDCD built several centres across the country with an aim to protect civilians and the built environment from the dangers of fire and natural disasters such as floods and earthquakes (Alharbi, 2013).

Nowadays, multiple agencies with varying roles and responsibilities are managing maritime disasters in Saudi Arabia. For example, the Gulf War oil spill disaster in 1991 had enormous implications for the people of Saudi Arabia. The disaster recovery plan was adopted by the Saudi Meteorology and Environmental Protection Administration who were supported by other countries, the USA, the United Kingdom, the Netherlands, Norway, Germany, Japan, New Zealand and Australia (Tawfiq and Olsen, 1993). In addition, when the Al-Salam Boccaccio vessel sank in the Red Sea in 2006 (one of the worst vessel disasters in recent history), the response plan was carried out by the Saudi Navy and Coast Guard. From the response to these two maritime disasters, it can be seen that more than one agency took responsibility for the development of a plan, which may cause conflict and a delay in response to future disasters.

Although emergency risk management in Saudi Arabia has improved considerably in recent years, the country still lacks capacity to proactively manage risks and vulnerabilities, as well as to prepare for potential future disasters such as the effects of climate change and manmade catastrophes. At present, the lack of an official central database of historical disasters in Saudi Arabia is a major concern. This is because such a database is a vital step towards building policies to improve disaster risk management in the country.

The current structural conflict affects critical incident response. The lack of communication and situational awareness between the negotiation and tactical teams increases the probability of mis-information, thereby reduces the efficiency of any disaster response actions. This is exemplified by the fact that large incidents may lead to the involvement of multiple agencies, some of which may have overlapping roles and responsibilities. It is particularly in these situations that conflict and confusion can arise, leading to much delayed resolutions.

The Jeddah flood disaster of 2009 was one of the worst disasters in Saudi history to have struck the Makkah region. This disaster highlighted the urgent need for all relevant authorities and agencies to revise their short and long-term plans for natural disasters. Structural conflicts affected the critical incident response due to the lack of inter-agency communication and an overlap of involvement and responsibility. As a result, the government was obliged to revise their emergency plans and set up a new centre for crisis management and disaster in the Makkah province, predominantly for the pilgrimage season (Altalhi, 2013). However, the country still lacks a national authority for emergency and disaster risk management.

There is, therefore, an urgent need in Saudi Arabia for joined-up national actions and policies on disaster risk management, including maritime disasters as they have the potential to significantly impact the economy and society. Literature suggests that an integrative national authority or department is best placed to develop policies, evaluate practices and translate theories of disaster risk management into actions to achieve disaster-resilient communities (Chang and Shinozuka, 2004). Such an authority can establish programmes in coordination with other relevant agencies such as fire fighters, the police, coast guards and non-governmental organisations. Programmes can be developed to train individuals and organisations to work together and raise awareness, as well as provide them with tools and techniques to cooperate and coordinate during disasters. The authority can also train the public to help them understand their roles and responsibilities in the event of critical incidents, emergencies and disasters. Moreover, a strong leadership and a vision is required to tackle the multi-dimensional disaster risks in Saudi Arabia, now and in the future.

2.3 Summary

The systematic review conducted in this research has investigated the nature, occurrence, extent and impacts of maritime disasters affecting Saudi Arabia. Information from disparate sources is critically evaluated to create an understanding for use in the development of national actions, policies and disaster risk management frameworks.

The most frequently occurring natural disasters within the context of Saudi Arabia are tropical cyclones, tsunamis and an increase in sea level, while man-made disasters tend to be related to oil spills, piracy, terrorism and vessel disasters. In particular, this study highlights that due to being located on the Arabian Tectonic Plate, the Arabian Gulf is vulnerable to natural disasters, while the Red Sea, a key location for the exportation and transportation of oil to Europe, is most commonly affected by man-made natural disasters. This study also recognises the potential long-term impact of sea level rises due to anthropogenic global warming on Saudi Arabia's lowland areas. The projected sea level rise is most likely to result in the loss of land and a deterioration in water quality, with particularly detrimental impact on the economy and the inhabitants of the KSA.

There still remains a degree of work to be undertaken in this area. However, this current study can be considered to act as a testbed for the design of a coastal community resilience assessment framework of maritime disaster management for Saudi Arabia. This framework will, in the long-term, play a key role in decision-making within Saudi Arabia in relation to the reduction of the country's exposure and vulnerability to maritime disasters, while also enhancing its resilience. Furthermore, this study also has the potential to be implemented on a broader scale in countries that also experience regular maritime disasters. Its implementation is likely to yield positive results in terms of successful disaster management and control, thus stabilising economies and ensuring the security of local residents.

The undertaking of a summary of the major maritime disasters to have affected Saudi Arabia, along with those expected to occur in future, ensures that this research will be of interest to researchers, environmentalists and government officials who wish to assess the potential consequences of these disasters for Saudi Arabia, while simultaneously establishing how these can be mitigated.

Having identified the possible risks from maritime disasters to the coastal communities of Saudi Arabia, a review of the literature is now required to help establish available frameworks and their applicability for measurement of resilience of these coastal communities.

Chapter 3
Coastal community resilience frameworks

This chapter provides an overview of identified coastal community resilience frameworks for disaster risk management by starting with an explanation of the methodology used in identifying them and follows by giving a brief explanation of each framework. Furthermore, it details the timeline of the framework and the form of the framework. This section then proceeds to detail the dimensions, indicators and sub-indicators of each framework identified through this review. A comparison of the frameworks results in identification of their similarities and differences and the elucidation of the four dimensions of this study.

3.1 Overview

Assessing community resilience is an essential step towards reducing disaster risk and ensuring communities are better prepared to withstand and adapt to a broad array of natural and human-induced disasters (Burton, 2015). According to Lloyd et al. (2013) changes in climatic conditions have led to greater attention being directed towards the development and implementation of adaptive administrative practices to mitigate and address the unique conditions present in coastal regions. Cooper and Boyko (2010) observed that, in ideal circumstances, coastal communities and their infrastructure would be situated at a sufficient distance from the shore to guarantee adequate protection from the threat of disaster. In many countries, however, a large proportion of the coastal infrastructure and coastal population is located close to the shore, rendering them vulnerable to disasters events.

The increased encroachment of humans into narrow coastal land increases the vulnerability of communities to coastal disasters. Coastal resilience entails devising and deploying measures to minimise harm and ensure a rapid recovery. This makes it a promising approach to mitigating threats to coastal communities. Ewing and Synolakis (2011) report that the coastlines of the world have, for centuries, formed the epicentres of business, commerce, transportation and industry. The diversity of resources and opportunities positioned along these coastlines has attracted a large population, leading to the establishment of urbanism, ranging from sizeable towns to megacities. Various studies have established that approximately 40% of the global population resides within one hundred kilometres of the coast (Courtney et al., 2008, Ewing and Synolakis, 2011, Arbon, 2014, Chelleri et al., 2015).Furthermore, it is estimated that, due to the increasing rate of urbanisation, approximately half of the global population will live reside in coastal communities in future.

Spellman and Whiting (2006) and Sharifi and Yamagata (2016) note that the increasing rise in sea levels, along with the occurrence of coastal storms, necessitates the evacuation of communities situated close to shorelines and the establishment of infrastructural amenities further inland. However, these can prove unviable when faced by an increase in population and urbanization. The only viable alternative is to devise and implement measures to facilitate coastal sustainability and resilience. Arbon et al. (2016) state that one method of reducing the vulnerability of coastal communities and their infrastructure is to improve coastal resilience. In addition, Lloyd et al. (2013) and Meerow et al. (2016) define coastal resilience as the ability for both human and natural communities to resume their normal lives (i.e. 'recover') following events such as coastal storms, hurricanes and flooding, rather than simply reacting to the impact of such events. Thus, coastal communities that are better prepared and informed are more likely to rebound from climate and weather-related phenomena. Cutter et al. (2014) state that preparation can facilitate rapid recovery, and also minimize the negative impact on the safety of the communities and economy. Meerow et al. (2016) consider that an evaluation of community resilience not only facilitates an in-depth understanding of disasters, but also assists in the formulation of informed, evidence-based strategies, capable of minimising the impact of natural events while simultaneously hastening the pace of recovery. Resilience has recently been integrated as a key element of the United Nations International Strategy for Disaster Reduction (UNISDR) (Alshehri et al., 2015b).

Cimellaro et al. (2016), Ameen et al. (2015) and Ahmad et al. (2016) observe the lack of any ubiquitous model or framework for the assessment of the resilience of a community in the face of disaster. A number of researchers, including e.g. Spellman and Whiting, (2006); Arbon, (2014) and Ahmad et al., (2016) emphasise the importance of focusing on resilience, rather than vulnerability, in the face of disasters. Although there is no universal approach to the assessment of community resilience, researchers agree that it is characterised by the status of several dimensions of wellbeing or 'rigidity', including political, social, economic and physical. There are a number of community resilience frameworks already in place, some of which are specific to coastal areas, e.g. the Community Resilience Index (CRI) and Coastal Community Resilience (CCR).

Young and Solomon (2009) argue that evidence-based practices require individuals to apply scientific findings to prevailing circumstances, by means of appropriate selection and critical appraisal of research findings relevant to their problem. This current study therefore aims to broaden the understanding of CCR assessment frameworks by critically reviewing nine selected frameworks. The specific objectives are: (1) to provide a detailed overview of the frameworks, i.e. their content, structure and development/implementation process; and (2) to establish common dimensions, indicators and sub-indicators for coastal community assessment frameworks.

The significance of this study derives from the fact that the coastal community assessment frameworks are currently employed within a still developing field that requires a greater body of evidence to establish it. These frameworks can, therefore, provide a platform for the involvement of stakeholders and experts in the planning and preparation processes, both within and beyond the community. This, in turn, leads to a potential to address in a more effective manner the various socio-economic and environmental challenges faced by communities. The frameworks may also contribute towards ensuring resilience becomes a 'governable strategy', through the development of iterative and quantifiable frameworks for resilience implementation (Young and Solomon, 2009).

3.2 Methodology

As the chief focus of this review concerns coastal community resilience assessment frameworks, a broad-based search strategy was implemented to develop knowledge regarding current assessment frameworks and tools applied at various levels of coastal communities (Arbon, 2014). Following an extensive scoping exercise, the key trends, themes and gaps in the chosen papers were identified and ranked in terms of importance. The following databases were used to conduct the searches: Science Direct; IEEE Xplore; Google Scholar; and the Web of Science Core Collection. To optimise the results, the searches employed a range of different key words related to 'frameworks', including: (1) 'models'; (2) 'tools'; 'indices'; and 'toolkits', as listed in Table 3-1.

The search of the databases identified 429 articles. Endnote software was used to compare the papers and delete any duplicates, resulting in the exclusion of 291 papers with 138 articles remaining for analysis. Figure 3-1 indicates that the initial searches were undertaken with the objective of extracting important information concerning community resilience. A manual examination of the titles and abstracts of the articles was subsequently undertaken to identify information on: (1) coastal community resilience; (2) coastal disasters; (3) climate-induced disasters; and (4) multi-disasters. This examination narrowed the number of articles down to forty. The final step involved a thorough reading of each article to analyse its content, focusing specifically on frameworks designed to examine coastal community resilience as a complete system including a number of different dimensions.

This step further narrowed down the number of articles to nine, all of which contained community resilience frameworks. These nine frameworks were then grouped under the following headings: (1) year of issue; (2) study location; (3) type of disaster; (4) type of assessment; and (5) assessment methods, as outlined in Table 3-2. Content analysis was selected as the method for all analyses discussed in this research. All nine frameworks are discussed in detail in the following section.

Table 3-1 Search word combinations and use of search operators

Search operators	**Databases**				
	Search term combinations	**Science Direct**	**IEEE Xplore**	**Google Scholar**	**Web of science**
"AND"	Coastal community resilience frameworks AND models	11	9	15	8
	Coastal community resilience frameworks AND tools	14	11	12	5
"OR"	Coastal community OR coastal population resilience frameworks	11	12	22	7
	Coastal community resilience frameworks OR models	14	16	28	8
"NOT"	Coastal community resilience NOT urban resilience	11	5	25	3
Exact phrases	Coastal community resilience frameworks	18	5	17	1
	Coastal community resilience tools	16	8	19	6
	Coastal community resilience models	14	1	12	2
Truncation	Coast* community resilience	8	9	8	7
	Coastal community* resilience	6	2	2	5
	Coastal community resilience*	9	4	1	2
Total		132	82	161	54

Note: *: any group of characters.

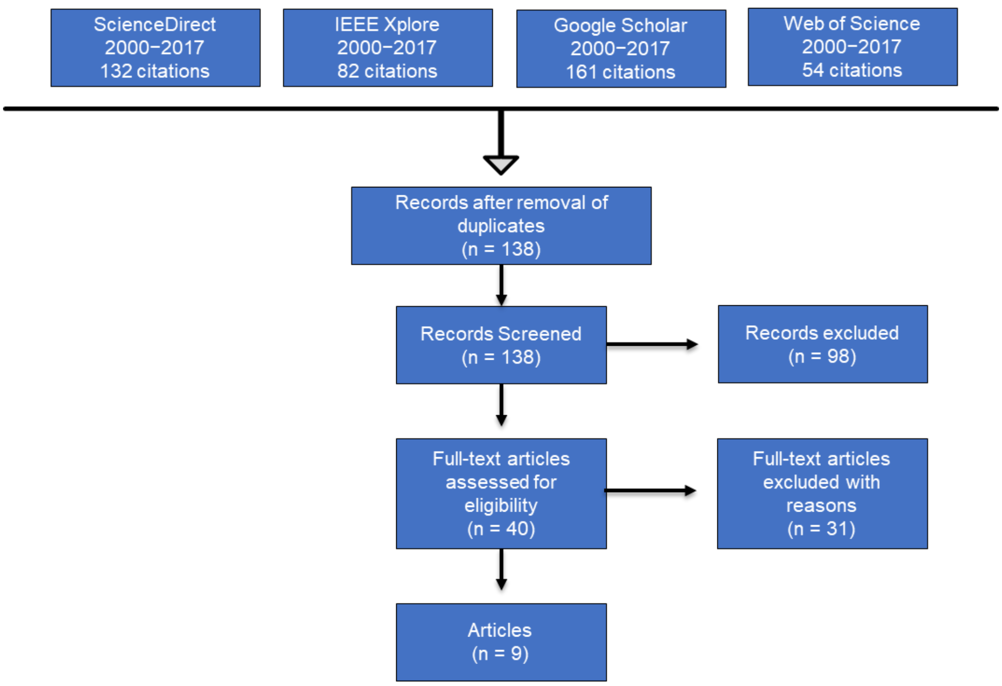

Figure 3-1 The prismatic process of identification, screening, eligibility and inclusion

Table 3-2 Key characteristics of the selected frameworks

Framework	Year of Issue	Study location	Disaster type	Assessment type	Format /s	Source
CCR	2008	Indian Ocean region (Thailand, Sri Lanka, Indonesia, India and the Maldives)	Coastal disaster	Summative	Toolkit	(Courtney et al., 2008)
CDRI 1	2009	South/South East Asia	Climate- induced disasters	Summative	Toolkit	(Shaw and Team, 2009)
CDRI 2	2010	US	Multi- disaster	Summative	Index	(Peacock et al., 2010)
LDRI	2012	The Philippines	Multi- disaster	Formative	Index	(Orencio and Fujii, 2013)
BRIC	2014	US	Multi- disaster	Summative	Index	(Cutter et al., 2014)
CDRI 3	2014	India, Chennai	Climate- induced disasters	Summative	Index	(Joerin et al., 2014)
RIM	2015	The Northern Gulf of Mexico in US, China, Netherland	Coastal disasters	Summative	Model	(Lam et al., 2015)
CRDSA	2015	Saudi Arabia	Multi- disaster	Summative	Index	(Alshehri et al., 2015b)
CCR2	2015	India	Coastal disaster	Summative	Index	(DasGupta and Shaw, 2015)

3.3 Coastal community resilience frameworks

The nine selected frameworks have been widely employed in their respective jurisdictions and in varying contexts. In addition, a body of knowledge exists regarding their effectiveness, applicability and flexibility. Table 3-2 provides a full list of the nine selected frameworks. Each paper (i.e. guidelines, policy paper, manual and peer-reviewed article) was evaluated using content analysis and an analytical framework, that will subsequently be described. The nine frameworks are summarised below:

3.3.1 Coastal community resilience (CCR1)

This framework was developed in 2008 with the participation of over one hundred governmental agencies and non-governmental organisations (NGOs) in the five countries that were most affected by the tsunami that occurred in 2004; namely, Thailand, Sri Lanka, Indonesia, India and the Maldives. All of these countries are involved in the US Indian Ocean Tsunami Warning System (US IOTWS) programme, which assesses coastal community resilience (CCR) to natural disasters. CCR1 assessment indicates that differences exist between the perceptions of the communities' ability to deal with these disasters appropriately in terms of the different stakeholders involved (Courtney et al., 2008, Kantamaneni et al., 2018).

3.3.2 Climate disaster resilience index (CDRI1)

The CDRI was developed in 2009. Its scope is limited to climate-induced disasters, such as cyclones, floods, heatwaves, droughts and heavy rainfall. It was part of the Global Center of Excellency (GCOE) programme 'Human Security Engineering for Asian Megacity', which is run by Kyoto University. The CDRI1 was created to measure the existing level of recovery from climate disasters within the targeted areas using a Climate Disaster Resilience Index. CDRI1 provides valuable knowledge and information to other local and national stakeholders, all of whom share the same aim of enhancing community resilience (Shaw and Team, 2009).

3.3.3 Community disaster resilience index (CDRI2)

In 2008, the CDRI2 was developed by Texas A&M University (TAMU), Texas A&M University at Galveston (TAMUG), and the Houston Advanced Research Center (HARC) in the US. Its aim was to focus on developing a series of indicators for community resilience that would be applicable on a regional and national level. It was developed to improve the recovery of coastal communities along the Gulf Coast, and was based on data from NOAA, which defined the coastal communities throughout the entire Gulf Coast region. These data and tools are available to the local communities, decision makers and stakeholders via interactive websites hosted by Texas A&M University at Galveston[5] and College Station[6] (Peacock et al., 2010).

3.3.4 Localized disaster-resilience index (LDRI)

The LDRI was developed in 2012. It proposed an index for a disaster-resilient coastal community at the local level in the Philippines. The process of this index followed the Delphi technique and involved twenty decision-makers in Baler, Aurora (Philippines) in identifying the criteria and elements that can be used to reduce the vulnerability of coastal communities, using paired comparisons for the Analytic Hierarchy Process (AHP) (Orencio and Fujii, 2013).

3.3.5 Baseline resilience indicators for communities (BRIC)

The BRIC was developed in 2014 to measure the resilience of communities in specific areas of the US. The BRIC was constructed by calculating the total scores for the composites of six sub-indexes for resilience. The potential scores range from zero to six, with higher scores corresponding to greater resilience and lower ones to less resilience. The BRIC provides a reference point or baseline for examining the current status of inherent resilience at the county level. The BRIC can be useful in guiding policy decisions. although not every individual indicator could, or should, be targeted directly at improvement (Cutter et al., 2014).

3.3.6 Climate disaster resilience index (CDRI 3)

The CDRI3 was developed in 2014 in Chennai, India, and aimed to measure, from a community perspective, a city's capability to withstand climate-related disasters. The CDRI3 focuses on comprehensively evaluating all sectors of a city to hasten the resilience building process in urban areas. This index is tailored specifically to disasters related to the climate, such as cyclones, droughts, floods and heat waves, which are more likely to occur in Chennai than in geophysical-related disasters. Engineers (experts) operating in the ten different zones of Chennai, who carry out civic work, were selected as representatives to provide responses to the CDRI3 questionnaire. The engineers weighed the importance of each variable and parameter in terms of its influence on the overall resilience score. The CDRI3 assessment integrates aspects related to the Hyogo Framework for Action 2005-2015 (HFA) (Joerin et al., 2014).

3.3.7 Resilience inference measurement (RIM)

The RIM was developed in 2015 to measure the resistance to coastal disasters of fifty-two counties along the Northern Gulf of Mexico coast in the US. These counties are

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[5] Texas A&M University at Galveston. URL: http://coastalatlas.tamug.edu
[6] Texas A&M University at College Station. URL: http://coastalatlas.tamu.edu

considered to be communities, as they belong to the five states of Texas, Louisiana, Mississippi, Alabama and Florida. Five major types of coastal disasters were included in the RIM: coastal (including coastal flooding and storm surges), floods, hurricanes, thunderstorms and tornadoes (Lam et al., 2015).

3.3.8 Community resilience framework (CRDSA)

In 2015, the CRDSA was developed in Saudi Arabia using a mixed-methods strategy (including quantitative and qualitative research). The CRDSA provides an assessment system, in which each criterion is weighted to evaluate the community's resilience in coping with future disasters. Based on a comprehensive literature search and a national survey of public perceptions of disasters in Saudi Arabia, the CRDSA was developed using the Delphi technique and the AHP (Alshehri et al., 2015b).

3.3.9 Coastal community resilience (CCR2)

CCR2 was developed in 2015 to measure the resilience of a particular community to natural coastal disasters in rural areas in the Indian Sundarbans. The CCR methodology is divided into two parts. The first is concerned with the development of a series of criteria and variables that can be applied on a local level in rural coastal areas, while the second aims to assess, through a methodical application of the framework, the ability of the particular area under study to recover (DasGupta and Shaw, 2015).

3.4 Comparison of the coastal community resilience frameworks

A quantitative comparison of the criteria and indicators within the nine selected frameworks can assist users and framework developers to identify shared knowledge and directions for future research and development. The assessment frameworks were compared on the basis of two aspects: key characteristics and structure.

The key characteristics of the assessment frameworks are presented in Table 3-2. They have been organized into five major categories: year of issue, study location, disaster type, assessment type and assessment methods. The findings of this comparison will be explained below.

3.4.1 Timeline

All of the selected frameworks have been developed between 2008 (CCR1) and 2015 (CCR2), thus confirming that the subject of coastal community assessment is a relatively recent development on an international level. The fact that several assessment frameworks were published within this relatively short period of time has attracted a great deal of attention from the scientific community in recent years (Sharifi, 2016).

3.4.2 The emergence location

The selected frameworks have been implemented in regions that are vulnerable to different types of maritime disasters, such as tropical cyclones and tsunamis. As shown in Table 3-2, three (CDRI 2, RIM and BRIC) of the nine selected frameworks were purposely developed to assess the resilience of territory in the US (Cutter et al., 2014; N. Lam et al., 2015; Peacock et al., 2010). The remaining six frameworks were used to assess resilience in Asian countries. For instance, CCR1 and CCR2 were used in India, LDRI in the Philippines, CDRI3 in China and India, CDRI1 in South East Asia and CRDSA in the Kingdom of Saudi Arabia (Alshehri et al. 2015; Courtney et al. 2008; DasGupta and Shaw 2015; Joerin et al. 2014; Orencio and Fujii, 2013; Shaw and Team, 2009). CCR1 is a cooperative framework (Courtney et al., 2008), and several countries (Thailand, Sri Lanka, Indonesia, India and the Maldives) participated in its development. This indicates the need for such frameworks in the Asian continent which is attributed to the higher number of maritime disasters affecting these regions. Furthermore, the frameworks have mainly been developed by international organisations and individual researchers.

It is important to note that there remains a lack of assessment frameworks that have been developed by local authorities and organisations in developing countries. The frameworks that have been developed by non-local stakeholders may fail to appropriately reflect the local needs and conditions of other countries or regions.

3.4.3 Disaster type

Assessing community resilience is recognised as a fundamental step towards reducing disaster disasters and being better prepared to withstand and adapt to a broad array of natural and human-induced disasters that threaten coastal communities. Therefore, all of the frameworks selected had been previously used to assess the resilience of different communities across the globe against a large percentage of the different types of disasters. Hence, explaining the significant differences that exist between the selected frameworks. For instance, as shown in Table 3-2, CCR1, RIM and CCR2 are designed to only address coastal natural disasters (Lam et al., 2015), while CDRI2, LDRI, BRIC and CRDSA are focused on multi- disasters and CDRI1 and CDRI3 address climate-induced disasters. Overall, it can be said that CCR1, CDRI1, CDRI2, CDRI3, LDRI, BRIC, RIM, CRDSA and CCR2 are broad-based and address most of the risks posed by the disasters occurring in multiple domains

3.4.4 Assessment type: formative vs. summative

Additionally, the assessment frameworks can be classified as either formative or summative (Sharifi 2016). Summative frameworks measure the effectiveness of resilience interventions following the occurrence of disasters, while formative frameworks, on the other hand, entail prior assessment and the continuous evaluation of resilience measures from their inception. Moreover, these frameworks are founded on process-based methodologies that seek to bring about an incremental improvement in conditions and the enhancement of adaptive capacities (Dolin et al., 2017). CCR1, CDRI1, CDRI 2, CDRI 3, BRIC, RIM, CRDSA and CCR2 can be classified as summative frameworks, while LDRI is the only formative framework that has been selected for this study. According to Cohen et al. (2016), formative frameworks, such as LDRI, are iterative. Thus, they are a suitable way of accounting for future uncertainty while simultaneously addressing the dynamism present in different dimensions. Furthermore, this type of framework provides opportunities for in-depth learning. According to Norris et al. (2008), formative frameworks, such as LDRI, are vital for the assessment of community resilience against baseline conditions. This is essential for determining how communities change over time with regard to their vulnerability to disasters. As such, formative frameworks may be compared to longitudinal studies that assess changes over time in order to make credible inferences. Conversely, summative frameworks, which form 90% of the selected tools in this review, are outcome-based. In this regard, they help communities to ascertain their standpoints concerning resilience. Sharifi (2016) notes that summative frameworks produce the evidence required for making important decisions concerning the changes needed to realign the resilience measures so that the interventions are more adaptive.

3.4.5 Assessment methods

The selected frameworks draw upon both quantitative and qualitative methods. According to Sharifi (2016), a mixed-methods approach is appropriate when data availability is problematic. Given that resilience is a value-laden concept that is influenced by attitudes and perceptions, this methodology enables the collection of ideas from community stakeholders regarding their needs that are used to address concerns about the subjectivity of the assessment process.

The resilience assessment approach can be divided into four main formats: models, scorecards, toolkits and indices (Cutter, 2016).

Models are used to reduce the complexity of the relationship between the risk and resilience factors, as well as to overcome any uncertainties or limitations related to predicting future events and their consequences. In this approach, past data on disasters are input into mathematical algorithms and scenario analyses to approximate future conditions (Cutter, 2016).

Scorecards allow the collection of values for performance which can be assessed against each criterion within the resilience assessment framework. The values often take the form of answers to questions, calculated statistical values or judgements/perceptions (Sharifi, 2016). When using judgements in assessments, scaled questions with Likert scales are used to allow the quantification of qualitative feedback.

Toolkits establish procedures for assessing resilience using one or more of the aforementioned methods (Cutter, 2016). Toolkits not only provide guidance on how to conduct assessments but also outline mechanisms for identifying the assessment criteria, collecting the required data, assigning weights, conducting assessments, suggesting interventions and monitoring action plans.

Indices rely on quantitative data, often using weighted averages or sums of scores obtained for all criteria in the assessment tool to obtain an aggregate index value (Cutter, 2016). Indices are often standardised for comparison purposes, or weights are assigned to them based on contextual and temporal factors (Table 3-2), using methods such as the Analytical Hierarchy Process (AHP) (Alshehri et al., 2015b). Index values make it possible to assign an overall performance rating to community resilience.

As shown in Table 3-2, most of the selected frameworks are organised in the format of indices and toolkits, and only one (RIM) is organised in a model format.

3.5 The structure of the frameworks

Despite the fact that a range of coastal community resilience frameworks have been developed over time to fulfil the same objective, these vary significantly in terms of their structure, potential and application (Courtney et al., 2008). To ensure the objectives of the review are met, the nine selected frameworks have been chosen due to their similarity with regard to their organisation, components and procedures. Table 3-3 demonstrates the general structure of the tools. This structure comprises three levels, which will be explained in the following sections.

Table 3-3 Structure of the selected frameworks.

Tool	Dimension	Indicators	No. of sub-indicator	Weight (%)
CCR	Policy and Planning Physical and Environmental Social and Cultural Technical and Financial	Governance	10	N/A
		Society and Economy	6	
		Coastal Resource Management	6	
		Land Use and Structural Design	7	
		Risk Knowledge	4	
		Warning and Evacuation	7	
		Emergency Response	4	
		Disaster Recovery	10	
		Total **8**	54	
CDRI 1	Physical	Electricity	N/A	N/A
		Water supply		
		Sanitation		
		Solid waste disposal		
		Internal road network		
		Housing and land use		
		Community assets		
		Warning system and evacuation		
		Total **8**		
	Social	Health status	N/A	N/A
		Education and awareness		
		Social capital		
		Total **3**		
	Economic	Income	N/A	N/A
		Employment		
		Households' assets		
		Access to financial service		
		Savings and insurance		
		Budget and subsidy		
		Total **6**		
	Institutional	Internal institutions and development plan	N/A	N/A
		Effectiveness of internal institutions		
		External institutions and networks		
		Institutional collaboration and coordination		
		Total **4**		
	Natural	Hazard intensity	N/A	N/A
		Hazard frequency		
		Total **2**		
CDRI 2	Social capital	Registered non-profit organizations	N/A	N/A
		Recreational centres (bowling, fitness, golf clubs) and sport organizations		
		Registered voters		

		Civic and political organizations		
		Census response rate		
		Religious organizations		
		Owner-occupied housing units		
		Professional organizations		
		Business organizations		
		Total **9**		
	Economic capital	Per capita income	N/A	N/A
		Median household income		
		Population in labour force, employed		
		Median value of owner-occupied housing units		
		Business establishments		
		Population with health insurance		
		Total **6**		
	Physical capital	Building construction establishments	N/A	N/A
		Heavy and civil engineering construction establishments		
		Highway, street and bridge construction establishments		
		Architecture and engineering establishments		
		Land subdivision establishments		
		Legal services establishments		
		Property and causality insurance companies		
		Building inspection establishments		
		Landscape architecture and planning establishments		
		Environmental consulting establishments		
		Environment and conservation organizations		
		Scientific research and development services		
		Colleges, universities, and professional schools		
		Housing units		
		Vacant housing units		
		Hospitals		
		Hospital beds		
		Ambulances		
		Fire stations		
		Nursing homes		
		Hotels and motels		
		Occupied housing units with vehicle available		
		Special need transportation services		
		School and employee buses		
		Owner-occupied housing units with telephone service		
		Newspaper publishers		

		Radio stations		
		Television broadcasting		
		Internet service providers		
		Temporary shelters		
		Community housing		
		Community food service facilities		
		Schools		
		Licensed child care facilities		
		Utility systems construction establishments		
		Total **35**		
	Human capital	Population with more than high school education	N/A	N/A
		Physicians		
		Population employed in health care support		
		Population employed in building construction establishments		
		Population employed in heavy and civil engineering constructions		
		Population employed in architecture and engineering establishments		
		Population employed in environmental consulting services		
		Population employed in environment and conservation organizations		
		Population employed in land subdivision services		
		Population employed in building inspection services		
		Population employed in landscape architecture and planning establishments		
		Population employed in property and causality insurance companies		
		Population employed in highway, street and bridge construction		
		Population employed in legal services		
		Population covered by comprehensive plan		
		Population covered by zoning regulations		
		Population covered by building codes		
		Population covered by FEMA approved mitigation plan		
		Community rating system (CRS) score		
		Population employed as firefighting, prevention or law enforcement workers		
		Population employed in scientific research and development services		
		Population employed in colleges, universities, and professional schools		

		Population who speak English language very well			
		Population employed in special need transportation services			
		Population employed in community and social services			
		Total	**25**		
LDRI	Environmental and Natural Resource Management	Understanding of functioning environment and ecosystems		N/A	7.42
		Environmental practices that reduce hazard risk			7.24
		Preservation of biodiversity for equitable distribution system			3.48
		Application of indigenous knowledge and technologies			3.89
		Access to community-managed common property resources			3.07
		Total	**5**		**25.10**
	Sustainable livelihoods	High level of local economic and employment stability		N/A	5.86
		Equitable distribution of wealth and livelihood in community			3.39
		Livelihood diversification in rural areas			6.09
		Fewer people engaged in unsafe livelihood			5.41
		Adoption of hazard-resistant agriculture			5.63
		Small enterprises with protection and business continuity/ recovery plans			4.49
		Local market and trade links protected from hazards			4.90
		Total	**7**		**35.78**
	Social protection	Social support and network systems on DRR activities		N/A	8.57
		Cooperation with local community for DRR activities			7.47
		Community access to basic social services			3.30
		Established social information and communication channels			2.84
		Collective knowledge and experience of management of previous events			3.07
		Total	**5**		**25.24**
	Planning regimes	Community decision making takes on land use and hazards		N/A	5.82
		Local disaster plans feed into local development and land use planning			2.79
		Local community participates in all stages of DRR planning			5.27
		Total	**3**		**13.88**
BRIC	Social	Educational attainment equality		N/A	N/A
		Pre-retirement age			
		Transportation			
		Communication capacity			
		English language competency			
		Non-special needs			

	Health insurance			
	Mental health support			
	Food provisioning capacity			
	Physician access			
	Total	**10**		
Economic	Home ownership		N/A	N/A
	Employment rate			
	Race/ethnicity income equality			
	Non-dependence on primary/tourism sectors			
	Gender income equality			
	Business size			
	Large retail-regional/national geographic distribution			
	Federal employment			
	Total	**8**		
Community capital	Place attachment-not recent immigrants		N/A	N/A
	Place attachment-native born residents			
	Political engagement			
	Social capital-religious organizations			
	Social capital-civic organizations			
	Social capital-disaster volunteerism			
	Citizen disaster preparedness and response skills			
	Total	**7**		
Institutional resilience	Mitigation spending		N/A	N/A
	Flood insurance coverage			
	Jurisdictional coordination			
	Disaster aid experience			
	Local disaster training			
	Performance regimes-state capital			
	Performance regimes-nearest metro area			
	Population stability			
	Nuclear plant accident planning			
	Crop insurance coverage			
	Total	**10**		
Housing/infrastructural	Sturdier housing types		N/A	N/A
	Temporary housing availability			
	Medical care capacity			
	Evacuation routes			
	Housing stock construction quality			
	Temporary shelter availability			
	School restoration potential			
	Industrial re-supply potential			
	High speed internet infrastructure			

		Total **9**		
	Environmental	Local food suppliers	N/A	N/A
		Natural flood buffers		
		Efficient energy use		
		Pervious surfaces		
		Efficient Water Use		
		Total **5**		
CDRI 3	Physical	Electricity	4	5.83
		Water	4	3.88
		Sanitation and solid waste disposal	3	3.32
		Accessibility of roads	5	4.85
		Housing and land use	5	4.24
		Total **5**		**22.12**
	Social	Population	4	3.11
		Health	4	4.66
		Education and awareness	5	3.99
		Social capital	4	3.45
		Community preparedness during a disaster	5	4.12
		Total **5**		**19.33**
	Economic	Income	4	3.77
		Employment	5	3.83
		Household assets	5	4.11
		Finance and savings	5	4.11
		Budget and subsidy	5	3.80
		Total **5**		**19.62**
	Institutional	Mainstreaming of disaster risk reduction and climate-change adaptation	3	4.13
		Effectiveness of zone's crisis management framework	4	4.62
		Knowledge dissemination and management	5	3.88
		Institutional collaboration with other organizations and stakeholders, during a disaster	4	4.90
		Good governance	4	4.36
		Total **5**		**21.89**
	Natural	Intensity/severity of natural hazards	5	3.84
		Frequency of natural hazards	4	2.98
		Ecosystem services	5	3.17
		Land use in natural terms	5	3.27
		Environmental policies	5	3.77
		Total **5**		**17.03**
RIM	Demographic	Percent African American	N/A	N/A
		Percent Hispanic		
		Percent under 5 years old		
		Percent over 65 years old		
		Average number of people per household		

		Total **5**		
	Social	Percent of the population over 25 with no high school diploma	N/A	N/A
		Percent of the workforce that is female		
		Percent female-headed households		
		Percent of homes that are mobile homes		
		Percent of the population that rents		
		Number of houses per square mile		
		Total **6**		
	Economic	Percent of the population living below poverty	N/A	N/A
		Percent of the workforce that is employed		
		Median value of owner-occupied housing		
		Median rent		
		Percent rural farm population		
		Total **5**		
	Government	Local government finance, revenue per capita	N/A	N/A
		Local government finance general expenditure per capita		
		Percent of the population that voted in 2000 presidential election		
		Local government finance expenditure on education		
		Total **4**		
	Environmental	Mean elevation of the county	N/A	N/A
		Total **1**		
	Health	5-year average infant mortality per 10,000 births	N/A	N/A
		3-year average chronic illness deaths per 10,000 individuals		
		Disabled and nonworking labour forces per 10,000 individuals		
		3-year total low-birth-weight babies per 10,000 live births		
		Households with no fuel used per 10,000 house units		
		Households with no plumbing per 10,000 house units		
		Non-federal active medical doctors per 10,000 individuals		
		Total **7**		
CRDSA	Health and wellbeing	Access to clean water and adequate sanitation	N/A	1.91
		Food security		1.89
		Availability of trained health workers		1.8
		Medical resources such as the availability of hospital beds		1.79
		Infection control		1.79
		Access to health assistance		1.76

	Hygiene			1.76
	Immunization programmes			1.75
	Effective biosecurity and biosafety systems			1.74
	Disease surveillance			1.74
	Family health education and training programmes			1.66
	Identification/definition of special needs			1.65
	Access to mental healthcare and psychological support programmes			1.64
	Medical intelligence gathering			1.63
	Total	**14**		**24.51**
Governance	Disaster plans and policies including mitigation and evacuation emergency management plans		N/A	1.82
	Unity of the leadership after the disaster			1.74
	The application of standards and regulations regarding buildings and infrastructure			1.7
	Shared information (Transparency)			1.68
	Considering scientific analysis of risk assessment			1.64
	Integration with development policies and planning			1.63
	Institutional collaboration and coordination			1.62
	Clear partnership modalities defined and cooperation between concerned entities including private sector			1.61
	Participation of community members (volunteerism) including women and children			1.56
	Integrating populations with special needs into emergency planning and exercises			1.54
	International collaboration and coordination framework			1.46
	Total	**11**		**18**
Physical and environmental	Lessons learnt from previous disasters		N/A	1.9
	Capacity of infrastructures to withstand extra pressure such as floodwater			1.84
	Integration of services such as transportation systems, electric power and telephone			1.82
	Shelter availability during emergencies such as schools and stadiums			1.79
	Accessibility to critical infrastructure			1.78
	Management of waste created by natural hazards			1.74
	Mobile resources for reconstruction including trained workers			1.73
	Location of built environment (probability of exposure to hazards)			1.72

		Monitoring of current built environment and existing services A		1.68
		Brown field treatment (contaminated land with low levels of hazardous waste and pollutants)		1.4
		Total **10**		**17.4**
	Economic	Funds available for reconstruction after disaster	N/A	2.67
		Access to financial services		2.35
		Level and diversity of economic resources		2.32
		Insurance coverage		2.27
		Home ownership status (home owner/renter)		2.17
		Income and employment situation		2.17
		Size of Gross Domestic Product (GDP) per capita		1.94
		Total **7**		**15.89**
	Information communication	Early warning system	N/A	1.81
		Reliability of communication systems		1.69
		Trusted sources of information		1.67
		Backup of critical data		1.62
		Responsibility of media		1.58
		Use of community platforms, e.g. mosques		1.54
		Visual alerting systems		1.5
		Ability to exploit social media		1.47
		Ability to cascade information from international through regional to local communities		1.42
		Total **9**		**14.3**
	Social	Risk awareness and training	N/A	1.02
		Risk perceptions		0.98
		Sense of community		0.97
		Personal faith and attitudes		0.96
		Trust in authorities		0.95
		Previous experience		0.94
		Social networks		0.91
		Faith organizations		0.88
		Education level		0.78
		Demography (age and gender)		0.77
		National language non-speaking (percentage)		0.74
		Total **11**		**9.9**
CCR2	Socio-economic	Demography	5	N/A
		Livelihood	5	
		Health	5	
		Social capital	5	
		Education and Awareness	5	

	Total	**5**	
Physical	Transportation	5	N/A
	Residential infrastructure	5	
	Electricity	5	
	Telecommunication	5	
	Water and Sanitation	5	
	Total	**5**	
Institutional	Laws and Policy	5	N/A
	Coordination	5	
	Emergency response	5	
	Adaptive action	5	
	Governance	5	
	Total	**5**	
Coastal Zone Management	Embankment and Shoreline	5	N/A
	Mangrove management	5	
	Coastal biodiversity conservation	5	
	Coastal pollution control	5	
	Coastal land use	5	
	Total	**5**	
Environmental/Natural	Frequency of natural disasters	5	N/A
	Climate components	5	
	Geophysical components	5	
	Bio-geochemical components	5	
	Environmental safeguard measures	5	
	Total	**5**	

3.5.1 Dimensions

In all of the chosen frameworks, four interrelated dimensions are covered: environmental and climate change, social and economic, infrastructure, and governance and institution, with varying degrees of emphasis on community resilience issues. This is based on local circumstances and reflects the nature of the indicators mentioned in each framework.

