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MULTI-HAZARD EARLY WARNING TO INCREASE DISASTER RESILIENCE IN COASTAL REGIONS

REGIONAL POSITION PAPER

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1.0	13th June 2018	Incorporating national position papers and regional surveys
2.0	28th February 2019	Incorporating regional survey of tsunami preparedness, conducted in conjunction with IOC-UNESCO IOTWMS

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Executive Summary

The Asia-Pacific region is regularly labelled as the most disaster-prone in the world due to a long history of both major catastrophic disasters and frequent small and medium-sized events. However, climate change, environmental degradation and other factors have resulted in a risk landscape for the region that is increasingly uncertain. Specifically, acute vulnerability to drought in so-called least developed countries, such as Myanmar, contributes significantly to the regional risk level.

This report makes clear the relationship between disasters, climate change and sustainable development clear. Climate-related hazards are particularly prevalent along coasts, which is where many Asian cities are located. Urban areas also concentrate risk and many of the region's urban population lives in informal settlements. People living informally will be the worst affected by disasters, because they lack access to basic services and security of tenure and do not have the voice or means to substantially improve their living conditions.

In order to address such disaster risk, this report has also stressed the important of effective, multi-hazard warning systems. Traditionally, many countries have been reactive to disasters experiencing significant losses in lives and livelihoods of their citizens. Adoption of the Hyogo Framework for Action (HFA) 2005–2015, and more recently, the Sendai Framework for Disaster Risk Reduction 2015-30, has led to a paradigm shift in disaster risk management, from emergency response to a comprehensive approach which also includes preparedness and preventive strategies to reduce risk.

The Sendai Framework for Disaster Risk Reduction 2015–2030 recognises the benefits of multi-hazard early warnings systems and enshrines them in one of its seven global targets: "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030".

In order to support achievement of this goals, the CABARET project was established to promote international cooperation at the regional level, between Higher Education Institutes (HEIs) in Asia (region 6) and Europe, and among Asian HEIs themselves, to improve multi-hazard early warning and increase resilience among coastal communities. It has sought to build capacity, foster regional integration and cooperation through joint initiatives, sharing of good practices and cooperation among HEIs in Asia and Europe. It also set out to strengthen relations between HEIs and the wider economic and social environment through its focus on coastal communities, many of which are under severe pressure resulting from planned and unplanned development, population growth and human induced vulnerability, coastal hazards with increasing frequency and magnitude, and the impacts of global climate change.

The report provides an understanding about the overall disaster status in Asia, the availability of early warning systems for tsunami and multi-hazard, the present status of regional cooperation, and enablers and barriers for an effective MHEW in Asia. In addition, the report considers the role of Higher Education Institutions (HEIs), and their present status in developing effective MHEW in Asia.

The findings and recommendations of this report are based upon:

- A conceptual framework developed from a literature review and outcomes of workshops conducted with partners and key stakeholders.
- The results of the ICG/IOTWMS and its "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP), which includes a survey of 20 countries in the Indian Ocean. The CABARET project supported the development and analysis of this regional survey.
- A regional literature review and expert survey.
- Five national position papers from five CABARET partner countries – Indonesia, Maldives, Myanmar, Philippines and Sri Lanka

This regional position paper is an attempt to engage users and beneficiaries, which increases the likelihood that the project can achieve a positive impact. This allows different audiences to have their input during the preparation and development phases, and not simply receive the results at the end. The specific problems to be addressed by CABARET are strategically important: Progress in MHEW is uneven across the Asian region, with some high-risk, low-capacity countries falling behind. Greater participation in regional MHEW will lower the cost, strengthen the sustainability and thus enhance the value for all members, as a single country would normally not be able to implement such a complex system without the cooperation of other countries and relevant regional and international organisations. Through improved regional cooperative mechanisms on MHEW, countries will be better able to share good practices, expertise and capacities in assessing risks, developing sustainable monitoring and warning services, creating proper dissemination and communication systems, and coordinating with communities to increase response capabilities. Higher Education, as a key actor in developing capacity and developing scientific knowledge, has an important role in improving this type of regional cooperation. Some of the key recommendations established through this paper include the following:

Improve capacities for tsunami preparedness

Hazard and risk assessments

1. Increase engagement of other national, regional or international actors in the carrying out of tsunami hazard and risk assessments
2. Increase the availability of publicly accessible data for tsunami hazard and risk assessments
3. Increase the capacity for tsunami hazard assessment, especially in the areas of evacuation mapping, hazard mapping and inundation mapping
4. Capitalise on the existing capacity in Member States for delivering training on hazard mapping and inundation mapping
5. Increase the capacity for city, village and community level tsunami risk assessments
6. Increase the capacity for developing products from tsunami risk assessments, such as risk maps, evacuation maps, guidelines and action plans

Policies, plans and guidelines

7. Provide support to increase availability of tsunami policies, plans and guidelines at the prevention and mitigation, preparedness, and recovery and reconstruction phases of disaster management
8. Provide support to increase availability of tsunami policies, plans and guidelines at the local level, either as standalone or as part of a multi-hazard approach

Detection, warning and dissemination

9. Provide support to increase the capacity for analysing real-time seismic and sea level data for tsunami threat
10. Provide support to increase the capacity for tsunami modelling to support generation of threat forecasts
11. Undertake a further study to examine whether there is a need for so many different software tools to be used to analyse data for tsunami threat or tsunami modelling
12. Increase the frequency of tabletop or similar tsunami warning exercises to review and test SOPs, and reduce the potential for complacency among countries that have not experienced a recent tsunami event

Public awareness, preparedness and response

13. Provide support for countries to improve their SOPs at the interface between upstream and downstream, including the operation of a 24/7 emergency operation centre, receiving information from the NTWC, and response criteria and decision making, as well as the associated human resources and infrastructure

14. Provide support for countries to improve their SOPs to address warning dissemination, communication with the NTWC, communication with other stakeholders, evacuation call procedures, communication with local government and media arrangements, as well as the associated human resources and infrastructure
15. Provide support for the development of community level evacuation SOPs
16. Capitalise on the willingness of countries to share their SOPs to share good practices across Member States

Evacuation infrastructure

17. Provide training and share Member States' experience of different types of evacuation infrastructure

Tsunami exercises

18. Provide support to incorporate tsunami level exercises into cities, villages, communities and schools

Public awareness

19. Provide training and share Member States' experience of different public engagement materials
20. Develop educational materials such as teaching kits, and encourage the incorporation of tsunami awareness into the school curricular
21. Raise awareness of the Global Disaster Risk Reduction Day and Tsunami Awareness Day

Improve capacities for MHEW

22. Significant efforts must be made to assure the adequacy of existing EW and communication of EW to reach "last mile" in the region.
23. Continuously evaluate and monitor the current status of existing early warning systems
24. Develop mechanisms for regional cooperation, including greater knowledge sharing and networking
25. Mainstream early warning into development planning
26. Increase disaster education and awareness raising
27. Develop inclusive and context specific disaster preparedness plans
28. Develop supportive policy and institutional frameworks
29. Develop technological systems for real time monitoring and forecasting
30. Increase multi-stakeholder partnerships, collaboration and networking

Increase engagement of HEIs in capacity development for MHEW

Education

31. HEIs should engage in capacity building among community through education, awareness and training
32. Develop more curriculum that address disaster risk reduction and resilience
33. Understand the needs to employers, including public authorities, NGOs and the private sector, to ensure that programmes for disaster risk reduction meet sector needs
34. Encourage students to conduct research in the area of disaster management, resilience and MHEW to facilitate evidence-based policy making
35. Incentives can be offered to encourage faculty to support capacity-building of stakeholders
36. Encourage the natural curiosity of students towards sciences in the midst of cultural expectations

Knowledge development

37. HEIs should be a place for training and technician incubators on disaster management in Asia
38. Build collaborations between HEIs and governments in conducting applied research
39. Deloading schemes are needed to allow faculty more time for research
40. Encourage relevant research with long term societal impact, fostering reflexive research attitude in young researchers
41. Provide an institutional environment that support trans disciplinary contextual research
42. Formulate and conduct research that integrates aspects such as long-term sustainability and resilience of communities as key focuses

Advocacy

43. Establish communication mechanisms between governments and HEIs to deliver outcome of evidence-based research
44. Create inter-ministerial cooperation
45. Give opportunities to more engage in local processes, as well as in international bodies and technical working groups
46. Academic staff should be trained to work with government organisations that have the specific mandates in the fields of MHEW and disaster resilience
47. Continuous dialogue is required among agencies to encourage better coordination, encouraging and supporting researchers to work with other stakeholders
48. HEIs should not be limited to evidence-based policy making but also need to create industry – HEI linkages for mutual benefits
49. Inter-HEI exchange (national and international) can be used as a way of increasing the role of HEIs in resilience education

1. Introduction

1.1. Aim and Scope of Report

This report is based on the work of CABARET, a project supported by the Erasmus+ Programme of the European Union. The findings are based on a literature review, outcomes of experts' workshops, national position papers, regional literature review and two regional surveys.

The report provides an understanding about the overall disaster status in Asia, the availability of early warning systems for tsunami and multi-hazard, the present status of regional cooperation, and enablers and barriers for an effective MHEW in Asia. In addition, the report considers the role of Higher Education Institutions (HEIs), and their present status in developing effective MHEW in Asia. The report comprises seven sections.

Section 2 presents the conceptual framework developed for the study. The conceptual framework was developed from a literature review and outcomes of workshops conducted with partners and key stakeholders.

Section 3 reports on the results of the ICG/IOTWMS and its "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP), which includes a survey of 20 countries in the Indian Ocean. The CABARET project supported the development and analysis of this regional survey.

Section 4 describes a regional perspective on MHEW, highlighting its relevance in Asia, the present status the current status of regional cooperation. This section is based on literature review and a regional expert survey.

Section 5 provides the basis for the development of effective MHEW in Asia, including enablers, barriers and opportunities. This section is written based on a regional literature review, national position papers from five CABARET partner countries – Indonesia, Maldives, Myanmar, Philippines and Sri Lanka, and the outcomes of workshops and a regional survey with experts, and a regional survey of tsunami preparedness.

Section 6 presents the role of Higher Education Institutions (HEIs) in disaster resilience and specifically in developing MHEW. It considers gaps and challenges faced by HEI in contributing to the development of effective MHEW in Asia.

Section 7 draws together the results from the literature reviews, national position papers and two regional surveys to identify a series of conclusions and recommendations on how to improve capacity for MHEW in Asia.

1.2. Background

When compared to the year 2000, the number of people living in low-elevation, coastal zones are expected to increase from 638 million to one billion by 2050 (Merkens, Reimann, Hinkel, & Vafeidis, 2016). Coastal communities face multiple hazards (Setyono & Yuniartanti, 2016) ranging from slow onset to rapid hazards. These include, among others, tsunami, sea level rise, coastal erosion, oil spills, wind storms, cyclones and flooding (Adger, Hughes, Folke, Carpenter, & Rockström, 2005). Coastal hazards are one of the natural hazards increasingly reported during last couple of decades due to changes of climatic conditions (Mark D Spalding, Susan Ruffo, & Imen Meliane, 2014). Increasing population (Seto, Fragkias, Güneralp, & Reilly, 2011), migration (Hugo, 2011), and diverging socio-economic conditions generate further complexities when dealing with coastal hazards (Mark D Spalding et al., 2014). This is worsened in small islands and tropical developing countries where coastal communities represent the poorest group in the society (Hale et al., 2009).

Of the reported 90 storms in 2015, 43 storms hit Asia and the Pacific region with massive impact on lives and property damages (Dutta & Basnayake, 2018). More than 64% fatalities were reported in Asia and the Pacific region in 2015 (UN-ESCAP, 2015a). For example, Cyclone Giri affected more than 75% of homes in Rakhine state in Myanmar in 2010 (Dutta & Basnayake, 2018). Typhoon Haiyan hit the Philippines on 8th of November 2013 killing more than 6,300 people, injuring more than 28,000 people and affecting more than 16,078,000 people (NDRRMC, 2013). Indian Ocean Tsunami in December 2004 killed more than 230,000 people in 14 countries in Asia and the highest impacts were recorded from Indonesia, Thailand, Sri Lanka and India. More specifically, more than 57% of affected people by coastal hazards were reported in Asia during 1985- 2006 (Zou & Thomalla, 2010). In addition, the latest tsunami incidents in Palu and Sulawesi in Indonesia (CNN, 2018) highlight the increasing frequency of occurrence of coastal hazards in Asia.

The five CABARET partner countries in Asia include communities that are highly exposed and vulnerable to the threat posed by multiple coastal hazards. Myanmar is exposed to a number of natural hazards, some of which have caused devastating damage in the recent past. According to the UN Risk Model, Myanmar ranks as the 'most at risk' country for natural disasters. With its long-awaited political changes and a civil society in need of access to funding, capacity building and technical training, there is an urgent need to develop capacity for disaster preparedness and climate change adaptation in Myanmar. Indonesia is located at one of the most active geological subduction zones in the world and has growing coastal populations. Future tsunamis are likely to occur due to increased tectonic tensions leading to abrupt vertical see floor alterations. Sri Lanka was one of the countries most affected by the 2004 tsunami and coastal erosion has been accelerated due to upstream anthropogenic activities and poorly planned coastal infrastructure development. 80% of the land area of Maldives is less than one meter above sea level and the Maldives identified as one of the most vulnerable countries globally to climate change and sea level rise. As a tropical archipelagic nation, the Philippines is particularly susceptible to coastal hazards, which are being exacerbated by climate change. The 2014 World Risk Report identifies the Philippines as the 3rd most hazard exposed country in the world, and the 2nd most at risk.

Experience over recent years of the impacts of coastal hazards such as tsunamis, storm surges, sea level rise and coastal erosion, has shown that inadequate preparation for, and response to, emergency situations have contributed to widespread damage and the avoidable loss of lives and livelihoods. These hazards set back economic development in both developed and developing economies, and tend to disproportionally affect the most vulnerable in society. The shortcomings in preparation have been due to a lack of warning through poor regional detection and communication systems, but they also reflect inadequate awareness, planning and coordination.

Recent studies and practical experiences of hazards suggest that more attention needs to be paid to the cognitive and normative challenges in positioning early warning systems and preparedness in the wider context of social change in the coastal societies and communities at risk. Better and more innovative platforms for knowledge sharing need to be established to enable stakeholders to collectively negotiate these challenges, to improve the integration of early warning with other priorities such as livelihoods improvement, natural resource management and community development, and to provide opportunities for critical reflection of 'on-the-ground' experiences and lessons learnt.

This situation, together with the increasing globalisation of risk, calls for strengthened MHEW systems at all levels. It also calls for an integrated and holistic approach to early warnings for multiple hazards and risks tailored to user needs across sectors. In this regard, international and regional collaboration as well as multi-stakeholder partnership at all levels is critically necessary, given the transboundary nature of most coastal hazards.

International frameworks have introduced a number of risk reduction strategies and resilience mechanisms emphasising significance and necessity of multi hazard early warning systems (MHEW) (Alfieri, Salamon, Pappenberger, Wetterhall, & Thielen, 2012; Benbrook, Zhao, Yáñez, Davies, & Andrews, 2008; UN-ESCAP, 2015a). The Sendai Framework for Disaster Risk Reduction (SFDRR) (2015-2030) as the leading global risk reduction initiative identifies the importance of MHEW as an effective way of enhancing resilience and reducing disaster risks. Its seventh target emphasises the necessity to substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030 (UNISDR, 2015).

Further, evidences show that MHEW could be more effective when it is integrated within regional and national strategies for enhancing resilience and reducing disaster risks (UN-ESCAP, 2015a, 2015b). As a result, the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) was established to ensure timely issue of early warning in Asia. After the Indian Ocean Tsunami in 2004, tsunami preparedness has become a significant aspect in the research and practice of disaster resilience. It became fully operational in 2013.

Although the development of IOTWMS and other initiatives have been largely successful in promoting regional cooperation to develop technical hazard detection infrastructure for tsunami threat, progress at the national and sub-national level has been far more variable (Intergovernmental Oceanographic Commission, 2015). A review of national report on recent earthquakes and tsunami threat responses, and practice evacuation exercises suggest that uneven progress across the region, with some high-risk, low-capacity countries falling behind. Hence, member countries in the region have been calling for a capacity-building programmes for increasing public awareness and preparedness are considered as urgent need through procedural knowledge transformation (Intergovernmental Oceanographic Commission, 2015).

There remains the significant challenge of building capacity to sustain the achievements to date and continue to enhance the systems now in place, including detection and warning systems, community awareness and preparedness. There is also a need to build capacity to broaden early warning to provide a comprehensive, multi-hazard framework.

1.3. Definitions

Hazards: A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation (UNISDR, 2017).

Disaster Risk Reduction: Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development (UNISDR, 2017).

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).

Multi-Hazard Early Warning: An early warning system is an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events (UNISDR, 2017).

Higher Education Institutions: Higher Education Institutions are referred in the report as institutions that provide higher, post-secondary and tertiary education to students.

Region 06: According to the European Commission, following countries are categorised within the Region 6: Afghanistan, Bangladesh, Bhutan, Cambodia, China, DPR Korea, India, Indonesia, Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam.

Members states of the Indian Ocean Tsunami Warning and Mitigation System: Twenty-eight (28) Member States within and boarding the Indian Ocean: Australia, Bangladesh, Comoros, Djibouti, France (Indian Ocean Territories), India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, Thailand, Timor-Leste, United Arab Emirates, United Kingdom (Indian Ocean Territories) and Yemen.