Resilience in terms of the environmental and climate change dimension can be roughly linked to a coastal area’s exposure to specific coastal disasters (i.e. rising sea levels). Within each community, there is a different level of exposure to natural disasters. Equally, the distribution of risks to disasters is not uniform across different communities (Lam et al., 2015). This means that the level of natural/environmental resilience linked to each area will vary. Additionally, the environmental safeguarding action for each indicator has been introduced to incorporate specific actions that may be carried out to mitigate the threats arising from climate change. These actions will also be adapted in accordance with the existing risk response mechanisms of local governments. While these factors may, at times, be considered to be negligible, they also have the potential to become highly detrimental to a society and its economy during periods of catastrophe.

In all nine frameworks, the importance of the social and economic resilience dimension has been widely emphasised. In coastal communities, social and economic resilience refers to the ability of a community to survive on limited natural resources when they are typically highly dependent on such resources (DasGupta and Shaw, 2015). Table 3-3 illustrates that the various indicators and sub-indicators that can be categorised under 'social and economic resilience' include demographics, livelihood, awareness, training, culture, employment, safety and security. All of these variables have been carefully selected.

In terms of the infrastructure resilience dimension, utilities, communication and public services are all essential for reducing the impact of disasters (Mc Daniels et al., 2008). When essential public services are discontinued, this has a negative impact on any rescue and relief operations which, in turn, can affect recovery. Thus, it is necessary for the infrastructure resilience to be robust and dynamic. A lack of modern infrastructural facilities, including potable water, reliable public transportation and electricity, all leave a community vulnerable in the aftermath of a disaster. The assessment indicators that fall under infrastructure resilience were all drawn from the nine frameworks that have been assessed. These include transportation, health, utilities, communication, embankment and shoreline.

The study will also consider the dimension of governance and institution resilience. This can be described as the role that governments and associated institutions play in helping to build resilient communities. A proper understanding of governance must incorporate the roles and responsibilities of all levels of government (local, state and federal), as well as the extent to which these either impede or facilitate community resilience. For example, farmers' groups, fishermen's groups and faith-based organisations can also have a strong impact on communities. They can play a role in promoting disaster-risk education and community-based support measures. With this in mind, the institutional indicators and variables were created based on an understanding of socio-political issues within the study area. The general aim of these variables is to measure the institutionalization of disaster risk reduction.

3.5.2 Assessment indicators and sub-indicators

To assess coastal community resilience, several methodological approaches have been adopted. Many of these assessment indicators have been used within a framework that aims to generate relevant, usable information that will increase the size of the current database, which draws information from a variety of sources (Cutter et al., 2014).

Indicators can be described as parameters that help to describe the conditions or circumstances within a specific region that cannot be obtained directly. Indicators can also be used to assess the success and performance of these evaluation systems. They can also estimate qualitative data and assess quantitative data and are also suitable for application in a range of different contexts. This means that indicators can be referred to by various names (i.e. categories, indicators and sub-indicators). Furthermore, indicators can cover a range of aspects, such as demographics, employment, livelihood, community awareness, land use and warning and evacuation systems (DasGupta and Shaw, 2015).

Each chosen framework is made up of indicators that are associated with aspects that can be used to assess community resilience when coastal disasters occur. As Table 3-3 shows, these indicators generally consist of one or more sub-indicator (Alshehri et al., 2015b) that illustrate their multifaceted nature. Community resilience indicators and sub-indicators can be associated with particular values or roles that enhance a community's resilience to a maritime disaster (Courtney et al., 2008). These can include infrastructure and public facilities, the accessibility of roads, education level, voluntary groups, marine pollution and the frequency of natural disasters. There are two main categories of indicator: common indicators for all frameworks, and specific indicators for particular countries or regions. Examples include mangrove management and sea rise level in CCR2, means elevation of the area in RIM and DRR strategies in CDRI3 and LDRI.

3.6 Results and discussion

In ideal circumstances, the coastal community resilience frameworks should provide a holistic framework to incorporate multiple dimensions and aspects of resilience during the assessment process (Kafle, 2012). The different dimensions of resilience addressed in each of the selected frameworks are shown in Table 3-3 A thorough review of the criteria for each framework led to the identification of four common dimensions: society and economy, environment and climate change, infrastructure, and governance and institutions. Table 3-4 illustrates each dimension, split into indicators, which are then further divided into resilience sub-indicators.

However, all of the frameworks suffer from various shortcomings in terms of their design and implementation (Spellman and Whiting, 2006). This study focuses on the discussion of two focal points, as detailed below.

Table 3-4 Common criteria for coastal community resilience assessment frameworks

Society and economy		Environment and climate change	Infrastructure		Governance and Institutions
Demographic	**Livelihood**	**Coastal pollution control**	**Health**	**Communication**	**Laws & policy**
• Population density • Age Dependency • Disability • Level of education • Property ownership and type	• Coastal resources • Household income • Poverty	• Water quality • Marine pollution • Mangrove cover	• Hospitals • Hospital beds • Number of physicians • Number of ambulances • Health insurance • Health care support workers	• Access to mobile phones • Access to radio/television • Reliability of communication systems. • Internet services	• Regulations and policies • Environmental regulation • Participation in DRR planning • DRR strategies
Awareness & training	**Culture**	**land use**	**Transportation**	**Utilities**	**Institutional action**
• Disaster exercises and drills • DRR training • Awareness of disaster and climate change risks • Multilingual awareness programmes • Awareness campaigns	• Social capital • Religious organizations	• Agricultural land • Urban green space • Building code • Mean elevation of the area • Vulnerable built up area	• Roads accessibility • Vehicle ownership • Special need transportation services • School and employee buses	• Infrastructure and public facilities • Renewable energy • Fire stations	• Observation and Monitoring • Institutional collaboration and coordination • Voluntary Groups
Employment	**Safety and security**	**Slow onset disasters**	**Rapid onset disasters**	**Embankment & shoreline**	**Warning and evacuation**
• Employment • Employment dependence on coastal resources	• Riots, conflicts and homicide incidents • ISPS code compliance • Safety and security systems	• Exposure and risk to increasing temperature • Sea level rise	• Frequency of natural hazards • Intensity/severity of natural hazards	• Vulnerable shoreline • Age of embankments • Maintenance of embankments	• Early warning system • Availability of evacuation centre • Emergency Aids • Hotels and motels

3.6.1 Disparities regarding the community resilience dimensions and indicators

The metric can be described as applicable to the integration and assessment of the compatibility of the frameworks. Table 3-5 provides a detailed analysis of the selected frameworks and their magnitude of relevance or applicability within different dimensions, and relative to specific indicators and sub-indicators. Superficially, it can be inferred that nearly all of the frameworks are incompatible or loosely integrated. These can be exemplified, in the society and economy dimension, nearly all frameworks fail to capture vital factors that determine the capacity of a coastal community to overcome the effects of natural disasters to their ordinary lives. Moreover, under the “demography” indicator, most frameworks loosely or fail to capture population growth rate. For example, the CCR1 framework is 67% inapplicable, 24% semi-applicable and 10% applicable in the social and economic dimension.

It is important to assess the extent of the integration of the frameworks on an individual basis. Table 3-5 reveals that the most applicable frameworks in the dimension are CCR2 (61%) and CRDSA (39%). Evidently, the CCR2 framework is the most broadly integrated across the four dimensions. Additionally, concerning the majority of the sub-indicators, the framework is either mainly or partially applicable. Its dominance across all dimensions occurs because CCR2 is specifically designed for application to coastal disasters. However, this premise might not hold, given that CCR1, which was also designed specifically for this purpose, is highly incompatible with the dimensions included in this review. With the exception of the dimension of governance and institutions, the framework appears to be less well integrated into the other dimensions, as shown by its high rate of irrelevance. Similarly, despite affording a specialist framework for coastal disasters, the RIM framework appears to be completely disconnected from the dimensions. In fact, it is wholly inapplicable in the governance and institutions dimension but, in the other dimensions, incompatible with the majority of the sub-indicators.

It can thus be argued that the nine frameworks tend to concentrate more on governance and institutions and less on the environment and climate change. As such, the frameworks are highly compatible and well-integrated into the legal policies surrounding the establishment of coastal community resilience interventions. This is the main reason why frameworks such as CCR2 and CRDSA exhibit impressive applicability indices in the dimension of governance and institutions. Conversely, there are only a few indicators in the environment and climate change dimension, which suggests that the environmental dimension is neglected within coastal community resilience interventions.

However, it is essential to note that the CCR2 framework is highly effective in capturing the sub-indicators of the main indicator, which is coastal pollution control.

From Figure 3-2 and Figure 3-3, it is evident that the selected frameworks place greater emphasis on the government and institutions dimension (37%), followed by the dimensions of infrastructure (34%), society and economy (32%), and environment and climate change (16%),respectively. Their emphasis on government and institutions could suggest the mass presence of external forces and factors that impede the efforts to enhance community resilience. In the ranking of the dimensions provided above, relatively less attention is paid to the environmental dimension, despite its major role in informing and shaping community resilience. Orencio and Fujii (2013) suggest that less regard to the environment in designing coastal community frameworks may emanate from a lack of clear understanding of how environmental processes contribute to changes in climatic conditions. Matyas and Pelling (2015) note that research affords sufficient evidence to confirm that the presence of natural geographical assets, ecosystem protection and resource management is vital for absorbing the shocks arising from natural disasters. Therefore, where community resilience is principally founded on environmental preservation, resilience tends to be formidable, and the likelihood of a speedy recovery is heightened. On the other hand, Sharifi (2016) observes that a failure to ensure the adequate integration of the environmental dimension increases the likelihood that coastal community resilience will be undermined.

Within the four dimensions of coastal community resilience, the society and economy dimension’s indicators include livelihood, demography, employment, culture, awareness and training, and safety and security. As mentioned previously, the evidence regarding the environment and climate change dimension is somewhat truncated. As such, it is mainly characterised by coastal pollution control, land use, slow onset disasters, and rapid onset disasters. In contrast, the infrastructure dimension is broad, encompassing a variety of indicators and sub-indicators. The chief indicators of the infrastructure dimension are health, utilities, transportation, communications and embankments. Finally, the governance and institutions dimension comprises laws and policy, institutional action, and warnings and evacuations as the principal indicators of coastal community resilience, as shown in Table 3-4.

Table 3-5 Coverage of indicators and sub-indicators in the nine selected frameworks

Dimension	Indicator	Sub-indicator	CCR2	CRDSA	RIM	CDRI 3	BRIC	LDRI	CDRI 2	CDRI 1	CCR	Average
Society and economy	Demographic	Population growth rate	●	○	○	●	**○**	**○**	○	○	○	
		Population density	●	●	**○**	●	○	○	○	○	**○**	
		Age Dependency	●	●	●	**○**	**○**	○	**○**	○	○	
		Disability	○	●	●	○	**○**	○	**○**	○	○	
		Level of education	●	●	**○**	●	●	○	●	●	**○**	
		Property ownership and type	●	●	●	**○**	●	**○**	●	**○**	○	
	Livelihood	Coastal resources	●	○	○	**○**	**○**	○	○	○	○	
		Household income	○	●	○	●	**○**	**○**	●	●	○	
		Poverty	●	○	●	●	○	●	○	**○**	**○**	
	Employment	Employment	○	●	●	●	●	●	**○**	●	○	
		Employment dependence on coastal resources	○	○	○	○	**○**	○	○	○	○	
	Awareness & training	Disaster exercises and drills	●	**○**	○	●	**○**	●	○	○	○	
		DRR training	●	○	**○**	**○**	●	**○**	○	○	**○**	
		Awareness of disaster and climate change risks	●	**○**	○	●	○	●	○	●	**○**	
		Multilingual awareness programmes	○	●	○	**○**	●	○	**○**	●	○	
		Awareness campaigns	○	○	○	●	○	○	○	●	○	
	Culture	Social capital	●	**○**	○	●	●	○	**○**	●	●	
		Religious organizations	○	●	○	○	●	○	●	○	●	
	Safety and security	Riots, conflicts and homicide incidents	●	○	○	○	○	○	○	○	○	
		ISPS code compliance	○	○	○	○	○	○	○	○	○	
		Safety and security systems	○	○	○	○	○	○	○	○	○	
		○ Not applicable	43%	43%	62%	29%	33%	62%	57%	57%	67%	50%
		○ Semi applicable	0%	14%	14%	24%	33%	19%	24%	10%	24%	18%
		● Fully applicable	57%	43%	24%	48%	33%	19%	19%	33%	10%	32%
Environment and climate change	Coastal pollution control	Water quality	●	○	○	○	○	○	○	○	○	
		Marine pollution	●	○	○	**○**	○	○	○	○	○	
		Mangrove cover	●	○	○	○	○	○	○	○	○	
	land use	Agricultural land	●	○	○	●	○	○	**○**	○	●	
		Urban green space	●	**○**	○	○	○	**○**	**○**	○	●	

		Building code	○	○	○	●	◉	○	●	○	◉	
		Mean elevation of the area	◉	○	●	◉	◉	○	◉	○	◉	
		Vulnerable built up area	○	○	○	◉	○	◉	◉	◉	○	
	Slow onset disasters	Exposure and risk to increasing temperature	○	○	○	○	○	○	○	○	○	
		Sea level rise	●	○	○	○	○	○	○	○	○	
	Rapid onset disasters	Frequency of natural disasters	●	◉	○	●	○	○	◉	●	○	
		Intensity/severity of natural disasters	◉	○	○	●	○	○	●	●	●	
		○ Not applicable	25%	83%	92%	42%	83%	83%	42%	75%	58%	66%
		◉ Semi applicable	17%	17%	0%	25%	17%	17%	42%	8%	17%	19%
		● Fully applicable	58%	0%	8%	33%	0%	0%	17%	17%	25%	16%
Infrastructure	Health	Hospitals	◉	●	○	●	●	○	●	●	○	
		Hospital beds	○	●	○	○	●	○	●	●	○	
		Number of physicians	●	●	●	○	●	○	●	●	○	
		Number of ambulances	◉	●	○	○	○	○	●	○	○	
		Health insurance	○	●	○	●	●	○	●	◉	○	
		Health care support workers	○	●	○	◉	○	○	●	○	○	
	Transportation	Roads accessibility	●	◉	○	●	●	●	◉	◉	●	
		Vehicle ownership	○	○	○	●	●	○	●	◉	○	
		Special need transportation services	◉	○	○	○	○	◉	●	○	○	
		School and employee buses	●	○	○	○	○	○	●	○	○	
	Utilities	Infrastructure and public facilities	●	●	◉	●	○	●	○	●	●	
		Renewable energy	●	○	○	●	○	○	○	○	○	
		Fire stations	○	○	○	○	●	○	●	○	○	
	Communication	Access to mobile phones	●	●	○	●	●	◉	●	○	○	
		Access to radio/television	●	○	○	●	○	◉	●	○	○	
		Reliability of communication systems.	●	●	○	○	○	○	○	○	○	
		Internet services	●	◉	○	●	●	○	●	●	○	
	Embankment & shoreline	Vulnerable shoreline	●	○	○	○	◉	◉	◉	○	◉	
		Age of embankments	●	○	○	○	○	○	○	○	○	
		Maintenance of embankments	●	○	○	○	○	○	○	○	○	
		○ Not applicable	25%	45%	90%	50%	50%	70%	25%	60%	85%	56%
		◉ Semi applicable	15%	10%	5%	5%	5%	20%	10%	15%	5%	10%

		● Fully applicable	60%	45%	5%	45%	45%	10%	65%	25%	10%	34%
Governance and Institutions	Laws & policy	Regulations and policies	●	●	○	●	○	⭘	⭘	⭘	●	
		Environmental regulation	●	⭘	○	●	○	⭘	⭘	○	⭘	
		Participation in DRR planning	⭘	○	○	●	○	●	○	⭘	●	
		DRR strategies	○	○	○	●	○	●	○	○	○	
	Institutional action	Observation and monitoring	●	●	○	○	○	○	○	○	●	
		Institutional collaboration and coordination	●	●	○	●	○	⭘	○	●	○	
		Voluntary Groups	●	●	○	●	●	○	○	⭘	●	
	Warning and evacuation	Early warning system	●	●	○	●	○	○	○	●	●	
		Availability of evacuation centre	●	●	○	●	⭘	○	⭘	●	⭘	
		Emergency aids	●	●	○	⭘	⭘	●	⭘	○	⭘	
		Hotels and motels	○	○	○	○	●	○	●	○	○	
		○ Not applicable	18%	27%	100%	18%	64%	46%	55%	45%	27%	44%
		⭘ Semi applicable	9%	9%	0%	9%	18%	27%	36%	27%	27%	18%
		● Fully applicable	73%	64%	0%	73%	18%	27%	9%	27%	46%	37%
Total		○ Not applicable	30%	48%	67%	64%	53%	66%	45%	59%	64%	55%
		⭘ Semi applicable	9.3%	13%	6%	16%	19%	20%	23%	14%	17%	15%
		● Fully applicable	61%	39%	27%	20%	28%	14%	31%	27%	19%	30%

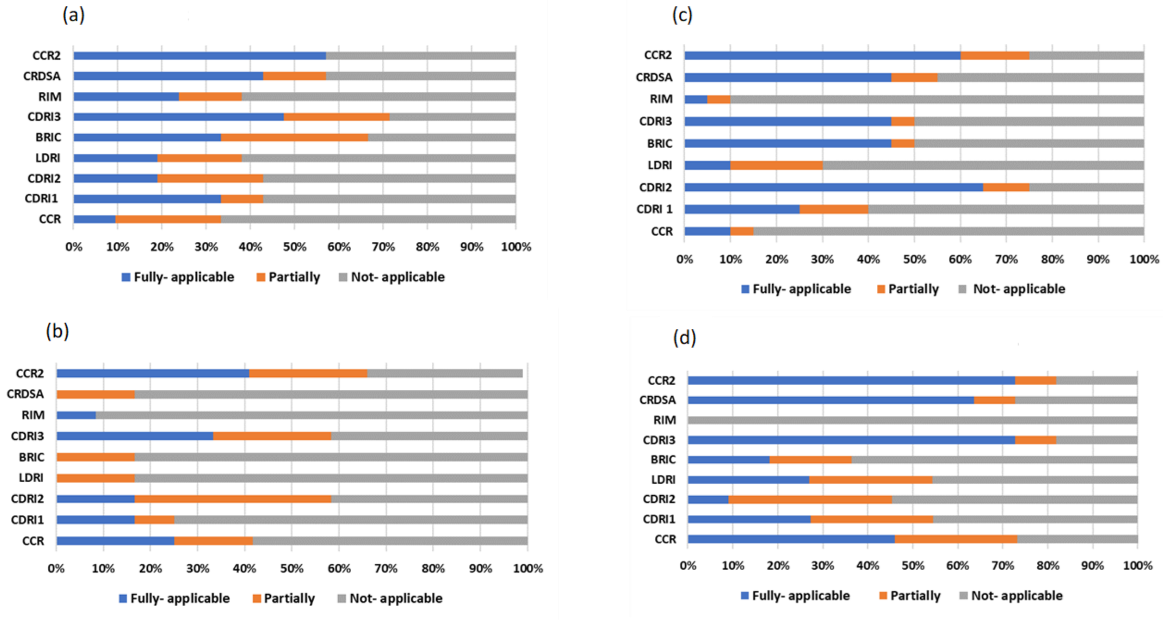


Figure 3-2 Dimensional coverage in the nine selected frameworks. a. Society and economy. b. Environment and climate change. c. Infrastructure. d. Governance and Institutions

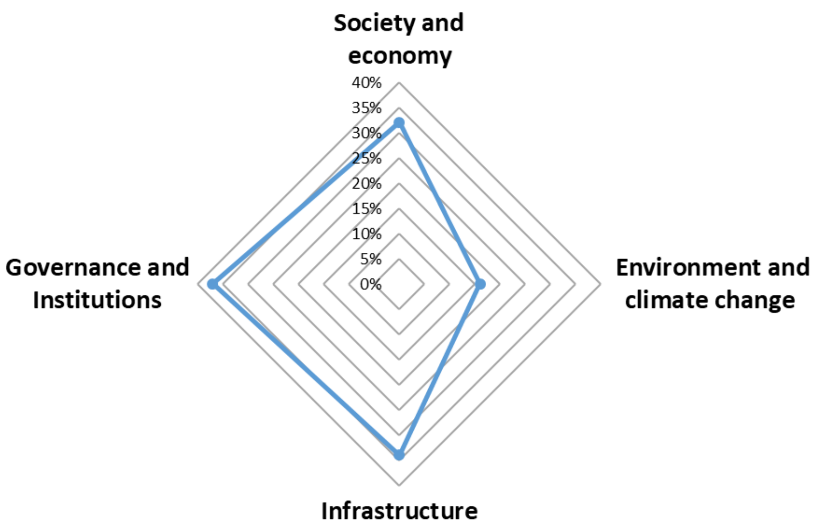


Figure 3-3 Focus of the investigated coastal community resilience frameworks

3.6.2 Construction of the coastal community resilience frameworks

The frameworks were mainly developed by identifying an initial list of indicators following an extensive literature search, and by using stakeholders and experts opinions and perceptions. This was performed to achieve a consensus regarding the key indicators and to assigning weights to each to assess community resilience and the ability to cope with disasters. The majority of the frameworks employed a combination of both quantitative (i.e. numerical data) and qualitative (i.e. expert's opinions) methods (Alshehri et al., 2015).

When various stakeholders are involved, the benefits of using participatory methods are numerous. As Table 3-6 indicates, 90% of the chosen frameworks were developed using extensive literature reviews and experts' opinions. Only one framework (BRIC) depended solely on a literature review. Although community members have in depth knowledge of their community's needs, vulnerabilities and coping capacities, most existing resilience assessment frameworks have been created without the involvement of public; however, the participation of public is vital to establishing disaster resilience (Ostadtaghizadeh et al., 2016). Consequently, the local needs and conditions are frequently not reflected appropriately in these frameworks.

Sharifi (2016) claims that participatory methods can build capacity, improve the local understanding of resilience and risk and establish a platform for sharing experiences and knowledge. They can also encourage collaborative design, and the development of techniques to enhance accuracy. Additionally, the assessment metric enables selected interventions to reflect the priorities of a community and thus improve local leadership, legitimacy and decisions in terms of trade-offs (Cohen et al., 2016, Ahmad et al., 2016, Arbon et al., 2016).

As a consequence of the review, it emerged that there is currently no comprehensive method through which to develop a community resilience framework using both literature reviews and the perceptions of stakeholders and experts. Thus, there is an urgent need to develop a new framework utilizing a participatory methods.

Table 3-6 Method of the selected frameworks and time-based continuum

Framework	Method*	Time-based continuum			Lit. review	Public Opinion/ Perception	Expert Opinion/ Perception	Expert Consultation
		Past	Current	Future				
CCR	Qualitative	√	√	√	√	√		
CDRI 1	Both	√	√	×	√		√	
CDRI 2	Both	√	√	×	√		√	
LDRI	Both	×	√	×	√		√	√
BRIC	Quantitative	×	√	×	√			
CDRI 3	Both	×	√	√	√		√	√
RIM	Both	√	√	×	√		√	
CRDSA	Both	×	√	×	√		√	√
CCR2	Both	×	√	×	√	√		

* Qualitative or quantitative

During this process, it was also necessary to assess how each framework captured risk. In this case, there is a thin veil between capturing risk and how well the frameworks integrate within the resilience-building programmes. Therefore, the extent to which the selected frameworks capture risk may be linked to the manner in which the frameworks are compatible with the coastal community resilience intervention programmes in the first place. Table 3-6 reveals that only 45% of the frameworks focus on the present conditions, while 35% consider the past and 20% examine both the present and future. If the frameworks only encompass the past and present and neglect to encompass the future, they risk ignoring the changing climatic conditions. Therefore, it is clear that the frameworks must consider the past, present and future if they are to understand the system dynamics more effectively and develop strategies for coping with potential changes in the future.

Collier et al. (2016) believe that coastal community resilience should be evaluated on a temporal continuum to guarantee that risk is captured at all times. Sharifi (2016) supports this point, arguing that all stages are linked to events that take place before or after any assessment. This may explain why risk is poorly integrated into the dimensions. Of the current frameworks, CCR2 and CRDSA offer good examples of risk capture, because they consider both present and future conditions. Sharifi (2016), Cimellaro et al. (2016) and Arbon et al. (2016) all believe that monitoring changes along a temporal continuum differentiates the assessment of resilience from evaluations of vulnerability. The assessment of resilience considers the past and future, while evaluations of vulnerability focus solely on the present.

3.7 Summary

Resilience is an important goal when preparing coastal communities for natural and human-made disasters, a fact that is compounded by the increasing exposure of populations to these disasters. Community resilience to disasters is essential if an affected community is to be able to rebuild itself to pre-disaster levels.

It is essential to identify coastal community resilience frameworks that have been applied across the globe and to enhance community resilience by identifying beneficial criteria that will make this possible. In this study, nine selected frameworks were critically analysed, and different resilience dimensions addressed in each of the selected frameworks presented. Four common dimensions were identified, based on a thorough review of the criteria of each framework. These dimensions are society and economy, environment and climate change, infrastructure and governance and institutions. These were subsequently divided into eighteen indicators and sixty-four sub-indicators.

Comparison matrices were developed to assess the extent of the applicability of the different frameworks across several sub-indicators within four dimensions. The review found that most of the frameworks were significantly broad in scope. Additionally, it emerged that, despite the fact that several of the frameworks were designed specifically for coastal areas, these were largely incompatible, and consequently poorly integrated into resilience programmes. Crucially, many of the frameworks employed a narrower scope when dealing with the environment and climate change dimension when contrasted with that for the other dimensions. In this review, it was confirmed that ecosystem protection and resource management is vital for absorbing the shocks contributed to by natural disasters. Therefore, where environmental preservation is the principal foundation of community resilience then resilience is formidable, and the likelihood of a speedy recovery from disaster is heightened.

The frameworks were also assessed according to different metrics which demonstrated the existence of a significant mismatch between the frameworks and the most widely used dimensions of resilience. It is important to note that those experts who determine the indicators ought to consider local standards to ensure that their frameworks remain sufficiently objective.

Accordingly, the next chapter will provide an outline of the methodology used in this research together with the expert opinions sought. It will follow on from this chapter by demonstrating how the identified assessment criteria (dimensions, indicators and sub-indicators) will be analysed.

Chapter 4
Methodology

In this chapter, an overview of the methodology that will be used to achieve the objectives of this thesis will be outlined. This overview will include the procedures used to undertake the research, as well as the philosophical assumptions and design strategies that underpin the study. In addition, the data collection and analysis procedures will be documented.

4.1 Research philosophy paradigms and research methods

The research methodology can be described as an outline of the strategy used to collect and analyse data with the aim of addressing the research questions and achieving the research objectives. Despite the fact that there is no universal philosophical paradigm in terms of research method, various universal schools of thought exist. Oates (2005) cites positivism, interpretivism and pragmatism as the three predominant schools.

Positivism is strongly related to the concept of objectivism. In this paradigm, the concern of researchers is to collect data from a large sample rather than focus on specific research details (Muijs, 2010). Within the social sciences, positivism considers human behaviour to result from a reaction to external stimuli in the environment. This means that it can be assessed using deductive methods (Bowling, 2014).

In contrast, **interpretivism** is said to be "predicated upon the view that a strategy is required that respects the differences between people and the objects of the natural sciences" (Bryman, 2016). Under this paradigm, one person's reality is believed to be different from another as a result of their varied social perspectives. This means that it is important for interpretivist researchers to outline the truth from each participant's perspective. Interpretivism largely uses qualitative research methods, such as interviews, focus groups and observations (Saks and Allsop, 2012).

Pragmatism is a combination of both positivism and interpretivism, and it has experienced a recent revival after having declined in use for some time. Giacobbi Jr et al. (2005) describe pragmatism as "a philosophy of knowledge construction that emphasizes practical solutions to applied research questions and the consequences of inquiry." Thus, according to Saunders et al. (2009), it is a useful philosophical approach for mixed methods research. Therefore, this approach will be used.

Based on the above paradigms, the next section will focus on the two primary classifications of research methods: quantitative and qualitative. According to Bryman (2016), it is important to distinguish between these two basic strategies in research to resolve any methodological issues.

4.1.1 Quantitative research

Quantitative research entails the collection of numerical data with the aim of explaining a particular phenomenon (Saunders et al., 2009). Researchers carrying out quantitative research largely depend on statistical and numerical measurements, which help develop or expand knowledge on social life. Saunders and Tosey (2013) note that quantitative research largely uses surveys (both descriptive and analytic), experimental design (quasi-experiments) and classic experiments (studies with control and experimental groups).

4.1.2 Qualitative research

Qualitative research, in contrast, depends primarily on human experience and knowledge, and is strongly linked to cultural and social investigations. Qualitative research is favoured in the social sciences for its ability to systematically help researchers to understand various sociocultural problems (Myers, 1997, Yin, 2011). This type of research tends to be inductive and interpretivist, relying largely on ethnography (observation), interviews, focus groups and case studies (Bryman, 2016).

4.1.3 Mixed methods

Johnson and Onwuegbuzie (2004) define mixed methods research as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study.” With this in mind, mixed methods can be considered as “the third major research approach or research paradigm, along with qualitative research and quantitative research” (Johnson et al., 2007). The mixed methods approach has numerous advantages, including the ability to answer research questions that other methodologies cannot, to provide stronger inferences and to open up a broader range of perspectives (Tashakkori and Teddlie, 2003). Saunders (2009), in particular, argues that mixed methods is a stronger approach to qualitative or quantitative approaches alone because it can help achieve different objectives, which improve the strength of findings, and it can allow triangulation, due to the combination of different methods (i.e., interview and questionnaire). Bowling (2016) lists numerous mixed methods approaches, such as case studies, consensus methods, action research, rapid appraisal techniques and document research. In the context of disaster research, there is a need to use a mixed methods approach. With this in mind, this thesis has chosen to adopt such an approach, drawing upon web surveys, Delphi surveys and the Analytic Hierarchy Process (AHP).

4.2 Research structure design

As stated above, this thesis will use a mixed methods approach, consisting of both quantitative and qualitative research. This will include a literature review, web surveys, Delphi surveys and the AHP. Figure 4-1 shows the design, which consists of five stages. The previous literature review has revealed the research gap in terms of disaster risk management. The quantitative approach will be used to explore stakeholder opinions for identifying relevant factors and their importance. The qualitative Delphi survey will be used in the third stage, followed by AHP to establish a framework of coastal community resilience to disaster in Saudi Arabia.

4.3 Stage one: Comparison of resilience assessment frameworks

The systematic literature review involved the selection of research publications, which were collected, appraised and synthesised. A rigorous and documented procedure was put in place for both the search strategy and the process of selecting the research papers. Bealt and Mansouri (2017) argue that a systematic literature review requires a scientific approach enabling researchers to conduct a detailed article search, while promoting transparency and relevance and avoiding bias. Moreover, a systematic literature review enhances the knowledge base of the researcher, thus having a positive impact on both practice and policy. For the current study, relevant papers were selected using a comprehensive process of planning, searching, screening and reporting.

The search strategy adopted was comprehensive and extensive aiming to capture a range of frameworks applied globally and concerning the assessment of coastal community resilience to maritime disasters. Various databases were targeted and a number of key words used in the search as detailed in section 3.2 (methodology).

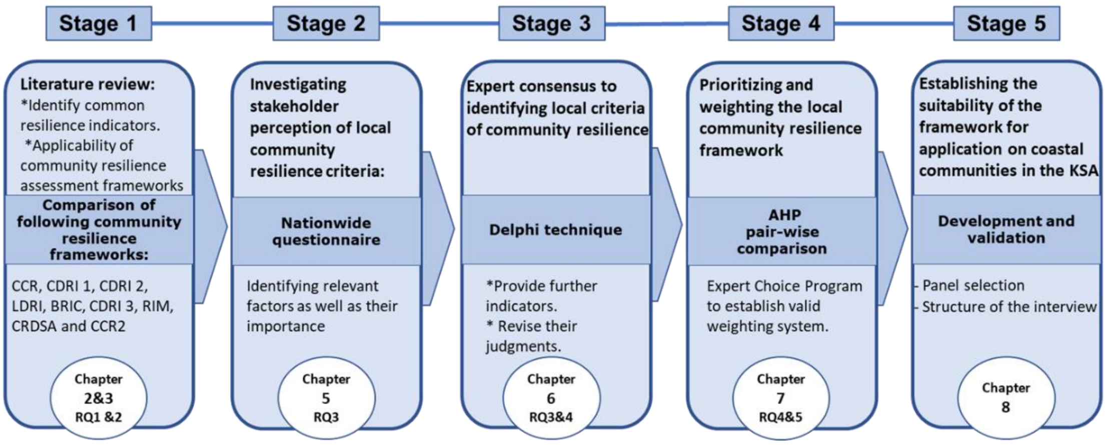


Figure 4-1 Research design and workflow

The majority of the methodological approaches were designed (or developed) in relation to the needs of a specific region of the world. This resulted in each possessing varying indicators for each dimension of resilience. The current study therefore excluded any frameworks considering only one aspect of community resilience, i.e. frameworks designed to enhance community resilience for health security (Chandra et al., 2011) and those focused on a single form of natural disaster (Ainuddin and Routray, 2012).

A list was subsequently drawn up of the initial important and common criteria related to coastal community resilience by means of a thorough review of the criteria of each of the nine selected frameworks (CCR, CDRI1, CDRI2, LDRI, BRIC, CDRI3, RIM, CRDSA and CCR2). The selected criteria were categorised into four common dimensions and several matrices were developed, with the criteria set out in the rows and the frameworks in the columns. Comparison matrices were created to ensure that all related criteria were included in the list, as well as to assess the extent of the applicability of the different frameworks across several indicators and sub-indicators within the four dimensions. Following a detailed review and after comparing the criteria for each of the nine chosen frameworks, a list of coastal community resilience to maritime disasters indicators were identified and were thought to be commonly used as noted in the third chapter. These significant indicators will form a starting list that will be the basis for the subsequent research phases. The chosen indicators are comprehensive and precise, thereby decreasing the chance of overlap between the dimensions of resilience.

4.4 Stage two: Stakeholders’ perception of resilience to maritime disasters

Resilience assessments can be used as a first step to identifying key indicators (e.g. socio-economic and environmental) and can then be linked together to build resistance capacities. Through these indicators, it is possible to examine the various associations between the enhancement or diminishment of economic stability in communities, particularly in terms of livelihoods. A key economic factor linked to livelihood is dependency on a small amount of natural resources. These indicators also help assess the amount of private property that could be vulnerable to damage and economic losses resulting from a potential disaster (Cutter et al., 2010). This information can then aid decision-makers to develop better strategies for improving community resilience (Cai et al., 2016). Therefore, various researchers have established frameworks and resilience indicators (Alshehri et al., 2015a, Joerin et al., 2012, Orencio and Fujii, 2013, Cutter and Director, 2008). Nonetheless, measuring community resilience still poses a challenge (Alshehri et al., 2015b).

Although community members have deep knowledge of their community's needs, vulnerabilities and coping capacities, most existing resilience assessment frameworks have been created without the involvement of stakeholders; however, the participation of stakeholders is vital to establishing disaster resilience (Ostadtaghizadeh et al., 2016). Therefore, one of the main objectives of this study, is to fill this gap in the literature by collecting the views of stakeholders on community resilience challenges in the context of Saudi Arabia, to identify the key priorities of the stakeholders as a significant first step towards integrating their participations into the development of community resilience assessment frameworks based on local priorities. The customary methodology used to examine stakeholder perceptions is the employment of a questionnaire used in various fields (Huang, 2006). As stated by Lindell (2013) the questionnaire was the most prevalent technique used in gathering of numerical data in disaster studies. Stakeholders in this research include the members of the public, experts, development organisations, and the Government who have an interest in disaster resilience and risk management in KSA.

4.4.1 Questionnaire design and respondents

To achieve the goals set, the research design employed a quantitative methodology. An important component of the data collection process was the collection of data from individuals from a range of age groups, with different educational attainment levels and from different geographical locations. To accomplish this, a questionnaire was created and distributed to members of the Saudi Arabian public.

According to Leung (2001), designing a questionnaire has two objectives: to obtain a large number of respondents; and to receive accurate answers on a particular topic. To achieve these two objectives it is crucial that a questionnaire is simple, have clear presentation and unambiguous wording and that both questions and answers are kept together (Bryman, 2016). Bowling (2005) claims that having a well-designed questionnaire is equally important. This is because the design would have a considerable effect on the type of results. For the purposes of this study, the questionnaire was designed in the following manner:

- Classification questions: These questions concern demographic information about the respondent, including gender, age, occupation, qualifications and location (including region).
- Knowledge questions: These questions are used to assess the level of factual information that each respondent has regarding the construction of community resilience to socio-economic and environmental impacts in his/her city and region.

- Responsibility questions: These questions assess the respondent's priorities regarding a range of relevant factors.
- Perception questions: These questions are aimed at understanding and determining the awareness that each stakeholder has in terms of community resilience enhancement issues for maritime disasters.

The structure of the questionnaire was based on similar surveys carried out by (Alshehri et al., 2013, Ameen and Mourshed, 2017). An initial list of coastal community resilience challenge indicators was identified based on an extensive review of the literature with particular reference to maritime disasters in Saudi Arabia and surrounding regions based on socio-economic and environmental impact. The questionnaire consisted of twenty-five questions, of which the majority were multiple choice questions. It also featured several open-ended questions, which enabled the respondents to add any comments or other significant information that they deemed important. Respondents were also asked to provide details of their age, gender, occupation, academic qualifications, region and location.

4.4.2 Conducting the questionnaire and response rate

Between September and October 2017, a pilot study was carried out with ten participants. The study took roughly twenty to thirty minutes. Following feedback, a number of adjustments were made to correct and clarify items for the final version. The questionnaire was uploaded to Survey Monkey (www.surveymonkey.com), in both Arabic and English.

A link to the questionnaire was sent to potential participants via email and social media (e.g. WhatsApp). The snowball sampling technique was also used to ensure a target sample size was achieved. Sampling took place between November 2017 and February 2018. The only participation requirement was that respondents needed to be older than eighteen. All the respondents were informed in writing that their participation was voluntary and that their data would be retained confidentially.

According to Bird and Dominey-Howes (2008), snowball sampling is a non-probability sampling technique that enables researchers to gain access to an anonymous community and identify and recruit key participants (Bird, 2009). Huang (2006) argued that this can be useful in situations where it is difficult or expensive to locate suitable participants. Alshehri et al. (2013) used the example of Saudi Arabia to illustrate this point, stating that the country's customs and traditions make it difficult to recruit female respondents. Moreover, snowball sampling is generally claimed to provide economical, efficient and effective results. When using this method, data was collected by identifying participants through direct contacts who then go on to recruit others (Sadavoy et al., 2004), and this process continues until the target sample is obtained. Snowball sampling can be carried out via emails, phone calls, or face-to-face contact (Bird, 2009). As Saudi Arabia is a large country, emails and social media were used in this study to distribute the questionnaires. This proved to be more cost-effective, provided recipients time to consider their responses and resulted in overall higher response rates.

4.4.3 Data analysis and quality

To carry out the statistical data analysis, IBM SPSS Statistics for Windows version 20.0 software was utilised (Bryman, 2015). This software enabled the computation of descriptive statistics regarding indicators and scale frequencies, response percentages, means, modes and standard deviations (SD). A descriptive analysis was also conducted on the demographic data by calculating their frequencies and percentages. Cronbach's alpha (α) was used to assess internal consistency reliability (Cronbach, 1951). It was applied to questionnaire items to measure reliability through the provision of one single estimate regarding internal consistency and average correlation (Webb et al., 2006). According to Hassad (2010), past social studies recommended $\alpha = 0.70$ as the threshold of acceptable reliability. In the current study, all seventeen indicators were assessed using principal component analysis, which helped to determine the underlying structure by grouping together correlated variables. The significance of each component was assessed by testing the scree plots and the contribution of each to total variance (>5%). Using the results of the PCA, variance maximisation (varimax) was also applied. This is referred to as an 'orthogonal rotational strategy', which in the case of this study helped reduce the number of factors for variables with high loadings. It also facilitated the interpretation of the analysis (Ameen et al., 2015). Moreover, as Kim and Mueller (1978, p. 50) pointed that, "It can be argued that employing a method of orthogonal rotation may be preferred over oblique rotation, due to the former is much simpler to understand and interpret". The criterion for including an item was a factor loading of more than 0.40. To identify significant correlations between items, Bartlett's test of sphericity was used. Sampling adequacy was assessed using the Kaiser-Meyer-Okin (KMO) measure, which for this study was 0.921. This meant that a KMO greater than 0.8 was considered good; thereby indicating that the PCA was appropriate for such variables (Cerny and Kaiser, 1977).

4.5 Stage three: Identification resilience assessment factors

This research methodology was selected to answer the following research question: what are the applicable coastal community resilience factors needed to manage disasters in the Saudi Arabian context? To answer this question, a survey based on the Delphi technique will be used. The Delphi method has been reported in the literature as an iterative multistage process to combine opinion into group consensus (McKenna 1994, Lynn et al. 1998 and Hasson et al. 2000). The initial questionnaire employed in this research collected qualitative comments that were fed back to the participants in a quantitative manner through a second questionnaire. The use of both qualitative (round 1, collected opinions and new indicators) and quantitative (round 2, provided mean and median) data makes it a mixed-method approach. The term, mixed-method has also been used in previous research to describe the Delphi (Alshehri et al., 2015). (Okoli and Pawlowski, 2004) state that the Delphi technique is a method used to structure communication amongst a panel of experts when seeking their opinion on a complex matter. The Delphi technique is systematic in nature and can help a researcher to reach a consensus on a subjective issue based on group judgement. The technique is widely recognised as being robust and reliable. Rowe and Wright (1999) and Loo (2002) argue that the technique is characterised by four fundamental features:

- **Iteration –** The Delphi technique consists of multiple stages, thereby requiring the participants to participate in several rounds. The iterative nature of this technique means that panellists have the opportunity to review all previous responses of the other experts. This means that they can reflect and adapt their judgement accordingly if necessary.
- **Anonymity –** A key aspect of the Delphi technique is the anonymity of the participants. This must be maintained by the coordinator to reduce any possible effects of the position, influence or social dominance of particular experts. This anonymity allows everybody to state their opinion without any concerns or influence.
- **Controlled feedback –** Data exchanged between the panellists is filtered and exchanged in a controlled manner. After each round, the coordinator will analyse any relevant information that may help in the development of the next stage. This process is essential in reducing the possibility of heated debates and facilitating a smooth transition to the next stage of the study.
- **Statistical group response –** The Delphi technique often entails complex issues. Thus, it necessitates the use of reliable analytical methods that ensure the study reflects the overall group judgement with accuracy. With this in mind, a range of statistical indices (mean, median and IQR) will be used to help achieve this goal, as well as reduce any pressure or influence for individuals to conform to expected or dominant views.

4.5.1 Justification

The study under investigation in this thesis is a multi-dimensional subject encompassing various types of maritime disasters including both man-made and natural. It also involves the examination of a number of well-established frameworks for assessment of coastal community resilience that have been employed globally. In addition, to help analyse all this data the opinions of the public and a large number of key stakeholders and experts in the field were sought. Thus, it is evident that a consensus technique that can be comprehensive in nature and inclusive would be required to ensure all angles and players are accounted for in this study. To this end the Delphi technique was selected as also supported by (Chew and Das, 2008). Loo (2002) highlighted the suitability of the Delphi technique for attaining consensus. Two primary features of the Delphi technique that make it extremely suitable for analysis of the assessment criteria is first, the anonymity afforded the participants and second, the inclusive nature of the technique allows experts from across the globe to present their opinions. Experts participating in discussions would not be pressurised or swayed in their opinions by knowledge of the participation of other influential experts. They would freely be able to present their opinion making their choices more honest and trustworthy.

The ease of selecting a suitable communication technique that also helps to maintain confidentiality is another key feature of the Delphi technique. This range of communication options (conventional or real time) is made possible by the researcher being given the choice of Delphi technique to apply: classical, decision, ranking or policy Delphi (Okoli and Pawlowski, 2004, Linstone, 1985, Rowe and Wright, 1999).

Finally, the statistical methods applicable to this technique make it possible to define a consensus opinion born of the choices of many key players. This increases the robustness of the technique and ensures a criteria-based and expert-guided decision is reached

Therefore, the study has been designed in keeping with the Delphi process; utilising anonymous rounds and gathering feedback following each round. The criteria, scale and format to be used for the questionnaire were determined and a pilot survey involving 10 participants was run. This examined the simplicity of taking the survey. This indicated the requirement for particular changes which were implemented prior to being distributed online via SurveyMonkey® (www.surveymonkey.com) between the 15th of April to 15th of June 2013.

4.5.2 Types of the Delphi technique

The Delphi technique involves a multi-phase survey that is anonymous in nature. It consists of rounds through which responses and group opinions are collected. Rounds continue until a consensus is obtained for each criterion (Dalkey and Helmer, 1951, Dalkey and Helmer, 1963, Landeta and Barrutia, 2011). There are different types of Delphi technique, of which the classical, policy and decision forms are the three most well-known (Hanafin, 2004, van Zolingen and Klaassen, 2003, Keeney et al., 2006).

In the **classical Delphi technique**, experts are brought together to agree on a specific aspect of a piece of research. Views and opinions are gathered over a series of rounds. The outcomes of these rounds are subsequently distributed to the experts, serving as background information for future rounds. Three or more rounds is the most common, while conventional post is deemed as the most common method of communication (Hasson et al., 2000). With this technique, the principal aim is to maintain the anonymity of participants through an iteration process until a consensus is reached (van Zolingen and Klaassen, 2003).

The **policy Delphi technique** consists of several iterative rounds that are used to gather information from experts. However, in this case, the aim is not to obtain a consensus from these experts. Instead, its objective is to collect contrasting views on a particular topic. Normally, the chosen experts are policy makers who offer a range of opinions. Just as with the classic Delphi approach, repetitions can take place. In this case, the mode of communication can vary, including group meetings between members. With this approach, confidentiality is an important aspect of the first round when experts respond to queries individually, but in future rounds, it is not deemed important because group meetings with varying perspectives are required (Hasson and Keeney, 2011, Linstone, 1985).

The **decision Delphi technique** aims to organise a decision-making process for future issues by coordinating thoughts on a particular topic through the careful consideration of possible developments and changes in the field (Rauch, 1979, Rowe and Wright, 1999). Here, all panellists are chosen according to their position and interest in resolving the problem. This means that the panel does not have to be large, as it is expected that imminent decisions will be made and implemented. With the decision Delphi technique, decisions are made through a combination of repetitions and response management. Moreover, three rounds are not necessary (Hasson and Keeney, 2011). Rauch (1979) claims that this type of Delphi is more general and comprehensive than the classical and policy techniques. Van Zolingen and Klaassen (2003) outline five particular aspects of this Delphi: quasi anonymity (i.e. all experts know each other by name before the study is started); iteration; feedback; statistical group response; and consistency in responses.

In this study, the style selected for the Delphi technique is the classical Delphi. This ensured flexibility in means of communication. Moreover, the iterative nature of this style and the ability to maintain anonymity was crucial in reaching consensus without undue pressure on experts to agree with other opinions.

4.5.3 Selection and size of the Delphi panel

It has been widely stated that selecting the panel is an essential component of any successful Delphi study (Rowe and Wright, 1999). With this in mind, a number of guidelines have been followed to obtain a suitable panel both in size and in composition (Okoli and Pawlowski, 2004, Schmidt et al., 2001). To obtain a size of Delphi panel, some studies have employed over 60 experts while others have involved as few as 15 experts (Hasson et al., 2000). Its primary consideration must be that the panel is large enough to allow patterns to be seen in terms of responses, yet not so large that it leads to confusion and arguments (Okoli and Pawlowski, 2004, Witkin and Altschuld, 1995).

In most studies, the Delphi panel size was maintained below 50 participants. This is in keeping with Clayton's rule-of-thumb which specifies an ideal panel size would be in the range between 15-30 (Clayton, 1997; Witkin, 1995). Other studies, however, have indicated a range between 20 to 50 to be the ideal (Endacott, 1999). According to Dalkey and Halmer (1963), research should not consider the size of a panel in terms of its statistics, as this is not an important aspect of the Delphi technique. Instead, research must focus on selecting experts that have the knowledge, professional qualifications and relevant experience in the particular field in question (Loo, 2002). In particular, four 'expertise' requirements must be considered: knowledge and experience of the field of study; ability and willingness to participate; adequate time to participate and effective communication skills (Adler and Ziglio, 1996). Other essential factors are number of years of experience, number of publications, in addition to any other expert qualifications.

For the purposes of this study, a list of experts in disaster risk management was drafted. These experts were then asked to identify other experts in the same field. The end result was a Delphi panel of sixty-five members, made up of professionals and local experts from academia, government and industry. All of them had at least five years' experience in disaster risk management and a relevant degree.

Table 4-1 indicates that panel members came from diverse backgrounds both governmental and non-governmental organisations, as well as the private sector. This ensured a balanced representation. Rådestad et al. (2013) suggest that Delphi panels must consists of experts with varying expertise and geographic locations. Moreover, they should come from a range of different disciplines (Hill and Fowles, 1975, Keeney et al., 2001). Taking this advice on board, all experts were recruited from various disciplines of disaster risk management, as well as from local and international contexts. All also had in-depth knowledge of national and global issues. Jirwe et al. (2009) and Rådestad et al.

(2013) have stressed the importance of informing all experts about the context of the study and defining any key terms used in the research, such as 'community'. Following this recommendation, all experts were contacted by email, phone or face-to-face and were informed of the purpose of the study, particularly in terms of its context and key concepts. All experts were educated about the questionnaire rounds based on the Delphi method.

Table 4-1 Composition of The Expert Panel

Expert	Organisation	Distribution
Academia	King Abdelaziz University	15% as follows. Professor: 2% PhD: 17% MSc: 26% BSc: 46% Other: 6%
	University of Dammam	
	King Faisal University	
	Al-Baha University	
	Najran University	
	King Fahd Security College	
	Taibah University	
Government official	General Directorate of Civil Defence	63%
	Crisis and Disaster Risk Management Center in Makkah Region	
	Ministry of Municipal and Rural Affairs	
	Saudi Arabian Border Guards	
	Royal Saudi Naval Forces Riyadh	
	General Directorate of Medical Services of the Royal Saudi Armed Forces	
	Saudi Ports Authority	
	Presidency of Meteorology and Environment	
	Ministry of Energy, Industry and Mineral Resources	
	Saudi Red Crescent Authority	
	Ministry of Education	
	Ministry of Health	
Non-Government Organisation	The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden	17%
	Saudi Aramco	
	National Water Company	
	Saudi electricity co	
	General Authority of Civil Aviation (GACA)	
Regional and international	Petroleum Development Oman CO	3%
	Iraq Engineering College	

4.5.4 Development of the Delphi survey

A questionnaire was compiled that would allow all experts to express their judgements, with extra space provided for them to add, remove, criticise or justify their responses. The questionnaire was designed by drawing upon the potential community resilience factors (four dimensions and eighteen indicators and sixty-four sub-indicators) identified from a comparative study of global assessment frameworks, as well as the findings gathered from a nationwide questionnaire of Saudi Arabia. Moreover, a pre-test pilot questionnaire was issued to 10 academic professionals before the Delphi rounds took place. Their feedback was used to improve its quality and clarity. Each participant was given a link to the online questionnaire (in English), which was available at www.surveymonkey.com. Respecting the Delphi procedure, a guarantee of confidentiality was given to all participants. The opinions of all respondents were collected on a 5-point Likert scale ranked from 'Unimportant' to 'Very important'. In the initial round, seventy-three experts were invited, with a response rate of 89% (n = 65).

All the experts who took part were invited to participate in the second round. For this reason, the response rate for the second round was 79% (n = 58). As the second round achieved a complete consensus, there was no need for any further rounds.

4.5.5 Delphi process and measuring consensus

In theory, the Delphi process may be continually carried out until a general consensus is obtained amongst all participants. According to Hasson *et al.* (2000), the process involves collecting opinions without having to bring panellists together physically due to the use of successive questionnaires. It is generally agreed that two or three rounds are expected when carrying out this process. However, many researchers Miller (2001), Kaynak and Marandu (2006), Mason and Alamdari (2007) and Giannarou and Zervas (2014) have suggested that two rounds are usually enough to collect all the necessary information and obtain a consensus amongst participants. Each round is expected to change the judgements of panellists, thus resulting in the desired level of consensus. It is the role of the researcher to determine when data collection must end, as well as the definition of consensus within the confines of the study. Hasson et al. (2000) gives the example of an opinion receiving just over 50% agreement in round one being fed back to participants in round two. They claim that this is problematic because it may bias the range of opinions offered in successive rounds.

The main statistics to be used in Delphi studies include measures of central tendency (i.e., mean, median, mode) and level of dispersion (standard deviation, inter-quartile range). These measures help present information on the collective opinions of respondents (Hasson et al., 2000). In the majority of cases, median and mode are favoured. However, the mean is also drawn upon at times (Murray and Jarman, 1987). Nonetheless, the appropriateness of the mean has been questioned by Witkin (1984) who argues that if scales are used in a Delphi study, using the mean to measure the responses can cause issues when they are not delineated at equal intervals. Researchers, such as Hsu and Sandford (2007) and Hill and Fowles (1975), have all favoured the median, based on a Likert scale. With this in mind, this study has used the three measures together to assess the consensus:

- The interquartile range (IQR) was $0 \leq IQR \leq 1$ (Alyami et al., 2013, Aldossary et al., 2015).
- The standard deviation (SD) was between 0 and 1 ($0 < \sigma > 1$) (Rayens and Hahn, 2000, Giannarou and Zervas, 2014)
- Any items with a consensus on neutral opinion (median < 3.5) were excluded from the subsequent round (Mombaerts et al., 2017).

A two-round Delphi process was used in this study. In the first round, the expert panel was presented with an initial list of all items (dimensions and indicators) of the community resilience assessment framework with the aim of assessing their perceptions on the importance of each item in reference to disaster risk management in Saudi Arabia. All participants had to rate each item on a 5-point Likert scale (1 - Unimportant, 2 - Of little importance; 3 - Moderately important; 4 - Important; and 5 - Very important. Participants were also given the opportunity to share any comments or opinions on new items related to community resilience and disaster risk management in Saudi Arabia. Any items that reached consensus in this round were not re-rated in the subsequent round, while any new items suggested by the experts were included. Items that obtained an IQR and SD of more than 1 suggested a non-consensus; therefore, they were moved into the next round. In contrast, those with a neutral opinion (median < 3.5) were not carried through to round two. In round two, a complete consensus was obtained, thus there was no need for any further rounds. The next stage of analysis will employ a multi-criteria decision making (MCDM) approach referred to as Analytic Hierarchy Process (AHP).

4.6 Stage four: Prioritisation of resilience assessment factors

This study aims to develop a framework for the examination of a coastal community's resilience to maritime disasters in Saudi Arabia. This requires the contribution of various factors at various levels of significance. The AHP allows for the structuring of this data in hierarchical form thereby allowing its measurement and synthesis leading to the attainment of a consensus on the desired framework.

AHP was developed in the 1970s by Saaty (1994). Its strength lies in its ability to structure complex criterions dimensions, indicators and sub-indicators into a more simplified hierarchical structure. This allows various decision makers to then contribute to the elucidation of the level of importance of each criterion by quantitative means, namely pairwise comparisons. Therein lies the second strength of this methodology its conversion of subjective data into a mathematical form. Each criterion is measured against other criteria and alternatives which determine its level of significance and preference on a ratio scale. The process then builds up on these factors by the assignation of weights to each criterion, thereby leading to the development of a comprehensive and logical framework. This therefore allows both quantitative and qualitative criterions to be assessed (Samari et al., 2012). Moreover, experts in the field may be biased in their selections or their selections may raise discrepancies that may hinder the development of a framework. Such challenges are diminished by the application of AHP to the analysis of the criterions governing a framework (Poveda and Lipsett, 2011). Lastly, the use of commercial software removes the challenges posed by the incorporation of mathematical formulae in the AHP.

4.6.1 Justification for employment of AHP

The increasing risk visited on coastal communities by maritime disasters can lead to increasing mortality rates and financial losses. These are chief reasons for stakeholders seeking to decrease the impact of such disasters to develop a framework based on the use of reliable scientific methodology. In the context of this study such a framework would define indicators and sub-indicators specific for the Saudi Arabian communities.

The absence of a local coastal community framework specifically for Saudi Arabia and the involvement of various agencies and organisations in the response to such disasters in Saudi Arabia are two primary reasons for the employment of AHP. The involvement of so many experts and drivers of response necessitates the use of a methodology that would allow the equal contribution of all stakeholders.

Similarly, a certain complexity is also introduced by the various established community resilience frameworks. These frameworks vary on several fronts including their specificity to coastal areas (Lam et al., 2015), the specific country (community) of previous application (which continent, a developed or developing country), the number and types of disasters they encompass etc. The various frameworks place varying levels of significance on the various dimensions, indicators and sub-indicators. To be able to achieve the research aims there was a need to employ a methodology that could break down the criterions into associated sub-classes to allow their organisation into a logical framework (Vaidya and Kumar, 2006, Alidi, 1996). This would help identify coastal community resilience factors that are applicable specifically to Saudi Arabia. Furthermore, the methodology selected must have a reliable weighting structure outlined that would aid in the measurement of community resilience in the context of Saudi Arabia. Finally, the methodology should also allow the organisation of the criterions into a local coastal community resilience framework. AHP allows that achievement of this through its hierarchical organisation (Ishizaka and Labib, 2009), its accounting for both quantitative and qualitative data (Vaidya and Kumar, 2006) and it deployment of computational software (e.g. expert Choice) for handling large numbers of criterions (Viswanadhan, 2005). This is possibly AHPs strongest feature. A researcher does not need to be a mathematician to employ this methodology. Moreover, the use of Expert Choice can also aid the attainment of consensus one of the chief goals required to develop a framework (Vaidya and Kumar, 2006). In this study, the weighting was carried out on the four dimensions rather than the sub-indicators. This was performed on this level because of the need to avoid a large number of criteria as exemplified in the sub-indicator level. Various studies had previously established the challenges of performing a large number of comparisons larger defined as greater than seven comparisons (Bahurmoz, 2006; Saaty and Vargas, 2012). By ensuring minimal numbers are used, and thus the possible alternatives are limited, the judgements attained would remain consistent (Bahurmoz, 2006). As the number of indicators used in this study was 18 and sub-indicators 68, it was therefore logical to perform the weighting on the four dimensions of the first level.

To perform the AHP process, 21 experts were invited of which 19 eventually participated. This number may be considered small by some researchers but various studies have demonstrated how AHP can be performed by a small number of experts (Lee and Walsh, 2011; Omar and Jaafar, 2011).

The method applied in the AHP can be broken down into the following sections as described by Lin et al. (2010) and Farzad and Aidy (2008):

- Hierarchy determination.
- Data collection and prioritisation of the elements be constructing pair-wise comparisons.
- Develop judgements to achieve the weightings of each factor or the overall aim.
- Assess and test judgement consistency.

4.6.2 The analytic hierarchy process

The main step in AHP involved the design of the hierarchy which ultimately breaks down the research problem into manageable parts. These are typically divided into the goal which relates to the research question and is the highest level, therefore the dimensions. Next, is the ‘category’ which details criterions or indicators that consist of the resilience components and the final level includes the criteria and alternatives which includes the sub-indicators that can be tailored to a community. The top level directly addresses the research issue while the lower two levels help in the evaluation of the issue (Saaty, 1994). To address the needs of this research study, four dimensions were derived and made up the first level and these are: environmental and climate change; society and economy; governance and institutions and infrastructure. Next, 18 indicators that were directed by the resilience dimensions made up the second level. Whereas the third level was made up of sub-categories of level 2 thereby consisting of 68 sub-indicators.

4.6.3 Pairwise comparison

This is the fundamental mathematical step in the AHP (Saaty, 1994). This step follows hierarchy determination and involves the performance of pairwise comparisons between the various criterions and/or dimensions as determined by the comparison scale (Saaty, 2008).

A pair-wise comparison was performed between the different criterions to help determine which criterion was of greater importance than the other or if they were identical to each other Table 4-2. The comparisons were made on a nine-point relative importance scale listed in Table 4-3. A value of one would indicate the criterions were identical, whereas, a value of nine would indicate a criterion of extreme importance. The Delphi technique formed the basis for the values of the pair-wise comparison for the dimensions. The results of the pair-wise comparison are discussed in the results section.

Table 4-2 An example of pair-wise comparison

9 = Extreme 7 = Very strong 5 = Strong 3 = Moderate = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme																		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Society and economy البُعد الاجتماعي والاقتصادي	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Environment and climate change البُعد البيئي وتغير المناخ
Society and economy البُعد الاجتماعي والاقتصادي	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure أبعاد البنية التحتية
Society and economy البُعد الاجتماعي والاقتصادي	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Governance and Institutions بُعد الحوكمة والمؤسسات

Table 4-3 Relative importance scale (1-9) of AHP (Saaty 1994)

Intensity of importance	Definition and explanation
1	Equally Important
2	Equally to moderate more important
3	Moderately important
4	Moderate to strong more important
5	Strongly important
6	Strong to very strong more important
7	Very strongly important
8	Very to extremely strongly more important
9	Extremely more important

4.6.4 Analysis of synthesis and consistency

The quality of the decisions made is a key factor in ensuring the framework developed is impartial and applicable. This quality depends on the consistency in the judgement of the panel of experts. To this end lies the significance of the weighting system applied. Not only does employment of a weighting system allow the researcher to determine the validity or the data but it also allows them to determine its consistency.

By analysing the data inputted and by applying various mathematical formulae, the weighting method is determined. Moreover, in AHP a consistency ratio (CR) is used to assess the consistency of judgement. As indicated by Saaty (1990)and Cutter et al. (2014) a CR of less than 0.1 is required to ensure the discrepancy between the decisions of the experts is kept to a minimum. If this is achieved then the weight employed is deemed reliable. To this end Expert Choice (2013) software was applied in the analysis of AHP formulae.

4.6.5 Expert choice

Expert choice (2013) was employed to convert the pairwise comparisons between the various assessment criteria into weighted measures. When analysing such a vast number of criteria there is increased risk that errors will occur if performed manually. Automated software therefore circumvents this issue.

One central calculation afforded by AHP is the consistency ratio (CR) explained above (Liedtka, 2005). The various aspects of the CR are considered by Expert Choice. The judgements of the experts are subjective data which is presented through various decision-making rounds. Each decision-making step would include information on the various opinions being fed back from previous rounds. Thus, when making a choice the expert would not only make a choice based on their own knowledge but also based on the opinion of the collective panel. Therefore, opinions may change and if this occurs a lot the consistency ratio would increase thereby decreasing the reliability of the method. Ensuring the data is reliable is paramount and therefore the use of Expert Choice is crucial in that respect.

Two other key features of Expert Choice are its ability to provide automatic computation of priorities and several means of determining sensitivity (Ishizaka and Labib, 2009, Yang et al., 2007). These three features together make this an extremely robust software for achievement of consensus.

4.7 Mathematical and statistical constructs employed in this research

As detailed previously, the Delphi technique together with AHP were used in achieving consensus. To this end mathematical formulae were adopted that transformed both quantitative and qualitative values into a weight for each assessment criterion.

Regarding the Delphi technique the statistical measures employed included the measurement of the inter-quartile range (IQR) and the standard deviation (SD) referred to as the level of dispersion. These were employed at the close of each round and aimed to evaluate the responses given by the participant experts. The IQR was used to assess the degree of agreement between the experts. This was calculated as IQR = Q3-Q1 and was given a value less than or equal to 1 (Alyami et al., 2013, Aldossary et al., 2015). The standard deviation on the other hand was assigned a value between 0 and 1 ($0 < \sigma > 1$) (Rayens and Hahn, 2000, Giannarou and Zervas, 2014).

Establishing weightings for a large number of criteria is challenging because the number of pair-wise comparisons needed increase with addition of each variable, which can be expressed using the theory of combinations in Equation (1).

$$C(n,2) = \frac{n!}{(n-2)!\,2!} \qquad (1)$$

where a pair (2) is taken from n factors each time and $C(n,2)$ denotes the number of pair-wise comparisons needed. For example, only one comparison is needed for two factors, three comparisons needed for three factors and six needed for four factors. However, for all 68 indicators in this research, a total of 2278 comparisons will be required. Putting aside the computational challenges and the reluctance of the participants to respond, it is challenging to make judgements on these many pairs.

However, if the pair-wise comparisons of dimensions from AHP is applied on the mean Delphi scores of sub-indicators, the appropriate weighting for the sub-indicators can be developed. This involved the following procedure:

- Calculate the total mean value for each dimension. This was carried out by summing up the means of all sub-indicators under each dimension obtained from the Delphi method (Equation 2).
- The mean of each sub-indicators was then divided by the total mean of the corresponding dimension (Equation 3).
- The results for each sub-indicator from step (2) was then multiplied by the weight of its dimension obtained from the AHP (Equation 4).

$$\bar{t} = \sum_{i=1}^{n} \bar{m}_i \quad (2)$$

then:

$$\bar{t} = \bar{m}_1 + \bar{m}_2 + \bar{m}_3 + \cdots + \bar{m}_n$$

where, $\bar{t}$ is the total means of the dimension's sub-indicators; $\bar{m}_i$ is the mean of sub-indicator (Delphi method).

$$p_i = \frac{\bar{m}_i}{\bar{t}} \quad (3)$$

where, p_i is the proportion of sub-indicator to the remainder sub-indicators in the same dimension

$$wc_i = p_i \times wd \quad (4)$$

where, wd is the weighting of a particular dimension derived from AHP; wc_i is the weighting of each sub-indicator.

Once the various sub-indicators had been weighted, the contribution of each sub-indicator to its dimension had to be defined as a percentage. This was performed through the following equation from:

$$tp = \sum_{i=1}^{n} pi \quad (5)$$

then:

$$tp = p_1 + p_2 + p_3 + \cdots + p_n$$

where tp refers to the proportion total of sub-indicators for the particular dimension.

Next, for each of the four dimensions the new dimension weight was determined using the following equation:

$$WD_i = wd \times tp \quad (6)$$

where, WD_i refers to the dimensions newly calculated weight.

Finally, the total assessment of the framework to coastal community resilience to maritime disasters (CCRMD) is calculated using Equation 7:

$$CCRMD = \sum_{i=1}^{4} WD_i \qquad (7)$$

then:

$$CCRMD = WD_1 + WD_2 + WD_3 + WD_4$$

4.8 Stage five: Development and validation of the framework

The validation of the developed framework were carried out to assess the applicability of the framework for assessment of resilience in the KSA. As previously mentioned in the literature review, the nine frameworks that were analysed were found to contain indicators and sub-indicators that could be separated into four dimensions; namely, infrastructure, environmental and climate change, social and economic and governance and institutions. The degree of emphasis on each dimension as determined by the nine selected frameworks from the literature was 37% (governance and institutions), 34% (infrastructure), 32% (society and economy) and 16% (environmental and climate change). The lack of emphasis on the environmental and climate change dimension compared to the other three dimensions indicates a lack of understanding or appreciation of the impact that environmental changes have on climatic changes and how this can contribute to maritime disasters. The importance of this dimension was outlined by two studies. The first, detailed how shocks originating from environmental disasters would be better absorbed by the presence of ecosystem protection, natural geographical assets and the management of the various resources (Matyas and Pelling, 2015). Thus, the better prepared the environment is, the greater its resilience and therefore the less damage that would ensue. Which also means that any damage would be rapidly fixed. Second, Sharifi (2016) demonstrated that if the environmental dimension is ignored or lacking in inclusion that this would lead to the undermining of the resilience of a coastal community.

To this end, it was essential that the developed framework increased the emphasis on the environmental dimension in relation to the other three dimensions while also assessing the applicability of the framework in the absence of real data. To determine this the mean weighting of each dimension was determined and then each dimension's percentage contribution to the framework was also assessed to confirm an increase in the contribution of the environmental dimension to the overall framework. Moreover, the framework was compared to other frameworks previously identified in the literature to investigate the potential of its applicability for assessing resilience of the coastal communities in the KSA.

Furthermore, the literature review of maritime disasters outlined in the second chapter indicated a lack of data on maritime disasters that had previously impacted the KSA. This lack of data was attributed to the lack of a central database that would be used for the recording of such data.

Within the lack of data, and in order to validate the relevance and applicability of the proposed framework, semi-structured interviews with experts were conducted. This approach was suggested by Harrell and Bradley (2009) as a method to assess the validity of frameworks. Semi-structured interviews involve a qualitative approach, which according to Jogulu and Pansiri (2011) provides in-depth insights and rich data that includes the subjective views of participants. Semi-structured interviews allow for an exploration of the views of interviewees on a particular topic without the restrictions of closed questions. That is, semi-structured interviews have open-ended questions with no limit in the choice of answers of the interviewees (Srivastava and Thomson, 2009, Gubrium and Holstein, 2002, McCracken, 1988) The governmental, organizational and academic leadership had been selected for these interviews to participate in the validation of the proposed framework. The goal of using semi-structured interviews as an approach to validate the framework is to assure that the scope of the framework is applicable to the context of the country and to identify implementation challenges. This would involve evaluating the completeness and relevance of the indicators, the proposed weighting and ranking indicators, and any further contextual/policy implementation.

4.9 Summary

The chapter opens by explaining the type of data (quantitative and qualitative) and therefore the types of studies required. The use of a mixed methods approach is justified on this basis. The research structure’s design was outlined and illustrated in a systematic way demonstrated to involve five stages. The first stage was alluded to as it was covered in the previous chapter. This stage was part of the theoretical arm of the study which exposed gaps in disaster risk management and therefore in the robustness of resilience frameworks.

The next stage of the methodology is explained in detail in this chapter and include the examination of stakeholder perception of the assessment criteria with regards to maritime disasters in the context of coastal communities in Saudi Arabia. The types of questions required and their contribution to the research is key in defining the types of experts participating in the research project, the range of their knowledge and their understanding of the need for the development of a resilience framework are all assessed. The third stage includes the use of the Delphi technique to examine the assessment criteria more deeply while taking account of alternatives that can be employed to strengthen the resilience of coastal communities in the face of maritime disasters. This was defined as involving several rounds of questionnaires that would use the conventional postal method for communication of expert opinions. The fourth stage involved an explanation of the AHP and its use in prioritising and determining the significance of the assessment criteria through assignment of weighting. The importance of using Expert Choice software to compute these priorities and significance of the various sub-indicators is explained. Its importance in affording this study a reliable and dependable result is paramount in increasing stakeholder confidence in the results of the study. To complete stage four, details and definitions of the mathematical formulae used throughout the experimental steps are given. The final stage then ends with an assessment of the suitability of the framework by means of validation of the framework. The next few chapters will expand on stages two, three, four and five of the methods outlined in this section.

Chapter 5
Stakeholders' perception of resilience to maritime disasters

This chapter investigates stakeholders' perceptions of coastal community resilience indicators to maritime disasters. It details quantitative methodology employed in the form of a questionnaire with the aim of defining both the participants and their opinions. Statistical methods are employed to help define these factors and to allow their comparison to previous studies. The respondents' characteristics were collected and analysed. Perceptions of respondents on the various indicators is detailed and the significance is measured with respect to their specific characteristics using Principal Component Analysis. The significance of the indicators is then used to aid prioritisation of the indicators, thereby giving a clear explanation of the publics' perception and of coastal community resilience and the dangers caused by maritime disasters.

5.1 Questionnaire development

The questionnaire utilised in this study aimed to use a quantitative methodology to gather data from a range of participants from across the KSA. All participants were asked to provide their demographic data to aid with the analysis. Of the 25 questions posed, the majority were styled as multiple choice questions and the remainder were open-ended questions allowing for the collation of a range of data.

5.2 Respondents' characteristics

Seven hundred twenty-four responses were received, and five hundred seventeen respondents had answered all of the survey questions. Therefore, the analysis presented in this paper is based on the 517 valid responses. Figure 5-1 illustrates the demographic details of the respondents. It indicates that they were all from different age groups, educational levels and locations across Saudi Arabia.

Gender: Roughly three quarters (74.7%) of respondents were male and 25.3% were female. Alshehri (2013) noted that, according to the customs and traditions of Saudi Arabia, recruiting female respondents can be challenging.

Age: 25% of participants were between 25 and 30 years old. This represented the highest rate of participation. The second biggest group consisted of 31 to 35-year-old (24%). The smallest group was made up of those above the age of 61 which comprised 1% of the study sample.

Occupation: More than half (58%) of the respondents were employed by the government. The second largest occupation group consisted of non-government employees (18%); 9% of the respondents were employed in the private sector and 15% of participants were unemployed or students.

Qualifications: 47% of respondents had an undergraduate degree as their highest qualification, 36% had a postgraduate degree, and 2% had no formal qualification.

Geographical coverage: Most respondents came from the Western Region of Saudi Arabia (38%), followed by the Central Region (24%), Eastern Region (18%), Northern Region (11%), and Southern Region (10%).