1.4. Introduction to CABARET

This regional position paper has been developed as part of CABARET (Capacity Building in Asia for Resilience EducaTion), a project co-funded by an EU Erasmus+ programme within the European Union that aims to strengthen research and innovation capacity for the development of societal resilience to disasters. CABARET is providing support to build capacity for international and regional cooperation between HEIs in Asia (region 6) and Europe, and among Asian HEIs themselves, to improve MHEW and increase disaster resilience among coastal communities.

CABARET is addressing the cognitive and normative challenges in positioning early warning and preparedness in the wider trajectories of social change in societies and communities at risk. It is an imperative to take an integrated and holistic approach to early warnings for multiple hazards and risks tailored to user needs across sectors.

The new UN Sendai Framework for Disaster Risk Reduction, agreed by member states in 2015, includes a strong call for higher education to support the understanding of disaster risk and promote risk-informed decisions and risk sensitive planning from local to global levels. Researchers and academics, therefore, must work at the regional level, and with policy makers and practitioners to co-design and co-produce research that can be used effectively. Higher education must also play a vital role in translating that research into action through its educational programmes. Capacity should be developed through scientific research and development of knowledge bases as well as through education and training.

CABARET runs for three years, from October 2016 to October 2019. The project is led by the University of Huddersfield's Global Disaster Resilience Centre (GDRC), based in the United Kingdom. They are joined by a consortium of 15 European and Asian HIEs from Bulgaria, Indonesia, Latvia, Maldives, Malta, Myanmar, Philippines, Spain, Sri Lanka and the UK. Further the project works with 3 associate partners of Asian Disaster Preparedness Centre (ADPC), IOC/UNESCO and the Federation of the Local Governments Association in Sri Lanka (FSLGA).

The project sets out to identify research and innovative capacity needs across Asian HEIs in Indonesia, Maldives, Myanmar, Philippine and Sri Lanka, and to build capacity to broaden early warning to provide a comprehensive, multi-hazard framework. This regional paper sets out a clear statement on those research and innovative capacity needs.

1.5. Methodology

In order to inform the workplan and capacity building of CABARET, several tasks were carried out during the first 18 months of the project.

An initial literature review considered 16 peer reviewed journal articles, 16 official reports, and 10 official websites. The findings of this review informed an initial conceptual framework.

In addition, several workshops have been conducted with experts and project partners. Outputs of these workshops are reflected in this report. These workshops were convened in parallel to project meetings held in Sri Lanka and Spain. At these workshops, the initial conceptual framework and its elements were discussed in detail. These helped in the finalisation of the conceptual framework and preparation of data collection instruments for national and regional surveys.

Each partner country produced a national position paper to reflect MHEW status and the role of HEIs. These reflected national perspective. Research teams conducted interviews and focus group discussions at national level based on the guidelines given to partners to assure consistency in data collection. In total, 81 interviews and 4 focus group discussions were carried out by partners from Indonesia, Maldives, Myanmar, the Philippines and Sri Lanka.

In addition, a regional level literature review was conducted to better understand the present the status of MHEW in Asia, to identify any enablers and barriers for the development of MHEW, and the role of HEIs in disaster resilience. Further, it aimed at evaluating the status of international and regional cooperation among HEIs. The regional literature review was conducted using scientific peer reviewed journal papers, books, official reports and official web sites published by international and national agencies relating to multi-hazard early warnings.

A regional survey was launched as a questionnaire survey using Survey Monkey instrument. The survey was carried out during July- October 2017 as an online survey. The survey was circulated among practitioners, policy makers, academics and experts who are interested in MHEW in Asia. 199 responses were collected by launching the survey and only 136 completed responses were used in final analysis. Data were analysed qualitatively and quantitatively and presented in the forms of tables and graphs. Further information about the survey methodology can be found in Annex 1.

In addition, in 2018, the CABARET project team, through its partners Dr Harkunti Rahayu, Professor Richard Haigh and Professor Dilanthi Amaratunga, were invited to support the ICG/IOTWMS and its “Task Team on Capacity Assessment of Tsunami Preparedness” (TT-CATP). Section 4 of this reproduces the report prepared by the Task Team and published in 2019, including the key findings on the capacity of tsunami preparedness in the Indian Ocean. Details of the methodology underpinning the survey are provided in section 3.1.

2. Conceptual Framework of Capacity Building for MHEW

Figure 1 illustrates the conceptual framework that underpins the CABARET project. Findings from literature review and opinions of partners and stakeholders through a consultative process, provided the basis for developing the final conceptual framework (Haigh, Amartunga, & Hemachandra, 2018).

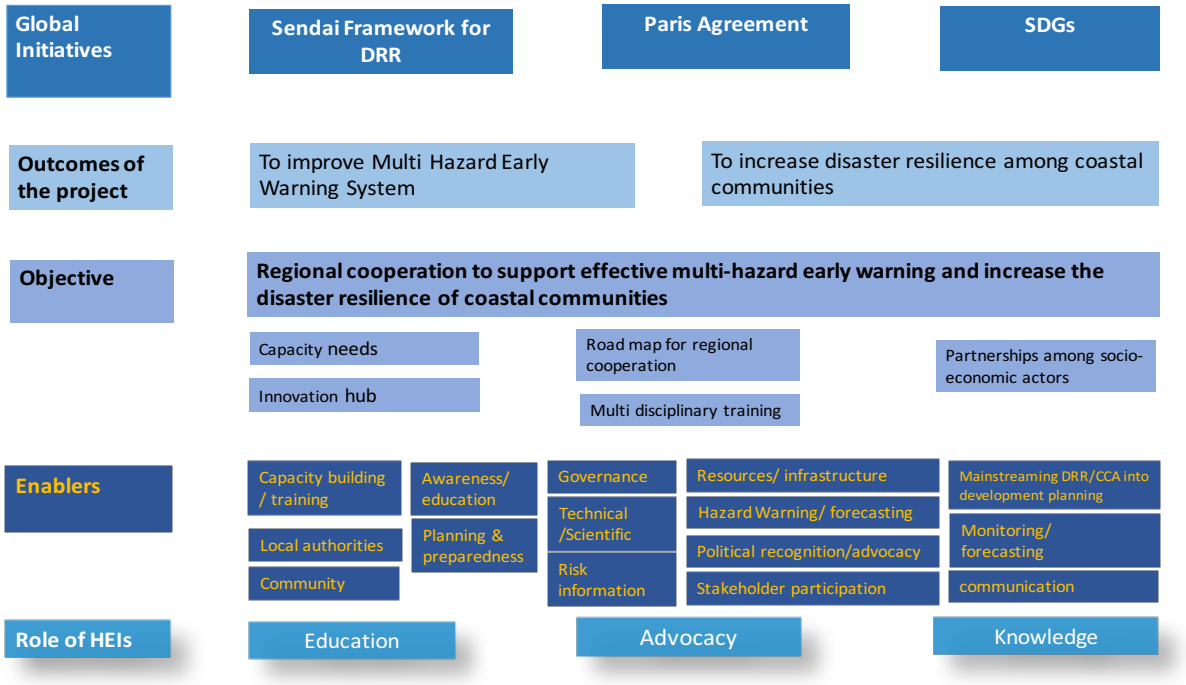

Figure 1: Conceptual framework to describe how could HEIs contribute to achieve global initiatives through the development of effective MHEW

2.1. Global initiatives

Global, national and local efforts to reduce disaster risks and climate change risks have co-existed in recent years but there has been rising attention to the relationship between climate change adaptation and disaster risk reduction. There are substantial similarities in the types of interventions needed to reduce both kinds of risks and there is considerable opportunity for mutual learning.

Climate-related disasters have also become a rallying point in the international climate negotiations – a tangible, immediate reason to push for more ambitious climate action. The relationship between climate change and disaster risk – and between strategies to address them – have become a very timely and policy-relevant issue.

Background to the post-2015 development agenda

When they were introduced, the Millennium Development Goals (MDGs) were the most widely supported and focused poverty reduction targets established on a global scale. Eight goals were signed up to by 191 nations in 2000. They included 18 targets and 48 indicators for progress.

When the world community signed up to the Millennium Development Goals (MDGs) in 2000, disaster risk reduction was not included in strategies of their attainment. Although the Millennium Declaration did recognise that disasters can jeopardise development and included a commitment 'to intensify our collective efforts to reduce the number and effects of natural and man-made disasters' in the General Assembly Resolution, disaster risk was not subsequently taken into account in formulation of the goals and indicators.

In January 2005 and following the devastation caused by the 2004 Indian Ocean Tsunami, at the World Conference on Disaster Reduction, in Kobe, Japan, 168 Governments adopted a 10-year plan to make the world safer from disasters. The Hyogo Framework for Action, had as its key goal the substantial reduction of disaster losses by 2015 in lives and the social, economic and environmental assets of communities and countries.

The Framework offered guiding principles, priorities for action and practical means for achieving disaster resilience for vulnerable communities. It became increasingly clear that disasters are one of the key factors holding back progress towards halving poverty and the other MDGs. As donor governments and the international community increasingly focused their work through the prism of attainment of the MDGs there was a need to pull together the various attempts which have been made to integrate disaster risk reduction into a common set of assessment guidelines which can be used by national governments.

Various reviews of the HFA were carried out during its implementation. They found that progress in DRR was occurring, especially institutionally in the passing of national legislation, establishing of early warning systems, and strengthening disaster preparedness and response. However, they also raised concerns about:

1. the lack of systematic multi-hazards risk assessments and early warning systems factoring in social and economic vulnerabilities
2. the poor integration of DRR into sustainable development policies and planning at national and international levels
3. the insufficient level of implementation of the HFA at the local level.

Specifically, the reviews tended to highlight the need to integrate climate change adaptation and DRR at the national and local levels through integrated plans to enhance resilience of communities. They also recognised that guidance alone is not sufficient and that standards to ensure quality in the delivery of the guidance are necessary.

The final review recommended the development of a joint action plan to help generate and crystallise such coherence. On a post-2015 framework for DRR, the review examined the pros and cons of a legally-binding agreement, and how it would work.

Sendai Framework for Disaster Risk Reduction

The Sendai Framework is a 15-year, voluntary, non-binding agreement which recognises that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders. It aims for the following outcome:

The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.

The Sendai Framework is the successor instrument to the HFA. It is the outcome of stakeholder consultations initiated in March 2012 and inter-governmental negotiations held from July 2014 to March 2015.

The Framework included seven global targets:

a) Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015.

b) Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020 -2030 compared to the period 2005-2015.

c) Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.

d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.

e) Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.

f) Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.

g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

It also included four priorities for action:

Priority 1. Understanding disaster risk

Priority 2. Strengthening disaster risk governance to manage disaster risk

Priority 3. Investing in disaster risk reduction for resilience

Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

The Sendai Framework has some significant differences to its predecessor agreement. The Sendai Framework focuses on disaster risks while the HFA focuses on disaster losses. In addition, the Sendai Framework focus more on "the how" while the HFA focus more on "the what". It also adds man-made hazards, as well as biological hazards and increases the scope of action in recovery, rehabilitation and reconstruction, as compared to the HFA.

2030 Agenda for Sustainable Development

The Transforming Our World: The 2030 Agenda for Sustainable Development outcome document recognises and reaffirms the importance of reducing the risk of disasters in the future. There are three types of links or recognition of disaster risk reduction in the outcome document. The first are direct references to the outcomes of the Third UN World Conference on Disaster Risk Reduction and the Sendai Framework for Disaster Risk Reduction 2015-2030. The second are where reducing the risk of disasters will be highly relevant and critical to the achievement of the goal or target, for example in reducing exposure and vulnerability of the poor to disasters or building resilient infrastructure. The third are goals and targets that are highly conducive to a disaster risk reduction approach.

The Transforming Our World: The 2030 Agenda for Sustainable Development outcome document can be viewed through the lens of disaster risk reduction. These include the following direct and highly relevant references to disaster risk reduction:

The outcome document highlights the drivers of disaster risk including gaps in governance, urbanisation, the impact of poor management of natural resources and ecosystems, as well as poverty and the implications of climate change. In paragraph 14 of the outcome document, the challenge "more frequent and intense natural disasters" present to sustainable development is clearly underscored. The Transforming Our World agenda further outlines the underlying principles and the major policy shifts required to support the implementation of the SDGs, specifically calling for application of technology that is climate-sensitive and resilient, safe and resilient human habitats, and the promotion of resilience and disaster risk reduction.

There are multiple targets on disaster risk reduction and resilience in the Transforming Our World: The 2030 Agenda for Sustainable Development outcome document. These focus on poverty eradication; strengthening resilience of sectors such as agriculture, education, and infrastructure; reducing mortality and economic losses from disasters; and enhanced planning around resilience and adaptation.

- SDG 1 calls for an end to poverty in all its forms everywhere and recognizes that reducing exposure and vulnerability of the poor to disasters is essential for sustainable poverty eradication (target 1.5).
- SDG 4 on quality education promotes safe learning environments (target 4.a) which echoes the Sendai Framework call for resilience and safety of schools to be strengthened in structural and non-structural ways.

- SDG 9 focuses on building resilient infrastructure with target 9.1 specifically asks to develop quality, reliable, sustainable and resilient infrastructure. Target 9.a aligns one of the targets of the Sendai Framework on the substantial reduction of disaster damage to, and strengthening of, critical infrastructure.
- SDG 11 on inclusive, safe, resilient and sustainable cities and human settlements has explicit links are seen with the Sendai Framework targets. Target 11.5 calls for reducing the "number of deaths" and "direct economic losses relative to global GDP" caused by disasters, which align directly with the global targets (a), (b) and (c) of the Sendai Framework. Target 11.b calls for an increase in the number of cities and human habitats with integrated plans on inclusion, resource efficiency, adaptation to climate change and resilience to disasters "in line with the Sendai Framework for Disaster Risk Reduction 2015-2030", calling for aligned implementation on the ground. Other targets under this goal promote enhanced urban planning and upgrading of slums, which also tackle key risk drivers for disaster losses.
- SDG 13 is on combating climate change and where all the targets can be linked to the Sendai Framework, for example target 13.1 which calls for strengthening resilience and adaptive capacity to disasters.
- Finally, SDG 15 aims to protect, restore and promote sustainable use of terrestrial ecosystems. The goal reinforces the need to protect the ecosystem services which includes vital hazard regulating services. The goal specifically calls for efforts to combat desertification and restore land affected by drought and floods. This is closely aligned with the goals and ecosystem-related priorities of the Sendai Framework and reinforces the linkages with related international decisions on ecosystems and disaster risk.

Other targets in the Transforming our World, including those on health and water management, also relate to disaster risk reduction by virtue of promoting the principle of early warning and addressing disaster risk drivers, and aiming to reduce vulnerability and/or exposure of people and planet to hazards.

Despite these clear alignments to DRR, the SDGs have been criticised for being inconsistent, difficult to quantify, implement and monitor. Some analysis suggests that there exists a potential inconsistency in the SDGs, particularly between the socio-economic development and the environmental sustainability goals. Critiques also raise questions on the measurability and monitoring of the broadly framed SDGs. The goals are non-binding, with each country being expected to create their own national or regional plans. Moreover, the source(s) and the extent of the financial resources and investments for the SDGs are ambiguous.

Paris Agreement on Climate Change

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016. The agreement's language was negotiated by representatives of 196 state parties at the 21st Conference of the Parties of the UNFCCC in Le Bourget, near Paris, France, and adopted by consensus on 12 December 2015. As of November 2019, 195 UNFCCC members have signed the agreement, and 187 have become party to it.

The Paris Agreement addresses crucial areas necessary to combat climate change. Some of the key aspects of the Agreement are set out below:

Long-term temperature goal (Art. 2) – The Paris Agreement, in seeking to strengthen the global response to climate change, reaffirms the goal of limiting global temperature increase to well below 2 degrees Celsius, while pursuing efforts to limit the increase to 1.5 degrees.

Global peaking and 'climate neutrality' (Art. 4) –To achieve this temperature goal, Parties aim to reach global peaking of greenhouse gas emissions (GHGs) as soon as possible, recognising peaking will take longer for developing country Parties, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of the century.

Mitigation (Art. 4) – The Paris Agreement establishes binding commitments by all Parties to prepare, communicate and maintain a nationally determined contribution (NDC) and to pursue domestic measures

to achieve them. It also prescribes that Parties shall communicate their NDCs every 5 years and provide information necessary for clarity and transparency.

Voluntary cooperation/Market- and non-market-based approaches (Art. 6) – The Paris Agreement recognises the possibility of voluntary cooperation among Parties to allow for higher ambition and sets out principles – including environmental integrity, transparency and robust accounting – for any cooperation that involves internationally transferal of mitigation outcomes. It establishes a mechanism to contribute to the mitigation of GHG emissions and support sustainable development, and defines a framework for non-market approaches to sustainable development.

Adaptation (Art. 7) – The Paris Agreement establishes a global goal on adaptation – of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change in the context of the temperature goal of the Agreement. It aims to significantly strengthen national adaptation efforts, including through support and international cooperation. It recognizes that adaptation is a global challenge faced by all. All Parties should engage in adaptation, including by formulating and implementing National Adaptation Plans, and should submit and periodically update an adaptation communication describing their priorities, needs, plans and actions. The adaptation efforts of developing countries should be recognized

Loss and damage (Art. 8) – The Paris Agreement recognises the importance of averting, minimising and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. Parties are to enhance understanding, action and support, including through the Warsaw International Mechanism, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change.