Location: Respondents lived in cities spread across all of Saudi Arabia. The greatest number of participants came from Riyadh (21%), the largest city in the country. Other participants came from Jeddah (19%) and Dammam and Tabuk (7%).

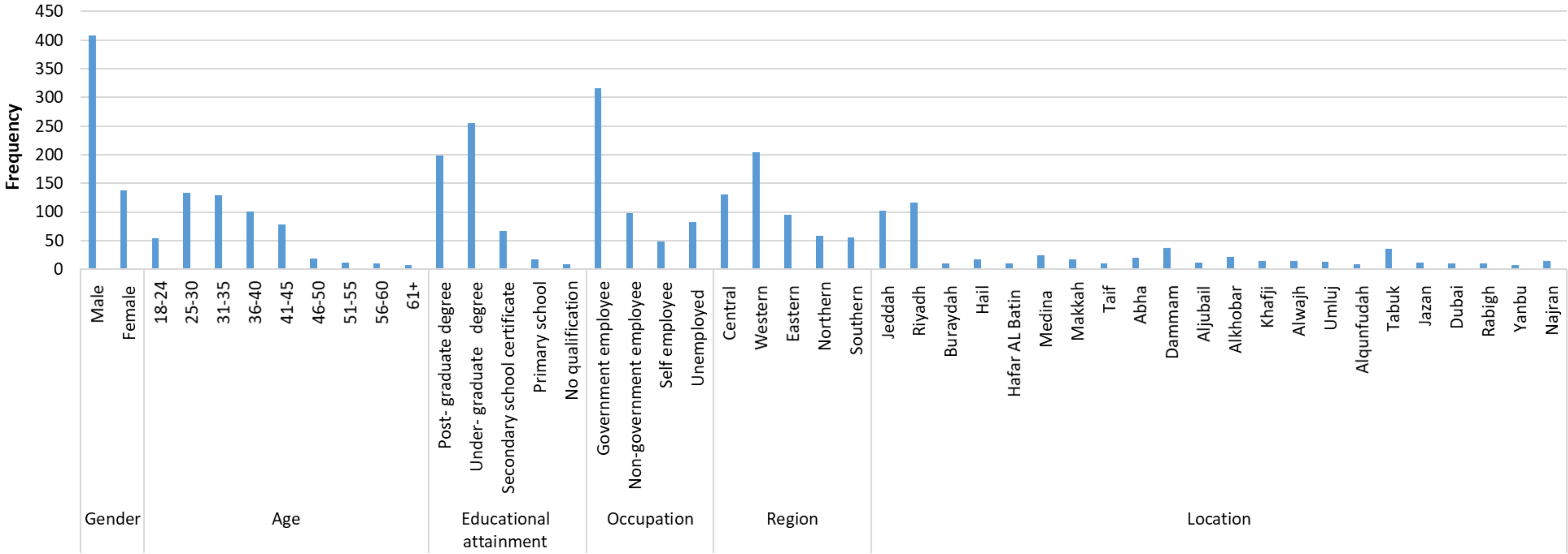


Figure 5-1 Demographic characteristics of the respondents

5.3 Principal component analysis (PCA)

The experience of daily living and places of work and study all influence the perceptions of stakeholders. As shown inTable 5-1, 17 items were investigated in this study and ranked (from lowest to highest) according to mean scores ranging between 3.40 and 4.56, which were obtained using a Likert-type scale of 1-5.

Table 5-2 shows the results of the PCA, as well as the factor loadings after rotation, eigenvalues, and percentages. The substantial factor loading for all questionnaire items was found to be in the range of 0.5 and 0.8. From the 17 items, three summated indices were extracted: ‘human and environmental impacts’, ‘impact on livelihood’, and ‘awareness and training’. An initial analysis for each component revealed the eigenvalue for the Kaiser criterion, which was greater than 1.0. The total eigenvalues for each of the factors ranged from 2.542 to 5.693. Bartlett's test of sphericity revealed a significant correlation between questionnaire items ($p<0.000$). This indicated that all selected variables were related to one another and were appropriate for further analysis. Next, the KMO measure (0.921) confirmed the sampling adequacy, supporting the fact that the variables were suitable for factor analysis and were considered high (Ameen et al., 2015). The percentage of total variance was 64.38%. The ‘human and environmental impacts’ component was clustered into 11 items, which made up the largest percentage of explained variance (33.49%). The other two components (impact on livelihood and awareness training) only consisted of three items each, which accounted for 15.95% and 14.95% of the variance, respectively. Dual loading was not identified for any of the 17 items. Based on the large sample size, as well as the convergence of the scree plot and the Kaiser criterion results, only three components were retained for final analysis. When the reliability estimates were applied using Cronbach’s alpha for all generated components, reliability was found to be greater than 0.60 (Table 5-2). This suggested a robust internal reliability between questionnaire items with similar attributes. In total, Cronbach’s alpha was 0.926, which implied a high level of reliability overall (Ahmad and Ahlan, 2015).

Table 5-1 Descriptive analysis of coastal community resilience factors

Items	**1***	**2***	**3***	**4***	**5***	**Mean**	**Mode**	**SD**
Tackling oil spillages in coastal areas	0.9	2.0	7.2	14.1	75.8	4.62	5.00	0.79
Security systems and safety procedures	1.3	1.8	9.0	23.9	63.9	4.47	5.00	0.84
Poverty rate	1.8	2.6	9.0	23.4	63.2	4.42	5.00	0.91
Compliance with international standards (ISPS Code)	1.3	2.4	10.4	26.4	59.5	4.40	5.00	0.87
DRR training programmes	1.8	4	10.8	20.0	40.8	4.39	5.00	0.96
Building codes	1.7	4.1	10.7	22.1	61.5	4.37	5.00	0.95
Coastal resources such as fishing	0.6	2.2	11.4	29.8	56.0	4.37	5.00	0.82
Monitoring of coastal water quality	1.5	3.3	10.5	27.4	57.3	4.36	5.00	0.92
Awareness campaigns	1.5	5.7	12.6	25.3	55.0	4.27	5.00	0.98
Availability of urban green space	2.0	4.0	10.5	29.4	54.0	4.27	5.00	0.96
Safety considerations for man-made disasters	1.7	4.6	10.6	31.5	51.7	4.26	5.00	0.95
Household income	2.0	3.1	14.7	33.5	46.6	4.19	5.00	0.95
Projected sea level rise	1.8	4.0	14.0	34.2	46.0	4.17	5.00	0.95
Mean elevation of the area	1.7	4.8	15.4	37.3	40.9	4.10	5.00	0.95
Multilingual awareness programmes	3.1	6.8	16.9	28.4	44.8	4.04	5.00	1.09
Exposure and risk of increasing temperature	3.3	6.4	15.8	35.3	39.2	4.00	5.00	1.06
Conservation of mangroves	4.1	8.4	17.3	26.5	43.7	3.96	5.00	1.16

Notes: * Response (%) scale. 1: Unimportant; 2: Of little importance; 3: Moderately important; 4: Important; 5: Very important

Table 5-2 Rotated component matrix of the survey items

Items	Component		
	Human and environmental impacts	**Impact on Livelihood**	**Awareness & Training**
Projected sea level rise	0.766	–	–
Security systems and safety procedures	0.740	–	–
Exposure and risk of increasing temperature	0.736	–	–
Compliance with international standards (ISPS Code)	0.727	–	–
Building codes	0.719	–	–
Mean elevation of the area	0.717	–	–
Safety considerations for man-made disasters	0.708	–	–
Monitoring of coastal water quality	0.684	–	–
Availability of urban green space	0.633	–	–
Tackling oil spillages in coastal areas	0.615	–	–
Conservation of mangroves	0.522	–	–
Household income	–	0.865	–
Poverty rate	–	0.836	–
Coastal resources such as fishing		0.596	
Awareness campaigns	–	–	0.863
DRR training programmes	–	–	0.823
Multilingual awareness programmes	–	–	0.795
Cronbach's alpha (0.926)	0.921	0.810	0.837
Eigenvalues	5.693	2.711	2.542
Percentage of explained variance (64.389)	33.489	15.950	14.950

5.4 Relationship between personal information and perception of socioeconomic and environmental impact indicators

To summarise the data analysis and interpretation, the participants and variables were re-categorised thereby revealing the non-normal distribution of the data. Thus, non-parametric tests had to be carried out on all survey items with non-normal distribution. These tests included the Mann-Whitney U-test for gender and the Kruskal-Wallis test for occupation, qualification, region and location. Table 5-3 shows that all demographic characteristics demonstrated statistically significant differences.

Gender was proven to have a significant effect on participants' perception of rising sea levels, exposure and risk of increasing temperature, building codes, the availability of urban green space, safety considerations regarding man-made disasters, security systems and safety procedures, compliance with international standards (International Ship and Port Facility Security Code), the conservation of mangroves and poverty rate. Similarly, age had a significant effect on participants' perception of multilingual awareness programmes. Regarding the other findings, it was clear that occupation affected perceptions of household income and poverty rate, and region influenced perceptions of mean elevation of the area, rising sea levels, building codes, security systems and safety procedures, compliance with international standards (International Ship and Port Facility Security Code), coastal resources (i.e., fishing), household income and poverty rate. Finally, location had an effect on participants' perception of mean elevation of the area, monitoring of coastal water quality, conservation of mangroves, coastal resources (i.e., fishing), household income and poverty rate.

Table 5-3 Results of non-parametric test

PCA	Items	Mean	Non-parametric test (p-value*)					
			Gender†	Age group‡	Occupation‡	Qualification ‡	Region‡	Location ‡
Environmental impact	Tackling oil spillages in coastal areas	4.62	0.094	0.765	0.764	0.899	0.334	0.329
	Security systems and safety procedures	4.47	**0.000***	0.714	0.316	0.26	**0.022***	0.186
	Compliance with international standards (ISPS Code)	4.40	**0.012***	0.902	0.173	0.434	**0.026***	0.079
	Building codes	4.37	**0.000***	0.984	0.332	0.58	**0.017***	0.075
	Monitoring of coastal water quality	4.36	0.150	0.261	0.422	0.439	0.100	**0.048***
	Availability of urban green space	4.27	**0.045***	0.470	0.874	0.829	0.797	0.787
	Safety consideration for man-made disasters	4.26	**0.000***	0.301	0.298	0.41	0.05	0.135
	Projected sea level rise	4.17	**0.000***	0.419	0.067	0.374	**0.034***	0.209
	Mean elevation of the area	4.10	**0.029***	0.105	0.152	0.816	**0.004***	**0.024***
	Exposure and risk of increasing temperature	4.00	**0.001***	0.666	0.391	0.328	0.216	0.601
	Conservation of mangroves	3.96	**0.016***	0.086	0.586	0.097	0.054	**0.026***
Impact on Livelihood	Poverty rate	4.42	**0.027***	0.782	0.88	**0.003***	0.005	**0.010***
	Coastal resources such as fishing	4.37	0.10	0.195	**0.001***	0.135	**0.000***	**0.001***
	Household income	4.19	0.899	0.379	0.253	**0.000***	**0.008***	**0.002***
Awareness & Training	DRR training programmes	4.39	0.119	0.769	0.336	0.272	0.970	0.689
	Awareness campaigns	4.27	**0.038***	0.062	**0.005***	0.777	0.33	0.619
	Multilingual awareness programmes	4.04	0.106	**0.036***	0.056	0.619	0.098	0.18

Notes: * $p < 0.05$, † Mann-Whitney U-test, ‡ Kruskal-Wallis test

5.5 Discussion

In total, approximately 76% of the respondents stated that 'tackling oil spillages' posed the most significant community resilience challenge for coastal cities, as shows in Table 5-1. This item was given the highest mean score of 4.62 and the lowest SD of 0.79. This was followed by 'security systems and safety procedures', 'poverty rate', 'compliance with international standards (International Ship and Port Facility Security Code)' and 'DRR training programmes', respectively. The least important item for respondents was 'the conservation of mangroves', which received the lowest mean score of 3.96 and the highest SD of 1.16. Another low-ranking item was 'exposure and risk of increasing temperature'. These findings indicate that most stakeholders considered issues regarding the wider community resilience to be of greater importance; i.e., 'projection of rising sea levels', 'availability of urban green space', 'building codes', 'security systems and safety procedures' and 'awareness campaigns'. This is similar to the findings of the previous studies conducted on community resilience outlined in the literature review. In the current study, all indicators received mean scores greater than 4 (important), with the exception of one example, which had a mean score of 3 (moderately important).

The principal component analysis revealed the existence of three structured components, all with high internal consistencies. However, as shown in Table 5-2, several factors only contained three items. The following sub-sections discuss community resilience in terms of PCA components grouped according to their importance and priority, as indicated in Table 5-3.

5.5.1 Human and environmental impacts

The largest PCA component was found to be 'human and environmental impacts', which was made up of 11 items and had a mean score greater than 4.00. This indicated that all items were of high importance. Furthermore, gender had a significant effect on perception for most of the items, which illustrates the ways in which women and men respond to and recover from disasters based on their own life experiences. According to Joerin et al. (2012), men and women have different abilities and ways of responding to disasters, which result in different impacts. Within this component, 'tackling oil spillages' was considered most important. Akyuz et al. (2017) noted that oil spillages are commonly regarded as the greatest cause of maritime environmental damage. Saudi Arabia's location and its vast oil reserves have made it particularly vulnerable to oil spillages. The country has roughly 161 large oil deposits across the Arabian Gulf, which makes it the world's leading nation in terms of exposure to a potential oil spill disaster. A recent UNESCO report highlighted this fact, stating that 75% of global oil spills take place in this area, which results in billions of dollars of damage every year (Alamri, 2010, Bjornstig and Forsberg, 2016). Oil spills are a human-induced threat that could also impact the Red Sea coastal plain of Saudi Arabia, because it is a major route for transporting oil between the Arabian Gulf and the Western world (Hereher, 2016). Therefore, it is necessary to tackle the issue of oil spillages to enhance environmental resilience.

'Security systems and safety procedures' was the second most important item identified by the respondents. Respondents stated that security and safety programmes are vital for identifying, assessing and monitoring disaster risks and in enhancing early warning systems to control the coastal community for the purpose of reducing the threat of man-made maritime disasters such as terrorism and vessel accidents (Coaffee et al., 2008). Thus, region had a significant effect on stakeholders' perception regarding this item. Decision-makers need guidance on security systems and safety procedures to improve the resilience of communities and make them less vulnerable to disruptive events, including natural and man-made disasters.

The third most important item was identified by participants as 'compliance with international standards (International Ship and Port Facility Security Code)'. The ISPS Code was born of growing threats of terrorist and piracy attacks on ships and port facilities. Nowadays, ports are required to demonstrate critical infrastructure resilience, particularly due to their role as important national and international economic resources. If a terrorist attack occurred at a port or on a ship, this would result in significant disruption of supplies and lead to several negative outcomes. For example, a suicide bombing using a vessel on an oil platform would considerably disrupt oil and gas supplies and pollute the sea. Moreover, the loss of vessels, cargo and human lives, as well as the need to divert productive resources to increase security measures would also have a negative effect on the country's economic activities (Barnes and Oloruntoba, 2005). Therefore, it is clear that 'compliance with international standards' is an important item for Saudi Arabia's society and economic resilience.

The item 'building codes' was identified by participants as the fourth most important item. Livelihoods and infrastructure are particularly vulnerable to the negative impacts of maritime disasters; therefore, it is important to reduce exposure and potential disaster damage through the enhancement of building codes. This may also result in lower investment costs (Aerts et al., 2014). Bosher et al. (2007) noted that building codes also help to strengthen buildings and infrastructure exposed to disasters. On the whole, it has come to be understood that construction practices must have greater sensitivity to disasters if it is going to be possible to effectively mitigate their impacts (Chmutina and Rose, 2018). In this way, the development of building codes must involve guidelines for design and construction, as well as standards for health and safety, amenities and sustainability. The safety element is particularly significant because this will help to protect human lives and wellbeing when disasters occur.

The fifth most important item in the 'human and environment impacts' group identified by respondents was 'monitoring of coastal water quality'. The Saudi Arabian coastline has experienced considerable urban development in recent years, resulting in the installation of many desalination plants, power stations and wastewater treatment facilities. The primary source of freshwater in the country is desalinised water, with 3.29 million m3 being produced for the Western Region daily from the Red Sea (Hereher, 2016). These desalination plants and their disposal of treated wastewater into the sea will potentially increase the salinity of the seawater, threatening the marine environment and communities dependent on coastal resources. Thus, to ensure environmental resilience, Saudi Arabia must monitor its coastal water quality.

The other items that made up the 'human and environmental impacts' component in this paper have also been identified in previous studies. These items include 'the availability of urban green space', 'safety considerations of man-made disaster', 'projection of rising sea levels', 'mean elevation of the area', 'exposure and risk of increasing temperatures and 'conservation of mangroves'. According to Parry (2007), coasts are the most vulnerable locations for global climate change. In the last century, the increase in global temperature has resulted in rising sea levels. This global warming trend is expected to continue in the future. As Saudi Arabia has the longest coastline of the Red Sea and Arabian Gulf, this makes it particularly vulnerable to climate change (Hereher, 2016). Rising sea levels are a problem that affects coastal areas globally and are of particular concern with flat beaches. In Saudi Arabia, lowland areas could become overwhelmed by an increase in sea level, resulting in flooding, loss of lives and property, and the deterioration of water resources. Furthermore, an increase in water temperature because of global warming could also affect mangroves in the area. These mangroves are an essential part of the local and global ecosystems, as they absorb carbon dioxide and other pollutants from the air and water, which helps to protect coastal communities from cyclones and rising sea levels and enable water purification. However, they are increasingly threatened by human and environmental impacts (Almahasheer et al., 2016, Ghosh et al., 2016).

5.5.2 Impact on livelihood

The second PCA component identified in this study related to livelihood and was made up of three items. 'Poverty rate' was deemed the most important item by respondents, with the highest mean score of 4.42. It was also rated the third most important indicator in the questionnaire. This may be because, as Ainuddin and Routray (2012) stated, poverty is the main factor that increases disaster risks. When a disaster occurs, people are often forced into poverty. For this reason, it is extremely difficult to eradicate poverty completely. However, the impact of poverty is not homogeneous; it can vary according to local capacity (Hallegatte et al., 2016). This explains why, for this item, location was rated by stakeholders as a significant factor (as shown in Table 5-3). Hallegatte et al. (2016) claimed that disasters strongly impact poverty, thereby emphasising the importance of building disaster resilience in poor communities, which could help to prevent future disaster events from impoverishing people. This would protect their livelihoods and assets, which, in turn, would help them recover at a faster rate.

Coastal resources, such as fishing, was the second most important item identified for this group. Coastal resources have a high economic productivity, particularly reefs and mangroves, which provide many marine species with nursery and feeding areas. Moreover, these coastal resources also increase protection against storms because they act as buffer areas (IOTWSP, 2007). However, human activities in coastal areas are causing a major problem by damaging coastal resources. The overuse of such resources creates excess pressure, which can increase risks to such areas. For this reason, it is necessary to manage human use of coastal resources to increase the communities' disaster resilience.

The third most important item identified by respondents was 'household income', which Cai et al. (2016) noted to be a significant and positive predictor. Yoon et al. (2016) stated that communities with higher incomes can absorb, respond to and recover from emergencies more rapidly because they have large budgets to spend on disaster recovery. In this way, communities with higher economic vitality are better able to respond and recover from disasters, as they have both the funds and resources to assist inhabitants. Therefore, they are more resilient than communities with less economic vitality. This also explains why lower income populations tend to live in poor quality housing located in high risk disaster areas. Indeed, region and location had a significant effect on stakeholder perception for this item.

5.5.3 Awareness and training

The final PCA component was 'disaster risk reduction (DRR) training programmes and was made up of three items related to awareness and training. DRR training programmes are an important way of helping communities increase their awareness, skills, and abilities to deal with disasters effectively, thereby enhancing community resilience (Liu et al., 2016). DRR training programmes include themes such as search and rescue, first aid, temporary shelter construction, food distribution and evacuation management (IOTWSP, 2007). Drills and exercises, such as those taught in the training programmes, must be carried out regularly to safeguard community responses and to identify any gaps or deficiencies for future consideration. If a community is resilient, it will have community members who are able to respond quickly when an incident occurs, by drawing on their training, education and drills.

Respondents considered the second most important item for this component to be ‘awareness campaigns. Disaster resilience can be enhanced by raising risk awareness, as demonstrated in studies conducted by , Hereher (2016) and Alshehri et al. (2013), who demonstrated that warning systems are not effective if sufficient education and outreach has not been achieved. If communities are unable to understand information about warnings or do not know how to respond to them, the risk of loss of life increases significantly. When a large disaster occurs in Saudi Arabia, multiple agencies are involved, some of which may have overlapping roles and responsibilities. This can often reduce the efficiency of the disaster response. With this in mind, it is important that awareness programmes notify staff and organisations of this issue. This may also explain why the stakeholders considered ‘occupation’ a significant factor for stakeholders for this item. Through comprehensive public awareness campaigns, members of the community could be informed regularly about disaster risks, warning procedures and evacuation plans, which would improve community resilience. Joerin et al. (2014) identified a significant correlation between education, awareness and community preparedness. Thus, it is clear that raising awareness would result in better prepared communities.

The final item identified for this component was ‘multilingual awareness programmes’, which entail similar awareness training to DRR training programmes but in multiple languages. It is important that disaster information is disseminated to all the people living in a country, including foreign residents or travelers who may not understand the country’s native language (Hasegawa et al., 2005). Saudi Arabia has more than 10 million foreign residents from a wide range of countries (as of 2016), which represents approximately 33.1% of the country’s total population and is increasing year by year (Algarni et al., 2018). This is particular crucial for a country such as Saudi Arabia as foreign visitors to the KSA come from all over the world. Thus, it is clear that disaster prevention and refuge information must be provided in multiple languages. This information must be disseminated to people at appropriate times in suitable formats and in a range of languages to bolster community resilience.

5.6 Summary

This chapter has expanded on the outline laid out in the previous chapter. This study has presented the perceptions of various stakeholders regarding community resilience and the challenges it entails. It has also identified several important priorities, based on the views of these stakeholders, within the context of Saudi Arabia. It has reported that it is necessary for all at-risk individuals, organisations, and institutions to work together before a disaster occurs to decrease the level of risk. Thus, public participation is a key component of building disaster community resilience. Using these findings, this study concludes by outlining some of the key recommendations for decision-makers, practitioners, and researchers regarding how to build community resilience to maritime disasters as summarised below.

The study has identified **tackling oil spills** as the most notable challenge in Saudi Arabia. Due to the country's location and its vast oil reserves, it is particularly vulnerable to the possibility of oil spillages. Every year, 75% of global oil spills take place in Saudi Arabia, which can lead to billions of dollars of damage.

The improvement of **building codes** offers one way to reduce exposure and potential disaster damage. Improved codes could strengthen buildings and infrastructure exposed to disasters risk.

Compliance with international standards, such as the **ISPS (International Ship and Port Facility Security) Code** is also essential for the prevention of man-made disasters, such as terrorist acts and piracy against ships and port facilities.

Furthermore, the human use of **coastal resources** must be managed. Overuse can result in extreme pressure on resources, heightening the risk of damage to such areas. This is a major concern, because these areas provide nursery and feeding areas to many marine species, as well as serving as buffer zones to offer protection against storms.

This study also been identified that increasing the provision of **DRR training programmes** is an important way to help communities build awareness, skills and abilities to deal with disasters effectively. Furthermore, such information must be made available to the necessary people at appropriate times in a range of suitable formats and languages.

Thus, **multilingual awareness programmes** must also be offered to foreign residents or travelers who do not speak Arabic. This is critical, given that over ten million foreign residents (i.e. 33.1% of the country's total population) live in Saudi Arabia.

These findings have provided evidence of the various social, economic and environmental factors that can make communities more resilient to disasters. A community's resilience to disaster depends largely on its socioeconomic status, as well as upon environmental factors and understandings of disaster risk. Therefore, it is important that less resilient communities are particularly prioritised for support to enhance their disaster coping capacity.

The data from this chapter will be further analysed using empirical methods in the form of the Delphi technique and Analytical Hierarchy Process to work towards developing the framework for coastal community resilience against maritime disasters.

Chapter 6
Identification resilience assessment factors

This chapter aims to identify coastal community resilience assessment framework factors through the collation of expert's opinions using the Delphi technique. This is the third stage in the research process. The chapter first discusses the Delphi technique and its origins, applicability and advantages. A reminder of the assessment criteria that originated from the literature reviews are then referenced the four dimensions and their indicators and sub-indicators are detailed. The Delphi technique is summarised together with the background of the experts involved. In this study, a consensus was achieved after two rounds. Next, the analysis of the Delphi results is detailed and explained in the context of the significance of each dimension. The following research questions are addressed in this Chapter.

- *RQ3 - Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?*

- *RQ4 - How can identified resilience factors be incorporated into a local coastal community resilience assessment framework?*

6.1 Introduction

This chapter details the Delphi technique which has its basis in Greek mythology the oracle at Delphi, a wise Greek figure that had the answers to all questions put to her by the Greeks and distant travellers and through listening to her many informers. This technique's ability to essentially answer difficult questions from gaining the input of various opinions is why it has inherited the name Delphi. As outlined by Skulmoski et al. (2007), this technique has been adopted in various fields including engineering, defence, education and many more.

There are various consensus methods that could have been employed such as the Nominal Group Technique described by Bowling (2014). The Delphi technique, however, has several advantages as described in Chapter 4. The first of these is the privacy afforded participants which prevents other participants having knowledge of who else is taking part. This is beneficial as it prevents the intimidation of participants by individuals they deem superior and it eliminates the pressures stemming from socio-psychological pressures (Bailie, 2011, Okoli and Pawlowski, 2004). The exclusion of these pressures serves to improve the rate of response as the responses increase in validity.

The second advantage of the Delphi technique originates from the way in which the questions and responses are communicated and gathered. When using the Delphi technique, participants can be located across the globe and could be numerous (Keeney et al., 2006). As demonstrated through various studies, the third benefit of the Delphi technique is further strengthened through its iterative and feedback processes which serve the attainment of a consensus (De Villiers et al., 2005, Keeney et al., 2006).

Finally, the need to employ experts in the decision-making process is the fourth advantage which accounts for its robustness (Okoli and Pawlowski, 2004). The experts' range of knowledge and expertise greatly increase the reliability, applicability and significance of responses given.

6.2 Results and analysis

The Statistical Package for Social Sciences (SPSS) version 20.0 has been used to analyse the collected data. The data was derived from a survey designed to determine whether participant experts could reach a consensus regarding the importance of community resilience criteria (four dimensions) for disasters that occur in Saudi Arabia.

6.2.1 The Delphi survey respondents

Chapter 4 indicated that seventy-three prospective panellists were contacted initially with an invite to take part in the survey. Of these seventy-three, sixty-five were involved in the first round and fifty-eight in the second round. During the second round, a general consensus was obtained. This decision eliminated the need for further rounds. According to previous studies (Hasson et al., 2000) and (Okoli and Pawlowski, 2004), this was deemed an appropriate number of experts. All experts came from a range of disciplines that dealt with disaster risk management; consisting of international experts, professionals and highly informed local experts from the world of academic, government and non-government. All had at least five years of experience in disaster risk management and a relevant degree.

6.2.2 The framework for assessing coastal community resilience to maritime disasters in Saudi Arabia

Based on the consensus obtained amongst the expert panel, a final framework was created that integrated a number of factors that were regarded as important for building community resilience to disasters. The basic framework is outlined in Table 6-1 and includes the hierarchy of factors. The first level consists of four dimensions: society and economy, environment and climate change, infrastructure and governance and institutions. The second level is made up of eighteen indicators, while the third level includes sixty-eight sub-indicators.

Table 6-1 Coastal community resilience to maritime disasters framework in KSA

Coastal community resilience assessment framework of maritime disasters management for Saudi Arabia

Society and economy	
Indicator	Sub-indicator
Demographic	Population growth rate
	Population density
	dependent population
	Disability
	Level of education
	Foreign population
Livelihood	Population dependent on coastal resources
	Household income
	Poverty
Employment	Employment dependence on coastal resources
	Nonprofit organization (NPO)
Awareness & training	Disaster exercises and drills
	DRR training
	Awareness of disaster and climate change risks
	Multilingual awareness programmes
	Awareness campaigns
Culture	Social capital
	Integrating DRR into school curriculum
Safety and security	Riots, conflicts and homicide incidents
	ISPS code compliance
	Safety and security systems

Environment and climate change	
Indicator	Sub-indicator
Coastal pollution control	Water quality
	Marine pollution
	Mangrove cover
	Industrial wastewater discharge
land use	Agricultural land
	Urban green space
	Built up area
	Building codes and regulation
	Mean elevation of the area
Slow onset disasters	Exposure and risk of increasing temperature
	Relative rate of sea level rise
	Implementation of IPCC Rules and Procedures
Rapid onset disasters	Frequency of natural hazards
	Intensity/severity of natural hazards
	Seabed seismic monitoring

Infrastructure	
Indicator	Sub-indicator
Health	Hospitals (#) in 100 people
	Hospital beds (#) in 100
	Number of physicians (#) in 100 people
	Number of ambulances (#)
	Health insurance (#) in 100 people
	Health care support workers (#) in 100 people
Transportation	Roads accessibility
	Vehicle ownership
	School and employee buses
	Special need transportation services
	Public transportation modes
Utilities	Infrastructure and public facilities
	Renewable energy
	Fire stations
Communication	Access to mobile phones
	Access to radio/television
	Reliability of communication systems
	Internet services
Embankment & shoreline	Vulnerable shoreline
	Age of embankments
	Maintenance of embankments

Governance and Institutions	
Indicator	Sub-indicator
Laws & policy	Regulations and policies
	Environmental regulation
	Participation in DRR planning
	DRR strategies
	Compliance with international standards that consider hazard risks
Institutional action	Observation and Monitoring
	Institutional collaboration & coordination
	Voluntary Groups
Warning and evacuation	Early warning system
	Availability of evacuation centre
	Emergency Aids
	Hotels and motels

As part of the first round, sixty-five experts received the criteria relevant to each dimension. These experts were asked to provide an opinion on the importance of each factor and to include any further relevant criteria. A 5-point Likert scale (1 – unimportant, 2 – of little importance, 3 – moderately important, 4 – important, 5 – very important) was used to indicate their rating. Table 6-2 lists the resulting mean ratings. All responses were analysed to assess the degree of perceived importance. Moreover, the responses were further analysed to determine whether or not a consensus was reached across the panel of experts. This was achieved by determining the inter-quartile range (IQR). The values of the mean ranged from 3.5 to 4.8 signifying the importance of all the criteria. At the end of round one, nine new criteria were suggested by the expert panel. Seven of these were accepted but two failed to qualify due to not gaining a general consensus (IQR<1). Table 6-3 details this information. The nine criteria included were non-profit organisation (NPO), foreign population, integrating DRR into school curriculum, industrial wastewater discharge, public transportation modes, implementation of IPCC rules and procedures, compliance with international hazards that are considered disaster risks, unemployment rate and sex ratio. The last two criteria; specifically unemployment rate and sex ratio were excluded. Sex ratio is not an essential means of defining the population as its impact on resilience would be minimal. Two other criteria population density and population growth rate both afford a better assessment of population contribution to the framework. Resilience is also likely to be impacted by the effect of those who are less able. This is also accounted for by two criteria; namely disability and the dependant population.

The unemployment rate criterion was also deemed to be unimportant. This is because an issue arose in the methodology used to measure unemployment, as this criterion could be measured in different age groups. Furthermore, a criterion already exists that serves the same purpose as the employment criterion. Finally, both criteria cannot be included as it would essential be equal to measuring this aspect of resilience twice. This would therefore make the calculation of resilience inaccurate. Thus, the unemployment rate criterion was excluded.

Round two was completed by fifty-eight experts. This time, all sixty-eight criteria (sub-indicators) under the four dimensions obtained means between 3.6 and 4.5 (See Table 6-4 To Table 6-7). This means that they were all considered to be important. Moreover, all criteria obtained an IQR between 0 and 1, which indicates that a general consensus was achieved for all criteria. In addition, there was a standard deviation of less than 1 for all criteria which demonstrates a high level of consensus was agreed by the expert panel across all criteria. Given this fact, there was no need to carry out any further rounds.

Table 6-2 Round 1

Dimension	Indicator	Sub-indicator	Total experts	Mean	Median
Society and economy	Demographic	Population growth rate	65	4.1	4.00
		Population density	65	4.2	4.00
		Dependent population	65	3.5	4.00
		Disability	65	3.9	4.00
		Level of education	65	3.9	4.00
		Property type	65	3.5	4.00
	Livelihood	Population dependent on coastal resources	65	3.9	4.00
		Household income	65	3.4	4.00
		Poverty	65	3.6	4.00
	Employment	Employment	65	3.4	3.00
		Employment dependence on coastal resources	65	4	4.00
	Awareness & training	Disaster exercises and drills	65	4.5	5.00
		DRR training	65	4.6	5.00
		Awareness of disaster and climate change risks	65	4.6	5.00
		Multilingual awareness programmes	65	4.2	4.00
		Awareness campaigns	65	4.4	5.00
	Culture	Social capital	65	3.6	4.00
		Religious organisations	65	3.3	3.00
	Safety and security	Riots, conflicts and homicide incidents	65	3.5	4.00
		ISPS code compliance	65	4.3	4.00
		Safety and security systems	65	4.3	5.00
Environment and climate change	Coastal pollution control	Water quality	65	4.2	4.00
		Marine pollution	65	4.5	5.00
		Mangrove cover	65	3.8	4.00
	land use	Agricultural land	65	3.6	4.00
		Urban green space	65	3.8	4.00
		Built up area	65	4	4.00
		Building code	65	4.4	5.00
		Mean elevation of the area	65	4.2	4.00
	Slow onset disasters	Exposure and risk of increasing temperature	65	3.8	4.00
		Sea level rise	65	4.1	4.00
	Rapid onset disasters	Frequency of natural hazards	65	4.2	4.00
		Intensity/severity of natural hazards	65	4.3	4.00
Infrastructure	Health	Hospitals	65	4.4	5.00
		Hospital beds	65	4.3	4.00
		Number of physicians	65	4.1	4.00
		Number of ambulances	65	4.2	4.00
		Health insurance	65	3.9	4.00
		Health care support workers	65	4.1	4.00
	Transportation	Roads accessibility	65	4.5	5.00
		Vehicle ownership	65	3.4	3.00
		School and employee buses	65	3.6	4.00
		Special need transportation services	65	4.1	4.00
	Utilities	Infrastructure and public facilities	65	4.6	5.00
		Renewable energy	65	4	4.00
		Fire stations	65	4.6	5.00
	Communication	Access to mobile phones	65	4	4.00
		Access to radio/television	65	3.7	4.00
		Reliability of communication systems.	65	4.3	4.00
		Internet services	65	4.2	4.00
	Embankment & shoreline	Vulnerable shoreline	65	4.2	4.00
		Age of embankments	65	4.1	4.00
		Maintenance of embankments	65	4.3	5.00
Governance and Institutions	Laws & policy	Regulations and policies	65	4.5	5.00
		Environmental regulation	65	4.3	4.00
		Participation in DRR planning	65	4.3	4.00
		DRR strategies	65	4.2	4.00
	Institutional action	Observation and Monitoring	65	4.1	4.00
		Institutional collaboration & coordination	65	4.4	5.00
		Voluntary Groups	65	4.4	5.00
	Warning and evacuation	Early warning system	65	4.7	5.00
		Availability of evacuation centre	65	4.8	5.00
		Emergency Aids	65	4.7	5.00
		Hotels and motels	65	3.7	5.00

Table 6-3 Total criteria reaching consensus in rounds 1 & 2

Dimension	**Round 1**				**Round 2**		
	Total criteria	Consensus criteria	%	#criteria proposed by expert	Total criteria	Consensus criteria	%
Society and economy	21	15	71	2	21	21	100
Environment and climate change	12	10	83	3	15	15	100
Infrastructure	20	16	80	1	20	20	100
Governance and Institutions	11	11	100	1	12	12	100
Total	64	52	85	7	68	68	100

6.2.3 The society and economy dimension

The standard deviations for the various criteria in the Society and Economy dimension are shown in Table 6-4. All criteria score less than 1, ranging from 0.54 to 0.99 more specifically. Furthermore, the IQR for all criteria is 1, while the mean values range between 3.6 and 4.6. Thus, the analyses indicate that there is a consensus on all twenty-one criteria in the Society and Economy dimension.

6.2.4 The environment and climate change dimension

According to Table 6-5 the Environment and Climate Change dimension obtained standard deviations of less than 1 for all criteria, ranging between 0.70 and 0.99 more specifically. The IQR for each criterion was =1, while the mean values were in the range of 3.6 and 4.5. This indicates that a consensus was obtained on the fifteen criteria in the Environment and Climate Change dimension.

6.2.5 The infrastructure dimension

In Table 6-6, the standard deviations for the criteria under the Infrastructure dimension are shown. All are less than 1 and range between 0.57 and 0.97 respectively. Moreover, the IQR for all criteria is equal to 1, while the mean values run from 3.38 to 4.58. This proves that there is a general consensus for the twenty criteria under the Infrastructure dimension.

Table 6-4 Society and economy criteria consensuses final round

Society and Economy Dimension	Round 2			
	Mean	Median	Std. Deviation	Interquartile Range (IQR)
Society and economy				
Demographic				
Population growth rate	4.1	4.00	0.87	1.00
Population density	4.2	4.00	0.92	1.00
dependent population	3.5	4.00	0.92	1.00
Disability	3.9	4.00	0.92	1.00
Level of education	4.0	4.00	0.87	1.00
Foreign population*	3.6	4.00	0.88	1.00
Livelihood				
Population dependent on coastal resources	3.9	4.00	0.90	1.00
Household income	3.4	4.00	0.94	1.00
Poverty	3.6	4.00	0.99	1.00
Employment				
Employment dependence on coastal resources	4	4.00	0.85	1.00
Non-profit organization (NPO)*	4.1	4.00	0.89	1.00
Awareness & training				
Disaster exercises and drills	4.5	5.00	0.69	1.00
DRR training	4.6	5.00	0.54	1.00
Awareness of disaster and climate change risks	4.6	5.00	0.60	1.00
Multilingual awareness programmes	4.2	4.00	0.75	1.00
Awareness campaigns	4.4	5.00	0.73	1.00
Culture				
Social capital	3.6	4.00	0.89	1.00
Integrating DRR into school curriculum*	4.3	5.00	0.85	1.00
Safety and security				
Riots, conflicts and homicide incidents	3.6	4.00	0.84	1.00
ISPS code compliance	4.3	4.00	0.77	1.00
Safety and security systems	4.3	5.00	0.64	1.00

*: Proposed by expert

Table 6-5 Environment and climate change Criteria Consensuses Final Round

Environment and Climate Change Dimension	Round 2			
	Mean	Median	Std. Deviation	Interquartile Range (IQR)
Environment and climate change				
Coastal pollution control				
(1) Water quality	4.2	4.00	0.87	1.00
(2) Marine pollution	4.5	5.00	0.73	1.00
(3) Mangrove cover	3.8	4.00	0.99	1.00
(4) Industrial wastewater discharge*	4.20	4.00	0.73	1.00
land use				
(5) Agricultural land	3.6	4.00	0.87	1.00
(6) Urban green space	4.1	4.00	0.80	1.00
(7) Built up area	4	4.00	0.88	1.00
(8) Building codes and regulation	4.4	5.00	0.81	1.00
(9) Mean elevation of the area	4.2	4.00	0.81	1.00
Slow onset disasters				
(10) Exposure and risk of increasing temperature	3.6	4.00	0.87	1.00
(11) Relative rate of sea level rise	4.1	4.00	0.75	1.00
(12) Implementation of IPCC Rules and Procedures*	4.1	4	0.73	1.00
Rapid onset disasters				
(13) Frequency of natural disasters	4.2	4.00	0.77	1.00
(14) Intensity/severity of natural disasters	4.3	4.00	0.71	1.00
(15) Seabed seismic monitoring*	4.50	5.00	0.70	1.00

*: Proposed by expert

Table 6-6 Infrastructure criteria consensuses final round

Infrastructure Dimension	**Round 2**			
	Mean	**Median**	**Std. Deviation**	**Interquartile Range (IQR)**
Infrastructure				
Health				
(1) Hospitals (#) in 100 people	4.4	5.00	0.75	1.00
(2) Hospital beds (#) in 100 people	4.3	4.00	0.83	1.00
(3) Number of physicians (#) in 100 people	4.1	4.00	0.85	1.00
(4) Number of ambulances (#) in 100 people	4.2	4.00	0.63	1.00
(5) Health insurance (#) in 100 people	4	4.00	0.85	1.00
(6) Health care support workers (#) in 100 people	4.1	4.00	0.91	1.00
Transportation				
(7) Roads accessibility	4.5	5.00	0.62	1.00
(8) School and employee buses	3.6	4.00	0.97	1.00
(9) Special need transportation services	4.1	4.00	0.87	1.00
(10) Public transportation modes*	4.1	4.00	0.74	1.00
Utilities				
(11) Infrastructure and public facilities	4.6	5.00	0.58	1.00
(12) Renewable energy	4	4.00	0.91	1.00
(13) Fire stations	4.6	5.00	0.57	1.00
Communication				
(14) Access to mobile phones	4	4.00	0.72	1.00
(15) Access to radio/television	3.7	4.00	0.86	1.00
(16) Reliability of communication systems	4.3	4.00	0.92	1.00
(17) Internet services	4.2	4.00	0.77	1.00
Embankment & shoreline				
(18) Vulnerable shoreline	4.2	4.00	0.79	1.00
(19) Age of embankments	4.1	4.00	0.86	1.00
(20) Maintenance of embankments	4.3	5.00	0.80	1.00

*: Proposed by expert

Table 6-7 Governance and institutions criteria consensuses final round

Governance and Institutions Dimension	**Round 2**			
	Mean	**Median**	**Std. Deviation**	**Interquartile Range (IQR)**
Governance and Institutions				
Laws & policy				
(1) Regulations and policies	4.5	5.00	0.73	1.00
(2) Environmental regulation	4.3	4.00	0.74	1.00
(3) Participation in DRR planning	4.3	4.00	0.73	1.00
(4) DRR strategies	4.2	4.00	0.84	1.00
(5) Compliance with international standards that consider disaster risks*	4.5	5.0	0.74	1.00
Institutional action				
(6) Observation and Monitoring	4.1	4.00	0.81	1.00
(7) Institutional collaboration & coordination	4.4	5.00	0.69	1.00
(8) Voluntary Groups	4.4	5.00	0.62	1.00
Warning and evacuation				
(9) Early warning system	4.7	5.00	0.66	0.00
(10) Availability of evacuation centre	4.8	5.00	0.45	0.00
(11) Emergency Aids	4.7	5.00	0.49	0.00
(12) Hotels and motels	3.7	5.00	0.80	1.00

*: Proposed by expert

6.2.6 The governance and institutions dimensions

Table 6-7 shows the standard deviations for each criterion in the Governance and Institutions dimension. All are less than 1 and range between 0.45 and 0.80. Moreover, all criteria have an IQR of <1 and mean values between 3.7 and 4.8. This data shows that all twelve criteria under the Governance and Institutions dimension obtained a consensus.

6.2.7 Overall ranking of all framework dimensions

The above findings indicate that a general consensus has been obtained for all four dimensions in the framework of coastal community resilience to disaster in Saudi Arabia. In Table 6-8, provides a summary of the analysis for the four dimensions on the consensus status for the final Delphi round. This clearly shows the agreement across all members of the expert panel for all four dimensions. In total, the standard deviations are less than 1 and range between 0.56 and 0.78. Furthermore, all dimensions obtained an IQR of <1 and mean values between 3.9 and 4.5.

Table 6-8 Dimensions of the framework consensus final round

Dimension	Mean	Median	Std. Deviation	Interquartile Range (IQR)
Society and economy	3.9	4.00	0.78	0.00
Environment and climate change	4.4	4.50	0.56	1.00
Infrastructure	4.5	5.00	0.56	1.00
Governance and Institutions	4.2	4.00	0.76	1.00

6.3 Discussion

6.3.1 Society and economy dimension

One of the most important factors when considering resilience is the social and economic dimension, which deals, not only with communities' vulnerability, but also with their ability to learn, cope and adapt when faced with changes (Cutter and Director, 2008). The social component deals with people and their related issues, such as decreased mobility (which may be associated with gender, age or disabilities). Increased awareness and training of the public aids in the augmentation of resilience at the social level. Such improvements could be realised through the continuous education of community members on the risks emanating from disasters, processes used in warning systems and evacuation procedures. Maritime disasters may lead to disruption of communications, loss of property and fatalities. Among the resilience indicators found in the economic component, the percentage of social security recipients in the community is identified. In this sense, communities with more wealth and resources at their disposal display a greater ability to recover from disasters. In a community with a lower proportion of low-income residents, a larger amount of money is available to be spent to absorb, respond to and recover from disasters (Yoon et al., 2016). The economic component deals with issues inherent to the economy of the affected area. Maritime disasters can adversely affect a great number of activities, such as coastal resources or fisheries (Simonovic and Peck, 2013). The economic vitality of a community can be measured using indicators such as household incomes and unemployment levels. This is directly related to the livelihood capital that can be used to enable the community to adopt strategies to mitigate the risk of disasters (Hung et al., 2016). It is because of this that factors such as demographics; livelihood; employment; awareness and training; culture; and safety and security are identified when exploring this dimension. All of these criteria achieved high consensus with the panel of experts, who expected that communities with a higher proportion of women and elderly in total population or unemployed individuals, and a lower level of education would be more vulnerable to disaster and would demonstrate a lower level of resilience than communities with opposing characteristics(Teo et al., 2013).

Moreover, the factor referencing the foreign population and non-profit organisation (NPO) which were included in this group by the panellists, also achieved the level of consensus. NPOs have been shown to increase the ability of a community to cope with disaster and to rebuild and provide relief wherever they are present (Alshehri et al., 2015a). As stated by Hasegawa et al. when circulating disaster related guidance to a community, provision should be made for non-locals who reside in the area or are likely to travel through the area. Such provisions would mostly concentrate on circulating the information in their language and enhancing their understanding of the local culture. This is particular crucial for a country such as Saudi Arabia as foreign visitors to the KSA come from all over the world (Algarni et al., 2018). It therefore follows that any guidelines on the prevention of disasters and how to seek refuge should be circulated in various languages in the KSA. Moreover, such distribution of guidelines should be performed in a timely manner and in various formats allowing all individuals' sufficient time to prepare for such disasters, thereby enhancing a community's resilience.

6.3.2 Infrastructure dimension

An essential part of any community resilience framework is represented by the infrastructure dimension, which refers to an assessment of the physical capability of a community's infrastructure to respond to, withstand and recover from disaster. Transportation, the first key area within the dimension, refers to the ability of people to move to secure places and to obtain essentials such as food or water, which are crucial elements to sustain the community while it is displaced and during the recovery period. Utilities, the second key area, references the facilities and support available to the public such as fire engines that are essential services used to sustain life. It must be mentioned that the provision of such services, though essential for recovery, is beyond the control of the community (Teo et al., 2013). Health is also a big player and here it references the availability of hospitals, ambulances, health workers (e.g. physicians and care staff) and also insurance policies. These factors are all crucial for the recovery phase and once again are out of the control of the public. The communication systems in this dimension form an extension to the warning and evacuation systems as without them the public could not be informed nor could recovery take place in an efficient manner. Finally, the resilience derived from the physical presence of the embankment and the shoreline is also crucial and must be maintained as it forms a first line defence against maritime disasters. All these factors, including utilities, transport, healthcare and communication are crucial to mitigating the effects of a disaster and increasing the ability of the community to cope with them. The panel of experts was in agreement with all of this and determined that infrastructural resilience must show robustness and dynamism in a resilient community, with coastal communities being no exception to the rule. One study, however, demonstrated how communities in developing countries lack such infrastructure, public transport being one of them (Peacock et al., 2010). For this reason, the panel of experts added modes of public transport to the framework under this dimension, expecting to find a clear correlation between their existence and the community's resilience to disaster. For example, it is expected that a community with a poor transport network will struggle to evacuate its citizens, and hence show diminished resilience. These indicators are used in this study to provide a measurement of the infrastructural capacity of a community and to identify basic vulnerabilities related to infrastructural deficiencies (Teo et al., 2013). Lack of critical facilities and physical infrastructure may hamper a community's ability to prepare for, respond to and recover from disaster, as they play an important role in ensuring the availability of resources and support in these cases (Peacock et al., 2010). The indicators explored in this study also include an overall assessment of the quantity of particularly vulnerable private property (e.g., housing built before the enactment of mandatory building codes) that may lead to economic losses during a disaster (Cutter et al., 2010).

6.3.3 Governance and institutions dimension

The governance and institution dimension makes up one of the fundamental parts of any community resilience framework. Under this dimension, resilience consists of various factors related to local government, particularly regarding its performance and in its ability to reduce the negative impacts of disasters (Yoon et al., 2016). It also features elements related to mitigation, planning and prior disaster experience. In this case, the capacity of communities to reduce risk is affected by resilience, as well as their ability to involve local residents in mitigation (on a voluntary basis), to create links with organisations and to build and protect social systems within a community (Cutter et al., 2010). Policy and planning now form key issues in disaster risk management. The fact that coastal communities are at risk of the consequences of maritime disasters necessitates the development of special policies and planning specifically for coastal communities. Planning referenced here is not merely planning for disaster risk management. As it is not possible to prevent natural catastrophes from taking place, it is essential to construct plans to aid communities in facing disasters ensuring minimum loss and rapid recovery. Planning is also necessary in the preparedness phase through regulation of land use and compliance with international standards. Such measures serve to protect the population from disasters by insuring minimal risk prior to disaster onset.

Rahman (2013) notes that planning is also an important element of emergency response and disaster recovery. A community with robust warning and evacuation systems demonstrates increased resilience as it is capable of receiving notifications and alerts of coastal disasters, which allows it to warn at-risk populations in a timely manner and also allowing the efficient and timely response of individuals acting on the alert. Local government has responsibility for distribution of warning information thereby ensuring the public are forewarned and prepared to act (Rahman and Kausel, 2013). Given the above, it is clear that laws and policies, institutional actions and warnings and evacuations must also be considered under this dimension. All of these criteria achieved high consensus with the panel of experts.

6.3.4 Environment and climate change dimension

This dimension is central to the issue of disaster recovery as noted in Kesavan and Swaminathan (2006) who noted that the frequency of disasters can be decreased by improvement of environmental and climatic conditions. Additionally, the more robust the ecological construct of a community then the greater resilience it shows in terms of reduced damage and rapid recovery. Moreover, Biggs et al. (2012) had indicated the importance of environmental conservation in enhancing a communities financial capability through tourism which in turn would fund recovery from disasters more rapidly.

The first area of reference in this dimension concerned marine life. Marine life is key not only to resilience of a community but also to the adaptation of a community to the conditions of climate change as indicated in (Roberts et al., 2017). Including adaptation to sea level rises and tropical cyclones. To ensure this is maintained mangroves in the region must be maintained, thereby forming a protective barrier for the community and marine life. Next, the quality of the water must be high through reduced pollution including release of industrial waste. The latter was an additional sub-indicator included by the expert panel. To ensure this criterion is managed it must be individually referenced in this dimension.

Next, the land use indicator highlights the importance of greenspace, building regulations and elevation data all these criteria play an important role of maintaining the ecological environment of a community and ensuring it is protected from rogue actions that could reduce its resilience.

The final two indicators outline the central point of the issue in the form of the feature associated with natural man-made disasters. Their frequency, intensity, climate change and sea level rises should all be monitored for planning and recovery purposes. Disaster risk management should also concentrate on ensuring that regulations governing the monitoring of all these disasters is carried out. The 'Implementation of IPCC Rules and Regulations' and 'Seabed Seismic monitoring' are two sub-indicators that were added by the expert panel. This highlights the importance implementation of such regulations and monitoring and ensuring that policies applied are at the international level and in agreement with international bodies.

The environmental dimension is not only considered at the local level but also at the national and international level. Disasters occur all over the globe and countries would serve each other well by sharing information and coming to agreements to monitor and address climate change. Such actions would only serve to enhance a country and a communities resilience.

6.4 Summary

The methodology used in this chapter was one of the main stages in the development of a broad, inclusive and robust framework for the measurement of criteria that are crucial for the assessment and development of a communities resilience to maritime disasters. The involvement of a range of experts from various fields related and concerned with disaster risk management was key to the comprehensive nature of this framework. Moreover, the inclusion of local and international experts ensured that a wealth of experience and knowledge supplemented the development of this framework.

As a consensus-based technique, the Delphi technique ensured that a collective strategy was implemented in reaching a consensus. 65 experts responded to the first round of questions and of those, 58 responded to the second round of questions at which point a consensus was achieved for all indicators and sub-indicators and therefore for all four dimensions. This included the introduction of seven new sub-indicators by the panel of experts; three for the environment and climate change dimension, two for the society and economy dimension and one for each of governance and institutions and the infrastructure dimensions. These additions illustrate the need for a more comprehensive framework for resilience particularly regarding the environment and climate change dimension and more specifically regarding the importance of monitoring and application of policies and regulations in the enhancement of resilience.

Finally, this chapter has served to address two objectives and two research questions in assessing the perspectives of the experts and determining which criteria were important regarding the maritime disasters challenging the KSA, the applicable resilience factors and how they can be incorporated in a framework in this case across the four dimensions specified.

Chapter 7
Prioritisation of resilience assessment factors

To help understand the data used in the AHP, this chapter starts by explaining the previous analytical steps that led to the elucidation of assessment criteria that were deemed significant by both the public and a panel of experts. The chapter explains the hierarchical breakdown of the assessment criteria; the dimensions, indicators and sub-indicators. The results of the weighting is then detailed for each tier with significant criteria highlighted.

7.1 Methodology to establish a coastal community resilience framework (CCRMD)

This research represents a mixed methods study (one that includes both quantitative and qualitative research) aimed at establishing a coastal community resilience framework (CCRMD). It comprises a literature review, stakeholder perception, a survey using the Delphi technique and prioritisation using the AHP (see Chapter 4). For the first stage of this study (Chapter 5), a quantitative strategy was employed to analyse the results of a survey carried out in Saudi Arabia. This survey analysed the public's perspective and aimed to determine the public perception on the topic. The results of this survey, in combination with the literature review enabled the establishing of criteria under four different dimensions.

Chapter 6 represents the second stage of the study, consisting of the Delphi consensus-based consultation. A panel was constructed consisting of experts in the field. The panel was communicated the details of the four dimensions and their corresponding criteria to ascertain their relevance with regards to community resilience to disaster risk management in Saudi Arabia. The CCRMD was completed following the Delphi survey, using the following criteria applied in the final stage with the aim to strengthen the framework.

The Delphi data was then fed into the final stage of this study. The AHP and a set of formulae were applied to establish how each dimension and criterion should be weighed. The AHP technique was employed due to its advantageous features including the ability to assess data presented in quantitative and qualitative forms (Wedley, 1990). Data gathered through the Delphi technique is of qualitative form. The AHP converts this qualitative data into analysable quantitative data. A Saaty rating technique was described by (Shapira and Simcha, 2009). This used a rating system ranging from 1 to 9 to allow the conversion of qualitative Delphi data into quantitative form. This chapter focuses on the use of the AHP methodology to ascertain the weight of each dimension, as well as on answering the following research question:

- RQ5- What is the most appropriate applicable weighting system *to reflect an accurate assessment of the* community resilience in the context of Saudi Arabia?

7.2 Development of the coastal community resilience framework prioritizing and weighting system

7.2.1 The AHP process and experts selection

Chapter 4 details the process that led to the development of the AHP used in this study. To facilitate the process a group of 21 experts from the original Delphi group were invited to take part in the AHP. As stated by Lin et al. (2010); the experts participating in the AHP need to come from the Delphi group to ensure that consistency is maintained and overlapping data is avoided. Of the 21 invited experts, 19 agreed to take part in this study, which is an acceptable number (Omar and Jaafar, 2011). The AHP is applicable with a small sample size. This fact was supported by various studies and was deemed to not be restrictive to the process (Tsyganok et al., 2012, Lee and Walsh, 2011).

There were several criteria that were used to determine who to select from the original Delphi group of experts. These criteria are as follows:

- The experts must have participated in this study's Delphi survey.
- The expert must have a minimum of five years of experience in the field of disaster risk management.
- The panel must constitute both national and international experts.
- All experts must have knowledge of disaster risk management issues in their region but also on global issues.
- The various fields of disaster risk management must be represented in the final panel.
- Regarding the international experts:
  - They must be able to appreciate the cultural and religious aspects of the KSA or have direct experience through work in the KSA.
  - They must have experience in working in developing countries and associated global organisations be able to apply this experience in this analysis.

7.2.2 Structuring the Hierarchy

As described in chapter 4 section 4.6.3, pair-wise comparisons were used to help prioritise the various elements of the assessment criteria. The pair-wise comparisons for each pair of assessment criteria were submitted to the 19 experts via email an in the form of a questionnaire. All responses were completed and submitted online. The consistency ratio (CR) described in section 4.6 was used to assess the degree of dependability of the responses. Of the 19 responses, two had CRs above the value of 0.1 indicating that there was a lack of consistency and therefore reliability in the results. These two results were therefore rejected. Finally, Expert Choice software was used to compute the weight or each assessment criterion and to determine the group consensus.

During the structuring of a hierarchy, the decision-making problem must be divided and simplified into three levels: goal; criteria and sub-criteria; and alternatives (Ishizaka and Labib, 2009). Figure 7-1 illustrates the components that were deemed to optimally describe coastal community resilience to disaster. These are described through the AHP in the form of a hierarchy consisting of three levels. This figure was the outcome of a consensus formed by the expert panel through the application of the Delphi technique, as described in Chapter 6. For the purpose of this study, the first level consisted of four dimensions that were extracted including: society and economy; environment and climate change; infrastructure; and governance and institutions. In the second level, 18 indicators based on resilience dimensions are found. These indicators are sub-divided further into 68 sub-indicators the third level.

7.3 Results and discussion

7.3.1 Allocation of weights

The weighting system offers an important way to assign appropriate credit distribution to each community resilience criterion based on local priorities (Ameen and Mourshed, 2019). When establishing a new method to assess community resilience, it is essential to adapt weighting systems to fit with local and regional priorities. This can be achieved through a consensus- built method with experts (Chew and Das 2008; Giannarou and Zervas 2014). Within the context of this study, experts were consulted and a series of pairwise comparisons were carried out using Expert Choice software. The software enabled the pairwise comparisons between the various assessment criteria to be converted into weighted measures. This ensured that the data was reliable and enabled the priorities to be calculated automatically. The total of all the weights computed to a value of 1 across the dimensions. The weights assigned were 0.191 + 0.242 + 0.215 + 0.352 = 1.000. With regards to determining the significance of each criterion the CR detailed above is used (Triantaphyllou and Mann, 1995). This is one of the AHP's most beneficial aspects as it allows for the reliability of the experts' opinions to be assessed. This is crucial and the possibility of a lack of consistency at this stage is raised(Ishizaka and Labib, 2009, Yang et al., 2007). In the case of this study, a CR of 0.040 was obtained when analysing pair-wise comparisons, a figure that is considered valid (Salmeron and

Herrero, 2005, Cutter et al., 2014). The weightings calculate were determined using the formulae detailed in chapter 4 section 4.7 (Alshehri et al., 2015b). At the end of the process, the environment and climate change dimension was shown to makes up 35.2% of the final weight of the hierarchy, making it the weightiest dimension. The second weightiest dimension was infrastructure with a percentage weighting of 24.3%. This was followed by the government and institutions dimension with a weighting of 21.5% and finally the society and economy dimension with a weighting of 19.1%. These results are illustrated in Figure 7-1.The details of the proportion (P) and the weight allocation (wc) occupied by each sub-indicator for each dimension are listed in Table 7-1 to Table 7-4. Based on these calculations, a weighted tool with a final (weighted) score, as well as individual (weighted) scores for each of its four dimensions (society and economy; environment and climate change; infrastructure; and governance and institutions) was successfully achieved. Therefore, it can be used within the context of the KSA to assess the resilience of coastal communities and the strengths and weaknesses as indicated for each criterion.

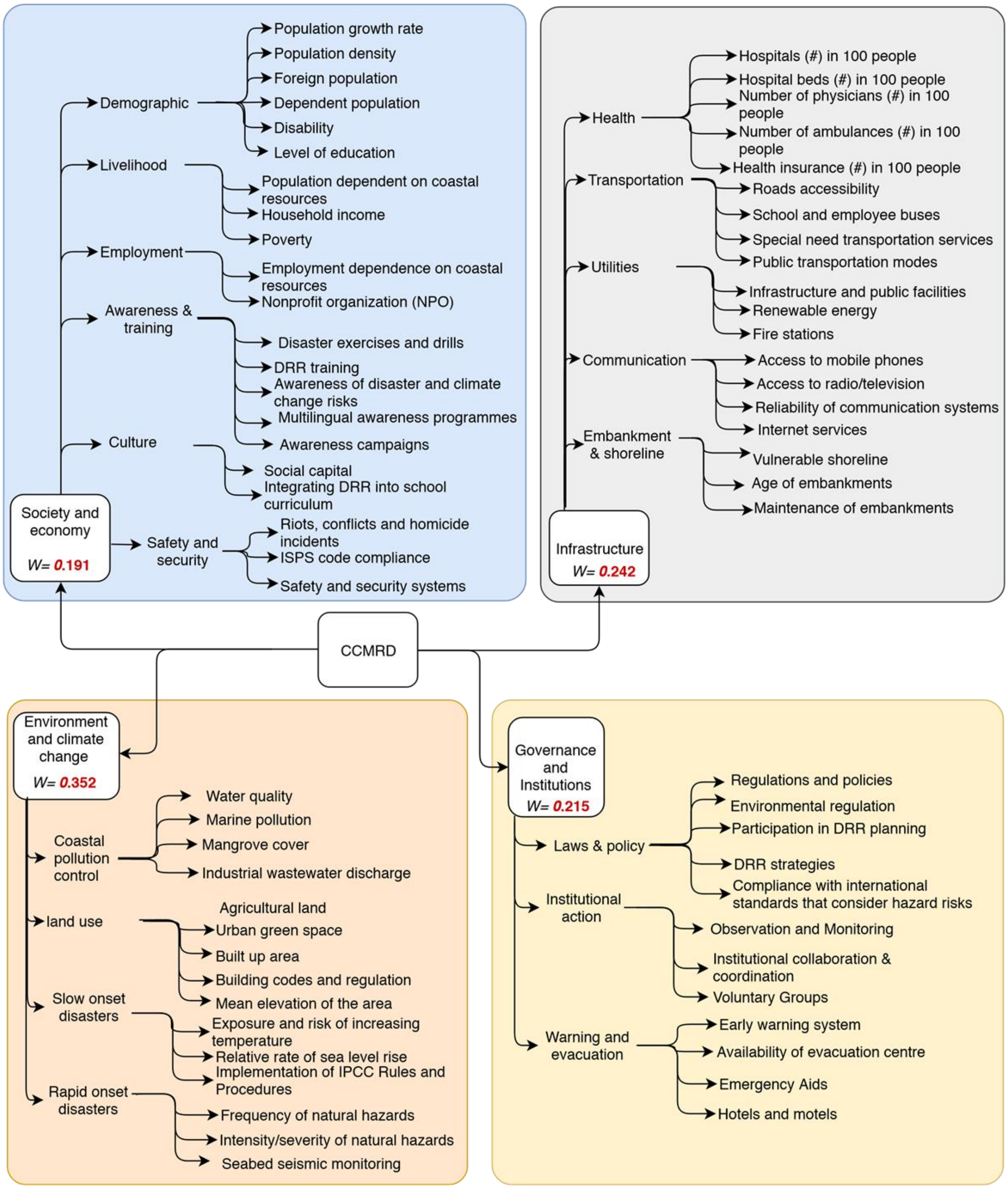


Figure 7-1 CCRMD hierarchical structure and dimension weightings

7.3.2 Environment and Climate change

The environment and climate change dimension was computed as the weightiest dimension (0.352) through this study. Table 7-1 details and confirms the weightiness in the allocation of the individual proportions for each sub-indicator. These ranged between 0.058 and 0.073. Of all the sub-indicators, marine pollution and seabed seismic monitoring appear to be classified as the most important, both allocated a weighting of 0.0256. This is logical as seismic monitoring is the easiest means of monitoring disasters that are initiated rapidly. The more efficient these techniques are the greater the opportunity afforded the community to prepare and safeguard themselves against the disaster. Regarding the marine pollution sub-indicator, this is crucial in that marine life can aid in delivering natural resilience to disasters. Kesavan and Swaminathan (2006) described, "The vicious spiral between environmental degradation and ever increasing frequency and intensity of hydro-meteorological disasters" a form of maritime disasters. Reduction of levels of pollution are expected to lead to an improvement in frequency of disasters, therefore forming a means of enhancing the resilience of a community.

Table 7-1 Indicator weighting for environment and climate change

Dimension	Indicators	Sub Indicators	$\mathcal{P}$	WC	WC%
Environment and climate change	**Coastal pollution control**				
		Water quality	0.068	0.0239	2.39%
		Marine pollution	0.073	0.0256	2.56%
		Mangrove cover	0.061	0.0216	2.16%
		Industrial wastewater discharge	0.068	0.0239	2.39%
	land use				
		Agricultural land	0.058	0.0205	2.05%
		Urban green space	0.066	0.0234	2.34%
		Built up area	0.065	0.0228	2.28%
		Building codes and regulation	0.071	0.0251	2.51%
		Mean elevation of the area	0.068	0.0239	2.39%
	Slow onset disasters				
		Exposure and risk of increasing temperature	0.058	0.0205	2.05%
		Relative rate of sea level rise	0.066	0.0234	2.34%
		Implementation of IPCC Rules and Procedures	0.066	0.0234	2.34%
	Rapid onset disasters				
		Frequency of natural disasters	0.068	0.0239	2.39%
		Intensity/severity of natural disasters	0.070	0.0245	2.45%
		Seabed seismic monitoring	0.073	0.0256	2.56%
			1.00	0.352	35.2%

7.3.3 Infrastructure

The criteria under the infrastructure dimension -the second weightiest dimension registering a weight of 0.242 are shown in Table 7-2. The proportions associated range from 0.043 and 0.055. The most significant in this dimension are infrastructure and public facilities and fire stations, both with weights of 0.0133. These two are closely followed by road accessibility (with a weighting of 0.0131. The necessity for fire stations would lie in the fact that these act as the first responders to disaster and thus constitute the beginning of resolving and restructuring a community. Controlling the extent of a disaster would mean that there would be less damage formed. This in turn would mean a community could return to normal faster. This also applies regarding the infrastructure and public facilities dimension in that it describes a utility that serves the whole community thereby allowing the return of the whole community to normal more rapidly. Finally, road accessibility is crucial in allowing disaster recovery. Ensuring accessibility of roads ensures that resources would reach the necessary regions rapidly leading to rapid recovery.

Table 7-2 Indicator weighting for infrastructure

Dimension	Indicators	Sub Indicators	$\mathcal{P}$	WC	WC%
Infrastructure	Health				
		Hospitals (#) in 100 people	0.053	0.0128	1.28%
		Hospital beds (#) in 100 people	0.052	0.0125	1.25%
		Number of physicians (#) in 100 people	0.049	0.0119	1.19%
		Number of ambulances (#) in 100 people	0.050	0.0122	1.22%
		Health insurance (#) in 100 people	0.048	0.0116	1.16%
		Health care support workers (#) in 100 people	0.049	0.0119	1.19%
	Transportation				
		Roads accessibility	0.054	0.0131	1.31%
		School and employee buses	0.043	0.0104	1.04%
		Special need transportation services	0.049	0.0119	1.19%
		Public transportation modes	0.049	0.0119	1.19%
	Utilities				
		Infrastructure and public facilities	0.055	0.0133	1.33%
		Renewable energy	0.048	0.0116	1.16%
		Fire stations	0.055	0.0133	1.33%
	Communication				
		Access to mobile phones	0.048	0.0116	1.16%
		Access to radio/television	0.044	0.0107	1.07%
		Reliability of communication systems	0.052	0.0125	1.25%
		Internet services	0.050	0.0122	1.22%
	Embankment & shoreline				
		Vulnerable shoreline	0.012	0.0122	1.16%
		Age of embankments	0.012	0.0119	1.13%
		Maintenance of embankments	0.012	0.0125	1.19%
			1.00	0.242	24.2%

7.3.4 Society and Economy

As seen in Table 7-3, this dimension is assigned a weight of 0.191 and comprises criteria with a range of proportions between 0.040 and 0.054. The most important criteria in this dimension are DRR training and awareness of disaster and climate change risks, with a credit of 0.0104. An awareness of the risks is half the battle. Prevention is better than cure is the popular phrase. Thus, awareness aids prevention which increases the resilience of a community as it allows the community to enhance is preparedness. Therefore, when disaster strikes, a better prepared community would suffer reduced damage indicating greater resilience. Higher levels of community awareness lead to a community with increased endurance levels against disaster, more likely to be able to handle emergencies and also more capable of returning to normal (Izadkhah and Hosseini, 2005). This also applies to increasing levels of preparedness by reducing risks that could result from disasters. Training a community on how to reduce their risks serves to increase resilience in a similar way to awareness. Awareness of the risks forms the first step and acting on the awareness and reducing the risks forms the second step. The benefits of training on DRR by a community are outlined in the United Nations document 'Building Disaster Resilient Communities - Good Practices and Lessons Learned' released in 2007 and include factors such as communities that "would be in a better position to engage with local government structures in the development of local disaster risk management plans". Thus, these two elements both strengthen resilience through a process of greater preparedness of a community.

Table 7-3 Indicator weighting for society and economy

Dimension	Indicators	Sub Indicators	P	WC	WC%
Society and economy	**Demographic**				
		Population growth rate	0.048	0.0092	0.92%
		Population density	0.050	0.0095	0.95%
		dependent population	0.041	0.0079	0.79%
		Disability	0.046	0.0088	0.88%
		Level of education	0.047	0.0090	0.90%
		Foreign population	0.043	0.0081	0.81%
	Livelihood				
		Population dependent on coastal resources	0.046	0.0077	0.88%
		Household income	0.040	0.0067	0.77%
		Poverty	0.043	0.0071	0.81%
	Employment				
		Employment dependence on coastal resources	0.047	0.0090	0.90%
		Non-profit organization (NPO)	0.048	0.0092	0.92%
	Awareness & training				
		Disaster exercises and drills	0.053	0.0101	1.01%
		DRR training	0.054	0.0104	1.04%
		Awareness of disaster and climate change risks	0.054	0.0104	1.04%
		Multilingual awareness programmes	0.050	0.0095	0.95%
		Awareness campaigns	0.052	0.0099	0.99%
	Culture				
		Social capital	0.043	0.0081	0.81%
		Integrating DRR into school curriculum	0.051	0.0097	0.97%
	Safety and security				
		Riots, conflicts and homicide incidents	0.043	0.0081	0.81%
		ISPS code compliance	0.051	0.0097	0.97%
		Safety and security systems	0.051	0.0097	0.97%
			1.00	0.191	19.10%

7.3.5 Governance and Institutions

This is the dimension with the lowest weight in the study (0.215). Its criteria are presented in Table 7-4 and have proportion ranging from 0.070 and 0.091. Availability of evacuation centre is the most significant criterion for this dimension. This sub-indicator is a great factor in the recovery phase of disaster risk management (0.0196). Better availability of evacuation centres will enhance response and safety therefore allowing the better recovery of a community. Thus, this means that improvements in shelter centre availability would enhance resilience. Next, the availability of early warning systems and emergency aid are also high on the weightings of this dimension. Early warning systems serve to inform the public of impending disasters thereby allowing them to prepare and possibly salvage what they can. At the other end of the disaster risk management scale is emergency aid. This is one of the first requirements of recovery. It is the means for a community to start helping itself through healing. These factors all influence resilience through different phases of the disaster risk management process. Nevertheless, whether discussing preparedness or recovery, it is always crucial that resilience is enhanced throughout all four phases. For example, if the evacuation systems are highly resilient yet the emergency aid is lacking, then a lot of people who survived the disaster well may suffer or recover slowly because of the lack of aid. Though the lack of resilience is only in one phase (recovery) of a framework it still has an impact on the communities resilience and therefore the framework as a whole. Once again we see that although some sub-indicators carry greater weight than others, each sub-indicator is similarly dependent on others to ensure the resilience of the framework and therefore the community as a whole.

Table 7-4 Indicator weighting for governance and institutions

Dimension	Indicators	Sub Indicators	$\mathcal{P}$	WC	WC%
Governance and Institutions	**Laws & policy**				
		Regulations and policies	0.086	0.0184	1.84%
		Environmental regulation	0.082	0.0176	1.76%
		Participation in DRR planning	0.082	0.0176	1.76%
		DRR strategies	0.080	0.0172	1.72%
		Compliance with international standards that consider disasters risks	0.086	0.0184	1.84%
	Institutional action				
		Observation and Monitoring	0.078	0.0168	1.68%
		Institutional collaboration & coordination	0.084	0.0180	1.80%
		Voluntary Groups	0.084	0.0180	1.80%
	Warning and evacuation				
		Early warning system	0.089	0.0192	1.92%
		Availability of evacuation centre	0.091	0.0196	1.96%
		Emergency Aids	0.089	0.0192	1.92%
		Hotels and motels	0.070	0.0151	1.51%
			1	0.215	21.5%

7.4 Summary

The identification of criteria–dimensions, indicators and sub-indicators that were key in developing a robust and comprehensive resilience framework constituted the initial stage. For these criteria to be applicable in the context of the coastal communities of the KSA, they had to be weighted according to their degree of importance. To this end, once again, a panel of experts were employed to process these indicators according to the Analytical Hierarchy Process.

Twenty-one were invited, all of whom had previously taken part in the Delphi technique. This not only ensured that they were experts in the field but that they were already familiar with the work being undertaken. Through pairwise comparisons and the use of Expert Choice software, each criterion was allocated a weighting which culminated in a final weighting for each dimension; 35.2% for the environment and climate change dimension, 24.3% for the infrastructure dimension, 21.5% for the governance and institutions dimension and 19.1% for the society and economy dimension. These weightings served to further highlight that the environmental dimension had certainly been under-emphasised in previous frameworks derived from the literature review as the highest weighting and therefore importance was assigned to this dimension. The use of the AHP to complete the classification of this framework certainly served to apply an approved weighting system to this framework and in doing so ensured the completion of the Coastal Community Resilience to Maritime Disasters (CCRMD) framework for use as a measure of resilience in the context of the KSA.

Chapter 8 **Development and validation of the CCRMD Framework**

This chapter demonstrates how the CCRMD framework would be implemented as a tool for the measurement and development of resilient coastal communities in Saudi Arabia. CCRMD is verified against three other existing frameworks to highlight its comprehensive and robust nature and the consideration of the local context. This is an essential step in the finalisation of any framework to ensure it works as intended and to prepare for its use application across Saudi Arabia.

8.1 Development of the CCRMD framework

The effective assessment of the impact of disasters on a region requires an initial understanding and appreciation of the region's resilience (Ewing and Synolakis, 2011). This in turn would aid communities and decision-makers in developing plans and policies to effectively handle different disaster stages including mitigation, response, preparedness and recovery (Tianzhuo and Linyan, 2014). Resilience, however, is a feature of a region that varies with time as it is dependent on various environmental and social factors, as well as infrastructure, governance, the economy and institutions. Therefore, as stated by Kirmayer et al. (2013), it is crucial that resilience is assessed over time in a continuous manner to ensure that a community's resilience measurements are always up to date.

The frameworks available were found to be developed for specific regions facing specific risks and although they overlapped in certain indicators, they, nevertheless, also differed in their make-up and applicability. Thus, these were deemed unsuitable for application to the KSA. However, some of them were considered useful for detailing a list of criteria necessary for assessing coastal community resilience. Four dimensions - society and economy; environment and climate change; infrastructure; and governance and institutions - were extracted from the collation of this data and were used as a basis to group the criteria further into indicators and sub-indicators forming a three-level framework that required further analysis.