Finance, technology and capacity-building support (Art. 9, 10 and 11) – The Paris Agreement reaffirms the obligations of developed countries to support the efforts of developing country Parties to build clean, climate-resilient futures, while for the first time encouraging voluntary contributions by other Parties. Provision of resources should also aim to achieve a balance between adaptation and mitigation.

Climate change education, training, public awareness, public participation and public access to information (Art 12) is also to be enhanced under the Agreement.

Transparency (Art. 13), implementation and compliance (Art. 15) – The Paris Agreement relies on a robust transparency and accounting system to provide clarity on action and support by Parties, with flexibility for their differing capabilities of Parties.

Global Stocktake (Art. 14) – A “global stocktake”, to take place in 2023 and every 5 years thereafter, will assess collective progress toward achieving the purpose of the Agreement in a comprehensive and facilitative manner. It will be based on the best available science and its long-term global goal. Its outcome will inform Parties in updating and enhancing their actions and support and enhancing international cooperation on climate action.

Mitigation of climate change by cutting emissions could be seen as the ultimate form of disaster risk reduction as it prevents the creation of new risk while also trying to reduce the stock of existing levels of risk. However, in a world that has already warmed by over 1°C on average, where sea-levels are rising and Arctic Sea ice and glaciers are disappearing, adapting to the impacts of climate change to reduce disaster risk will be essential regardless of efforts to cut emissions.

The interlocking nature of all risk drivers is evident in the Sendai Framework for Disaster Risk Reduction. It calls for more dedicated action to tackle underlying disaster risk drivers, including climate change and variability.

Likewise, the Paris Agreement has specific mention of the Sendai Framework in the preamble of the agreement, and the focus in Articles 7 and 8 on strengthening resilience and reducing vulnerability to climate change in language that resonates with the goals of the Sendai Framework to reduce both risk and disaster losses.

Specifically, the Sendai Framework seeks a substantial increase in the number of countries with national and local disaster risk reduction strategies by 2020. This links closely with the tasks set out in Article 7 of the Paris Agreement, particularly the formulation of "nationally determined prioritised actions, taking into account vulnerable people, places and ecosystems".

The Sendai Framework also calls for a substantial increase in the availability of, and access to, multi-hazard early warning systems and disaster risk information by 2030, an activity mentioned in Article 8 of the Paris Agreement which also references the resilience of communities, livelihoods and ecosystems.

Despite these efforts and the Paris Agreement in 2015, there have been significant challenges during implementation. 195 out of 197 parties originally approved the Agreement. Syria didn't sign because it was at war and therefore unable to attend the negotiations. Nicaragua was the only party in attendance that didn't sign as it deemed it a weak and unfair deal.

158 parties went on to ratify the deal and commit to its goals. Members include the UK, EU, China and India. The US ratified it but in 2019 initiated the process of leaving the Paris climate agreement, citing that it would undermine the US economy.

Other critics have highlighted that it is a voluntary agreement and countries must take necessary efforts – but there is no obligation to keep global warming below 1.5°C, or even 2°C. Many developing countries also require significant financial and technological support to cut their emissions, but there is limited support being provided by developed economies.

The COP25 summit in Madrid, held in November 2019, highlighted further problems. The UN Environment Programme's (UNEP) own emissions gap report, released just prior to the COP, showed the stretch 1.5C goal of the Paris Agreement was "slipping out of reach". Even if existing climate pledges – countries' Nationally Determined Contributions, or NDCs – are met, emissions in 2030 will be 38% higher than required to meet that target, the report concluded. The talks were also unable to reach consensus in many areas, pushing decisions into 2020 under "Rule 16" of the UN climate process. Matters including Article 6, reporting requirements for transparency and "common timeframes" for climate pledges were all pushed back into 2020, when countries are also due to raise the ambition of their efforts.

Links to the urban development agenda

The New Urban Agenda is a 20-year global blueprint adopted by United Nations Conference on Housing and Sustainable Urban Development or Habitat III, which closed in Quito, Ecuador, in October 2016. Among other components, it called for exploring and developing feasible solutions for climate and disaster risks in cities and human settlements. It was preceded by the establishment of the first urban SDG, known as SDG11. SDG11's definition is to 'make cities inclusive, safe, resilient and sustainable'.

In 2017, 54% of the world's population lived in urban areas and that proportion is expected to increase to 66% by 2050. There is now a consensus about the importance, perhaps even the centrality, of urban processes to securing sustainable futures in a range of fields including climate change, economic growth, poverty eradication, public health and food security. The assertion of a "new urban agenda" in global policy reflects a long campaign to locate cities at the centre of development debates.

Urbanisation has been a normal part of growth and expedites economic development. but it also brings challenges that need examination and treatment. Some of the crucial challenges include insufficient urban services, ageing infrastructure, informal settlements, poverty, increasing inequality, resource scarcity, social insecurity and environmental degradation.

The New Urban Agenda envisions an urban paradigm shift in which cities and human settlements must be for everyone. This means equal rights, the right to adequate housing and fundamental freedoms, along with functional social and civic systems, with participatory access. Gender equality, accessible urban mobility for all, disaster management and resilience, and sustainable consumption are envisaged.

Leaders committed to:

- Provide basic services for all citizens
- Ensure that all citizens have access to equal opportunities and face no discrimination
- Promote measures that support cleaner cities
- Strengthen resilience in cities to reduce the risk and the impact of disasters
- Take action to address climate change by reducing their greenhouse gas emissions
- Fully respect the rights of refugees, migrants and internally displaced persons regardless of their migration status
- Improve connectivity and support innovative and green initiatives
- Promote safe, accessible and green public spaces

When developing the agenda, it was anticipated that for implementation, it would require new urban rules and regulations, improved urban planning and design, and municipal finance, among other things. Long-term, integrated urban planning and design, and sustainable financing frameworks and the cooperation of all levels of government, with the participation of civil society and stakeholders, are some of the key components of the New Urban Agenda.

The New Urban Agenda has multiple connections beyond itself and contributes directly to achieving the targets set out in the Sustainable Development Goals, Paris agreement, Sendai Framework for Disaster Risk Reduction, Addis Ababa Action Agenda and several other international frameworks and agreements.

The New Urban Agenda has been receiving positive investment and funds, such as the Green Climate Fund, the Global Environment Facility and the Adaptation Fund, which are facilitating investments in urban development projects. Large financial institutions like the African Development Bank, the Asian Development Bank (ADB), the Inter-American Development Bank and the World Bank have shown keen interest and support for developing financial frameworks for investments in cities.

Though multiple cases suggest evidence of decent progress, there are still implementation challenges that have limited the uniform adoption of the New Urban Agenda. Studies have reported:

- A lack of measurable indicators
- Inadequate national and local capabilities
- Weak institutional frameworks, decision-making, and regulations
- Insufficient local ownership, authority and decision-making power
- Limited private sector engagement

These findings suggest that further work is needed, especially in building internal and external capabilities, institutional frameworks, collaborations and defining uniform data collection processes and methods.

Convergence of disaster risk reduction, climate change and development

In responding to the Sendai Framework and other post-2015 development agreements, including their calls for enhanced multi-hazard early warning, this paper describes the results of the first stage of a longer-term study into the capacity of MHEW across Asia. The first phase of the study involved the development of a regional capacity analysis framework for MHEW. The framework covers a range of dimensions, such as legislative, planning, infrastructure, technical and scientific, and institutional partnerships. The framework was developed through the processes of consultation and needs assessments by the project partners and relevant socio-economic actors.

Development faces a growing threat from a changing climate – particularly through the impact of more extreme events. The Organisation for Economic Co-operation and Development (OECD) estimates show that up to 50% of development assistance may be at risk because of climate change. In managing such risks to development, there is significant overlap between disaster risk reduction (DRR) and climate change adaptation (adaptation). However, these agendas have tended to evolve independently.

DRR can deal with current climate variability and be the first line defence against climate change, being therefore an essential part of adaptation. Conversely, for DRR to be successful, it needs to take account of

the shifting risks associated with climate change and ensure that measures do not increase vulnerability to climate change in the medium to long-term.

Many previous studies have revealed limited integration of DRR and adaptation despite the two agendas sharing similar goals and conceptual overlaps, and both struggling to be mainstreamed into regular development planning. At stake is policy coherence and effective use of resources, as studies show that continued separation results in administrative inefficiencies, duplication of efforts and damaging competition between different inter-sectoral coordination mechanisms.

For both adaptation and DRR, effective development planning and programming are essential. Managing risks and uncertainties for all shocks and stresses supports sustainable development, particularly in the face of mounting evidence that disasters are hampering development and poverty alleviation.

On the other hand, as experience has shown, neither adaptation nor DRR will happen naturally. There is often little political will or financial incentive to invest resources to ensure that something does not happen, rather than investing in visible infrastructure or social programs. The incentives are even more skewed given that the donor community provides generous humanitarian assistance after a disaster but largely fails to provide similar support for risk reduction. Attention to incentives, institutions and instruments to promote good risk-aware development is urgently needed.

However, both agendas suffer from a lack of political influence and human capacity to raise the profile of risk management in mainstream development planning and practice. In developing countries, adaptation and DRR typically have separate institutional “homes”, often ministries of environment for adaptation and ministries of the interior or similar agencies for DRR, each with their own intersectoral coordination groups, each with their own channels of funding, and each with separate entry points in the different international agreements described in earlier sections of this unit.

While sharing very similar objectives, and similar challenges in raising the profile of their agendas, they typically fail to coordinate among themselves. Such duplication of efforts, administrative inefficiencies, and even competition among various groups not only hampers DRR and adaptation efforts but compromises the overall effective use of resources.

At a more technical level, the growing climate change efforts may waste time and impact reinventing the wheel if they neglect existing experience, methods and tools developed for DRR. On the other hand, efforts on DRR that do not take account of changing hazards may not only fail to achieve their objectives, but even increase vulnerability, for instance when flood defences provide a false sense of security but will fail to provide lasting protection against rising flood risk.

2.2. Outcomes and objectives of the project

Building more resilient coastal communities is increasingly complex, demanding an ever-widening range of skills and input from diverse disciplines. Often, no single individual, institution or discipline will possess all the knowledge, skills and techniques required. This is a strategic partnership, sharing the mission to play a leading role in shaping preparedness and early warning systems to develop increased resilience among coastal communities.

Disasters hold back development and progress towards the Sustainable Development Goals and have macroeconomic impacts when the infrastructure, productive capital and stocks are damaged, creating long term effects on livelihoods and putting the poorest into poverty. The shortcomings in preparation have been due to a lack of warning through poor regional detection and communication systems, but they also reflect inadequate awareness, planning and coordination.

The CABARET project directly addresses some of the challenges set out by the United Nations Economic and Social Commission for Asia and the Pacific, which stresses the importance of a regional approach. Progress in MHEW is uneven across the Asian region, with some high-risk, low-capacity countries falling behind. There is also uneven progress by hazard type and subregion. CABARET focuses regional MHEW systems as an effective means of addressing many of the gaps identified above, in particular in sharing scientific knowledge and applications, building capacity, and addressing transboundary disasters.

It addresses the cognitive and normative challenges in positioning early warning and preparedness in the wider trajectories of social change in societies and communities at risk.

It is an imperative to take an integrated and holistic approach to early warnings for multiple hazards and risks tailored to user needs across sectors. In this regard, international and regional collaboration as well as multi-stakeholder partnership at all levels is critically necessary, given the transboundary nature of most natural hazards. CABARET is innovative through contributing to the development of a prominent "voice" for early warning at the international level that could raise the visibility and advance the agenda of MHEW regionally worldwide and advocate the usefulness of MHEW in international platforms and among key stakeholders, including donors, and across all sectors. It will develop regional innovation infrastructure to promote scientific cooperation and knowledge transfer.

Planned outcomes

CABARET aims to promote international cooperation at the regional level, between Higher Education Institutes (HEIs) in Asia (region 6) and Europe, and among Asian HEIs themselves, to improve multi-hazard early warning and increase resilience among coastal communities. It will build capacity, foster regional integration and cooperation through joint initiatives, sharing of good practices and cooperation among HEIs in Asia and Europe. CABARET will strengthen relations between HEIs and the wider economic and social environment through its focus on coastal communities, many of which are under severe pressure resulting from planned and unplanned development, population growth and human induced vulnerability, coastal hazards with increasing frequency and magnitude, and the impacts of global climate change.

CABARET will enhance regional and transboundary cooperation for MHEW, and empower individuals and organisations with the skills, competencies and credentials needed to promote and sustain regional cooperation within Asia and Europe, and within Asia itself, aimed at reducing the likelihood and impact of disasters in coastal communities. It will enhance the capacities of the partner HEIs in Asia to meet (match) the challenges and specific needs of the wider economic and social environment - strengthening the internationalisation of HEIs and their capacity to network effectively in research, scientific and technological innovation, faciliate the exchange of experience and practice despite of diversity, and increase the ability of partner HEIs in Asia to build relationships with relevant socio-economic actors. It will also provide a set of multi-disciplinary training courses tailored for rapid skill (knowledge, qualifications,) acquisition for professional teams involved in multi-hazard early warning.

Objectives of the capacity building

CABARET will achieve this by: 1) identifying intra and inter regional cooperation capacity needs across partner country HEIs for the development of more effective MHEW; 2) creating an innovation hub for resilient coastal communtities, promoting scientific cooperation and knowledge transfer in Higher Education within Asia, and between Asia and Europe on MHEW; 3) developing a capacity building roadmap to address regional gaps and priorities; 4) exploring, promoting and initiating opportunities for fruitful university partnerships with socio-economic actors in coastal communities; 5) developing innovative multi-disciplinary training courses tailored for rapid skill (knowledge, qualifications,) acquisition for professional teams involved in multi-hazard early warning at the national and regional level.

In order to support the achievement of objectives 1)identifying intra and inter regional cooperation capacity needs), sections 3 and 4 of this report examine the current status of capacity for tsunami and multi-hazard early warning in Asia.

2.3. Enablers

In supporting the achievement of the project outcomes, the project team carried out a literature review to better understand the enablers to develop capacity for multi-hazard early warning that can increase disaster resilience for coastal communities. The literature review was based on 16 peer reviewed journal articles, 16 official reports and 10 official websites. This is complemented with partners' views through

consultative process with 16 Asian experts representing Indonesia, Maldives, Myanmar, Philippines and Sri Lanka and 9 European experts representing Bulgaria, Latvia, Malta, Spain and the UK.

Based on the literature review and the consultative process with the partners and stakeholders, 15 enablers were identified: capacity building/ training, governance, communication, local authorities, education and awareness, planning and preparedness, technical and scientific, resources and infrastructure, hazard warning and forecasting, political recognition, stakeholder participation, mainstreaming DRR/CCA into development planning, and hazard monitoring.

This literature review is documented in a paper published by members of the project team (Haigh, et al, 2018).

2.4. Role of Higher Education Institutes

The role of Higher Education in supporting capacity building for disaster resilience has been explored in previous projects led by members of the CABARET project team, including ANDROID (Amaratunga, et al, 2015) and CADRE (Amaratunga et al 2017), and which informed the key elements of this conceptual framework: education, knowledge development, and advocacy. The ANDROID disaster resilience network was established in 2011 (Academic Network for Disaster Resilience to Optimise EducatIonal Development). The network was set up to promote co-operation and innovation among European Higher Education and in doing so, to increase society's resilience to disasters of human and natural origin. An underlying tenet of ANDROID was that higher education should be more innovative, providing opportunities to work in close collaboration with industry, communities, humanitarian agencies, private sectors and other higher education institutions. Several partners in CABARET were members of the ANDROID network. A summary of the key issues to emerge is discussed in this section. These are further explored in the context of multi-hazard early warning and coastal resilience, in section 6.

Capacity development

The concept of capacity building or capacity development appeared in the late 1980s and became deeply entrenched within the development agenda in the 1990s. Rather than representing a new idea, it reflected growing criticism of many development assistance programmes. In contrast to this extraneous approach, it emphasised the need to build development on indigenous resources, ownership and leadership and by bringing human resources development to the fore.

The concept of capacity development was therefore a move away from 'aid' or 'assistance' towards a 'help yourself' approach that was designed to prevent a dependency on aid emerging.

Capacity development is based on learning and acquisition of skills and resources among individuals and organisations. While this process may rely on some imported resources, external capacity is seen as a knowledge-sharing device, which allows the strengthening and developing of the local capacity. As such, it relates closely to some definitions of resilience, which stress the objective is to build resilience by maximising the capacity to adapt to complex situations, and whereby resilience describes an active process of self-righting, learned resourcefulness and growth.

Capacity development is committed to sustainable development, to a long rather than short term perspective, and attempts to overcome the shortcomings of traditional donor- led projects that have been prevalent in many pre- and post-disaster projects and — typically criticised for being too short-term rather than sustainable, and not always addressing the needs of the recipients. Development within a capacity building context allows communities and countries to identify their own needs, and design and implement the best resilience building strategy within the local context. As a process, it builds on monitoring and evaluation in order to identify existing capacities, deficiencies and the progress and achievements of development towards resilience.

According to capacity development principles ownership of disaster risk reduction and reconstruction projects is transferred from the donor to the recipient community. For this reason, capacity development is not necessarily linked to development aid but can also describe a community or country's effort to meet their resilience building goals regardless of external assistance.

Education

At the individual level, capacity building refers to the acquisition of skills, through formal education or other forms of learning. Although skills and knowledge can be acquired in various settings, formal education systems play a paramount role in this connection.

At the organisational level, capacity building focuses on infrastructure and institution building, the availability of resources and the efficiency of processes and management to achieve effective and quality results within existing infrastructures. In education, this level signifies the improvement of domestic educational resources and a better use of those already available. institutions, e.g. universities, through additional

At the sector/network level, capacity building seeks to enhance the consistency of sector policies and promote a better co-ordination between organisations. In education, capacity building could for example aim at improving links between vocational and academic educational institutions, between research-intensive and teaching-only institutions or to improve the co-ordination of institutions across different academic fields.

In general, the higher education sector plays a significant role in any capacity development strategy. The ultimate goal of a capacity development strategy is to achieve progress and development. Higher education has a unique privilege as a built-in feature of any capacity development strategy. Whatever the sector, including those engaged with disaster risk reduction and reconstruction, capacity building relies on the strengthening of individual capacity through training and learning, in order to raise the domestic or regional stock of human capital in a specific field. This can be done by setting up specific educational programmes in the formal education system or by other forms of learning. Although some of the necessary skills would typically be acquired on-the-job or through learning-by-doing, countries characterised by less efficient organisations of work or by obsolete technologies might need to rely more on formal vocational education and training. What level of education (primary, secondary or tertiary) is required to achieve this goal depends on the kind of competence to be built? Post-secondary education, including degree-granting tertiary education, is certainly important for developing capacity in building resilience to disasters due to the complexity of the associated challenges.

The ANDROID project identified some key changes in education that are required. There is an expanding field of disaster management, but simultaneously, a lack of young professionals with appropriate skills and knowledge to support the building of resilience within relevant stakeholders. There is a need to maintain and expand the network of key persons, including change agents and facilitators.

ANDROID's survey on education supply and demand found that despite considerable need for programmes to support the building of resilience, there is currently a lack of programmes that meet employer needs. It also found that the availability of programmes differed greatly across Europe, and that most programmes are recent developments, with very few having been in operation for over 5 years. This emphasises the immaturity of the discipline and the needs for further studies to better understand market needs.

Higher education within Europe must develop flexible and customised programmes and curricular, whether a module in regular Masters or Undergraduate curriculum, or as dedicated postgraduate programmes. Detailed market research is required to understand the need and interest in potential students, with clear linkages to future job markets. This will help to ensure that educational programme address the problems from the field and can promote affordable solutions, as per local context, including the cultural calibration of technology. Educational programmes should promote a multi-disciplinary approach and understanding, drawing upon a combination of different faculty.

The problem-based nature of the field determines that programmes should offer an appropriate balance of theory and field experiences. Internship programmes for students in government, NGOs, UN agencies, private sectors, research institutions should be strongly promoted.

At the same time, the pace of scientific discoveries demands that programmes are research linked to ensure that what is being taught by higher education is consistent with the state of the art. Improving the link between research, education and action will require the transfer of research knowledge into teaching but also recognising that the research and teaching link as a two-way knowledge transfer process. In a

'knowledge society' all graduates have to be researchers. Not only are they engaged in production of knowledge; they must also be educated to cope with risks and uncertainties generated by the advance of science.

Higher education programmes and research training must also develop the skills to shift perspectives easily, and continually see things in new ways. Researchers and students must be comfortable with multiple languages and a variety of ontologies, epistemologies, methods, tools, and theoretical perspectives, and shift easily among them.

Knowledge development

The Sendai Framework for Disaster Risk Reduction 2015-2030 aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health, and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries over the next 15 years.

It has been recognised that the success of this post-2015 framework hinges on creating and implementing policies that are built on the best available knowledge.

Higher education has a vital role in supporting this move to a more disaster resilient society by 2030. The previously published ANDROID project roadmap considered the challenges and opportunities that must be addressed by higher education in Europe if it to effectively support Sendai Framework for Disaster Risk Reduction 2015-2030.

The prime focus must be that the policy-science gap is closed with research that can be translated to action. Research studies document a trend of increasing disaster losses, but the translation of research findings into practical actions has proven difficult and remains a barrier that prevents the best use of science.

There remains a recognised need for higher education, through researchers and educators, to provide and communicate actionable knowledge with explicit links to inform effective, evidence-based decision-making.

ANDROID established that future knowledge development will require new approaches and partnerships. Higher education will need to develop multi-actor and multi-sector alliances to tackle the type of emerging priorities in areas such as understanding disaster risk, governance arrangements, investment decisions, preparedness, and rehabilitation and reconstruction.

These alliances will support the development of problem-based education and research programmes, and thereby help to create and implement evidence based, resilience building policies and practices.

An all-hazard, problem-focused approach should be used in resilience building research and education to address the complexity of disaster risk. This will require collaboration and communication across the scientific disciplines. Higher education can promote this approach by providing researchers and students with:

- Exposure to a variety of disciplinary work
- Exposure to interdisciplinary work
- Exposure to and experience with tools and methods from a variety of disciplines
- Exposure to and experience with interdisciplinary tools and methods
- Experience working with others in an interdisciplinary mode

Funders, publishers and editors must not reinforce disciplinary silos, and should promote and encourage the development and publication of multi- and interdisciplinary research. The scope of scientific panels and peer-reviewed journals should reflect the importance of problem-focused research, rather than be defined by traditional academic disciplines.

Review panels, editorial boards and scientific committees should reflect the diverse array of disciplines required to address major societal challenges such as building disaster resilience.

Researchers and educators must interact and collaborate with policy-makers and practice based actors at the local, national, regional and global levels. Collectively they must work to identify and address problems and knowledge gaps from the field. Rather than being passive recipients of new knowledge, policy makers and practitioners should join with higher education to form multi-stakeholder groups that work together from the outset to design and deliver new knowledge. The scientific results will be more relevant and actionable.

Higher education must also recognise the importance of public engagement before, during and after research,

in particular with institutions and individuals as risk of disasters. This can serve a number of often overlapping purposes:

- Informing: inspiring, informing and educating the public and making the work of higher education in building resilience more accessible.
- Consulting: actively listening to the public's concerns and insights - institutions and individuals at risk of
- disasters should be invited to participate in research (surveys, vulnerability assessments and other activities) to collect local knowledge.
- Collaborating: working in partnership with communities and the public to solve problems together, drawing on each other's expertise.
- Localisation: a lot of disaster knowledge has been developed at an abstract level, or based on a specific
- context. Public engagement can help calibrate knowledge to a local context, extending the impact and reach of existing research.

Advocacy

As well as creating new knowledge, higher education has a vital to play in capacity development and in doing so, providing a means by which effective knowledge transfer can take place.

Greater priority should be put on sharing and disseminating scientific information. The research community must make more effort to translate traditional outputs into practical methods that can readily be integrated into policies, regulations and implementation plans towards building resilience.

National research assessment exercises, the European Union and national funding bodies, and higher education promotion policies, which often emphasise traditional academic outputs (e.g., peer reviewed journal articles), should appropriately incentivise and reward non-standard scientific outputs, such as research summaries and policy briefs.

The recent shift towards open access of research outputs and education is to be welcomed and should continue to be encouraged. The high levels of disaster risk found in low-income countries make it an imperative that European research and education is made widely available. The European Union and other research funding bodies should require all funded scientific outputs to be made available as open access. This includes the use of green publishing routes where possible, or financially supporting gold publishing as necessary.

Higher education should be supported to develop open educational resources that are freely accessible and openly licensed, for use in teaching, learning, and assessing as well as for research purposes linked to building resilience.

Educators and the research community must take time and effort to understand the audience they are seeking to inform. Scientific results are often subject to misunderstanding due to poor comprehension of numbers and statistics, as well as conflicting languages and terminology.

Correct comprehension depends not only on the skills and knowledge of the reader, but also on the way the information is presented. By assuming a weaker background knowledge (e.g. of scientific language) and low "statistical literacy", evidence summaries can add information to help readers better understand

the strengths and limitations of the scientific evidence being summarised. Adding meta-information that explains concepts such as the quality of the evidence may help eliminate frustration and trigger reflection.

The volume of research activity and associated outputs has rapidly increased over recent decades. While expanding the knowledgebase may be considered positive in one sense, it has made the field increasingly difficult to navigate, whether it be for experienced researchers and educators, early career researchers and students, or other stakeholders, including policy makers. Identifying and accessing the most recent and high quality science is proving increasingly challenging despite the advance of technology.

Methods and tools for aggregating knowledge must be developed to facilitate access to science, technology and innovation outputs that help inform policymaking and practice, and also ensure that educational programmes and researchers have access to and can build upon the state of the art.

Science provides an evidence base that can be relevant to and therefore draw together different areas of policy. Knowledge integration provides a starting point for building and operationalizing resilience through the co-design of policies and interventions by scientists, practitioners, policy makers and communities themselves. Standardised definitions are essential to the operationalization of concepts such as resilience for research, monitoring and implementation purposes. For example, in epidemiology, case ascertainment/ definition is essential to accurately understanding the causal relationship between a disease exposure and its outcome.

Common understanding amongst all actors is essential for effective disaster risk reduction and management. Approaching towards 2015, the Joint Research Centre of the European Commission has been contributing to identifying the most common terms and definitions used in disaster risk reduction. This background information would provide a solid basis to continue updating the terminology and contribute to the implementation of the post-2015 framework on disaster risk reduction.

3. Capacity Assessment of Tsunami Preparedness in the Indian Ocean

In 2018, the CABARET project team, through its partners Dr Harkunti Rahayu, Professor Richard Haigh and Professor Dilanthi Amaratunga, were invited to support the ICG/IOTWMS and its "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP). The section reproduces the report prepared by the Task Team and published in 2019, including the key findings on the capacity of tsunami preparedness in the Indian Ocean. This can be accessed as follows:

Intergovernmental Oceanographic Commission Technical Series 143 ICG/IOTWMS Status Report Capacity Assessment of Tsunami Preparedness in the Indian Ocean 2019, available at http://www.ioc-tsunami.org/index.php?option=com_oe&task=viewDocumentRecord&docID=25354

3.1. Background to the survey

Soon after the boxing day tsunami, IOC-UNESCO coordinated an assessment of capacity building requirements for an effective and durable tsunami warning and mitigation system in the Indian Ocean by facilitating Expert Missions to 16 Member States affected by the tsunami. This assessment provided a regional overview of existing capacity as well as important support requirements of Member States to build regional capacity in tsunami warning and mitigation. An IOTWMS implementation plan was prepared in 2011 that guided the initial developments.

Much progress has since been made in establishing the IOTWMS which became fully operational on 31 March 2013 with Tsunami Service Providers (TSPs) established by Australia, India and Indonesia providing independent tsunami advisory services to the Member States of the Indian Ocean region. The IOTWMS created Risk Assessment Guidelines, enhanced observing networks (140 Seismic Stations, >100 Sea level Stations, 09 Tsunameters) generated awareness material and continues to conduct communication tests, capacity development workshops and tsunami drills. Current and future work of the Intergovernmental Coordination Group (ICG) for the IOTWMS is focused towards sustenance of and improvements to the system, as well as enhancing community awareness and response mechanisms in its Member States.

Considering the importance of conducting an up-to-date assessment of the tsunami preparedness in the Indian Ocean in order to focus future efforts, the ICG/IOTWMS at its 11th session (Putrajaya, April 2017) established the inter-sessional "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP). This assessment is meant to provide a baseline of the current status, identify specific gaps and prioritize capacity development requirements at both the regional and national level for strengthening the end-to-end tsunami warning and mitigation system in the Indian Ocean. The Task Team was chaired by Dr. Harkunti Rahayu (Indonesia) with representatives from Australia, India, Indonesia, Oman, Malaysia, Indian Ocean Tsunami Information Centre (IOTIC) and ICG/IOTWMS Working Groups and invited experts from the Global Disaster Resilience Centre of the University of Huddersfield.

Considering that the most optimal way to conduct the assessment is through an online survey, the TT-CATP prepared an online survey questionnaire covering all aspects of the end-to-end tsunami warning and mitigation system by updating the existing templates (ICG national report, post-IOWave survey and post-event assessment survey). The survey was set up using survey monkey and a secure link was shared with the IOTWMS Member States by the Secretariat through an IOC Circular Letter. Submission of responses was timed to coincide with Member State's formal reporting to the ICG/IOTWMS-XII Session (Iran, March 2019), eliminating the need for Member States to submit a separate national report.

Responses to this survey were submitted by Tsunami National Contact (TNC) of the Member States. The survey had 5 distinct parts, with each needing inputs from different stakeholders based on their national responsibility in the end-to-end tsunami warning and mitigation system. Information submitted by Member States was analysed by the TT-CATP for preparation of the IOTWMS Status report. This report will be presented for consideration of Member States at the ICG/IOTWMS-XII. Upon approval, it will be published as an IOC Information/Technical series document. Future capacity assessments will also be timed to coincide with the biennial ICG sessions to ensure that the status and progress of the IOTWMS is routinely and effectively monitored by the ICG.

3.2. Sample

A letter was sent, inviting them to complete the capacity survey, to the designated Tsunami National Contact point for each of the 28 Member States of the IOTWMS. The survey was made available through a SurveyMonkey link. This report is based on the responses received by 10th January 2019. Twenty responses were received by this date:

Australia, Bangladesh, Comoros, France Indian Ocean Territories, India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Singapore, Sri Lanka, Tanzania, Thailand, Timor-Leste.

The report from South Africa was submitted after the regional analysis had been undertaken and therefore it was not possible to include their responses in this aspect of the report.

3.3. Risk assessment and reduction

Hazard assessment

Countries were asked to confirm whether a hazard assessment has been carried out, and if so, what type of hazard assessment has been undertaken.

The results show that all 20 countries participating in this survey (100%) conduct hazard assessments to understand the hazard threats to their territory.

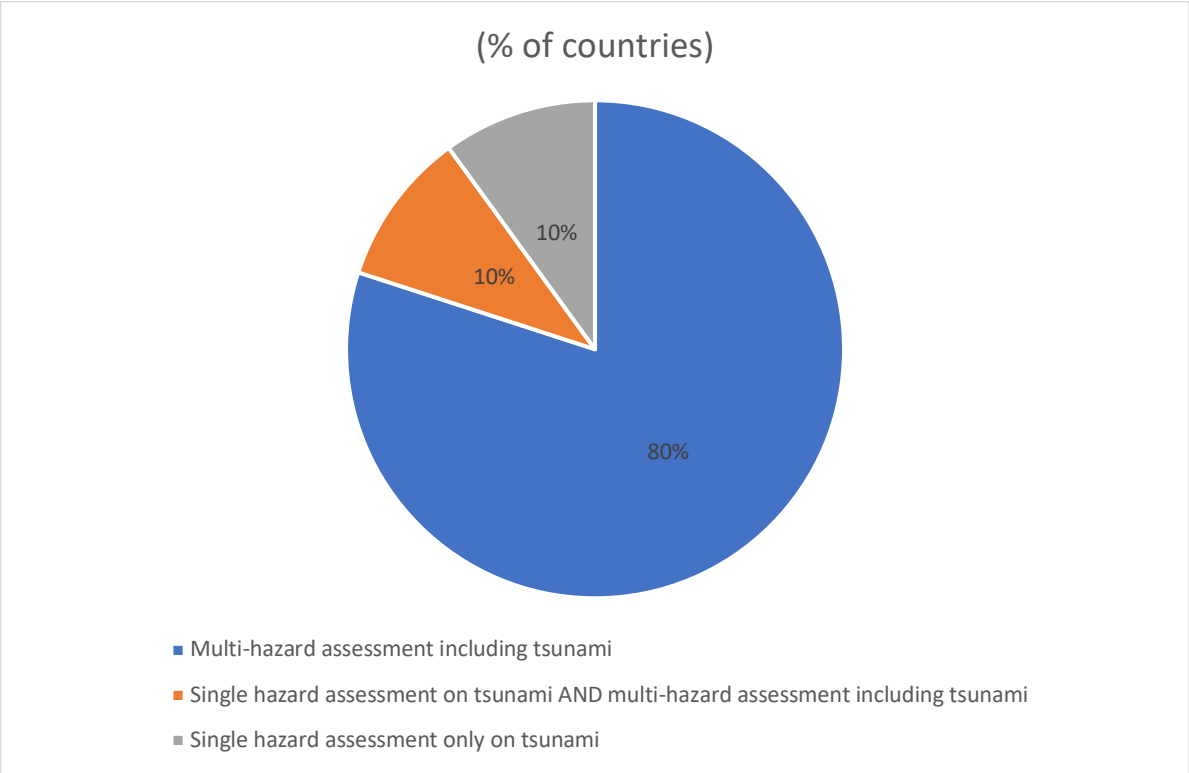

Figure 2: Type of hazard assessment

Figure 2 shows the type of hazard assessment carried out by each country. 16 countries (80%) reported conducting a multi-hazard assessment that included tsunami, 2 countries (10%) a single hazard assessment on tsunami AND a multi-hazard assessment including tsunami, and 2 countries (10%) a single hazard assessment on tsunami only.

For those countries that carry out multi-hazard assessments, respondents were then asked to identify the types of hazard included in the assessment.