Various studies have demonstrated that when assessing a community's resilience, the framework adopted should be designed specifically for the region in question (Gou and Lau, 2014, Seinre *et al.,* 2014). This is to ensure that the true effects of the environment and climate, as well as other factors (governance, society, economy, infrastructure and institutions), are comprehensively accounted for in the correct context. The specific climate of a region, coupled with the specific environment and capabilities of a region (e.g. oil production), highly individualise a community's possible disasters and resilience which, in turn, prevents the application of non-specific environmental analysis methodologies (Todd *et al.*, 2001). With this in mind, it was important to develop a new framework that was for maritime disasters affecting the Gulf region and more specifically, KSA, rather than use a pre-existing one. Nonetheless, nine previous frameworks were assessed and drawn upon to aid with the development of a new framework to address coastal communities in KSA.

A major advantage of many of these frameworks was that they were developed in part using criteria from previous frameworks. This served to increase their robustness and comprehensive nature (Courtney et al., 2008). Consequently, when developing the framework for this study - the Coastal Community Resilience to Maritime Disasters (CCRMD) framework – attention was also given to prior studies, as well as the knowledge and experience of local and international experts. However, it also became clear that when comparing the four dimensions in all nine frameworks, there was a lack of emphasis attributed to the environment and climate change dimension when compared with the other three dimensions. The literature review conducted emphasised that the environment, its protection and the maintenance of its resources were all crucial to enhancing the resilience of a community and easing its recovery from a disaster. Thus, the lack of emphasis attributed to the environment and climate change dimension was deemed a shortcoming of the nine frameworks that had to be corrected for the newly created CCRMD framework.

To further refine the indicators and sub-indicators to those relevant to the KSA, two opinion polls were carried out. The first was a questionnaire that was distributed to the public and the second was a consensus methodology. More specifically, the Delphi technique was used to gather the opinion of experts in the field to further determine indicators and sub-indicators that were deemed applicable in the context of the KSA and the disasters it faced.

This then fed into the AHP which was used to prioritise and specify a weighting to each level of the framework: the dimensions, indicators and sub-indicators. The software Expert Choice was employed at this stage owing to the high number of comparisons required. The final CCRMD framework developed was computed and the weighting of each dimension determined. The new framework demonstrated a higher weighting and therefore importance attributed to the environment and climate change dimension, which was previously shown to be a shortcoming of the final nine frameworks.-The end result was a weighted tool with four dimensions, which aims to evaluate the resilience of coastal communities in the KSA by providing a final (weighted) score for the framework as well as individual (weighted) scores for each of its four dimensions: society and economy; environment and climate change; infrastructure; and governance and institutions.

Table 8-1 is a representation of the final product of the CCRMD framework tool. To help simplify the calculations involved, each dimension is assumed to have a final weight of 100%. The Table lists the weighting each of indicator and sub-indicator involved.

Table 8-1 The CCRMD tool for measurement of resilience

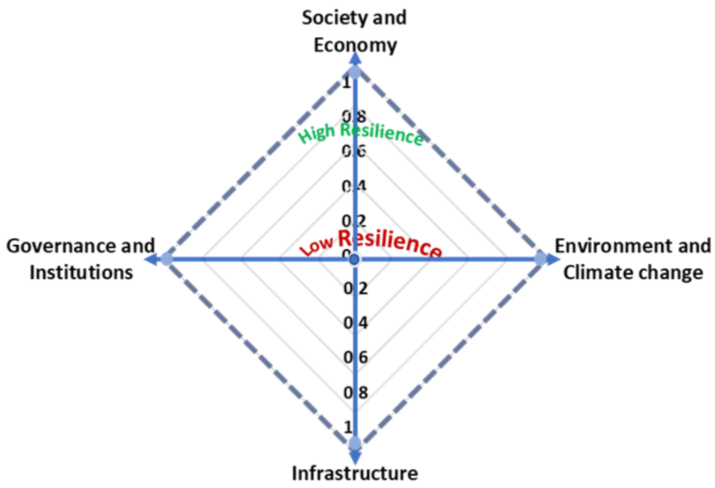
CCRMD Framework

Society and economy	WC%	New WC%
Demographic		
SD1	0.92	New
SD2	0.95	New
SD3	0.79	New
SD4	0.88	New
SD5	0.9	New
SD6	0.81	New
Livelihood		
SL1	0.88	New
SL2	0.77	New
SL3	0.81	New
Employment		
SE1	0.90	New
SE2	0.92	New
Awareness & training		
SA1	1.01	New
SA2	1.04	New
SA3	1.04	New
SA4	0.95	New
SA5	0.99	New
Culture		
SC1	0.81	New
SC2	0.97	New
Safety and security		
SS1	0.81	New
SS2	0.97	New
SS3	0.97	New
Total	19.10	New

Environment and climate change	WC%	New WC%
Coastal pollution control		
EC1	2.39	New
EC2	2.56	New
EC3	2.16	New
EC4	2.39	New
Land use		
EL1	2.05	New
EL2	2.34	New
EL3	2.28	New
EL4	2.51	New
EL5	2.39	New
Slow onset disasters		
ES1	2.05	New
ES2	2.34	New
ES3	2.34	New
Rapid onset disasters		
ER1	2.39	New
ER2	2.45	New
ER3	2.56	New
Total	35.2	New

Infrastructure	WC%	New WC%
Health		
IH1	1.28	New
IH2	1.25	New
IH3	1.19	New
IH4	1.22	New
IH5	1.16	New
IH6	1.19	New
Transportation		
IT1	1.31	New
IT2	1.04	New
IT3	1.19	New
IT4	1.2	New
Utilities		
IU1	1.33	New
IU2	1.16	New
IU3	1.33	New
Communication		
IC1	1.16	New
IC2	1.07	New
IC3	1.25	New
IC4	1.22	New
Embankment & shoreline		
IE1	1.16	New
IE2	1.13	New
IE3	1.19	New
Total	24.2	New

Governance and Institutions	WC%	New WC%
Laws & policy		
GL1	1.84	New
GL2	1.76	New
GL3	1.76	New
GL4	1.72	New
GL5	1.8	New
Institutional action		
GI1	1.68	New
GI2	1.8	New
GI3	1.8	New
Warning and evacuation		
GW1	1.92	New
GW2	1.96	New
GW3	1.92	New
GW4	1.51	New
Total	21.5	New



The CCRMD framework represents a starting point. It is the initial step required to help determine and build the resilience of the coastal communities of the KSA. One limitation to note, however, is that each community has its own specific elements which would either increase or decrease its level of resilience. Such elements may be geographical, economic, political or linked to the society or culture (Tam et al., 2013). The way in which each individual in the community interrelates with their community is both multifaceted and constantly changing. Thus, this results in the significance of each criterion to a community being a cause for variability between the communities in applying the framework. To ensure that this variation does not limit the benefit that can be derived from the CCRMD framework, it is crucial that such specific elements that define a community are defined and incorporated in the analysis of resilience.

8.1.1 Use of benchmarks

The use of benchmarking is a primary requirement in assessing community resilience to disasters as indicated by Doyle (1996). Some studies have used percentages whereas others have used values between 1 to 5 or 0 to 1. In general, a proportion of the scale was indicated as signifying an excellent level of resilience, a good, acceptable or poor level. For example, one study used percentages to determine the resilience of an organisation to disasters (Stephenson et al., 2010). In this study, an excellent level of resilience was indicated by a score ranging from 81-100% while any scores from 49% and lower indicated very poor resilience. This indicates five scores of resilience similar to the study by US-IOTWS (2007) which had 5 indication of resistance scores as indicated in Figure 8-1. Benchmark resilience scores in the context of KSA were then estimated for the CCRMD framework and given inTable 8-2.

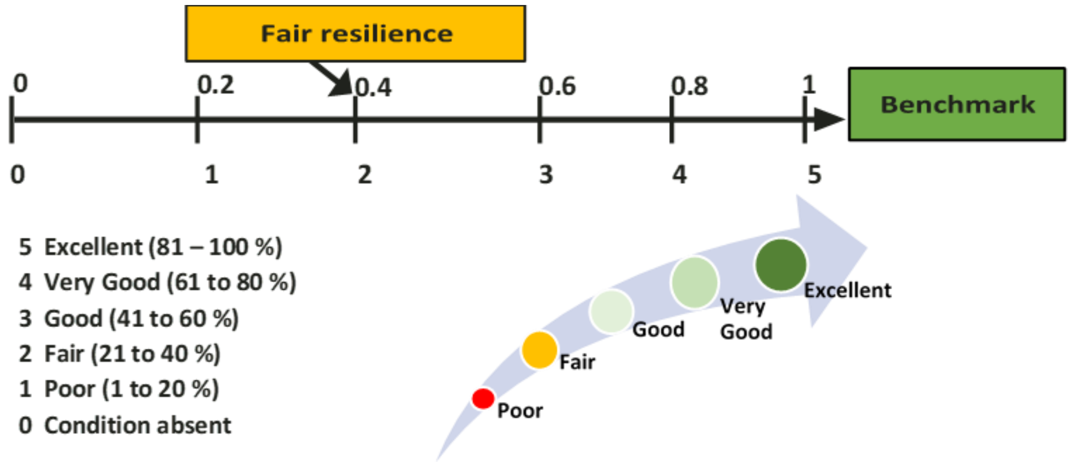


Figure 8-1 Benchmark resilience scores

Table 8-2 Description of the benchmark resilience scores of CCRMD

Resilience	Explanation
Absence of resilience R = 0	Resilience is non-existent in this community. This makes the community highly susceptible to disasters. Indication of this level signifies an urgent need to identify the elements of resilience that can be used to strengthen the community's resilience to maritime disasters.
Poor 1% < R < 20%	There is some resilience to disasters in this community, but it is extremely minimal, and the community is highly susceptible to disasters. Once again, elements that can be enhanced to increase resilience must be identified. This is crucial but not as critical as level 0.
Fair 21% < R < 40%	The degree of resilience present at this level is medium to low. The community is susceptible to disasters but it does have a base level of resilience that can be used to enhance the resilience of the community
Good 41% < R < 60%	The degree of resilience at this level is at a medium level making the community moderately resilient to disasters. 50% of the criteria are fulfilled but the community needs to improve non-performing criteria.
Very Good 61% < R < 80%	The degree of resilience at this level is high and can cope well with disasters. There, however, is room for improvement as some criteria are below the acceptable level and therefore can be improved to further enhance resilience of the community.
Excellent 81% < R < 100%	The degree of resilience at this level is outstanding and the community would be able to cope extremely well with disasters. Most criteria are attained.

This benchmarking scale is used to specify the resilience of a particular coastal community in the KSA and is based on the application of the four dimensions, 18 indicators and 68 sub-indicators. It can therefore be used to appraise a communities resilience and the strengths and weaknesses as indicated for each criterion.

From the Table it is clear that resilience is split into five levels ranging from a score of 0 to 100%. The degree of resilience of a community dictates the amount of work that needs to be performed to identify and improve sub-standard criteria. Communities' resilience is a feature that is likely to change over time as disasters hit the community and the make-up of the community changes not only with regards to the environment but also in terms of the support services, policies and regulations as well as the general population. This is why it is crucial that such a framework has been developed.

8.2 Validation of the CCRMD framework

Once the CCRMD framework was developed, it was important to assess its effectiveness in a range of ways. One such way was through comparison with other previous frameworks identified in the literature review in Chapter 3. Three of the nine previously analysed frameworks were chosen for comparison: the LDRI, CDRI 3 and the CRDSA frameworks. These three frameworks all concern developing economies - India, Philippines and KSA, respectively- which are defined as countries with low levels of per capita gross domestic product ($2190, $3250 and $23490, respectively, as defined by the International Monetary Fund in 2018). The respective populations of each country currently stand at 1.35 billion, 109.16 million and 33.87 million, respectively. The LDRI and CDRI 3 are international frameworks, while the CRDSA is a local framework specific for the KSA. These three frameworks were selected not only for the fact that they targeted developing countries and covered both the local and international perspectives, but also because they had weightings associated with their dimensions, which could be used to directly compare each of the dimensions to the CCRMD framework's dimensions, as shown in Table 8-3. Furthermore, as indicated in Chapter 3, one of the findings of the literature review was the lack of importance given to the environmental and climate change dimension compared to the other three dimensions. To be able to determine whether this has been rectified, a comparison has to be made between the developed CCRMD framework and some of the well-established frameworks listed in Chapter 3.

Table 8-3 Dimension weightings for CCRMD, LDRI, CDRI 3 and CRDSA

Dimension	**LDRI**	**CDRI 3**	**CRDSA**	**CCRMD**
Environment and climate change	25.1	17.03	17.40	35.20
Governance and Institutions	13.88	21.89	18.00	21.50
Society and economy	61.02	38.95	50.40	19.10
Infrastructure	0	22.12	14.00	24.30
Total	100%	100%	100%	100%

Framework validation usually requires a comparison to be made between current resilience information and information on resilience gathered prior to a disaster. However, within the context of KSA, there is a lack of information on resilience due to no official archives holding data on previous disasters. This was a major challenge and limitation of the project. Nonetheless, by comparing each framework directly against the CCRMD, this allowed the researcher to determine whether the framework is more comprehensive in general and if it is more inclusive particularly regarding the environmental framework, thus making it applicable in the context of KSA.

8.2.1 Comparison of the CCRMD framework against the LDRI framework

The Localised Disaster-Resilience Index or LDRI framework was employed in determining the resilience of a coastal-community in the Philippines. This was developed in 2012 and similarly to this study it employed both the Delphi and the AHP together with 20 experts in its construction (Orencio and Fujii, 2013). The framework had three aims: to provide a means of quantifying disaster resilience; to reduce the bias of assessments performed locally; and to improve on a local strategy for risk reduction.

Unlike other frameworks, the LDRI applied greater emphasis to both environmental and social dimensions which accounted for just over 80% of all criteria as demonstrated in

Table 8-3. This is a substantial amount and the majority of it is attributed to the social dimension. This is different from CCRMD which applied a 10% greater weighting to the environment and climate change dimension, which accounted for 35% of the weighting alone. Infrastructure was attributed a greater weighting than the society and economy dimension in the CCRMD framework. Infrastructure in the LDRI framework, however, was not given any weighting and therefore was found to be lacking. The society and economy dimension in CCRMD is approximately three times the weight of the society and economy dimension in the LDRI framework.

These discrepancies can be examined with respect to the varying populations of the two countries, their differing disaster risks and their respective populations.

It is clear that both frameworks differed greatly in highest weightings assigned. In the CCRMD framework the highest weighting was assigned to the environment and climate change dimension. This was certainly not the case with the LDRI framework which assigned an exceptionally high weighting just over 60% to the society and economy dimension. In the LDRI framework the environment and climate change dimension was related greatly to the livelihoods of people living in the community and didn't necessarily reference as many environmental criteria as the CCRMD framework in terms of regulations and policies amongst other. Moreover, the country to suffer the greatest number of disasters in 2009 was the Philippines. Orencio and Fujii (2013) had discussed how the lack of resilience in the Philippines was attributed more to governmental bodies than the environment due to failure in a lack of forecasting. This was related to the failure in interactions of social bodies and the vulnerability of the population. This may explain the extremely high weighting assigned to the society and economy dimension in the LDRI framework. In the CCRMD framework greater emphasis is given to the environment and climate change dimension due to the natural resources available in the KSA that can contribute to efficient recovery and therefore to enhanced resilience. The social dimension is considered the least important dimension of all the four in the CCRMD framework. This can also be explained by the lower population in the KSA compared to the Philippines. As indicated by the IMF data, the population of the Philippines and the KSA currently stand at 109.16 and 33.87 million of people, respectively. Thus, the population of the Philippines is three times greater than that of the KSA and therefore may require greater emphasis on the interactions of the society. This alone, however, cannot account for the high degree of emphasis on the society and economy dimension. Rather this over weighting of the society and economy dimension may be considered a flaw in the design of the framework as it is highly biased towards this dimension.

Finally, the lack of weighting indicated for the infrastructure dimension in the LDRI framework may be considered a weakness of this framework as the criteria for infrastructure are not being assessed as an individual dimension, rather they are being considered together with other dimensions. Infrastructure, however, forms a crucial backbone of any society. Transportation, health, communication, utilities, embankment and shoreline are all aspects that should be given their due importance for any coastal community facing maritime disasters. They should therefore be given significance in being assessed for resilience as a separate dimension. It is the author’s opinion that the LDRI framework would have been further strengthened by inclusion of specific criteria under the infrastructure dimension.

8.2.2 Comparison of the CCRMD framework against the CDRI 3 framework

The Climate Disaster Resilience Index (CDRI3) was established for measurement of resilience in Chennai, India against climate-related disasters e.g. heat waves, cyclones, floods and droughts. Ten experts were employed to determine the construct of this framework.

A key difference between these two frameworks is the area assessed. CCRMD was built to address maritime disasters in the context of the KSA as a whole while CDRI 3 was used to assess Chennai in India. The former would therefore assess a much greater number of maritime disasters that were both natural and man-made. Whereas, the latter chiefly assessed natural disasters. This makes the CCRMD framework more comprehensive regarding its coverage of maritime disasters.

Another point to note is that the criteria used in the CDRI 3 framework were more specifically tailored to a city, whereas the CCRMD framework was tailored to the KSA as a whole. This would indicate that the CCRMD framework can be enhanced by the inclusion of coastal community specific criteria. This would allow for differences between coastal communities in the KSA to be highlighted and improved upon.

In examining the specific weightings attributed to each dimension it is clear that both frameworks assign similar importance to both the governance and institutions and infrastructure dimensions, whereas, the CDRI 3 framework assigns reduced weighting to the environment and climate change dimension; this equates to half the weighting assigned in the CCRMD framework and it also assigns almost double the weighting to the society and economy dimension. This could be due primarily to the area being examined. The CCRMD framework needs to be more comprehensive with this respect as it covers a greater area and therefore a larger range of maritime disasters. Moreover, the experts involved in development of the CDRI 3 framework had all been engineers working locally at the zone level. This means the development of the framework was subjective in that it didn’t include experts from other fields concerning maritime disasters nor did it involve consultation with the public or other experts on the global level. This could highly bias the criteria included in the framework. Thus, although the CDRI 3 framework encompasses all the dimensions included in the CCRMD framework it doesn't appear to be as expansive as the CCRMD framework.

Finally, the "society and economy" dimension appears to be attributed a larger weighting in the CDRI 3 framework compared to the CCRMD framework. When comparing the populations of the two regions the population of the KSA was determined to be 33.87 millions of people by the IMF, whereas, that of Chennai was 14.9 million in 2009 expected to rise to 20.9 million by 2025; (Joerin et al., 2014). However, the area of Chennai is significantly smaller than that of the KSA. Thus, the population density of Chennai is significantly higher than that of the KSA. This may be reason for the greater weighting assigned the society and economy dimension in the CDRI 3 framework compared to the CCRMD framework. That is, such a high population density would require a lot of resources and finance filtered to systems that are developed to aid the public and the economy of the region. With such a high population, mis-management would be a far-reaching issue.

Finally, although not as comprehensive as the CCRMD framework, the CDRI 3 framework does involve community-related criteria that would enhance the applicability of the CCRMD framework.

8.2.3 Comparison of the CCRMD framework against the CRDSA framework

The Community Resilience to Disaster in Saudi Arabia (CRDSA) framework is the only framework of the three to be based on the Saudi population specifically (Alshehri et al., 2015b). Moreover, unlike the other three frameworks, the disasters targeted in the CRDSA framework relate to biological rather than coastal disasters. Similar to the CCRMD framework the CRDSA framework also based its development on the inclusion of public perception, the Delphi technique and the AHP.

In this respect it is understandable that a lower weighting is attributed to the environmental dimension and a higher one to the society and economy dimension. The resilience of the environment carries a greater degree of importance when discussing maritime disasters than biological disasters. Thus, it stands to reason that the weighting attributed in the CRDSA framework is half that of the CCRMD framework.

Furthermore, biological disasters have a much closer association to humans than environmental disasters as their effect would directly affect the public and their effect can also last a long time. This therefore explains the greater weighting attributed to the society and economy framework in the CRDSA framework compared to the CCRMD framework.

Finally, the CRDSA framework also included several criteria under a society and economy dimension that would have deviated weighting away from the other frameworks, thereby explaining the reduced weightings of the environmental, infrastructure and governance dimensions.

8.2.4 Comparison of all four frameworks

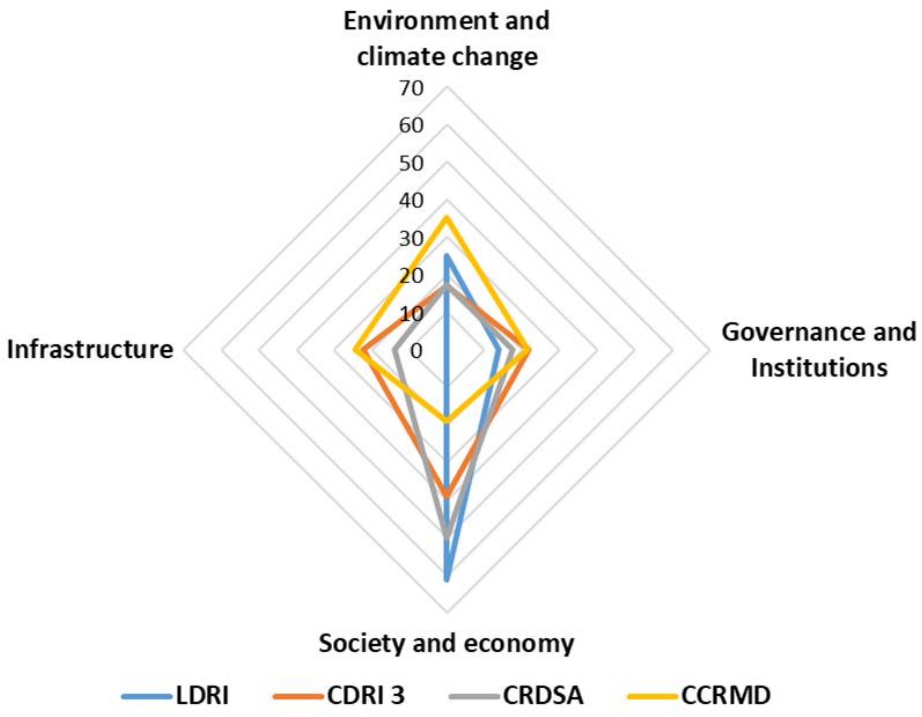


Figure 8-2 Weightings comparison of CCRMD dimensions across all frameworks

Figure 8-2 clearly illustrates the comparison between the CCRMD framework (yellow) and the LDRI (blue), CDRI 3 (orange) and the CRDSA (grey) frameworks. The CCRMD framework applies a greater weighting to the environmental dimension than the other three. This is understandable as the CCRMD framework was developed to measure resilience to maritime disasters for which environmental resilience is highly applicable. This also highlights the fact that both the LDRI and the CDRI 3 frameworks with environmental dimension weightings of 25.1 and 17.03, respectively, are lacking in this dimension. This is because although they both measure resilience to coastal and climate change disasters, yet their environmental weightings are closer to the CRDSA framework with a weighting of 17.4 and which measures biological disasters. This therefore makes the CCRMD framework superior with respect to coastal disasters.

Figure 8-2 Also illustrates the comprehensive nature of the CCRMD framework as it covers three of the four dimensions either equally more deeply than the other three frameworks. The exception to this is the society and economy dimension which is emphasised more in all three frameworks the LDRI, CDRI 3 and the CRDSA frameworks. This was addressed and explained earlier in the context of the population.

8.2.5 Semi-Structure Interviews

Empirical research was necessary in this study as much of the research into the development of assessment frameworks in resilience studies has failed to validate measures empirically, especially in terms of incremental validity (Irajifar et al., 2013). This is one of the major challenges of using assessment frameworks, as there is no simple way to obtain scientific validation of a particular framework (Davidson and Shah, 1997); therefore, the absence of empirical validation is a concern. In many circumstances, frameworks rely on empirical data that is far from perfect. While the best way for any type of metrics related to the disaster field to be validated would be to test them continually after major events and refine them accordingly, this would take a considerable amount of time (Simpson and Katirai, 2006). In addition, the lack of data is considered another obstacle to validate this framework. Therefore, the CCRMD framework has been validated through semi-structured interviews with experts.

A semi-structured interview was carried out with ten governmental leaders and three academic leaders, and four organisational leaders. These leaders were responsible for disaster management and the enhancement of resilience. As described in Chapter two, the responsibilities for disaster risk management in the KSA are entrusted to several organisations. This results in the absence of a general disaster management centre in the country. The profiles of the leaders who were interviewed are shown in Table 8-4.

Table 8-4 Profile of 17 leaders and managers interviewed in KSA

Category	Interviewee	Organisation	Job title
Government	A	General Directorate of Civil Defence	Manager of Safety
	B	Crisis and Disaster Risk Management Centre in Makkah Region	Head of Crisis and Disaster Risk Management Centre in Makkah Region
	C	Ministry of Municipal and Rural Affairs	Manager of disaster management
	D	Saudi Arabian Border Guards	Manager of Safety
	E	Royal Saudi Naval Forces Riyadh	Manage of Safety
	F	Saudi Ports Authority	Leader of safety and security
	G	Presidency of Meteorology and Environment (PME)	Leader of safety and security
	H	Saudi Red Crescent Authority	Leader of Safety
	I	Ministry of Education	Manager of safety and security
	J	Ministry of Health	Manager of safety and security
Academia	K	King Abdelaziz University	Manager of Emergency and Disaster Centre (EDC)
	L	King Faisal University	Director of Security and Safety
	M	King Fahd Security College	Director of Security and Safety
Organisation	N	Saudi Aramco	Leader of Industrial safety and security
	O	National Water Company	Leader of safety and security
	P	Saudi Electricity Company	Leader of safety and security
	Q	General Authority of Civil Aviation (GACA)	Leader of safety and security

The goal of using semi-structured interviews as an approach to validate the CCRMD framework was to cover all aspects. First of all, to ensure that the scope of the framework was applicable to the context of the country, interviewees 'B, C, and L' said that:

(B) *"the uniqueness of such a proposed framework is having four dimensions to assess all aspects of community resilience in the context of Saudi Arabia"* which was mentioned by interviewees Q and J as well.

(C) *"I highly recommended adopting this framework in our organisation because this new one has given a more comprehensive emphasis to the environmental dimension"* which was also stated by interviewees F, and B.

(L) "*Having three levels of the hierarchical structure will enable a deep and methodological examination of community resilience to disaster management"*

Although interviewee 'K' agrees with applying the framework, he stated that:

(K) "*This framework is applicable; however, it needs to be tested with real disaster"*

Moreover, to ensure the completeness and relevance of the indicators the interviewees, D and O said that:

(D) *"The useful relation between the indicators seem to establish a solid framework to deal with the possible disaster in Saudi Arabia and it may be possible to extend that to all of the Arab peninsula"*. The idea came from interviewee E.

(O) *"The existence of a relation between environmental indicators and governance indicators has shown clearly a dependency relationship which reflects the status quo"*

Interviewees 'A, K, and G' noted the below statement to give proposed weighting and ranking indicators.

(A) *"Giving the environment and climate change more importance tends to regenerate different prospective in this framework, which is significant for now!"*

(K) *"The proposed framework has clearly weighted the indicators and sub-indicators which has led to a reasonable value for each of them"*

(G) *"Given the high score of weighting for the environment, this reflects the logic of such a framework and its applicability"* (and M)

Nevertheless, the framework could face issues in addressing challenges/policy implementation as interviewees 'I, and N' said:

(I) *"From a first glance, it may same that such a detailed framework with all indicators will be difficult to apply. However, the hierarchical structure of the framework helps* *decision maker a complete and offer a broader picture of missing factors that were not considered before"*, interviewee H shared with the same point.

(N) *"The implementation of the framework may face some challenges due to the fact that some quantitative data is missing, but at the same time, using this framework will help to build and organise a comprehensive disaster database for Saudi Arabia"* which was concluded by interviewee P as well.

The above discussions illustrate the interviewees' level of agreement of the framework's applicability in Saudi Arabia. Moreover, many leaders accepted that the framework is applicable to the context of the country. For instance, the leaders highly recommended adopting this framework in their organisation. However, others mentioned that the framework needs to be tested with a real disaster. In addition, many of the interviewees noted that the indicators seem to establish a solid framework to deal with a possible disaster in Saudi Arabia which confirmed the streng relevance between the indicators. Similarly, many leaders proposed the weighting and ranking indicators of the proposed framework have clearly been weighted which has led to a reasonable value for each of them. It is also however important to note that the framework could face implementation challenges. For example, one leader said that the detailed framework with all its indicators would be difficult to apply, although it would help in examining the hierarchical structure to give decision makers a complete picture that includes any of the missing factors that were not considered before. Notwithstanding the above, the leaders confirmed that the CCRMD framework has been validated for enhanced community resilience to maritime disasters in the Saudi Arabian context.

8.3 Summary

To conclude, it is clear that there is a need for highly resilient coastal communities to better allow themselves to recover following an incident. By identifying the resilience of a community using the CCRMD framework, sub-standard criteria that can be used to further enhance this resilience can be identified and built upon. Through the mixed methods technique, this study employed a literature review, questionnaires, the Delphi technique and the AHP to develop a framework to be used in the context of the KSA. The CCRMD framework is the first framework to target the measurement of the resilience of a coastal community to maritime disasters in the KSA. Assessment of a community based on the various dimensions, indicators and sub-indicators would result in determining a community's resistance. This can then be compared to the benchmarking system to output measurable results.

To ensure the CCRMD framework would be suitable for measurement of resilience to maritime disasters in the context of the KSA, a suitable methodology was used for adaptation. This was carried out by an assessment of the significance of each of its dimensions against that of three weighted frameworks from the literature review. Two of these were developed for coastal resilience (LDRI and CDRI 3) and one for biological resilience (CRDSA). The two concerning coastal resilience were used to measure resilience in two other developing countries, whereas, the third was specifically developed for the KSA. In assessing the applicability of the CCRMD framework against these three frameworks the specificity of the CCRMD framework to the KSA and the Gulf region in general was evident. Moreover, it was clear that the CCRMD framework had addressed the gap indicated in the environment and climate change dimension in the literature review. Although the CCRMD framework had placed greater emphasis on the environment and climate change dimension, nevertheless, it did not do this at the expense of the other three dimensions. The weighting of these dimensions, though not as high as that of the environment and climate change dimension, was still sufficient for the purposes of the framework and in the context of the KSA. Finally, the inclusiveness and robustness of this framework can therefore be attributed to the methodology used in developing it, namely the Delphi technique, the AHP and the inclusion of the opinions of both the public and the panel of experts.

Chapter 9 **Conclusion**

This chapter concludes the study by first outlining the background of the research and reasons for its development. Next, it seeks to address the research questions stated at the start of this thesis, thereby demonstrating that all questions have been answered and the objectives fulfilled. After, contributions of this study to the body of knowledge on the subject of resilience to maritime disasters are outlined and its limitations are detailed and discussed. Finally, this study closes with recommendations for future research detailing directions to further the work carried out in this study.

9.1 Motivation

Globally there has been an awakening to the need for the development of coastal community resilience frameworks that are specific and targeted to a particular region. Such thoughts have arisen from the increased frequency and incidences of maritime disasters over the years that have taken place partially due to changes in our climate (natural maritime disasters) and partially as a result of the practices of a region (man-made maritime disasters).

KSA like many other countries has seen the mobilisation of communities to coastal regions as a result of growth in their populations and economy (Pararas-Carayannis, 2013). Specifically, for the KSA and as stated by Abualnaja (2011), approximately more than half the population reside within 100km of the Saudi coastline. As the KSA is situated in Asia, this means that it is located in the continent that is most prone to disasters. Moreover, as 90% of global disasters are maritime disasters and as the largest country in the Arabian Peninsula, the KSA coastline is extensive and, as a result, its exposure to maritime disasters is great (UNISDR, 2015). The maritime disasters to which the KSA is subjected are in part attributed to its geographical, tectonic and bathymetric profiles (Abualnaja, 2011, Lam et al., 2015, Ewing and Synolakis, 2011). Furthermore, the KSA's oil reserves are the largest in the world being made up of 161 giant oil deposits situated along the Arabian Gulf (Pararas-Carayannis, 2013). Over half the global exports of oil pass through the Arabian Gulf and the oil business is responsible for 70% of the KSA's economy (AlAli, 2013; Stats.gov, 2017). Therefore, the coastal regions are an essential part of the KSA's economy.

Over the years, the frequency of maritime disasters in this region and all over the world have intensified and grown. This has resulted in the loss of many lives, with over one thousand losing their lives in this region from maritime disasters over a fourteen-year period. Moreover, the costs of these disasters have amounted to billions of US dollars. These losses are highly significant, yet records on previous disasters are insufficient and limited (Pararas-Carayannis, 2013). Such systematic recordings of maritime disaster data are crucial for the development of policies and regulations to guide disaster risk management strategies and to ensure the impact of such disasters on the public, economy and environment is highly reduced through the enhancement of a community's resilience.

These factors demonstrated the need and urgency for a framework to measure coastal community resilience. Although there are many frameworks in the literature developed for the measurement of coastal community resilience, none of these were specifically designed for the KSA. This led to the creation of this study which aimed to develop a framework specifically for the measurement of coastal community resilience in the context of the KSA. This would therefore mark the initial step in the development of a tool for use in disaster risk management in the KSA. It is also the most important part of Saudi's government agenda in the area of risk management.

9.2 Addressing the research questions

The primary objective of this study was to develop a framework for the measurement of the resilience of coastal communities in the KSA. To this end, several research questions were developed ensuring that a stepwise approach was employed to achieve this primary objective. These research questions were addressed as follows:

9.2.1 RQ1

Which maritime disasters pose a risk to *the coastal communities of Saudi Arabia* and what are their likely impacts?

This research question sought to define the extent of the issues surrounding the KSA in terms of both man-made and natural maritime disasters. These were subsequently well defined in the literature review chapter following a comprehensive and detailed systematic review. Various articles were identified that were concerned with both man-made and natural maritime disasters which allowed for a map to be drawn out to illustrate the range of threats facing the KSA along both the Red Sea and the Arabian Gulf. This marine map illustrated the frequency and clustered location of each disaster. Tsunamis, tropical cyclones and sea level rises were all natural maritime disasters deemed to threaten the KSA mostly along the Arabian Sea and the Arabian Gulf. In contrast, the man-made maritime disasters were found to threaten the KSA mostly along the Red Sea and included maritime piracy, maritime terrorism, vessel disasters and oil spills.

9.2.2 RQ2

Are the well-established coastal community resilience assessment frameworks appropriate for the Saudi Arabian context?

This research question examined the available frameworks and their applicability to maritime disasters threatening the KSA. This also involved extensive and systematic literature mining using key words, which culminated in the extraction of nine frameworks from across the globe and applied in both developing and developed countries. Frameworks were analysed for their various criteria which were collated prior to their allocation into four specific dimensions as appropriate in the context of the KSA. The frameworks assessed were deemed lacking in the environment and climate change dimension when comparing all four dimensions. This fact was clearly addressed later in the research.

9.2.3 RQ3

Which applicable coastal community resilience factors are required for the management of risks of maritime disasters in the Saudi Arabian context?

To answer this research question, the resilience factors identified and collated from the literature review were analysed by both the public and a panel of experts. The data was grouped into three levels, namely dimensions, indicators and sub-indicators. It was subsequently analysed according to its necessity through a questionnaire that was presented to the public and through the classical Delphi technique which was presented to a select panel of experts. Criteria were agreed upon and a consensus on the applicable criteria developed. This also included the addition of seven extra sub-indicators by the panel of experts to ensure that the framework was both comprehensive and specific to measure the resilience of the coastal communities in the KSA.

9.2.5 RQ4

How can identified resilience factors be incorporated into a local coastal community resilience assessment framework?

To help structure the framework the various criteria were identified for their applicability by the Delphi technique and this aided the splitting of the framework into its various levels. Two successive rounds of structured consultations were conducted; firstly, a brainstorming phase to identify potential factors applicable in the Saudi context; furthermore, a revision and narrowing down of the creative list to the most important ones and secondly, a final rating on the agreed community resilience assessment factors (indicators and sub-indicators). The results identified the key local community resilience factors that were essential for the development of the CCRMD framework. The AHP was then employed to aid in the prioritisation of the criteria at the indicator and sub-indicator levels. This was achieved through the performance of various pairwise comparisons and involved the use of Expert Choice software, which was required to convert the pairwise comparisons between the various assessment criteria into weighted measures. This ensured that the data was reliable and that the priorities were computed automatically, which avoided human error.

9.2.6 RQ5

What is the most appropriate applicable weighting system to reflect an accurate assessment of the community resilience in the context of Saudi Arabia?

This question served to ensure each criteria's importance was measured and assigned correctly. This was achieved by the employment of mathematical formulae at the end of the AHP which served to assign a weighting to each criterion thereby indicating its significance relative to other criteria. The CCRMD framework demonstrated a higher weighting and therefore importance attributed to the environment and climate change dimension, which was previously shown to be a short coming of the nine frameworks that derived from the literature. This helped structure the framework and allowed for the development of a benchmarking scheme against which the resilience of the different coastal communities could be measured and compared.

9.3 Limitations of the research

The limitations of this research are as follows.

- One limitation of this project was one of the reasons why the necessity to develop the CCRMD framework arose. This was due to the lack of information currently available on previous disasters facing the KSA. This limitation eliminated the possibility of performing a validation, as that would require the ability to compare current resilience measures to older data. This, however, was overcome through the performance of a validation by comparing the CCRMD framework to three weighted frameworks.
- Another limitation of the study was that the CCRMD framework could only be compared to three of the nine frameworks discussed in the literature review (chapter 3). This is because the other six frameworks lacked weightings and so could not be compared directly as their data was qualitative rather than quantitative,
- One further limitation was recognised in the Adaptation stage which indicated the need to further specify the framework for a community as each community is specific in its features and characteristics. By allowing for this the framework would more specifically define the resilience of a community using its own specific characteristics.