Figure 3 shows the number of hazards included in the multi-hazard assessments conducted by each country. Out of the 18 countries that conducted a multi-hazard assessment, 4 countries included 7 hazards from Tsunami, Cyclone, Drought, Earthquakes, Epidemics, Flooding, Landslide, and Volcanic eruptions. 5 countries included 6 hazards, 2 countries included 4 hazards, and 4 countries included 3 hazards.

As shown in Figure 2 and Figure 4, all 20 respondent countries include tsunami in their hazard assessment. 17 of the countries who do multi-hazard assessments also include flooding (85% of total), 15 include cyclones (75% of total) and 14 (70% of total) include earthquakes (Figure 4). Less common hazards to be included are drought and landslide (55%), epidemics (35%) and volcanic eruptions (20%).

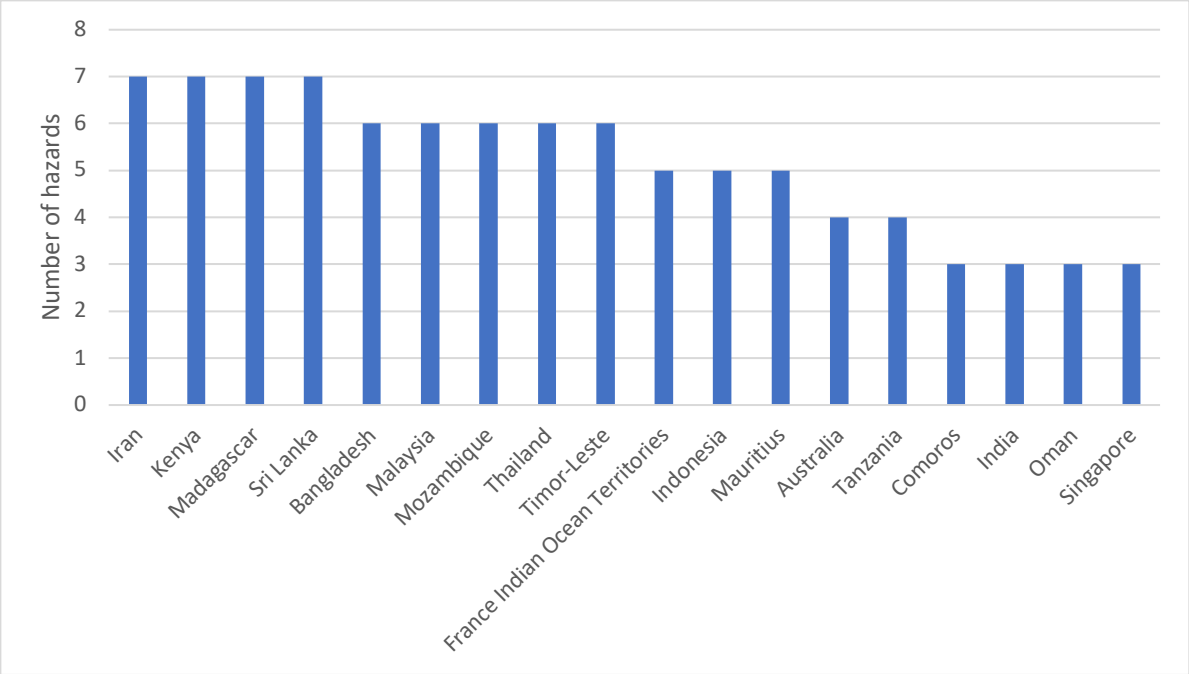

Figure 3: Number of hazards included in a multi-hazard assessment

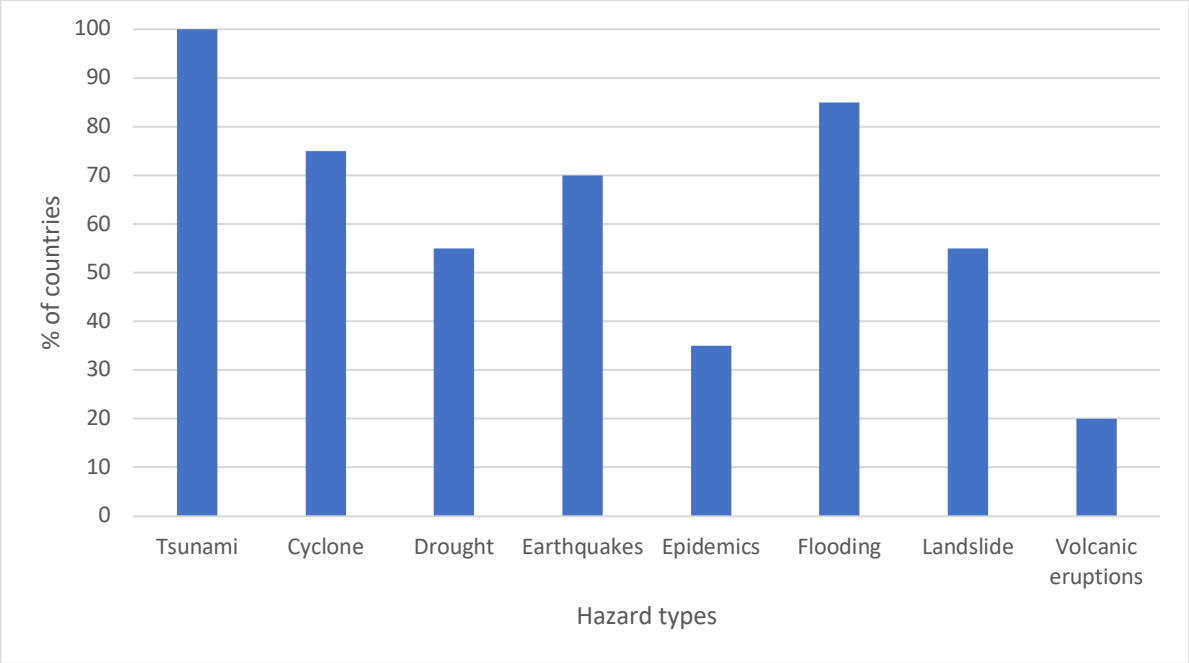

Figure 4: Types of hazard included in multi-hazard assessment

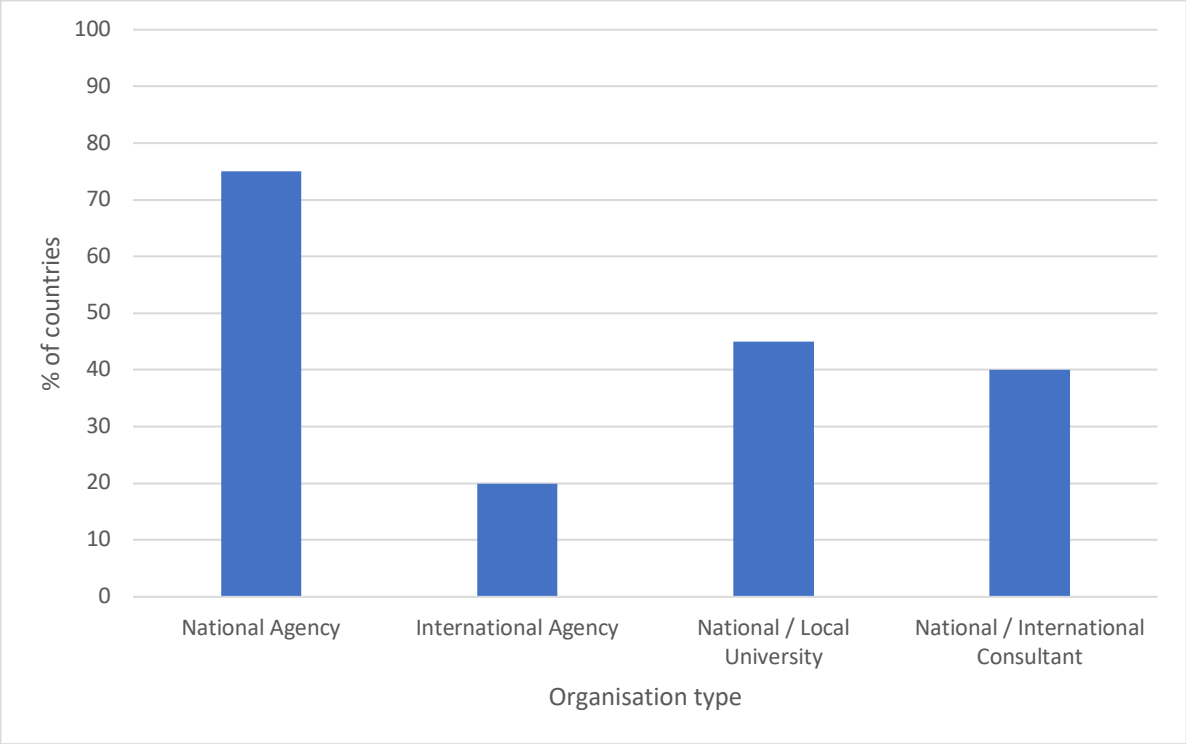

Figure 5: Organisation(s) responsible for the tsunami hazard assessment

Countries were then asked to identify which organisation(s) is/are responsible for the tsunami hazard assessment and at what level they are carried out.

75% of tsunami hazard assessments carried out by countries involve a national agency, 45% a national or local university, 40% a national or international consultant, and just 20% an international agency (Figure 5). 45% of tsunami hazard assessments involve multiple organisations.

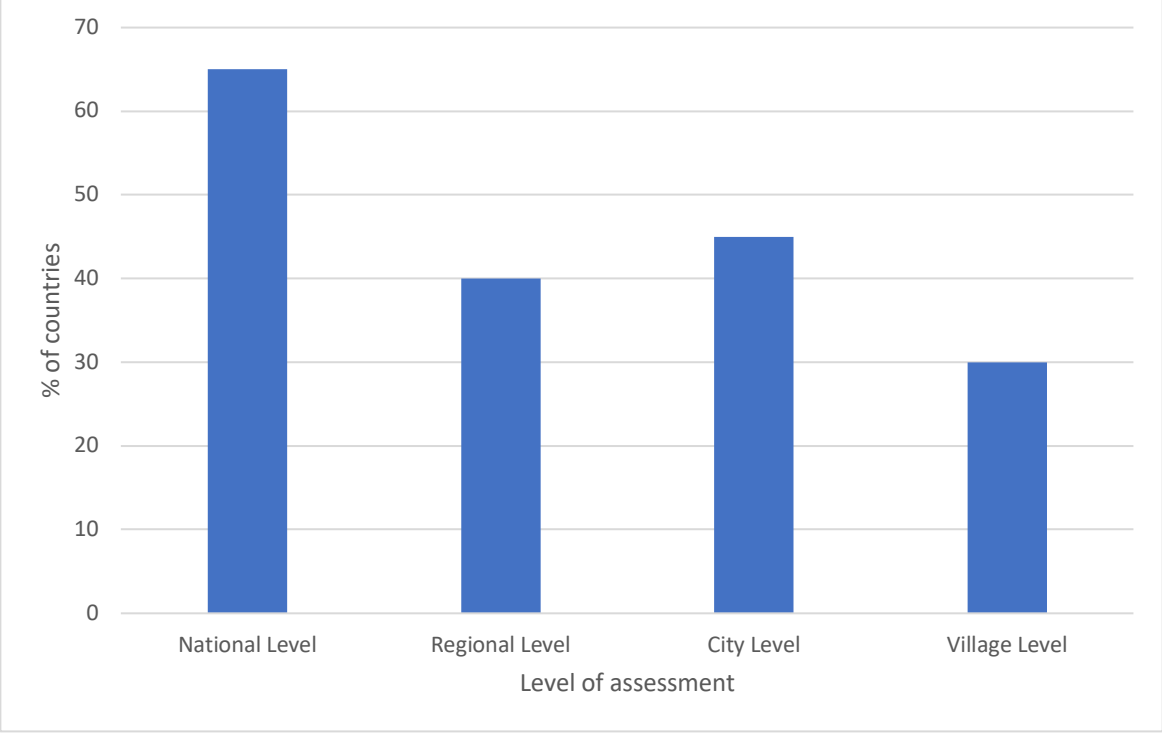

Figure 6: Level at which tsunami hazard assessment is carried out

65% of countries carry out the tsunami hazard assessment at a national level, 40% at the regional level, 45% at the city level and 30% at the village level (Figure 6). 50% of countries carry out hazard assessments at multiple levels.

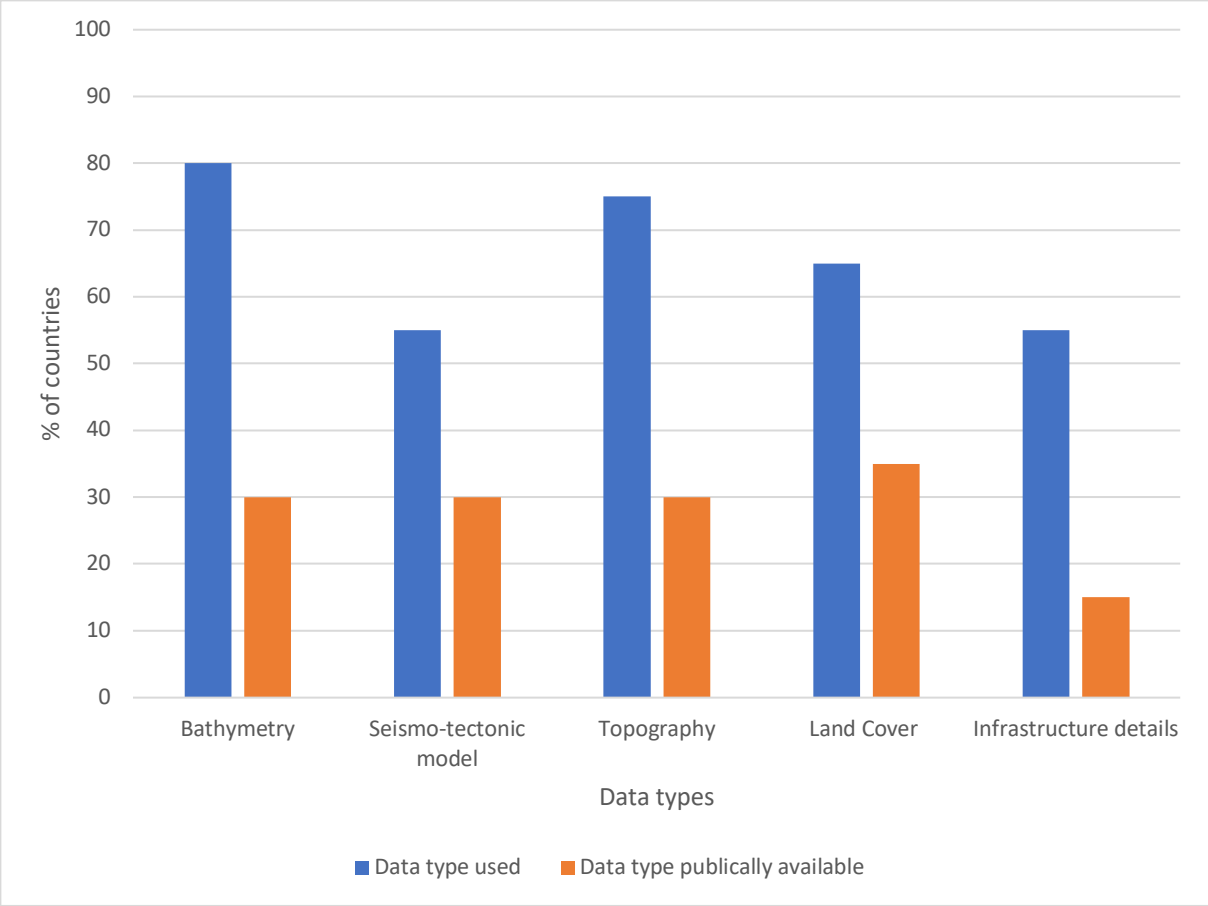

Figure 7: Data types used for tsunami hazard assessment

Countries were then asked to identify the type of data used to support their tsunami hazard assessment and whether that data is publicly available.

17 countries (85%) identify two or more data types used to support their tsunami hazard assessment, while 3 countries did not identify any data types. Bathymetry and topography are the most widely used data to inform tsunami hazard assessment (Figure 7). 55% of the 20 countries use seismo-tectonic models, and 55% of countries also use infrastructure details. However, none of the data sources are widely available to the public. Land cover data was reported as available in 7 of the 13 countries that use it, whereas infrastructure data is publicly available in just 3 of the 11 countries using this data to inform tsunami hazard assessments.

The number and type of products to emerge from the tsunami hazard assessment varies greatly across the 20 respondent countries. The most common products (Figure 8) are inundation maps (80%) and hazard maps (70%). The other products are developed by less than 50% of countries.

One country, Thailand, produces all seven products, while a majority of countries produces three products or less (Figure 9).