9.4 Recommendations for future research

As with any research study, there is an expectation that the findings will lead to further work being proposed. In the case of this study the following recommendations can be made:

- Trial of the CCRMD framework on all coastal regions in the KSA. This is an initial step towards the gathering of data that will help in the assessment of resilience following disasters.
- The further development of a coastal community specific dimension to account for differences between coastal communities. This will only be possible once the CCRMD framework has been trialled in different coastal regions as this will identify factors that vary between coastal regions.
- The implementation of the framework across the Gulf cooperation Council (GCC) member states. This should yield comparable results as the countries surrounding the KSA face similar maritime disasters.
- The development of policies and regulations to govern the application of the framework and in doing so also the implementation of disaster risk management systems and departments for the management of risks of maritime disasters in the KSA.

8.5 Summary

This study has covered a topic that is crucial for the Kingdom of Saudi Arabia due to the various dangers that it faces from maritime disasters. With the advent of global warming and the increased frequency of maritime disasters together with the increased incidence of man-made disasters through maritime piracy and terrorism, assessment of resilience is crucial. This is especially important as more people move to live near coastal regions and also as a large portion of the economy is dependent on oil.

This study has succeeded in fulfilling its aims and objectives in the development of a framework that is robust and comprehensive and and that has been validated against existing frameworks and through semi-structured interviews with experts .

By fulfilling the recommendations for future work, the KSA will be able to establish a disaster risk management system that will protect it and prepare it for all forms of maritime disasters. This study is the first in a line of studies to achieve this system.

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Appendix A **Public Perception Survey**

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

1.
introduction

Coastal communities around the world vulnerable to man-made maritime disasters, such as pollution, piracy and maritime terrorism, as well as natural maritime disasters such as tropical cyclones, tsunamis and sea-level rise.

Coastal cities in the Kingdom of Saudi Arabia are among the most vulnerable to these disasters due to their geographical location along the coasts of the Red Sea and the Arabian Gulf.

In order to mitigate the risks and effects of the maritime disasters on Saudi people, economy and environment, I aim to develop a disaster risk management framework as part of doctoral research at Cardiff University, UK.

The purpose of this questionnaire is to gain a better understanding of public perception of disasters in Saudi Arabia. Your response is essential in identifying the important indicators from the public's point of view. The data collected will be used for scientific research purposes only. For questions about this research and the questionnaire, please contact:

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تعتبر المجتمعات البحرية حول العالم من اكثر ألاماكن عرضه للمخاطر والكوارث البحرية سوءا كانت من صنع الإنسان مثل (التلوث والقرصنة والإرهاب البحري) أو من الكوارث الطبيعية مثل الأعاصير والفيضانات وكذلك ظاهرة ارتفاع سطح البحر.
المدن الساحلية في المملكة العربية السعودية تعتبر من اكثر ألاماكن عرضة لتلك الكوارث نتيجة لموقعها الجغرافي المطل على البحر الأحمر والخليج العربي.
ولتخفيف اثار ألازمات والكوارث على السكان والاقتصاد والبيئة، توصلت الأبحاث العالمية إلى امكانية ادارة الكوارث من خلال تطوير أطرعامة لقياس مرونة المجتمع لتعامل معها من خلال مجموع من المؤشرات الاجتماعية والاقتصادية والبيئية.
ان هذا الاستبيان هو جزء من متطلبات بحث الدكتوراه في جامعة كاردف، بالمملكة المتحدة يهدف إلى تطوير إطار خاص بالمملكة العربية السعودية لادارة ألازمات والكوارث البحرية ، وان فهم وجهات نظر شرائح المجتمع المختلفة هو الخطوة الأولى والمهمة للوصول إلى افضل الطرق لإدارة تلك الكوارث .

ان تجاوبكم و تخصيص جزء من وقتك لملئ الاستبيانإن ضروري في تحديد المؤشرات الهامة من وجهة نظر الجمهور.
ان البيانات التي يتم جمعها ستستخدم لأغراض البحث العلمي فقط.
ولطرح الأسئلة حول هذا البحث والاستبيان، يرجى الاتصال ب

عارف بن طلق المطيري
طالب دكتوراة
جامعة كاردف / المملكة المتحدة
Email: AlmutairiAT@cardiff.ac.uk

* 1. Consent to proceed: please select your choice below. By clicking on the "Accept" button you confirm that you are at least 18 years of age. You are free to withdraw at any time during your participation in this questionnaire.

الموافقة على الأستمرار بالاستبيان: يرجى تحديد أختيارك أدناه. بالضغط على زر" قبول" فأنت تؤكد أن عمرك لا يقل عن 18 سنة علما بأنك حر في الانسحاب في أي وقت خلال مشاركتك في هذا الاستبيان

- ◯ Accept
  قبول
- ◯ Decline
  رفض

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

Consent to proceed
الموافقة على الاستمرار
بالاستبيان

You have reached this page because you have selected "Decline" as an answer to proceed question. If you think this was a mistake, please go back to the survey introduction page and select "Accept" to proceed. If you dont wish to proceed with this survey, please close the browser window/tab. Thank you for your interest in project.

لقد وصلت إلى هذه الصفحة لأنك قد اخترت " رفض " كإجابة إلى " الموافقة على المضي قدما " بالسؤال. إذا كنت تعتقد أن هذا كان خطأ، يرجى الرجوع إلى الصفحة 1 واختر " قبول " والاستمرار. إذا كنت لا ترغب في الاستمرار في .هذا المسح، يرجى إغلاق نافذة المتصفح / علامة التبويب
شكرا لك على اهتمامك

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

Demographic information المعلومات الشخصية

Note: Please answer all questions to move to the next page
ملاحظة: يرجى الإجابة على جميع الأسئلة للانتقال إلى الصفحة التالية

* 2. Gender الجنس

- ◯ Male ذكر
- ◯ Female أنثى

* 3. Age العمر

- ◯ 18-24
- ◯ 25-30
- ◯ 31-35
- ◯ 36-40
- ◯ 41-50
- ◯ 51-55
- ◯ 56-60
- ◯ 61+

* 4. What is the highest level of education you have completed ?
ما هي اعلى شهادة علمية حصل عليها ؟

- ◯ Post-graduate degree (MSc, PhD etc.) شهادة عليا (ماجستير، دكتوراه الخ)
- ◯ Under-graduate degree حاصل على شهادة جامعية او معهد
- ◯ Secondary school certificate حاصل على الشهادة الثانوية
- ◯ No qualification بدون مؤهل علمي
- ◯ Other (please specify)
(أخرى (يرجى التحديد)

* 5. Occupation المهنة

- ◯ Government employee
  موظف حكومي
- ◯ Non-government employee موظف غير حكومي
- ◯ Self-employed أعمال حرة
- ◯ Other (please specify)
  اعمال أخرى يرجى التحديد

* 6. In which region do you live in Saudi Arabia?
في اي منطقة تعيش في المملكة العربية السعودية ؟

- ◯ Central Region
  المنطقة الوسطى
- ◯ Western Region
  المنطقة الغربية
- ◯ Eastern Region
  المنطقة الشرقية
- ◯ Northern Region
  المنطقة الشمالية
- ◯ Southern Region
  المنطقة الجنوبية

* 7. In which city do you live? في أي مدينة تعيش

Other (please specify)
(أخرى (يرجى التحديد

* 8. 5. Do you live in coastal area?
هل تعيش في منطقة ساحلية ؟

- ◯ Yes
  نعم
- ◯ No
  لا

* 9. 9. Do you live on coastal resources?
هل يعتمد مصدر دخلك على الثروات البحرية مثل الصيد الخ؟

- ◯ Yes
  نعم
- ◯ No
  لا

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

knowledge of hazards
معرفة المخاطر

Note: Please answer all questions to move to the next page
ملاحظة: يرجى الإجابة على جميع الأسئلة للانتقال إلى الصفحة التالية

* 10. Do you consider that your region is prone to disasters?
هل تعتقد أن منطقتك معرضة للكوارث؟

- ◯ Yes نعم
- ◯ No كلا
- ◯ I'm not sure لست متأكدا

* 11. Have you ever experienced a natural disaster?
هل سبق أن تعرضت مدينتك لكارثة ؟

- ◯ Yes نعم
- ◯ No كلا

12. Please specify the type of disaster
من فضلك حدد نوع الكارثة

- ☐ Earthquake زلازل
- ☐ Flood فيضانات السيول
- ☐ Volcanic eruption بركين
- ☐ Tsunami تسونامي
- ☐ Tropical cyclones الاعاصير البحرية
- ☐ Maritime terrorism الإرهاب البحري
- ☐ Marine pollution التلوث البحري
- ☐ Vessel disaster (كوارث السفن (تصادم ,غرق ,حريق
- ☐ Did not occur لم تحدث
- ☐ Other (please specify)
(أخرى يرجى التحديد)

* 13. To what extent do you agree or disagree with each of the following statements about disasters?

استنادا على معرفتك الشخصية بالكوارث, إلى أي مدى توافق أو لا توافق على كل من الفقرات التالية

	Completely agree أوافق بشدة	Mostly agree أوافق	Neither agree Nor disagree محايد	Mostly disagree لا أوافق	Completely disagree لا أوافق بشدة
I am aware of disasters risks انا لدي معرفة بمخاطر الكوارث	○	○	○	○	○
I am aware of the places prone to natural disasters in my city / region انا على معرفة بالأماكن المعرضة للكوارث الطبيعية في مدينتي / منطقتي	○	○	○	○	○
I know the route to evacuation place in my area انا على معرفة بطرق إماكن الإخلاء في مدينتي/منطقتى	○	○	○	○	○
I know the evacuation sign in my city /region انا على معرفة بعلامات ولوحات الإخلاء في مدينتي/المنطقة	○	○	○	○	○
I am trained to help my family and help others during disasters انا متدرب على مساعدة عائلتي ومساعدة الآخرين أثناء الكوارث	○	○	○	○	○
I am aware of the emergency procedures I need to follow if a disaster warning is issued أنا على دراية بإجراءات الطوارئ التي يجب اتباعها في حالة إصدار تحذير من الكوارث	○	○	○	○	○

	Completely agree أوافق بشدة	Mostly agree أوافق	Neither agree Nor disagree محايد	Mostly disagree لا أوافق	Completely disagree لا أوافق بشدة
I would be willing to participate in DRR program if one is available انا على استعداد للمشاركة التطوعية في برنامج الحد من مخاطر الكوارث	○	○	○	○	○

* 14. Are residents provided with the following required information before the disaster happen?
هل يتم تزويد السكان بالمعلومات التالية قبل تهديد او حدوث الكارثة؟

	Yes نعم	No كلا	I'm not sure لست متأكدا
Evacuation Routes طرق الاخلاء	○	○	○
Evacuation Bus Pick-Up Locations مواقع وسائل الاخلاء ((مثال : باص الخلاء	○	○	○
Location of Shelters مواقع الملاجئ	○	○	○
Emergency contact رقم اتصال الطوارئ	○	○	○

* 15. Please rate how important the following awareness and training programs are to cope with disasters in your area?

يرجى تقييم مدى أهمية برامج التوعيه والتدريب التالية في تعزيزحماية المجتمع من مخاطر الكوارث ؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
DRR training program /disaster drills such as search and rescue and first aid برامج التدريب الدورية على الحد من مخاطر الكوارث مثل البحث والإنقاذ، الإسعافات الأولية، بناء المأوى المؤقت، وإدارة الإخلاء	○	○	○	○	○
Awareness campaigns about the threats from Disasters and climate change حملات التوعية الدورية بشأن التهديدات الناجمة عن الكوارث وتغير المناخ	○	○	○	○	○
Multilingual awareness programmes اللغات المتعددة لبرامج التوعية	○	○	○	○	○

Other (please specify)
(غير ذلك (يرجى التحديد

* 16. 1. Do you have any previous knowledge about the maritime disaster?

هل لديك معرفة سابقة أو معلومات تتعلق بالكوارث البحرية ؟

○ Yes
نعم

○ No
لا

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

Socio-economic and environmental preparedness
الاستعداد المجتمعي والاقتصادي والبيئي للكوارث البحرية

Note: Please answer all questions to move to the next page

ملاحظة: يرجى الإجابة على جميع الأسئلة للانتقال إلى الصفحة التالية

* 17. Please rate how influential of the following natural maritime disasters are in coastal regions in KSA?

يرجى تقييم مدى تأثير الكوارث البحرية (الطبيعية) التالية على المدن الساحلية السعودية؟

	Not at all influential غيرمؤثر اطلاقا	Slightly influential مؤثر قليلا	Moderately influential مؤثربشكل معتدل	Very influential مؤثر جداً	Extremely influential مؤثر للغاية
Tsunami تسونامي (موجات البحر العالية)	○	○	○	○	○
Sea level rise ارتفاع مستوى سطح البحر على ساحل المنطقة	○	○	○	○	○
Tropical cyclones الأعاصير البحرية	○	○	○	○	○

* 18. Please rate how important preparedness of the following natural maritime disasters are for the coastal regions in KSA?

يرجى تقييم مدى أهمية الاستعداد لمواجهة الكوارث البحرية (الطبيعية) التالية بالنسبة للمدن الساحلية السعودية؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Tsunami تسونامي (موجات البحر العالية المدمرة)	○	○	○	○	○
Sea level rise ارتفاع مستوى سطح البحر على على ساحل المنطقة	○	○	○	○	○
Tropical cyclones الأعاصير المدارية	○	○	○	○	○

* 19. Please rate how important preparedness of the following man-made maritime disasters ?

يرجى تقييم مدى أهمية الاستعداد لمواجهة الكوارث البحرية (من صنع الإنسان) التالية ؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Maritime terrorism الإرهاب البحري	◯	◯	◯	◯	◯
Maritime piracy القرصنة البحرية (السطو المسلح)	◯	◯	◯	◯	◯
Vessel disasters كوارث السفن	◯	◯	◯	◯	◯
Marine pollution التلوث البحري	◯	◯	◯	◯	◯

* 20. Please rate how important the following factors are to enhance the protection of the coastal zone from the impacts of natural (natural)?

يرجى تقييم مدى أهمية العوامل التالية في تعزيز حماية المنطقة الساحلية من آثار الكوارث البحرية (الطبيعية) ؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Mean elevation of the area (Resilient communities were located along the coastline and elevation area). تحديد متوسط ارتفاع المنطقة عن سطح البحر لتحديد المناطق المنخفضة الخطرة	◯	◯	◯	◯	◯
Projection of rising sea level and its severity for the area التنبؤ بارتفاع مستوى سطح البحر وشدته على ساحل المنطقة	◯	◯	◯	◯	◯

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Exposure and risk of increasing temperature (The main cause of global sea level rise is the thermal expansion). مراقبة زيادة درجة حرارة الأرض (السبب الرئيسي في ارتفاع مستوى سطح البحر على الساحل وزيادة الكوارث الطبيعة في المنطقة)	○	○	○	○	○
Building code (Enforcement of Building Code to reduce vulnerability and risk). الزام تطبيق كود معاييرالبناء لتعزيز قوة تحمل مباني ومنشآت المنطقة من مخاطر الكوارث	○	○	○	○	○
Availability of urban green space (e.g. parks) that have positive effects on climate-related disaster resiliance. توفرالمساحات الخضراء الحضرية (مثل الحدائق) التي لها القدرة على تخفيف آثار الكوارث المرتبطة بالمناخ	○	○	○	○	○

Other (please specify)
(غير ذلك (يرجى التحديد

* 21. Please rate how important the following safety and security factors are for coastal regions form man-made disasters?

يرجى تقييم مدى أهمية عوامل الأمن والحماية التالية في تعزيز حماية مجتمع المناطق الساحلية من مخاطر الكوارث البحرية (صنع الإنسان)؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Safety consideration against man-made disaster such as piracy and terrorists acts تنوع و تطوير أساليب الحماية من أعمال القرصنة والإرهاب البحري والتلوث	◯	◯	◯	◯	◯
Security systems and safety procedures such as monitoring cameras, sensors, etc. تعدد أنظمة الأمن وإجراءات الحماية مثال كاميرات المراقبة، وأجهزة الاستشعار، الخ	◯	◯	◯	◯	◯
Compliance with international standards (International Ship and Port Facility Security Code) الالتزام بتطبيق المعايير الدولية للحماية (المدونة الدولية لأمن السفن والموانئ)	◯	◯	◯	◯	◯

Other (please specify)
(غير ذلك (يرجى التحديد

* 22. Please rate how important the following coastal pollution control factors are for coastal regions?
يرجى تقييم مدى أهمية عوامل مكافحة التلوث البحري التالية في تعزيز حماية المجتمع الساحلي من آثارها ؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Monitoring of coastal water quality مراقبة جودة المياه الساحلية	○	○	○	○	○
Tackling oil spillages in coastal areas معالجة تسرب النفط في المناطق الساحلية	○	○	○	○	○
Conservation of mangroves الحفاظ على غابات المانغروف البحرية (النباتات البحرية)	○	○	○	○	○

Other (please specify)
(غير ذلك (يرجى التحديد

* 23. Please rate how important the following livelihood factors in coastal regions?
يرجى تقييم مدى أهمية العوامل التالية لتعزيز حماية الحياة المعيشية لسكان المناطق الساحلية من مخاطر الكوارث البحرية؟

	Unimportant غير مهم	Of little importance قليل الاهمية	Moderately important مهم بشكل معتدل	Important مهم	Very important مهم جداً
Funds available for reconstruction after disaster توفرالأموال لإعادة الإعمار بعد وقوع الكارثة	○	○	○	○	○
Employment dependence on coastal resources حماية الوظائف المتعلقة بالموارد الساحلية والمهددة بخطر الكوارث مثل شركات صيد الأسماك والسياحة البحرية	○	○	○	○	○
Coastal resources such as fishing حماية دخل الفرد المعتمد بشكل مباشرعلى الموارد الساحلية مثل صيد الأسماك	○	○	○	○	○
Increase household income زيادة معدل دخل الأسرة	○	○	○	○	○
Reduce poverty rate تقليل معدل الفقر	○	○	○	○	○

Other (please specify)
(غير ذلك (يرجى التحديد

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

Risk governance (Response)
إدارة عمليات الكوارث

Note: Please answer all questions to move to the next page

ملاحظة: يرجى الإجابة على جميع الأسئلة للانتقال للصفحة التالية

* 24. Please rate the availability and effective of the following risk management in your city / region :

يرجى تقييم مدى توفر وفاعلية عوامل إدارة الكوارث التالية في مدينتك / منطقتك

	Not available غير متاح	Very bad سيئة جدا	Bad سيئة	Good جيدة	Very good جيدة جدا
Early warning systems نظم الإنذار المبكر	○	○	○	○	○
Emergency operations center مركز إدارة الكوارث بالمدينة	○	○	○	○	○
Emergency plans خطط الطوارئ	○	○	○	○	○
Availability of evacuation shelters توفر ملاجئ الاخلاء	○	○	○	○	○
Shelter's location outside of risk areas موقع الملجأ خارج مناطق الخطر	○	○	○	○	○
The route to evacuation place الطريق إلى مكان الإخلاء	○	○	○	○	○
The evacuation sign boards اللوحات الارشادية للإخلاء	○	○	○	○	○
Volunteer groups of evacuation مجموعة المتطوعين في عملية الاخلاء	○	○	○	○	○
Emergency aids, such as logistics, food, medicine, materials etc المساعدات الطارئة، مثل الخدمات اللوجستية والغذاء والدواء والمواد الخ	○	○	○	○	○

Public perception of maritime disasters in Saudi Arabia
التصور العام للكوارث البحرية في المملكة العربية السعودية

Self- assessment التقييم الشخصي

Note: Please answer all questions to move to the next page

ملاحظة: يرجى الإجابة على جميع الأسئلة للانتقال للصفحة التالية

* 25. How would you rate the preparedness of the following current public services and utilities of your city / region to cope with the future maritime disasters?
كيف تقيم جاهزية الخدمات والمرافق الحالية التالية لمواجهة الكوارث البحرية في حال حدوثها (لاسمح الله) في مدينتك ؟

	Not available غير متوفرة	Very bad سيئة جدا	Bad سيئة	Good جيدة	Very good جيدة جدا
Capability of health facilities (Number of hospitals, physicians and ambulances) القدرة الاستيعابية للمرافق الصحية (عدد المستشفيات والأطباء وسيارات الإسعاف)	○	○	○	○	○
Transportation infrastructure accessibility النقل العام (وسائط متعددة، طرق سهلة الوصول)	○	○	○	○	○
Public services availability such as water and sewage توفر الخدمات العامة (مثل المياه والصرف الصحي والكهرباء)	○	○	○	○	○
Alternative energy source promotion (solar, wind, etc.) توفرالطاقة البديلة (الطاقة الشمسية والرياح وغيرها)	○	○	○	○	○

	Not available غير متوفرة	Very bad سيئة جدا	Bad سيئة	Good جيدة	Very good جيدة جدا
Communication reliability (telephone and internet service, and Reliability of communication systems) الاعتمادية على شبكة الاتصالات (الهاتف وخدمة الإنترنت، وموثوقية أنظمة الاتصالات)	○	○	○	○	○

* 26. Please check the three best methods to deliver safety advice to you?
يرجى اختيار أفضل ثلاث وسائل اتصال لإيصال الارشادات العامة الخاصة بالكوارث لك؟

- ☐ Radio
  راديو
- ☐ Television
  التلفزيون
- ☐ Newspaper
  الصحف
- ☐ Internet
  الإنترنت
- ☐ Social media
  شبكات التواصل الاجتماعي
- ☐ Other (please specify)
  أخرى (يرجى التحديد)

Thank you for your participating in survey.
نشكر لكم تعاونكم معنا في تعبئة الاستبيان

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Appendix B **Delphi surveys Round 1**

Coastal community resilience to maritime disasters in Saudi Arabia (First Round: Brainstorming)

Introduction

Dear expert

First and foremost, I would like to take this opportunity to thank you sincerely for agreeing to participate in this research consultation. Your involvement is a vital component for the positive outcomes of this consultation.

Due to varying geographical and tectonic factors, the region of Saudi Arabia has been subjected to numerous maritime disasters during the last two decades. Some of these natural maritime disasters (including tropical cyclones and tsunamis) have been recorded in coastal areas that are connected with the Indian Ocean, including the Gulf of Aden, the Gulf of Oman and Arabian Gulf. The Indian Ocean is also widely regarded as the potential source of future destructive maritime natural disasters with significant capacity to affect the region. On the other hand, man-made maritime disasters (i.e. those arising from oil spills, piracy, maritime terrorism, and vessel disasters) are most likely to take place in the Red Sea and Arabian Gulf, which are key locations for the export of oil between Asia and Europe. There is a need to promote community resilience to disasters in various regions and coastal cities of the country to address uncertain future scenarios. The research aims at identifying and building consensus around a set of indicators and underpinning sub-indicators that can provide detailed accounts and assessment of the capacity of resilience of a coastal community to natural or man-made hazards.

Your response is essential in identifying the important indicators. The data collected will be used for scientific research purposes only. For questions about this research and the questionnaire, please contact:

Mr Arif T Almutairi
Doctoral researcher
Cardiff University/ UK
Cardiff, CF24 3AA
Email: AlmutairiAT@cardiff.ac.uk

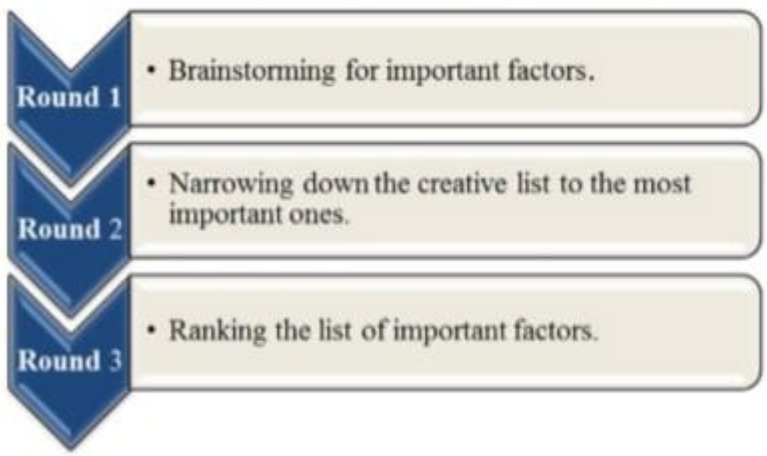
The proposed indicators and sub-indicators of framework for assessing the coastal community resilience to maritime disaster in Saudi Arabia

Coastal community resilience to maritime disasters in Saudi Arabia (First Round: Brainstorming)

Delphi technique

Delphi technique will be used in this consultation via a questionnaire method. The questionnaire will involve three rounds to reach consensus around community resilience dimensions and factors in Saudi Arabia. The first round of Delphi involves approving and extending a set of factors drawn from the literature in the field. The second round will synthesize results from the first round with the view of reaching consensus on a set of agreed factors. The third and final round will involve ranking the list of factors by levels of importance.

Delphi rounds (adpted from Okoli and Pawlowski (2004), Alshehri (2013))



Coastal community resilience to maritime disasters in Saudi Arabia (First Round: Brainstorming)

Personal Information

1. Please provide the following information

Name	
Company	
Positino	
City/Town	
Country	
Email Address	
Phone Number	

Coastal community resilience to maritime disasters in Saudi Arabia
(First Round: Brainstorming)

Society and Economy Dimension

In coastal communities, social and economic resilience refers to the ability of a community to survive on limited natural resources when they are typically highly dependent on such resources . economic resilience' include (1)**demographics**, (2)**livelihood**, (3)**employment,** (4)**awareness and training**, (5)**culture and** (6)**safety and security**.

Indicators and sub-indicators of society and economy dimension

*2. Please rate how important the following **demographic** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Population growth rate: Average yearly population growth rates.	○	○	○	○	○
Population density: Population Density in the area (number of person/sq. Km).	○	○	○	○	○
Age Dependency: Population less than 14 and more than 64 years of age.	○	○	○	○	○
Disability: The rate of people with disabilities.	○	○	○	○	○
Level of education: Qualification levels of the people.	○	○	○	○	○
Property ownership and type: The rate of owner-occupied housing units and types.	○	○	○	○	○

3. Please List further indicators of **demographic**, which not are mentioned above.

1 __________

2 __________

3 __________

4 __________

*4. Please rate how important the following **livelihood** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Coastal resources: The rate of the population who depends on coastal resources.	○	○	○	○	○
Household income: The average income earned by each person/family in a given area.	○	○	○	○	○
Poverty: The poverty rate is the ratio of the people whose income below the poverty line.	○	○	○	○	○

5. Please List further indicators of **livelihood**, which not are mentioned above.

1 __________

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* 6. Please rate how important the following **employment** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Employment: Labour force employed (% Employed per 10,000 labour forces).	○	○	○	○	○
Employment dependence on coastal resources: Employment opportunities include jobs related to coastal and ocean resources such as fishing and tourism.	○	○	○	○	○

7. Please List further indicators of **employment**, which not are mentioned above.

1 ______

2 ______

3 ______

4 ______

* 8. Please rate how important the following **awareness and training** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Disaster exercises and drills: Availability of disaster exercises and drills, in terms of number and frequency.	○	○	○	○	○

	Unimportant	Of little importance	Moderately important	Important	Very important
DRR training: A frequency of Disaster Risk Reduction (DRR) training program, it includes search and rescue, first aid, temporary shelter construction, food distribution, and evacuation management.	○	○	○	○	○
Awareness of disaster and climate change risks: Comprehensive public awareness campaigns provide constant reminders about hazards risks, warning procedures, and evacuation plans within coastal communities.	○	○	○	○	○
Multilingual awareness programmes: Capacity availability such as books, leaflets, etc. to disseminate disaster awareness programmes by different language.	○	○	○	○	○
Awareness campaigns: Awareness campaigns to reduce pollution.	○	○	○	○	○

9. Please List further indicators of **awareness and training**, which not are mentioned above.

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* 10. Please rate how important the following **culture** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Social capital: Population participating in community activities/clubs, acceptance level of participation in a decision-making process.	○	○	○	○	○
Religious organisations: Number of religious organisations.	○	○	○	○	○

11. Please List further indicators of **culture**, which not are mentioned above.

1
2
3
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* 12. Please rate how important the following **safety and security** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Riots, conflicts and homicide incidents: Occurrence of riots, conflicts or homicide incidents.	○	○	○	○	○
ISPS code compliance: Compliance with international standards ISPS Code (International Ship and Port Facility Security Code).	○	○	○	○	○
Safety and security systems: Security systems and safety procedures.	○	○	○	○	○

13. Please List further indicators of **safety and security**, which not are mentioned above.

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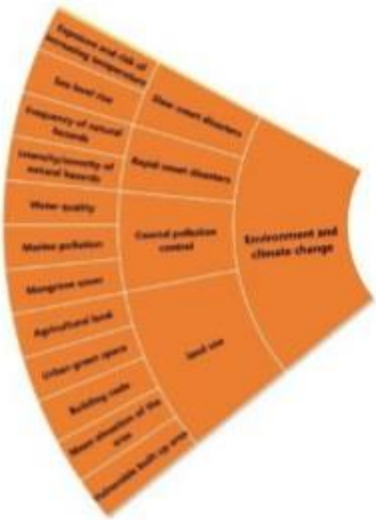
Environment and Climate change Dimension

Environmental and climate change dimension can be roughly linked to a coastal area's exposure to specific coastal hazards (i.e. Tropical cyclone, Tsunami and rising sea levels). The environmental safeguarding action for each indicator has been introduced in order to incorporate specific actions that may be carried out in order to mitigate the threats arising from climate change. While these factors may, at times, be considered to be negligible, they also have the potential to become highly detrimental to a society and its economy during periods of catastrophe. Its assessment indicators include (1)**coastal pollution control**, (2)**land use**, (3)**slow onset disasters** and (4)**rapid onset disasters**.

Indicators and sub-indicators of environment and climate change dimension



* **14.** Please rate how important the following **coastal pollution control** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Water quality: Frequency of monitoring of coastal water quality.	○	○	○	○	○
Marine pollution: Occurrence Oil spilling incidents from jetties, platforms and ships.	○	○	○	○	○
Mangrove cover: The percentage of forest cover as per land use of the area	○	○	○	○	○

15. Please List further indicators of **coastal pollution control**, which not are mentioned above.

1 ______

2 ______

3 ______

4 ______

* 16. Please rate how important the following **land use** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Agricultural land: Area of agricultural land (ha.)	○	○	○	○	○
Urban green space: The availability of urban green space (e.g. parks) that have positive effects on climate-related disaster resilience.	○	○	○	○	○
Building code: Enforcement of Building Code to reduce vulnerability and risk.	○	○	○	○	○
Mean elevation of the area: Resilient communities were located along the coastline and elevation area (Averaged elevation (m) above sea level).	○	○	○	○	○
Vulnerable built up area: Identify the developed land area, such as residential, commercial, recreational facilities, industrial and educational land uses (km2).	○	○	○	○	○

17. Please List further indicators of **land use** , which not are mentioned above.

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* 18. Please rate how important the following **slow onset disasters** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Exposure and risk of increasing temperature: The two major causes of global sea level rise are thermal expansion caused by warming of the ocean and increased melting of land-based ice.	○	○	○	○	○
Sea level rise: Projection of rising sea level and its severity for the area.	○	○	○	○	○

19. Please List further indicators of **slow onset disasters**, which not are mentioned above.

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* **20.** Please rate how important the following **rapid onset disasters** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Frequency of natural hazards: Frequency of natural disasters occurred in the area.	○	○	○	○	○
Intensity/severity of natural hazards: The severity of impact caused by the largest-scale of disaster occurred in the area.	○	○	○	○	○

21. Please List further indicators of **rapid onset disasters**, which not are mentioned above.

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2
3
4

Coastal community resilience to maritime disasters in Saudi Arabia (First Round: Brainstorming)

Infrastructure Dimension

Infrastructure resilience dimension, utilities, communication and public services are all essential for reducing the impact of disasters. When essential public services are discontinued, this has a negative impact on any rescue and relief operations which, in turn, can affect recovery. Thus, it is necessary for the infrastructure resilience to be robust and dynamic. The assessment indicators include (1)**transportation**, (2)**health**, (3)**transportation**, (4)**utilities**, (5)**communication** and (6)**embankment and shoreline**.

Indicators and sub-indicators of infrastructure dimension

* 22. Please rate how important the following **health** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Hospitals: Number of hospitals (per 1000 persons).	○	○	○	○	○
Hospital beds: Number of hospital beds (per 1000 persons).	○	○	○	○	○
Physicians: Number of physicians (per 1000 persons).	○	○	○	○	○
Ambulances: Number of ambulances (per 1000 persons).	○	○	○	○	○
Health insurance: The rate of population with health insurance	○	○	○	○	○
Health care support workers: Population employed in health care support.	○	○	○	○	○

23. Please List further indicators of **healt**, which not are mentioned above.

1 __________

2 __________

3 __________

4 __________

* **24.** Please rate how important the following **transportation** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Special need transportation services: Special need transportation services	○	○	○	○	○
Roads accessibility: The ability of people to move to secure places and obtain essential needs.	○	○	○	○	○
Vehicle ownership: Households/ persons with at least one vehicle.	○	○	○	○	○
School and employee buses: Number of school and employee buses.	○	○	○	○	○

25. Please List further indicators of **transportation**, which not are mentioned above.

1 ________________

2 ________________

3 ________________

4 ________________

* 26. Please rate how important the following **utilities** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Infrastructure and public facilities: Infrastructure and public facilities to support emergency management services, such as electricity, water, sewage.	◯	◯	◯	◯	◯
Renewable energy: The use of alternative source of electricity renewable of energy (Solar/wind etc.).	◯	◯	◯	◯	◯
Fire stations: Number of fire stations.	◯	◯	◯	◯	◯

27. Please List further indicators of **utilities**, which not are mentioned above.

1

2

3

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*28. Please rate how important the following communication indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Access to mobile phones: Percent of households with telephone service available.	◯	◯	◯	◯	◯
Access to radio/television: Percent of population having radio/television.	◯	◯	◯	◯	◯
Reliability of communication systems: Reliable communications create daily connectivity between places, people and services.	◯	◯	◯	◯	◯
Internet services: Percent of population having internet connection.	◯	◯	◯	◯	◯

29. Please List further indicators of **communication**, which not are mentioned above.

1 ______

2 ______

3 ______

4 ______

* 30. Please rate how important the following **embankment & shoreline** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Vulnerable shoreline: Vulnerable shoreline protected by dykes/embankments.	○	○	○	○	○
Age of embankments: Average age of embankments.	○	○	○	○	○
Maintenance of embankments: Frequency and quality of maintenance of embankments.	○	○	○	○	○

31. Please List further indicators of **embankment & shoreline**, which not are mentioned above.

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Governance and Institutions Dimension

Dimension of governance and institution resilience can be described as the role that governments and associated institutions play in helping to build resilient communities. A proper understanding of governance must incorporate the roles and responsibilities of all levels of government (local, state and federal), as well as the extent to which these either impede or facilitate community resilience. The assessment indicators include (1)**Laws & policy**, (2)**Institutional action** and (3)**Warning and evacuation**.

Indicators and sub-indicators of governance and institutions dimension

* 32. Please rate how important the following **laws & policy** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Regulations and policies: Regulations and policy of development plans of DRR including evacuation emergency management plans.	○	○	○	○	○
Environmental regulation: Implementation of environmental protection act and similar, implementation of efficient waste management system, implementation of mitigation policies to reduce air pollution.	○	○	○	○	○
Participation in DRR planning: Local community participation in Disaster Risk Reduction (DRR) planning.	○	○	○	○	○
DRR strategies: Disaster Risk Reduction (DRR) strategies integrate with climate change to increases the ability of community to adapt to the adverse impacts of face future hazards.	○	○	○	○	○

33. Please List further indicators of **laws & policy**, which not are mentioned above.

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* 34. Please rate how important the following **institutional action** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Observation and Monitoring: Observation and monitoring for built environment and existing facilities.	○	○	○	○	○
Institutional collaboration & coordination: Institutional collaboration and coordination of DRR (Government, non-government).	○	○	○	○	○
Voluntary Groups: Support from non-governmental organisations (NGOs) and community-based organisations (CBOs), population evacuating voluntarily, population participating in relief works.	○	○	○	○	○

35. Please List further indicators of **institutional action** , which not are mentioned above.

1

2

3

4

* 36. Please rate how important the following **warning and evacuation** indicators are for community resilience to maritime disasters in Saudi Arabia.

	Unimportant	Of little importance	Moderately important	Important	Very important
Early warning system: Existence of early warning system.	○	○	○	○	○
Availability of evacuation center: Number of temporary shelters during emergencies such as schools.	○	○	○	○	○
Emergency Aids: Availability of emergency aids, such as logistics, food security, medicine, materials etc.	○	○	○	○	○
Hotels and motels: The availability of hotels and motels.	○	○	○	○	○

37. Please List further indicators of **warning and evacuation**, which not are mentioned above.

1

2

3

4

Appendix C **Delphi surveys Round 2**

Coastal community resilience to maritime disasters in Saudi Arabia (Round 2)

إطار قياس قدرة صمود المجتمعات المحلية لإدارة الكوارث البحرية في المملكة العربية السعودية (الجولة الثانية)

Introduction

Dear Expert,

I would like to thank you very much for your efforts and taking the time to complete the first round of the Delphi questionnaire with your important comments.
For your information, the results have been presented based on your and other expert's responses to the questionnaire. The results are presented as a chart, each indicator being evaluated and reflected to you as statistical data (mean: the average rating of 56 Experts). The average rating is based on a 5-point Likert scale, where 5 means extremely important and 1 is not important.

I would like to invite you to participate in the second-round of the Delphi questionnaire, which requests you to re-rate the indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2. In addition, you are asked to rate the new indicators suggested by other experts in the first round, which are essential for the development of a community resilience assessment framework of maritime disasters management for Saudi Arabia.