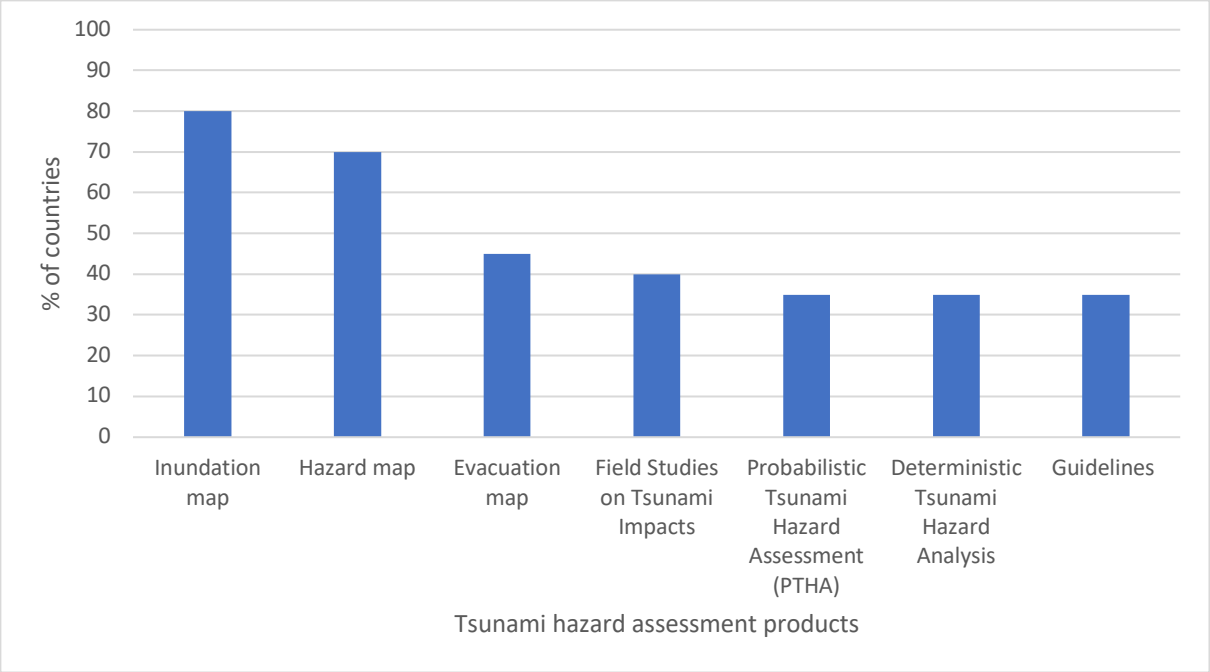

Figure 8: Products from tsunami hazard assessment

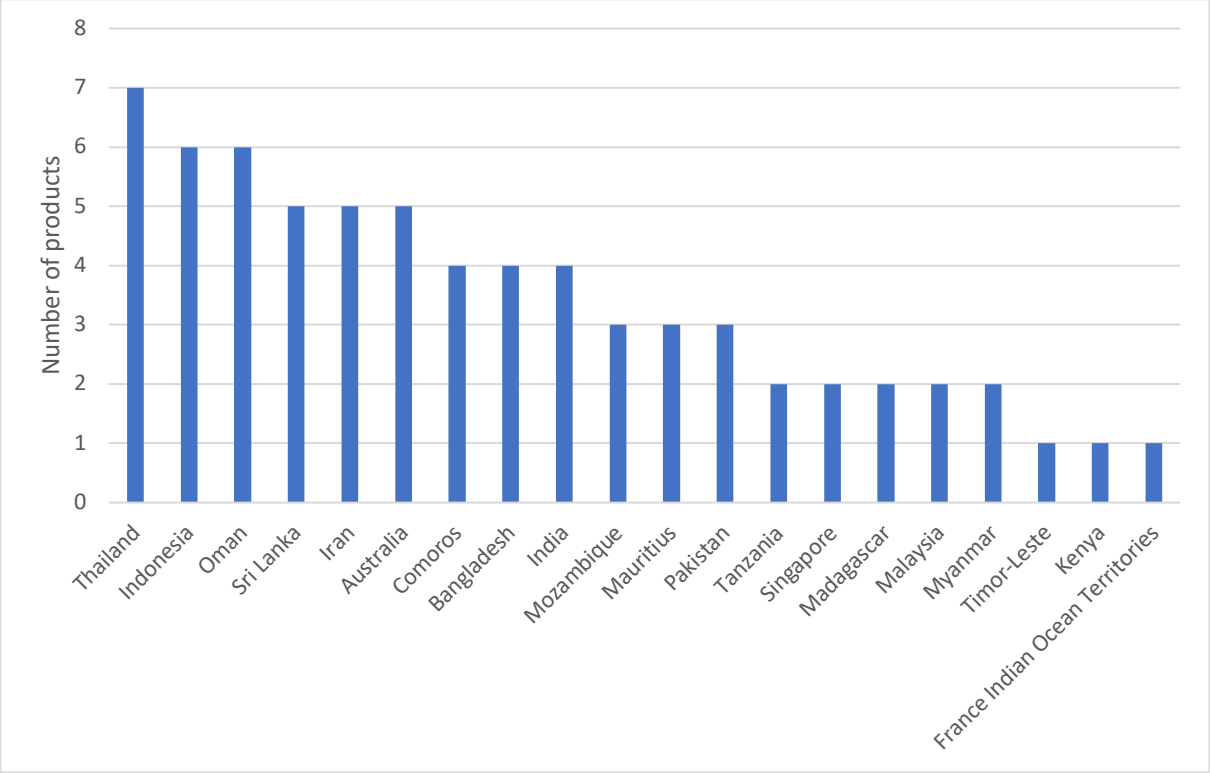

Figure 9: Number of tsunami assessment products

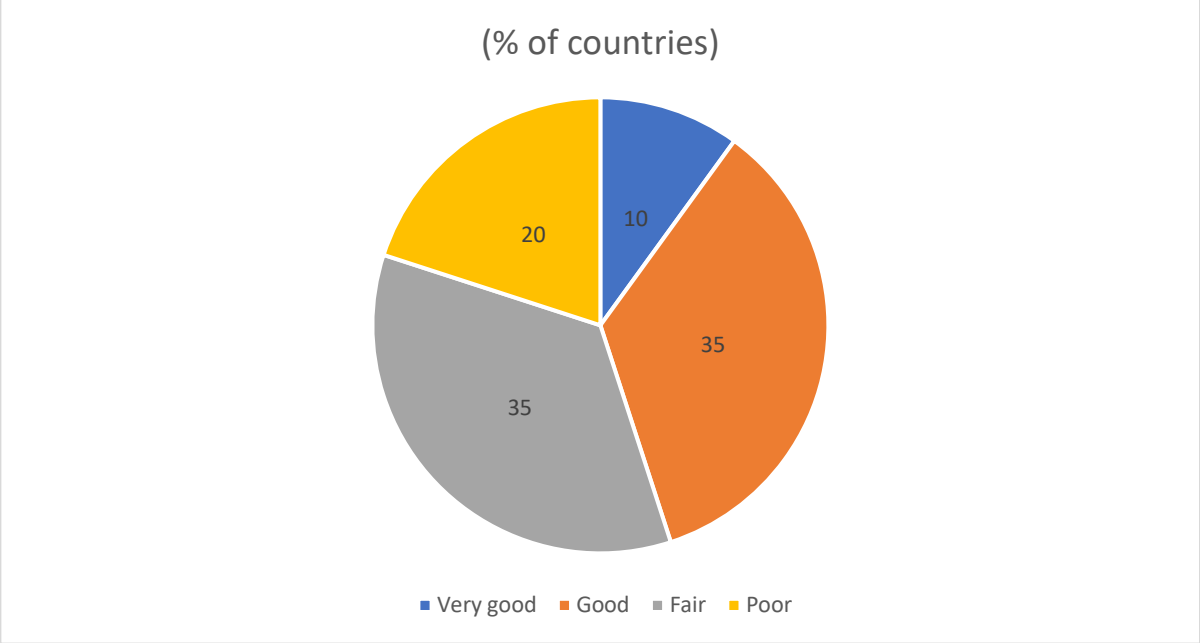

Figure 10: Capacity to undertake tsunami hazard assessments

Countries were then asked to rate their capacity to undertake tsunami hazard assessment using a five-point scale, from very poor to very good (Figure 10). The responses indicate wide ranging capacity across the 20 respondent countries. 45% of countries rate themselves as having very good or good capacity to undertake tsunami hazard assessments, while 35% of countries rate themselves as having fair capacity. 20% of countries rate themselves as having poor capacity.

In a similar manner, each respondent was then asked to rate their country's priorities for capacity improvement across six areas of tsunami hazard assessment, using a five-point scale, from not a priority to essential (Figure 11). The responses indicate that all areas require capacity improvement in at least some countries, but using a weighted response across the twenty respondent countries[1], evacuation mapping was ranked as the highest priority for capacity improvement, followed by hazard mapping and inundation mapping (Table 1).

Table 1: Ranking of priority areas for capacity improvement in tsunami hazard assessment

Areas of tsunami hazard assessment	RII	Rank
Evacuation map	0.89	1
Hazard map	0.84	2
Inundation map	0.84	3
Deterministic Tsunami Hazard Analysis	0.75	4
Field Studies on Tsunami Impacts	0.72	5
Probabilistic Tsunami Hazard Assessment (PTHA)	0.7	6

[1] $RII = \frac{\sum W}{AxN}\ (0 \leq R \leq 1)$

Where W is the weightage given to each factor, A is the highest weight, and N is the number of respondents

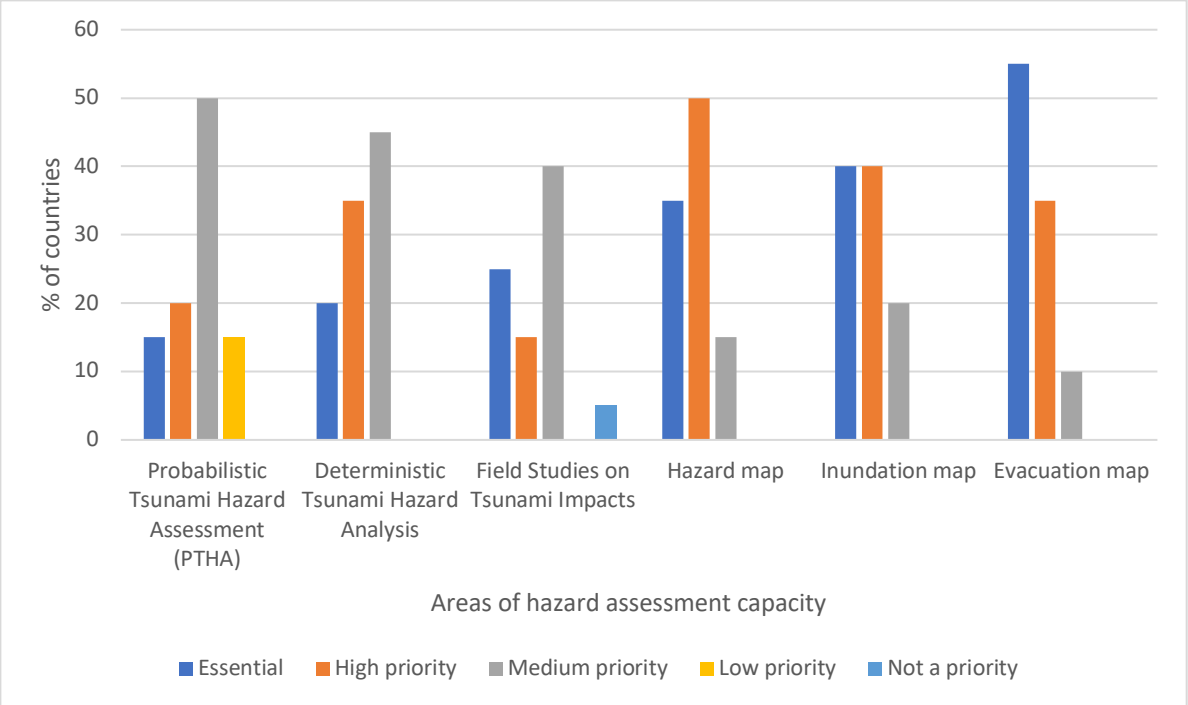

Figure 11: Capacity to undertake tsunami hazard assessments

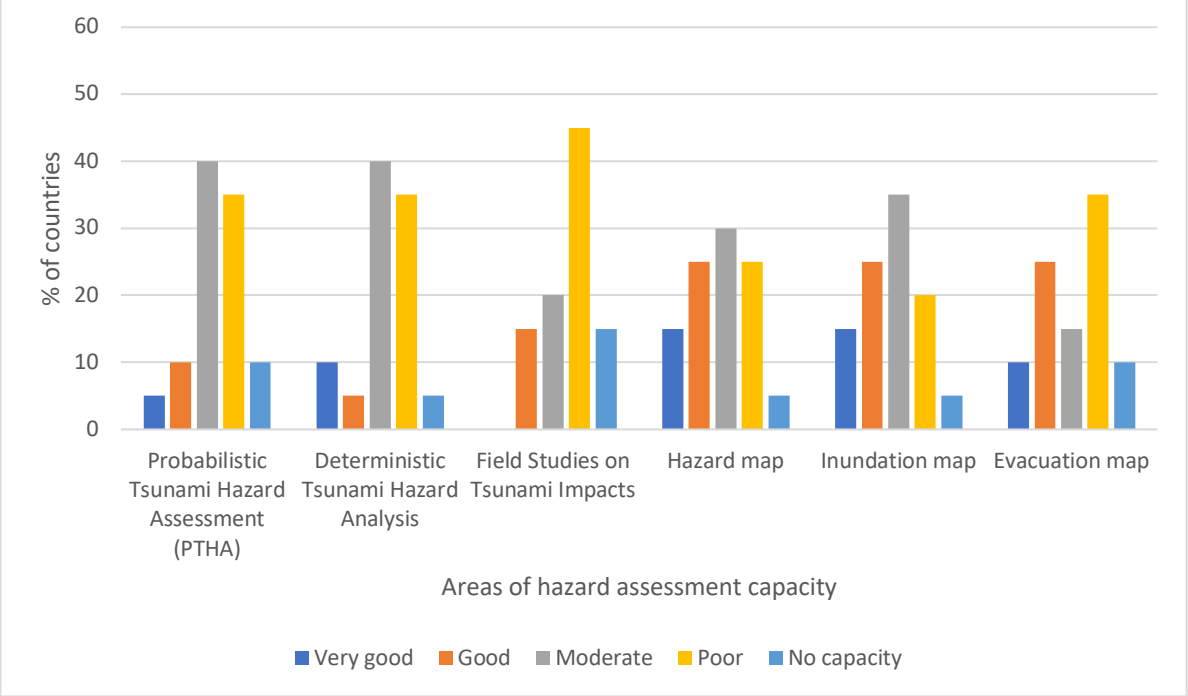

Figure 12: Capacity to give training and/or consultancy on tsunami hazard assessment to other countries

Countries were also asked to rate their capacity to give training and/or consultancy to other countries on the same six aspects of tsunami hazard assessment, using a five-point scale, from no capacity to very good capacity (Figure 12).

40% of countries indicate very good or good capacity to give training on hazard mapping and inundation mapping, while 35% of countries indicate the same on evacuation mapping. For the other three areas, probabilistic tsunami hazard assessment, deterministic tsunami hazard analysis and field studies on tsunami impact, just 3 (15%) of the 20 countries indicate very good or good capacity.

Risk assessment

Countries were then asked to consider the extent and nature of tsunami risk assessments carried out.

The results show that 16 of the 20 countries participating in this survey (80%) conduct tsunami risk assessments.

Figure 13 shows the type of risk assessment carried out by each country. 12 countries (60%) report conducting a multi-hazard risk assessment that includes tsunami, 3 countries (15%) a single hazard assessment on tsunami AND a multi-hazard assessment including tsunami, and 1 country (5%) a single hazard assessment on tsunami only.

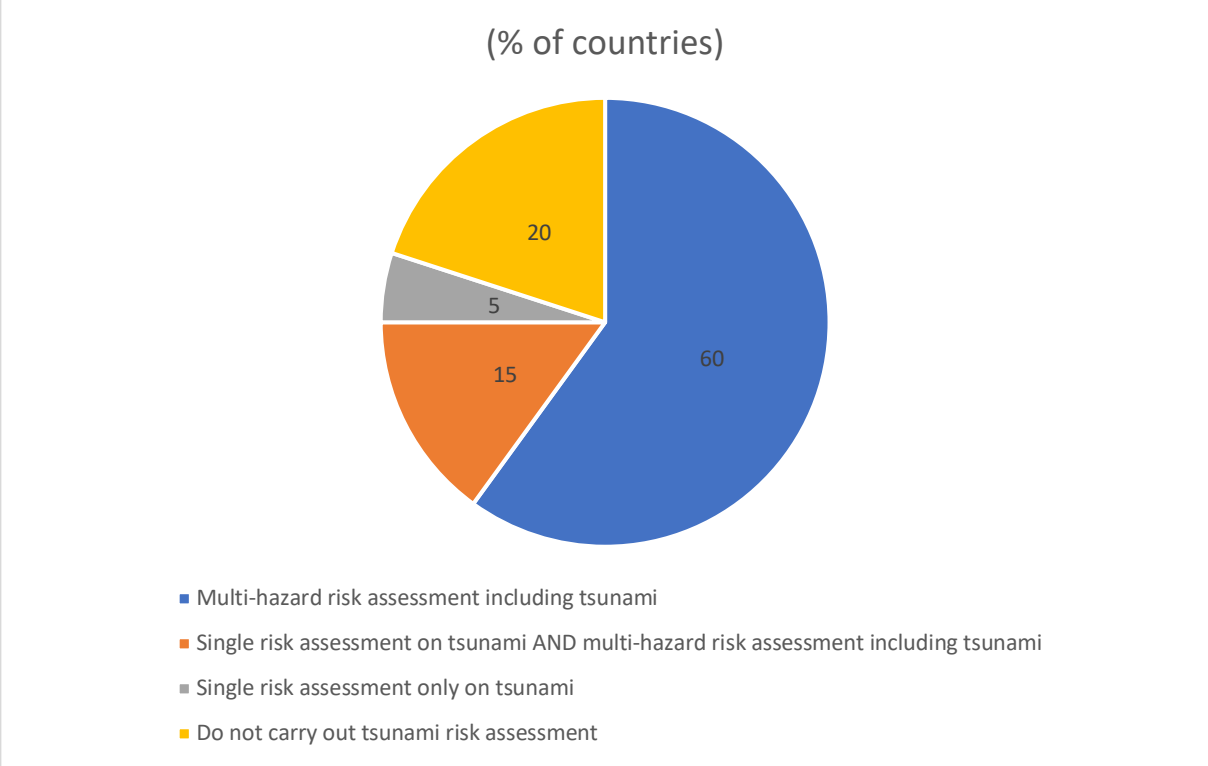

Figure 13: Types of risk assessment

All 15 countries that carry out multi-hazard risk assessments include tsunami, with flooding, cyclones and earthquakes considered by 50% or more of countries (Figure 14). Less common hazards to be included are epidemics and volcanic eruptions. Strong winds, forest fires and lightning are each considered by one of the 15 countries that carry out multi-hazard risk assessments.

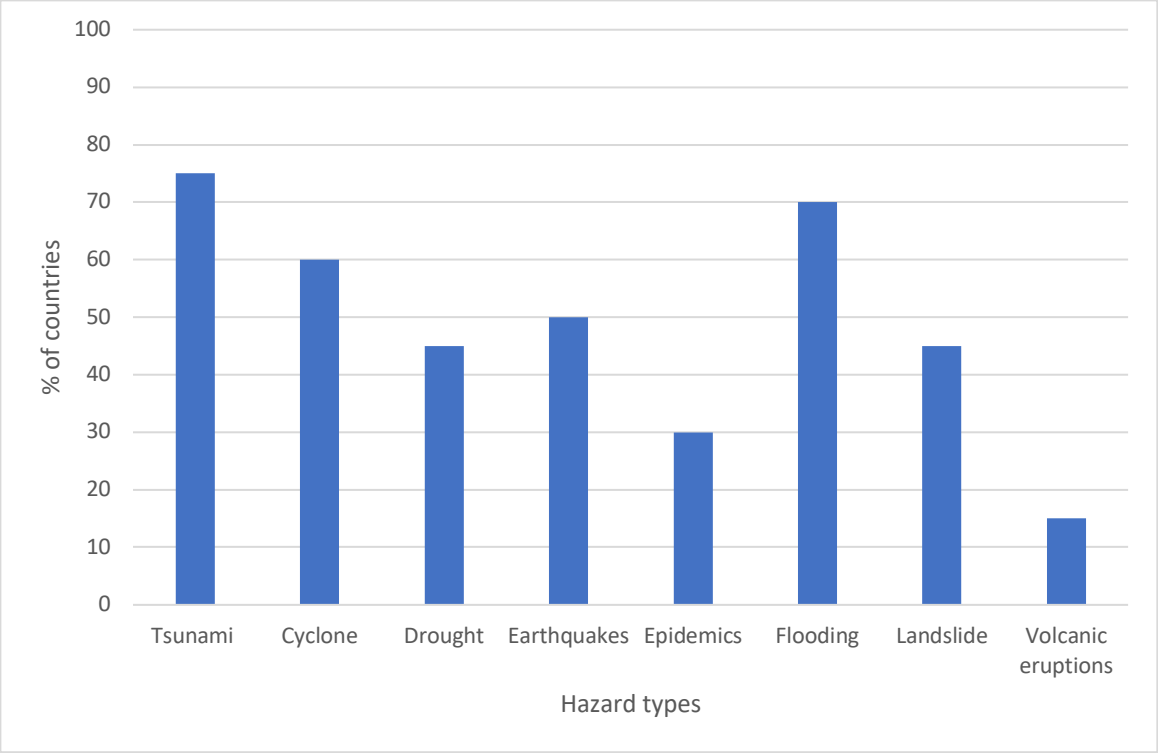

Figure 14: Types of hazard included in the multi-hazard risk assessment

Countries were then asked to identify the organisation(s) that is/are responsible for carrying out risk assessments and the level at which they are carried out.

The organisation(s) responsible for carrying out tsunami risk assessments vary across the respondent countries (Figure 15). In 55% of countries a national agency is fully or partially responsible, A national or local universities is at least partially responsible in 25% countries. A national agency or international consultant is at least partially responsible in 25% countries, while 20% countries indicated that an international agency is at least partially responsibleFigure 5. In 20% of countries, the tsunami risk assessment is the responsibility of multiple actors.

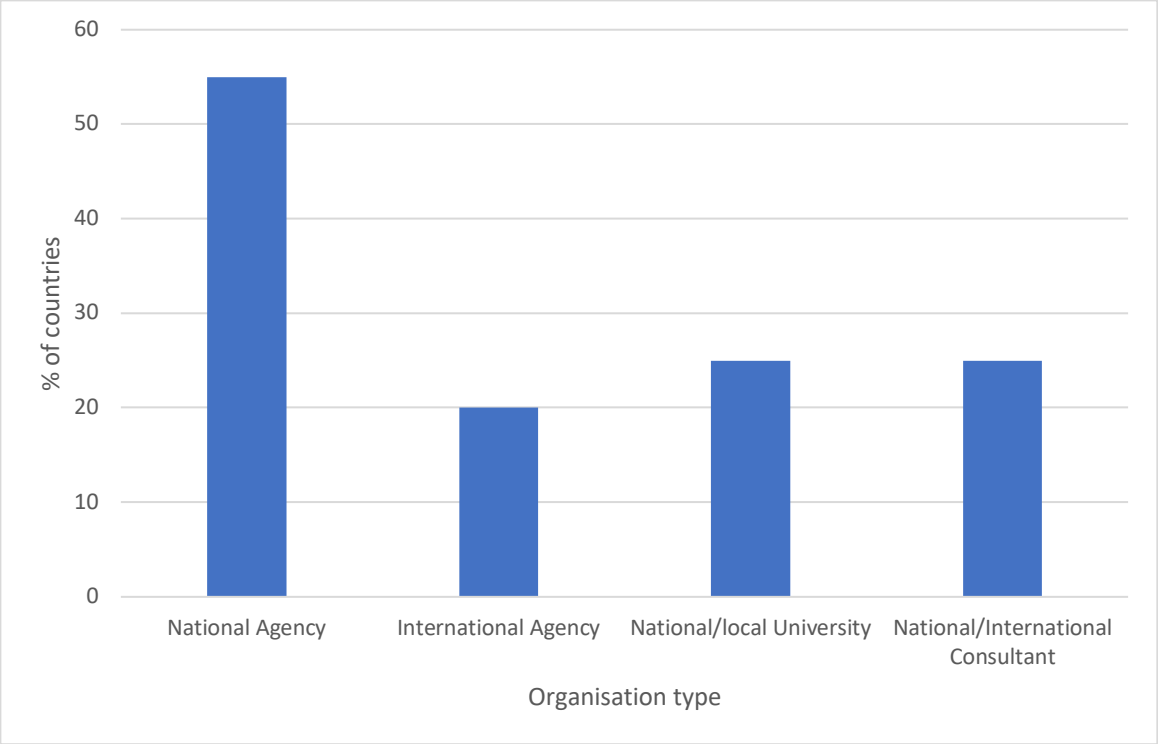

Figure 15: Organisation(s) responsible for the tsunami risk assessment

Of the 16 countries that carry out tsunami risk assessments, 11 conduct them at the national level, 8 at a regional level and 6 at a city level (Figure 16). Just 4 countries carry out village and/or community level risk assessments. 6 countries carry out risk assessment at multiple levels.

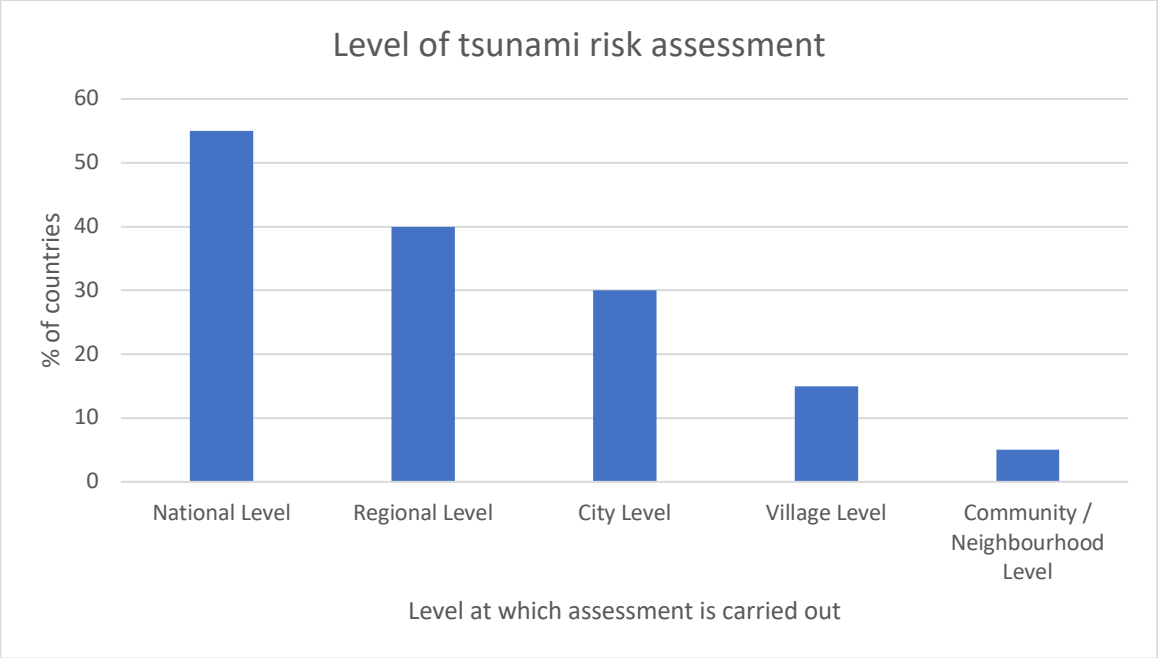

Figure 16: Levels at which the tsunami risk assessment is carried out

Countries were then asked to identify the type(s) of product that emerge from the tsunami risk assessment.

The number and type of products developed from the tsunami risk assessment varies across the respondent countries. A risk map is produced by 11 of the 16 countries (55% of all countries) that conduct tsunami risk assessments. Evacuation maps, guidelines and action plans are also produced, but each of them by less than half of the respondent countries that do tsunami risk assessments. 10 countries develop 2 products or more.

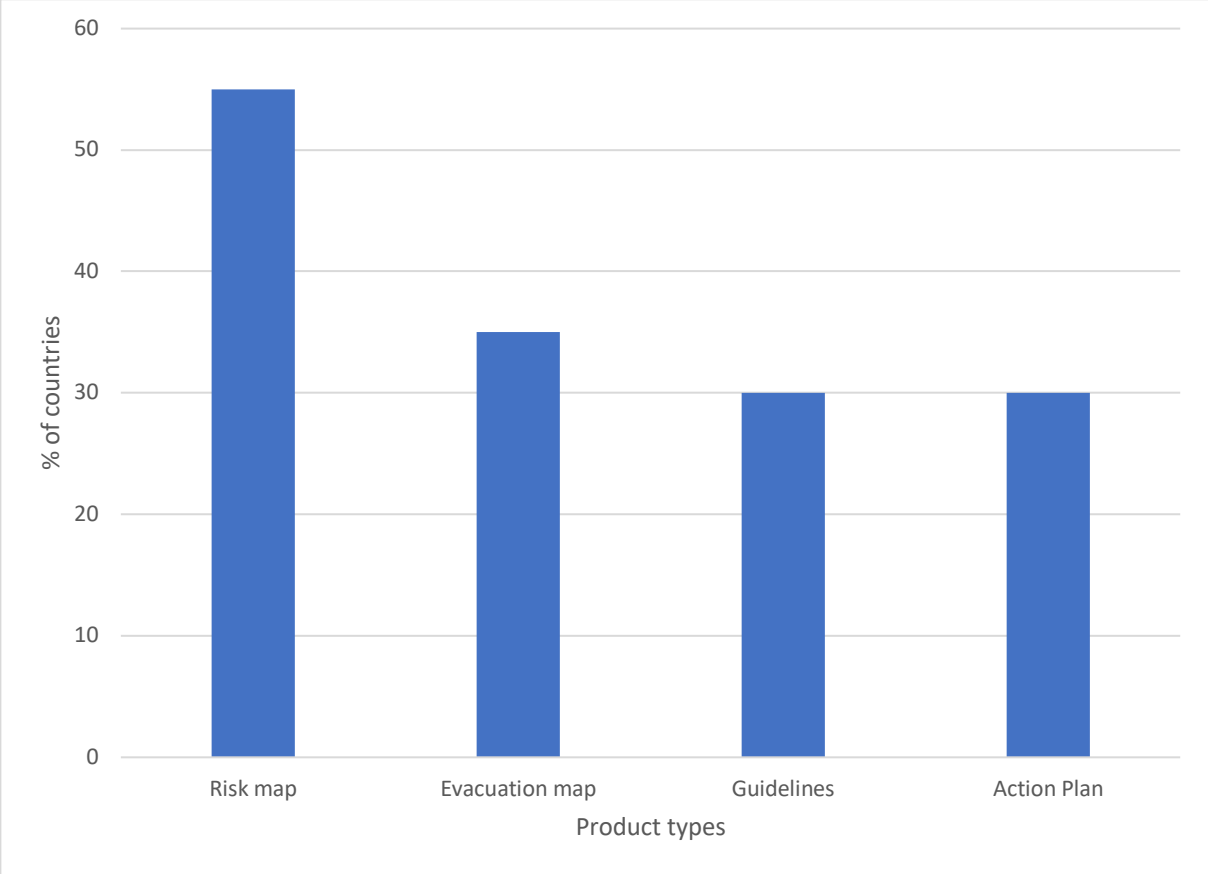

Figure 17: Types of product to emerge from the tsunami risk assessment

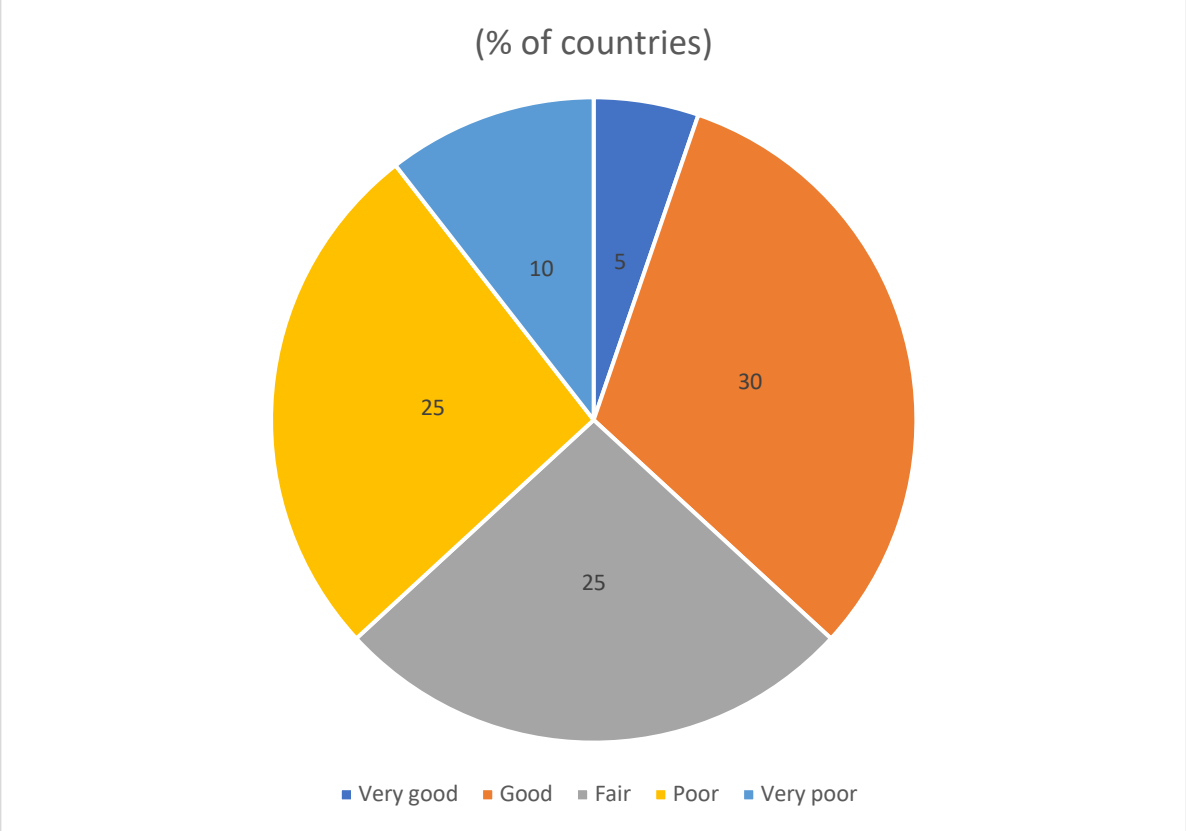

Figure 18: Capability to undertake tsunami risk assessment

Each country was then asked to rate their capacity to undertake tsunami hazard assessment using a five-point scale, from very poor to very good. The responses indicate wide ranging capacity to undertake tsunami risk assessment across the 20 respondent countries (Figure 18). 35% of countries rate their capacity as very good or good. 25% rate themselves as having fair capacity, and 35% of countries rate themselves as poor or very poor.