Yours Sincerely,

Arif Almutairi
Cardiff University, The UK

عزيزي الخبير

أود أن أشكركم جزيل الشكر على جهودكم ووقتك لإكمال الجولة الأولى من استبيان الاستشارة دلفي وتعليقاتكم الهامة
وقد تم تحليل وعرض النتائج استنادًا إلى ردودك وردود الخبراء الآخرين على الاستبيان. تم عرض النتائج على شكل جدول ، يوضح تقييم كل مؤشر ويعكس لك البيانات الإحصائية لها (يعني: متوسط تقييم 65 خبير). ويستند متوسط التصنيف على مقياس ليكرت 5 نقاط ، حيث 5 تعني بالغ الأهمية و 1 غير مهم
كما أود أن أدعوكم للمشاركة في الجولة الثانية من استبيان دلفي ، والتي تطلب منك إعادة تقييم المؤشرات التي لم يتم التوصل إلى توافق في الآراء بشأنها خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية. بالإضافة إلى ذلك ، طلب تقييم المؤشرات الجديدة التي اقترحها خبراء آخرون في الجولة الأولى ، والتي تعتبر ضرورية لتطوير إطار تقييم صمود مقاومة المجتمعات المحلية لإدارة الكوارث البحرية في المملكة العربية السعودية
وتقبلوا فائق الاحترام والتقدير

عارف المطيري
جامعة كارديف _ بريطانيا

Mobil: 00966506949531

Coastal community resilience to maritime disasters in Saudi Arabia (Round 2)
إطار قياس قدرة صمود المجتمعات المحلية لإدارة الكوارث البحرية في المملكة العربية السعودية
(الجولة الثانية)

Personal Information

* 1. Please provide the following information

Name الاسم	
Email Address الايميل	
Phone Number الجوال	

Coastal community resilience to maritime disasters in Saudi Arabia (Round 2)

إطار قياس قدرة صمود المجتمعات المحلية لإدارة الكوارث البحرية في المملكة العربية السعودية (الجولة الثانية)

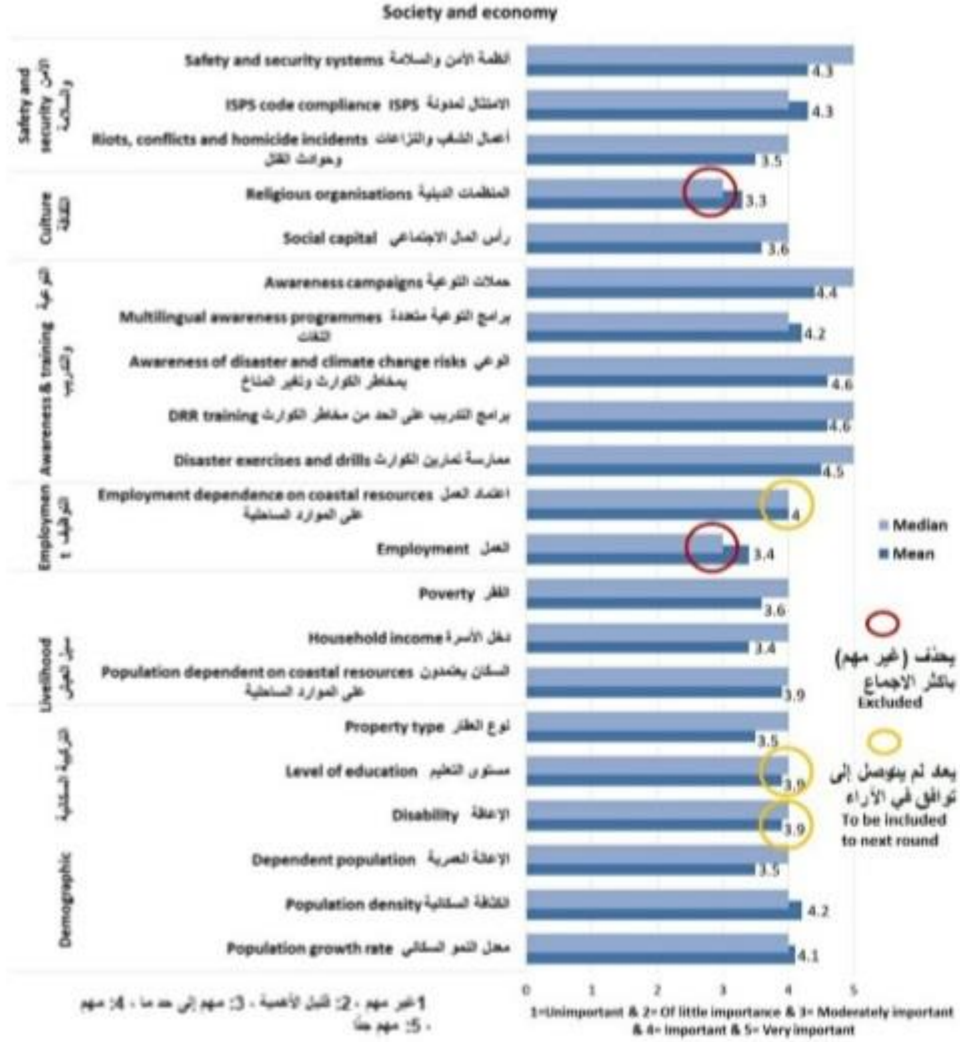
Society and Economy Dimension
الابعاد الاجتماعية والاقتصادية

Please see the below figure, there is consensus on the society and economy indicators in the first round of the survey. Then, please re-rate the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2, These are highlighted in yellow in the below figure. After that, please rate the proposed indicators in the same way as the indicators were rated in Round 1, that is, on a 5-point Likert scale from 1 (Unimportant) to 5 (Very important).

يرجى الاطلاع على الشكل أدناه ، هناك توافق في الآراء حول مؤشرات البعد الاجتماعي والاقتصادي في الجولة الأولى من المسح. بعد ذلك ، يرجى إعادة تقييم المؤشرات التالية التي لم تتوصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية ، وتم توضيحها باللون الأصفر في الشكل أدناه. بعد ذلك ، يرجى تقييم المؤشرات الجديدة المقترحة من الخبراء بالطريقة نفسها التي تم بها تصنيف العناصر في الجولة الاولى، أي على مقياس ليكرت من 5 نقاط من 1 (غير مهم) إلى 5 (مهم جدًا)

Society and Economy Dimension: average rating given by experts

مؤشرات المجتمع والاقتصاد: متوسط التقييم المقدم من قبل الخبرا



2. The feedback and re-evaluation

There is consensus on the society and economy indicators according to the level of importance in the first round of the survey. Thus, please re-rate the level of importance of the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2.

المؤاشرات التي لم تصل إلى توافق في آراء الخبراء وإعادة تقييمها

هناك توافق واجماع واسع بين الخبراء على مؤشرات البعد الاجتماعي والاقتصادي حسب مستوى الأهمية في الجولة الأولى من المسح. وبالتالي ، يرجى إعادة تقييم مستوى أهمية المؤشرات التالية التي لم تصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Disability: **الإعاقة :** The rate of people with disabilities. معدل الأشخاص ذوي الإعاقة	○	○	○	○	○
Level of education: مستوى التعليم : Qualification levels of the people. مستويات التأهيل للناس	○	○	○	○	○
Property ownership and type: **ملكية العقار : ونوعه** The rate of owner-occupied housing units and types. معدل الوحدات السكنية التي يشغلها مالكوها وأنواعها	○	○	○	○	○
Riots, conflicts and homicide incidents: **أعمال الشغب : والنزاعات وحوادث القتل** Occurrence of riots, conflicts or homicide incidents. عدد حدوث أعمال الشغب أو الصراعات أو حوادث القتل	○	○	○	○	○

Comments

* 3. **Further indicators from experts :**

The experts recommended the following indicators for inclusion under society and economy dimension. Please rate the importance of the proposed indicators for community resilience to maritime disasters in Saudi Arabia.

المؤشرات المقترحة من الخبراء

وأوصى الخبراء بالمؤشرات التالية في الجولة الاولى لإدراجها ضمن البعد الاجتماعي والاقتصادي. يرجى تقييم مدى أهمية المؤشرات المقترحة الجديدةلمقاومة صمود المجتمع للكوارث البحرية في المملكة العربية السعودية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Foreign population: لسكان الأجانب: % of population foreign persons without professional in Arabic النسبة المئوية للسكان الأجانب الغير ناطقين باللغة العربية	○	○	○	○	○
Sex ratio: نسبة الجنسين : The ratio of males to females in a population نسبة الذكور إلى الإناث في عدد السكان	○	○	○	○	○
Unemployment rate: معدل البطالة : Percentage of labour unemployed نسبة العاطلين عن العمل	○	○	○	○	○

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Integrating DRR into school curriculum: **دمج تعليم مخاطر: الكوارث والحد منها في المناهج الدراسية** The availability of incorporation of disaster education in schools توافر إدماج التثقيف في حالات الكوارث في المدارس	○	○	○	○	○

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Nonprofit organization (NPO): المؤسسات : الخيرية الغير ربحية A nonprofit organization are usually well integrated within local communities and thus often able to respond to disaster in a very short time span and their involvement in relief and reconstruction activities has also been crucial in fostering post-disaster recovery in many regions of the world. عادة ما تكون لمؤسسات الخيرية الغير ربحية متكاملة بشكل جيد في المجتمعات المحلية ، وبالتالي تكون قادرة في كثير من الأحيان على الاستجابة للكوارث في فترة زمنية قصيرة للغاية ، كما كان لمشاركتها في أنشطة الإغاثة وإعادة الإعمار دور حاسم في تعزيز الانتعاش بعد الكوارث في العديد من مناطق العالم	○	○	○	○	○

Comments

Environment and Climate change Dimension
الابعاد البيئية وتغير المناخ

Please see the below figure, there is consensus on the environment and climate change indicators in the first round of the survey. Then, please re-rate the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2. These are highlighted in yellow in the below figure. After that, please rate the proposed indicators in the same way as the indicators were rated in Round 1, that is, on a 5-point Likert scale from 1 (Unimportant) to 5 (Very important).

يرجى الاطلاع على الشكل أدناه ، هناك توافق في الآراء حول مؤشرات البعد البيئي وتغير المناخ في الجولة الأولى من المسح. بعد ذلك ، يرجى إعادة تقييم المؤشرات التالية التي لم تتوصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية ، وتم توضيحها باللون الأصفر في الشكل أدناه. بعد ذلك ، يرجى تقييم المؤشرات الجديدة المقترحة من الخبراء بالطريقة نفسها التي تم بها تصنيف العناصر في الجولة الاولى، أي على مقياس ليكرت من 5 نقاط من 1 (غير مهم) إلى 5 (مهم)

Environment and climate change: average rating given by experts

مؤشرات البعد البيئي وتغير المناخ: متوسط التقييم المقدم من قبل الخبراء

4. **The feedback and re-evaluation:**

There is consensus on the environment and climate change indicators according to the level of importance in the first round of the survey. Thus, please re-rate the level of importance of the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2.

المؤاشرات التي لم تصل إلى توافق في آراء الخبراء وإعادة تقييمها

هناك توافق واجماع واسع بين الخبراء على مؤشرات البعد البيئي وتغير المناخ حسب مستوى الأهمية في الجولة الأولى من المسح. وبالتالي ، يرجى إعادة تقييم مستوى أهمية المؤشرات التالية التي لم تصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Urban green space: **المساحات الخضراء في المناطق الحضرية** The availability of urban green space (e.g. parks) that have positive effects on climate-related disaster resilience. نسبة توفر المساحات الخضراء في المناطق الحضرية (مثل المنتزهات والحدائق) والتي لها آثار إيجابية على مرونة في تخفيف اثار الكوارث المرتبطة بالمناخ	○	○	○	○	○
Relative rate of sea level rise: المعدل النسبي لارتفاع مستوى سطح البحر Projection of rising sea level and its severity for the area. رسم توقع ارتفاع مستوى سطح البحر وشدته في المنطقة	○	○	○	○	○

Comments

*5. Further indicators from experts :

The experts recommended the following indicators for inclusion under the environment and climate change dimension. Please rate the importance of the proposed indicators for community resilience to maritime disasters in Saudi Arabia.

المؤشرات المقترحة من الخبراء

وأوصى الخبراء بالمؤشرات التالية في الجولة الاولى لإدراجها ضمن مؤشرات البعد البيئي وتغير المناخ. يرجى تقييم مدى أهمية المؤشرات المقترحة الجديدةلمقاومة صمود المجتمع للكوارث البحرية في المملكة العربية السعودية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Industrial wastewater discharge: تصريف مياه : الصرف الصناعي Extent of discharge of Industrial wastewater in coastal areas مدى تصريف مياه الصرف الصناعي في المناطق الساحلية	○	○	○	○	○
Implementation of IPCC Rules and Procedures: قواعد (IPCC) : وإجراءات الهيئة الحكومية الدولية المعنية بتغير المناخ Implementation of Intergovernmental Panel on Climate Change (IPCC) Rules and Procedures. تنفيذ قواعد وإجراءات الهيئة الحكومية الدولية المعنية بتغير المناخ	○	○	○	○	○

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Seabed seismic monitoring: **الرصد الزلزالي : في قاع البحار** Underwater earthquake monitors and tsunami رصد الزلازل تحت الماء وموجات التسونامي	○	○	○	○	○

Comments

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Coastal community resilience to maritime disasters in Saudi Arabia (Round 2)

إطار قياس قدرة صمود المجتمعات المحلية لإدارة الكوارث البحرية في المملكة العربية السعودية (الجولة الثانية)

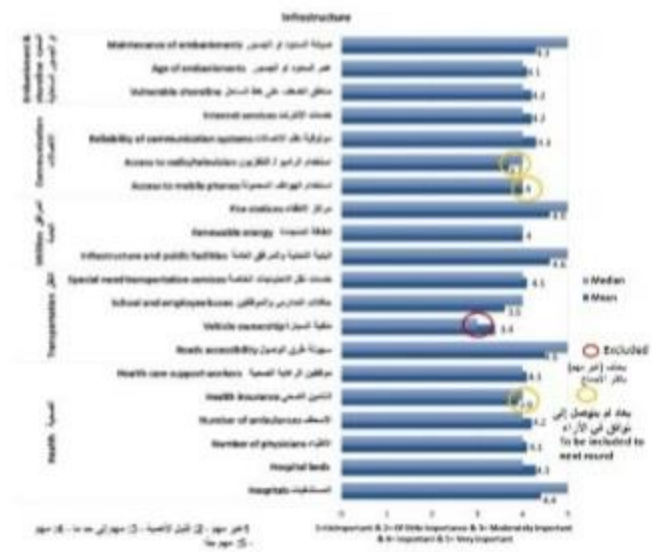
Infrastructure Dimension
ابعاد البنية التحتية

Please see the below figure, there is consensus on the infrastructure indicators in the first round of the survey. Then, please re-rate the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2. These are highlighted in yellow in the below figure. After that, please rate the proposed indicators in the same way as the indicators were rated in Round 1, that is, on a 5-point Likert scale from 1 (Unimportant) to 5 (Very important).

يرجى الاطلاع على الشكل أدناه ، هناك توافق في الآراء حول مؤشرات ابعاد البنية التحتية في الجولة الأولى من المسح. بعد ذلك ، يرجى إعادة تقييم المؤشرات التالية التي لم تتوصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية ، وتم توضيحها باللون الأصفر في الشكل أدناه. بعد ذلك ، يرجى تقييم المؤشرات الجديدة المقترحة من الخبراء بالطريقة نفسها التي تم بها تصنيف العناصر في الجولة الاولى، أي على مقياس ليكرت من 5 نقاط من 1 (غير مهم) إلى 5 (مهم)ا

Infrastructure dimension: average rating given by experts

مؤشرات ابعاد البنية التحتية: متوسط التقييم المقدم من قبل الخبراء



* 6. **The feedback and re-evaluation**

There is consensus on infrastructure indicators according to the level of importance in the first round of the survey. Thus, please re-rate the level of importance of the following indicators that did not reach consensus during the first round for inclusion or exclusion in Round 2.

المؤاشرات التي لم تصل إلى توافق في آراء الخبراء وإعادة تقييمها

هناك توافق واجماع واسع بين الخبراء على مؤشرات بعد البنية التحتية حسب مستوى الأهمية في الجولة الأولى من المسح. وبالتالي ، يرجى إعادة تقييم مستوى أهمية المؤشرات التالية التي لم تصل إلى توافق في الآراء خلال الجولة الأولى لإدراجها أو استبعادها في الجولة الثانية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Health insurance: التأمين الصحي : The percentage of population with health insurance معدل السكان مع التأمين الصحي	○	○	○	○	○
Access to mobile phones: استخدام الهواتف : المحمولة Percent of households with telephone service available. نسبة الأسر التي لديها خدمة هاتفية متاحة	○	○	○	○	○
Access to radio/television: استخدام الراديو / : التلفزيون Percent of population having radio/television. نسبة السكان الذين لديهم راديو / تلفزيون	○	○	○	○	○

Comments

* 7. **Further indicators from experts:**

The experts recommended the following indicators for inclusion under infrastructure Dimension. Please rate the importance of the proposed indicators for community resilience to maritime disasters in Saudi Arabia.

المؤشرات المقترحة من الخبراء

وأوصى الخبراء بالمؤشرات التالية في الجولة الاولى لإدراجها ضمن مؤشرات مؤشرات ابعاد البنية التحتية. يرجى تقييم مدى أهمية المؤشرات المقترحة الجديدةلمقاومة صمود المجتمع للكوارث البحرية في المملكة العربية السعودية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Public transportation modes: وسائط النقل العام : Availability of Public transportation modes توفر وسائط النقل العام	◯	◯	◯	◯	◯

Comments

Governance and Institutions Dimension

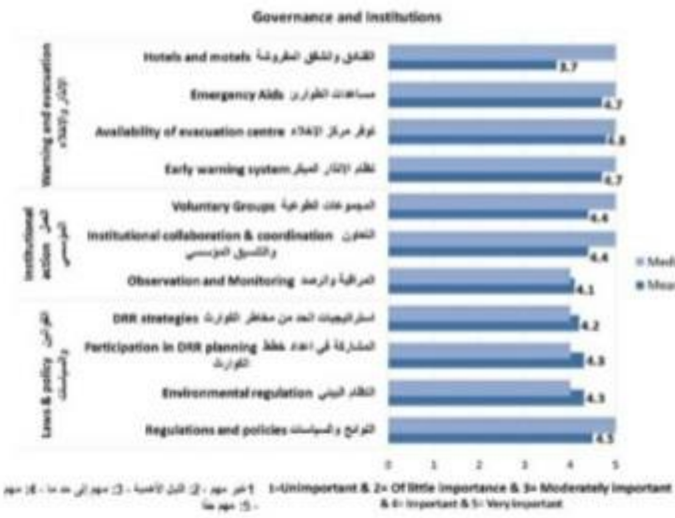
ابعادالحوكمة والمؤسسات

Please see the below figure, there is consensus on the governance and institutions indicators in the first round of the survey. Then, please rate the proposed indicators in the same way as the indicators were rated in Round 1, that is, on a 5-point Likert scale from 1 (Unimportant) to 5 (Very important).

يرجى الاطلاع على الشكل أدناه ، هناك توافق في الآراء حول مؤشرات ابعاد الحوكمة والمؤسسات في الجولة الأولى من المسح. بعد ذلك ، يرجى تقييم المؤشرات الجديده المقترحه من الخبراء بالطريقه نفسها التي تم بها تصنيف العناصر في الجولة الاولى، أي على مقياس ليكرت من 5 نقاط من 1 (غير مهم) إلى 5 (مهم)!

Governance and institutions dimension: average rating given by experts

مؤشرات ابعاد الحوكمة والمؤسسات: متوسط التقييم المقدم من قبل الخبراء



* 8. **Further indicators from experts:**

The experts recommended the following indicators for inclusion under governance and institutions Dimension. Please rate the importance of the proposed indicators for community resilience to maritime disasters in Saudi Arabia.

المؤشرات المقترحة من الخبراء

وأوصى الخبراء بالمؤشرات التالية في الجولة الاولى لإدراجها ضمن مؤشرات مؤشرات ابعاد الحوكمة والمؤسسات. يرجى تقييم مدى أهمية المؤشرات المقترحة الجديدة لمقاومة صمود المجتمع للكوارث البحرية في المملكة العربية السعودية

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Compliance with international standards that consider hazard risks: الامتثال للمعايير : الدولية التي تراعي مخاطر المخاطر Compliance with international standards that consider hazard risks مدى الامتثال للمعايير الدولية التي تراعي مخاطر المخاطر	○	○	○	○	○

Comments

* 9. This framework has four dimensions. Could you please rate how important the following dimensions are for the community resilience to maritime disasters in Saudi Arabia?

هذا الإطار يحتوي على أربعة أبعاد. هل يمكن أن تقيم مدى أهمية الأبعاد التالية لتقييم صمود المجتمعات المحلية في مواجهة الكوارث البحرية في المملكة العربية السعودية؟

	Unimportant غير مهم	Of little importance قليل الأهمية	Moderately important معتدل الأهمية	Important مهم	Very important مهم جدا
Society and economy ابعاد المجتمع والاقتصاد	○	○	○	○	○
Environment and climate change البعد البيئي وتغير : المناخ	○	○	○	○	○
Infrastructure ابعاد البنية التحتية	○	○	○	○	○
Governance and Institutions ابعاد الحوكمة والمؤسسات	○	○	○	○	○

Comments

Appendix D **The analysis of the Delphi survey responses by rounds**

Indicator	Round 1					Round 2				
	Mean	Median	Std. Deviation	Interquartile Range (IQR)	Status of Consensus	Mean	Median	Std. Deviation	Interquartile Range (IQR)	Status of Consensus
Society and economy	3.9	4.00	0.78	0.00						
Demographic										
Population growth rate	4.1	4.00	0.87	1.00	√ Achieved	__	__	__	__	__
Population density	4.2	4.00	0.92	1.00	√ Achieved	__	__	__	__	__
dependent population	3.5	4.00	0.92	1.00	√ Achieved	__	__	__	__	__
Disability	3.9	4.00	1.09	2.00	→ To be included to round 2	3.9	4.00	0.92	1.00	√ Achieved
Level of education	3.9	4.00	1.02	2.00	→ To be included to round 2	4.0	4.00	0.87	1.00	√ Achieved
Property ownership	3.5	4.00	1.03	1.00	→ To be included to round 2	3.2	3.00	__	__	× Excluded
Foreign population*	__	__	__	__	__	3.6	4.00	0.88	1.00	√ Achieved
Sex ratio*	__	__	__	__	__	3.2	3.00	__	__	× Excluded
Livelihood										
Population dependent on coastal resources	3.9	4.00	0.90	1.00	√ Achieved	__	__	__	__	__
Household income	3.4	4.00	0.94	1.00	√ Achieved	__	__	__	__	__
Poverty	3.6	4.00	0.99	1.00	√ Achieved	__	__	__	__	__
Employment										
Employment	3.4	3.00	__	__	× Excluded	__	__	__	__	__
Employment dependence on coastal resources	4	4.00	0.85	1.00	√ Achieved	__	__	__	__	__
Unemployment rate*	__	__	__	__	__	3.0	3.00	__	__	× Excluded
Nonprofit organization (NPO)*	__	__	__	__	__	4.1	4.00	0.89	1.00	√ Achieved
Awareness & training										
Disaster exercises and drills	4.5	5.00	0.69	1.00	√ Achieved	__	__	__	__	__
DRR training	4.6	5.00	0.54	1.00	√ Achieved	__	__	__	__	__
Awareness of disaster and climate change risks	4.6	5.00	0.60	1.00	√ Achieved	__	__	__	__	__
Multilingual awareness programmes	4.2	4.00	0.75	1.00	√ Achieved	__	__	__	__	__
Awareness campaigns	4.4	5.00	0.73	1.00	√ Achieved	__	__	__	__	__
Culture										
Social capital	3.6	4.00	0.89	1.00	√ Achieved	__	__	__	__	__
Religious organisations	3.3	3.00	__	__	× Excluded	__	__	__	__	__
Integrating DRR into school curriculum*	__	__	__	__	__	4.3	5.00	0.85	1.00	√ Achieved

Safety and security										
Riots, conflicts and homicide incidents	3.5	4.00	1.11	1.00	→ To be included to next round 2	3.6	4.00	0.84	1.00	√ Achieved
ISPS code compliance	4.3	4.00	0.77	1.00	√ Achieved	__	__	__	__	__
Safety and security systems	4.3	5.00	0.64	1.00	√ Achieved	__	__	__	__	__
Environment and climate change	4.4	4.50	0.56	1.00						
Coastal pollution control										
Water quality	4.2	4.00	0.87	1.00	√ Achieved	__	__	__	__	__
Marine pollution	4.5	5.00	0.73	1.00	√ Achieved	__	__	__	__	__
Mangrove cover	3.8	4.00	0.99	1.50	√ Achieved	__	__	__	__	__
Industrial wastewater discharge*	__	__	__	__	__	4.20	4.00	0.73	1.00	√ Achieved
land use										
Agricultural land	3.6	4.00	0.87	1.00	√ Achieved	__	__	__	__	__
Urban green space	3.8	4.00	1.02	2.00	→ To be included to round 2	4.1	4.00	0.80	1.00	√ Achieved
Built up area	4	4.00	0.88	1.00	√ Achieved	__	__	__	__	__
Building codes and regulation	4.4	5.00	0.81	1.00	√ Achieved	__	__	__	__	__
Mean elevation of the area	4.2	4.00	0.81	1.00	√ Achieved	__	__	__	__	__
Slow onset disasters										
Exposure and risk of increasing temperature	3.8	4.00	0.93	1.00	√ Achieved	__	__	__	__	__
Relative rate of sea level rise	4.1	4.00	1.01	1.00	→ To be included to round 2	4.1	4.00	0.75	1.00	√ Achieved
Implementation of IPCC Rules and Procedures*	__	__	__	__	__	4.1	4	0.73	1	√ Achieved
Rapid onset disasters										
Frequency of natural hazards	4.2	4.00	0.77	1.00	√ Achieved	__	__	__	__	√ Achieved
Intensity/severity of natural hazards	4.3	4.00	0.71	1.00	√ Achieved	__	__	__	__	√ Achieved
Seabed seismic monitoring*	__	__	__	__	__	4.50	5.00	0.70	1.00	√ Achieved
Infrastructure	4.5	5.00	0.56	1.00						
Health										
Hospitals (#) in 100 people	4.4	5.00	0.75	1.00	√ Achieved	__	__	__	__	__
Hospital beds (#) in 100 people	4.3	4.00	0.83	1.00	√ Achieved	__	__	__	__	__
Number of physicians (#) in 100 people	4.1	4.00	0.85	1.00	√ Achieved	__	__	__	__	__
Number of ambulances (#) in 100 people	4.2	4.00	0.63	1.00	√ Achieved	__	__	__	__	__
Health insurance (#) in 100 people	3.9	4.00	0.98	2.00	→ To be included to round 2	4	4.00	0.85	1.00	√ Achieved
Health care support workers (#) in 100 people	4.1	4.00	0.91	1.00	√ Achieved	__	__	__	__	__
Transportation										
Roads accessibility	4.5	5.00	0.62	1.00	√ Achieved	__	__	__	__	__
Vehicle ownership	3.4	3.00	__	__	× Excluded	__	__	__	__	__

School and employee buses	3.6	4.00	0.97	1.00	√ Achieved	__	__	__	__	__
Special need transportation services	4.1	4.00	0.87	1.00	√ Achieved	__	__	__	__	__
Public transportation modes*	__	__	__	__	__	4.1	4.00	0.74	1.00	√ Achieved
Utilities										
Infrastructure and public facilities	4.6	5.00	0.58	1.00	√ Achieved	__	__	__	__	√ Achieved
Renewable energy	4	4.00	0.91	1.00	√ Achieved	__	__	__	__	√ Achieved
Fire stations	4.6	5.00	0.57	1.00	√ Achieved	__	__	__	__	√ Achieved
Communication										
Access to mobile phones	4	4.00	0.95	1.50	→ To be included to round 2	4	4.00	0.72	1.00	√ Achieved
Access to radio/television	3.7	4.00	1.08	2.00	→ To be included to round 2	3.7	4.00	0.86	1.00	√ Achieved
Reliability of communication systems	4.3	4.00	0.92	1.00	√ Achieved	__	__	__	__	__
Internet services	4.2	4.00	0.77	1.00	√ Achieved	__	__	__	__	__
Embankment & shoreline										
Vulnerable shoreline	4.2	4.00	0.79	1.00	√ Achieved	__	__	__	__	__
Age of embankments	4.1	4.00	0.86	1.00	√ Achieved	__	__	__	__	__
Maintenance of embankments	4.3	5.00	0.80	1.00	√ Achieved	__	__	__	__	__
Governance and Institutions	4.2	4.00	0.76	1.00						
Laws & policy										
Regulations and policies	4.5	5.00	0.73	1.00	√ Achieved	__	__	__	__	__
Environmental regulation	4.3	4.00	0.74	1.00	√ Achieved	__	__	__	__	__
Participation in DRR planning	4.3	4.00	0.73	1.00	√ Achieved	__	__	__	__	__
DRR strategies	4.2	4.00	0.84	1.00	√ Achieved	__	__	__	__	__
Compliance with international standards that consider hazard risks*	__	__	__	__	__	4.5	5.0	0.74	1.00	√ Achieved
Institutional action										
Observation and Monitoring	4.1	4.00	0.81	1.00	√ Achieved	__	__	__	__	__
Institutional collaboration & coordination	4.4	5.00	0.69	1.00	√ Achieved	__	__	__	__	__
Voluntary Groups	4.4	5.00	0.62	1.00	√ Achieved	__	__	__	__	__
Warning and evacuation										
Early warning system	4.7	5.00	0.66	0.00	√ Achieved	__	__	__	__	__
Availability of evacuation centre	4.8	5.00	0.45	0.00	√ Achieved	__	__	__	__	__
Emergency Aids	4.7	5.00	0.49	0.00	√ Achieved	__	__	__	__	__
Hotels and motels	3.7	5.00	0.80	1.00	√ Achieved	__	__	__	__	__

* : Proposed by expert in round one

Appendix D **The scope of the CCRMD's factors and measurement methods**

Dimension	Indicator	Sub-indicator	Description	Level of difficulty in evaluation* High/ Medium/Low
Society and economy	Demographic	Population growth rate	Average yearly population growth rates	L
		Population density	Population density in the area (number of person/sq. Km)	M
		Dependent population	Population less than 14 and more than 64 years of age.	L
		Disability	The rate of people with disabilities	L
		Level of education	Qualification levels of the people	L
		Foreign population	Population foreign persons who came to Saudi Arabia	L
	Livelihood	Population dependent on coastal resources	Population who depends on coastal resources.	M
		Household income	The average income earned by each person/family in a given area	M
		Poverty	% of people whose income below the poverty line.	M
	Employment	Employment dependence on coastal resources	% of employment opportunities include jobs related to coastal and ocean resources such as fishing and tourism	M
		Non-profit organization (NPO)	Availability of non-profit organization (NPO)	M
	Awareness & training	Disaster exercises and drills	Availability of disaster exercises and drills, in terms of number and frequency	L
		DRR training	A frequency of disaster risk reduction (DRR) training program, it includes search and rescue, first aid, temporary shelter construction, food distribution, and evacuation management.	L
		Awareness of disaster and climate change risks	Comprehensive public awareness campaigns provide constant reminders about hazards risks, warning procedures, and evacuation plans within coastal communities.	L
		Multilingual awareness programmes	Effectiveness of disaster awareness programmes by different language.	H
		Awareness campaigns	Awareness campaigns to reduce pollution.	L

	Culture	Social capital	% of population participating in community activities/clubs, acceptance level of participation in a decision-making process.	M
		Integrating DRR into school curriculum	% of incorporation of disaster education in schools	L
	Safety and security	Riots, conflicts and homicide incidents	Occurrence of riots, conflicts or homicide incidents	M
		ISPS code compliance	Compliance with international standards ISPS Code (International Ship and Port Facility Security Code).	M
		Safety and security systems	Implementation of security systems and safety procedures	L
Environment and climate change	Coastal pollution control	Water quality	Frequency of monitoring of coastal water quality and remediation measures	M
		Marine pollution	Occurrence oil spilling incidents from jetties, platforms and ships	M
		Mangrove cover	The percentage of forest cover	M
		Industrial wastewater discharge	Extent of discharge of industrial wastewater in coastal areas	H
	land use	Agricultural land	Area of agricultural land	L
		Urban green space	% of urban green space (e.g. parks) that have positive effects on climate-related disaster resilience.	L
		Built up area	Percentage of the developed area of residential, commercial, industrial and educational land uses	L
		Building codes and regulation	Enforcement of building code to reduce vulnerability and risk.	L
		Mean elevation of the area	% of housing living above the normal flood line	M
	Slow onset disasters	Exposure and risk of increasing temperature	The two major causes of global sea level rise are thermal expansion caused by warming of the ocean and increased melting of land-based ice.	L
		Relative rate of sea level rise	Projection of rising sea level and its severity for the area	M
		Implementation of IPCC Rules and Procedures	Implementation of intergovernmental panel on climate change (IPCC) rules and procedures	H
	Rapid onset disasters	Frequency of natural hazards	Frequency of natural disasters occurred in the area	H

		Intensity/severity of natural hazards	The severity of impact caused by the largest-scale of disaster occurred in the area	H
		Seabed seismic monitoring	The availability of underwater earthquake monitors and tsunami	H
Infrastructure	Health	Hospitals	Density of hospitals (per 100 000 persons)	L
		Hospital beds	Number of hospital beds (per 1000 persons)	L
		Number of physicians	Number of physicians (per 1000 persons)	L
		Number of ambulances	Number of ambulances (per 1000 persons)	L
		Health insurance	% of population with health insurance	M
		Health care support workers	Population employed in health care support (per 1000 persons)	M
	Transportation	Roads accessibility	The ability of people to move to secure places and obtain essential needs	L
		School and employee buses	Availability of school and employee buses	L
		Special need transportation services	The availability of special need transportation services such as disabled and elderly	L
		Public transportation modes	Availability of Public transportation modes	L
	Utilities	Infrastructure and public facilities	Quality of Infrastructure and public facilities to support emergency management services, such as electricity, water, sewage	L
		Renewable energy	Implementation of alternative source of electricity renewable of energy (Solar/wind etc.)	L
		Fire stations	Availability of fire stations	L
	Communication	Access to mobile phones	Households with telephone service available	L
		Access to radio/television	% of population having access to radio/television	L
		Reliability of communication systems.	Reliable communications create daily connectivity between places, people and services.	L
		Internet services	Percent of population having internet connection	L
	Embankment & shoreline	Vulnerable shoreline	% of vulnerable shoreline protected by dykes/embankments.	M
		Age of embankments	Average age of embankments	M

		Maintenance of embankments	Frequency and quality of maintenance of embankments	M
Governance and Institutions	Laws & policy	Regulations and policies	Regulations and policy of development plans of DRR including evacuation emergency management plans	L
		Environmental regulation	Implementation of environmental protection act and similar, implementation of efficient waste management system, implementation of mitigation policies to reduce air pollution	M
		Participation in DRR planning	Participation of local community participation in DRR planning	L
		DRR strategies	DRR strategies integrate with climate change to increases the ability of community to adapt to the adverse impacts of face future hazards	M
		Compliance with international standards that consider hazard risks	Compliance with international standards that consider hazard risks	
	Institutional action	Observation and Monitoring	Observation and monitoring for built environment and existing facilities	L
		Institutional collaboration & coordination	Participation of non-government in DRR	L
		Voluntary Groups	Support from non-governmental organisations (NGOs) and community-based organisations (CBOs), population evacuating voluntarily, population participating in relief works	L
	Warning and evacuation	Early warning system	Existence of early warning system	L
		Availability of evacuation centre	Availability of temporary shelters during emergencies such as schools	L
		Emergency Aids	Availability of emergency aids, such as logistics, food security, medicine, materials etc.	L
		Hotels and motels	Availability of hotels and motels	L

* where:

High: Information is difficult to obtain or the information collected by government
Medium: Information collected bit publicly
Low: collected routinely

Example:
Demographic:
% of average yearly population growth rates

1	2	3	4	5
>3.0 %	2.0-2.9%	1.6-1.9%	1.2-1.5%	<1.1%

Population Density in the area (number of person/sq. Km)

1	2	3	4	5
> 1000	999-800	800-401	400-101	<100

Dependent population [(% of Population aged less than 15 + % Population more than 65/ % population between 15-64) x 100]

1	2	3	4	5
> 80	50-80	30-50	15-30	<15

Note: How to Calculate age dependency ratio: For example, if 41% of its population less than 15, and 4% is over 65. This makes 55% (100 - (41+4)) between the ages of 15 and 64. Hence, Dependency Ratio is [41 + 4]/55 x 100= 81.8 which means 81.8 persons depend on 100 working persons.
Livelihood:
% of population who depends on coastal resources.

1	2	3	4	5
> 90%	51-90%	31-50%	10-30%	<10%

% of people whose income below the poverty line. [< 1.25 USD/day, World Bank 2008]

1	2	3	4	5
> 50%	35-50%	16-35%	6-15%	0-5%

Note: May be given in terms of BPL population as defined by Government of KSA
Safety and security:
Occurrence of riots, conflicts or homicide incidents

1	2	3	4	5
More often	Often	Seldom	Very Much rare	No incidents

% of the compliance with international standards ISPS Code (International Ship and Port Facility Security Code).

1	2	3	4	5
Very poor	Poor	Medium	Good	Very Good

Coastal pollution control:
Frequency of monitoring of coastal water quality and remediation measures

1	2	3	4	5
Never happened	Very Rare	Rare	Frequent	Very Frequent

Extent of discharge of Industrial wastewater in coastal areas

1	2	3	4	5
Regularly discharged without treatment	Regularly discharged with treatment	Occasionally discharged without treatment	Occasionally discharged after treatment	Not discharged

Slow onset disasters:
Projection of rising sea level and its severity for the area

1	2	3	4	5
Very high	high	Moderate	Low	No predicted Impact

Rapid onset disasters
Frequency of natural disasters occurred in the area

1	2	3	4	5
Once in 5 years	Once in 10 years	Once 50 years	Once in 100 years	No reported Tsunami event

Health:
Number of hospital bed (per 1000 persons)

1	2	3	4	5
> 2000	1800-1601	1600-1401	1400-1200	<1000

Transportation:
Availability of Public transportation modes

1	2	3	4	5
Very poor	Poor	Medium	Good	Very Good

Embankment & shoreline:
% of vulnerable shoreline protected by dykes/embankments

1	2	3	4	5
> 5%	5-25%	25-50%	51-80%	80-100

Average age of embankments

1	2	3	4	5
> 30 years	30-20 years	10-19years	5-10 years	< 5 years