Using a similar approach, each country was then asked to rate their priorities for capacity improvement across five levels of tsunami risk assessment, using a five-point scale, from not a priority to essential (Figure 19). The responses indicate that all areas require capacity improvement in at least some countries, but using a weighted response across the twenty respondent countries[2], city level risk assessment is ranked as the highest priority for capacity improvement, followed by village and community levels (Table 2).

Table 2: Priorities for capacity improvement in tsunami risk assessment

Priority level	**RII**	**Rank**
Tsunami risk assessment at city level	0.821053	1
Tsunami risk assessment at village level	0.821053	2
Tsunami risk assessment at community / neighbourhood level	0.821053	3
Tsunami risk assessment at national level	0.726316	4
Tsunami risk assessment at regional level	0.673684	5

[2] $RII = \frac{\sum W}{AxN} \ (0 \leq R \leq 1)$

Where W is the weightage given to each factor, A is the highest weight, and N is the number of respondents

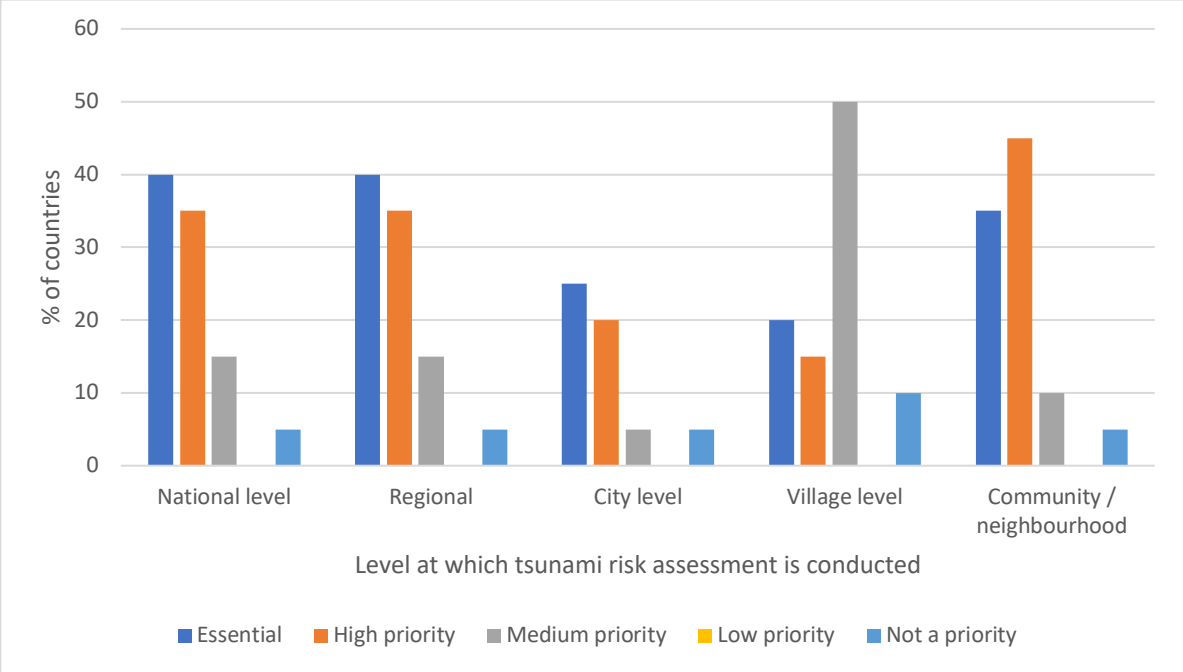

Figure 19: Priorities for improvement in capacity for tsunami risk assessment

Each country was also asked to rate their capacity to give training and/or consultancy to other countries on the same five levels of tsunami hazard assessment (community to national), using a five-point scale, from no capacity to very good capacity (Figure 20). For each level, there were no countries indicating very good capacity to deliver training on tsunami risk assessment. 30% of countries rate themselves as having good capacity to give training at the national level, and 20% at the regional and city levels. Only 15% of countries rate themselves as having good capacity to deliver training at the village or community level.

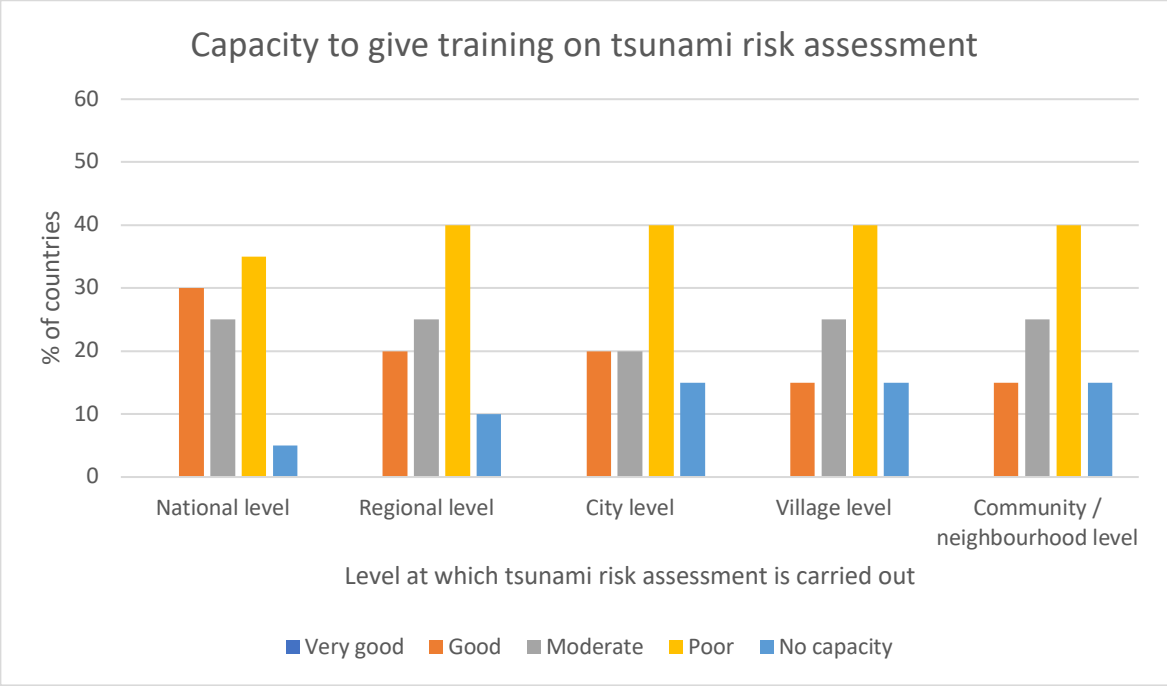

Figure 20: Capacity to give training on tsunami risk assessment

Policies

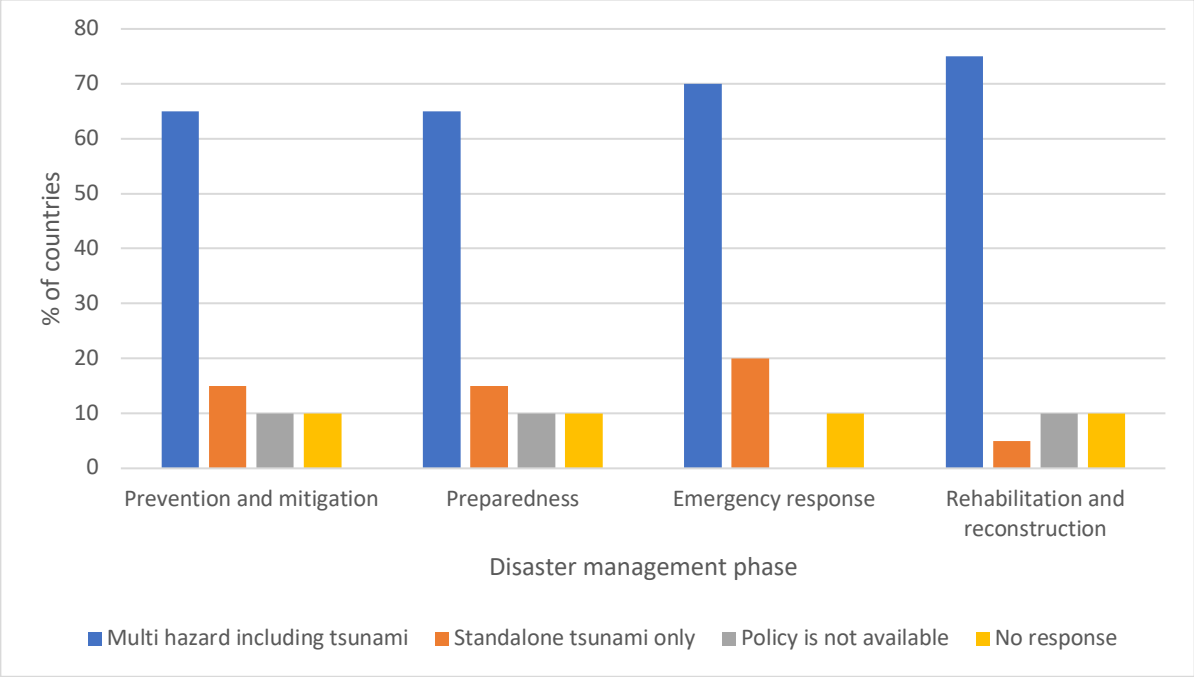

Figure 21: Types and phases of national tsunami policy

Countries were asked to confirm the availability and type of national tsunami policy they have, including whether it is multi-hazard or standalone, and which phases of the disaster management lifecycle it addresses, from prevention and mitigation, through to preparedness, emergency response, and rehabilitation and reconstruction (Figure 21).

The responses indicate that 19 of the 20 countries (95%) have some form of national tsunami policy and the country without one commented that it is under development. A large majority address tsunami as a part of a multi-hazard policy. 90% of countries have a national policy have addresses the emergency response phase and 80% one that addresses the rehabilitation and reconstruction phase. 75% of countries have a national policy that addresses the prevention and mitigation phase and/or the preparedness phase.

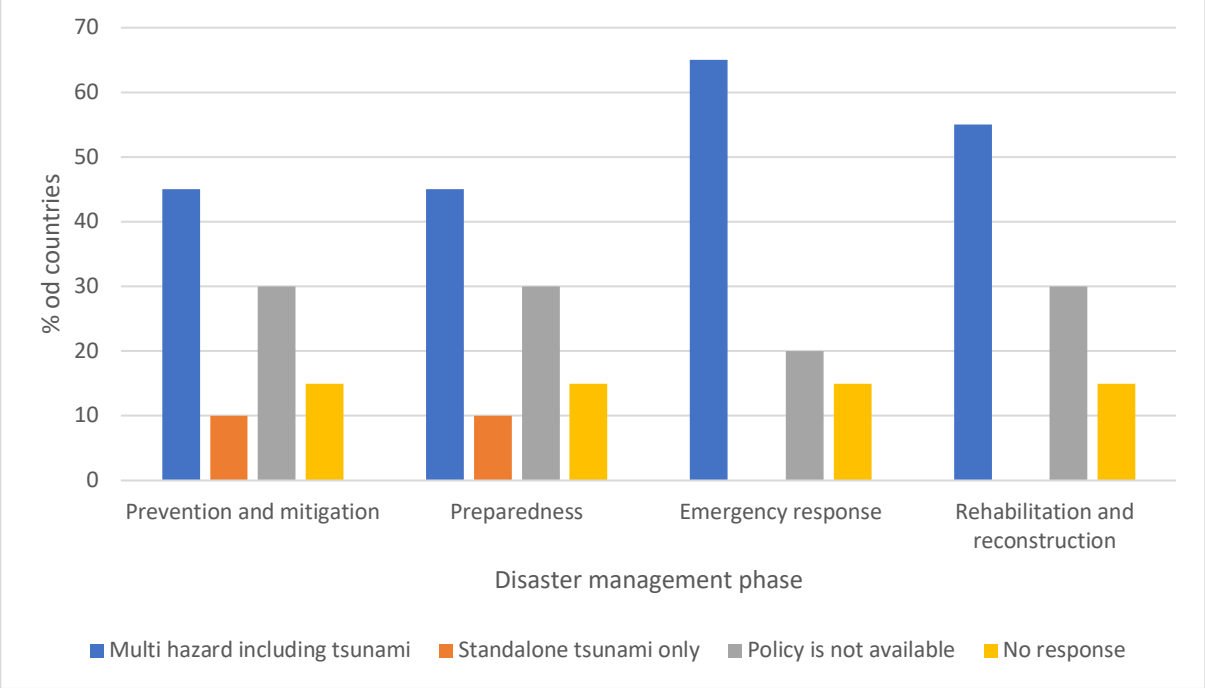

Figure 22: Types and phases of local tsunami policy

Using the same approach, countries were asked to confirm the availability and type of local tsunami policy they have, including whether it is multi-hazard or standalone, and which phases of the disaster management lifecycle it addresses, from prevention and mitigation, through to preparedness, emergency response, and rehabilitation and reconstruction (Figure 22). The responses indicate that 15 of the 20 countries (75%) have some form of local tsunami policy, and 3 of the countries without, commented that it is under development. For those countries with some form of local tsunami policy, the majority address tsunami as a part of a multi-hazard policy. 75% of countries have a policy have addresses the emergency response phase, whereas for each of the other phases, only 55% countries address tsunami, either as a standalone or multi-hazard policy.

Plans

Countries were asked to confirm the availability, level and type of tsunami risk reduction plans they have, including whether it is multi-hazard or standalone, whether it is at the national, local or community level, and which phases of the disaster management lifecycle it addresses, from prevention and mitigation (Figure 23), through to preparedness (Figure 24), emergency response (Figure 25), and rehabilitation and reconstruction phases (Figure 26).

The responses indicate that 90% of countries have some form of tsunami disaster risk reduction plans, while 1 of the 2 without plans commented that they are under development.

A significant majority of countries address tsunami risk reduction as a part of a multi-hazard plan, rather than as standalone plans.

Across all four phases of the disaster management lifecycle, availability of plans is significantly higher at the national level, followed by the local level. There is least availability at the community level. For example, at the emergency response phase, 75% countries have national level plans, while 55% have local and 40% have community level plans. This pattern is similar in all phases of disaster management.

Availability of tsunami plans is highest during the emergency phase. For example, the 75% of countries with national plans at the emergency phase, exceeds those during the prevention and mitigation phase (65%), the preparedness phase (70%) and the rehabilitation and reconstruction phase (55%). This pattern is replicated at the local and community levels, with availability at the emergency phase exceeding other phases.

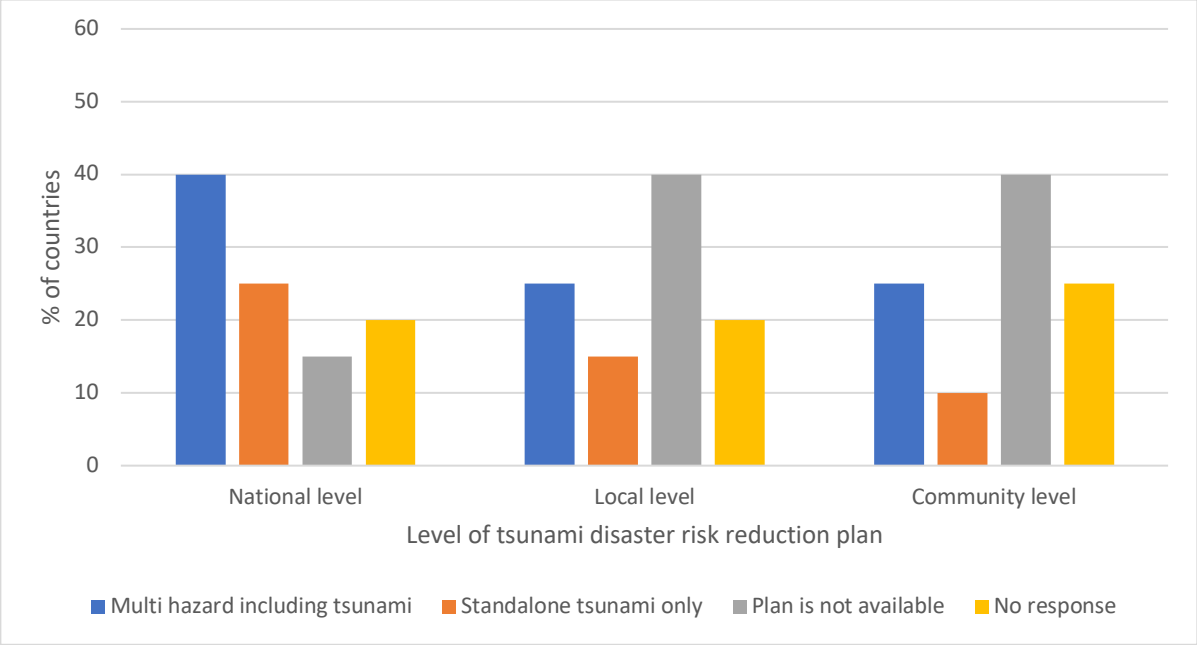

Figure 23: Availability of national, local and community level tsunami disaster risk reduction plans during prevention and mitigation phase

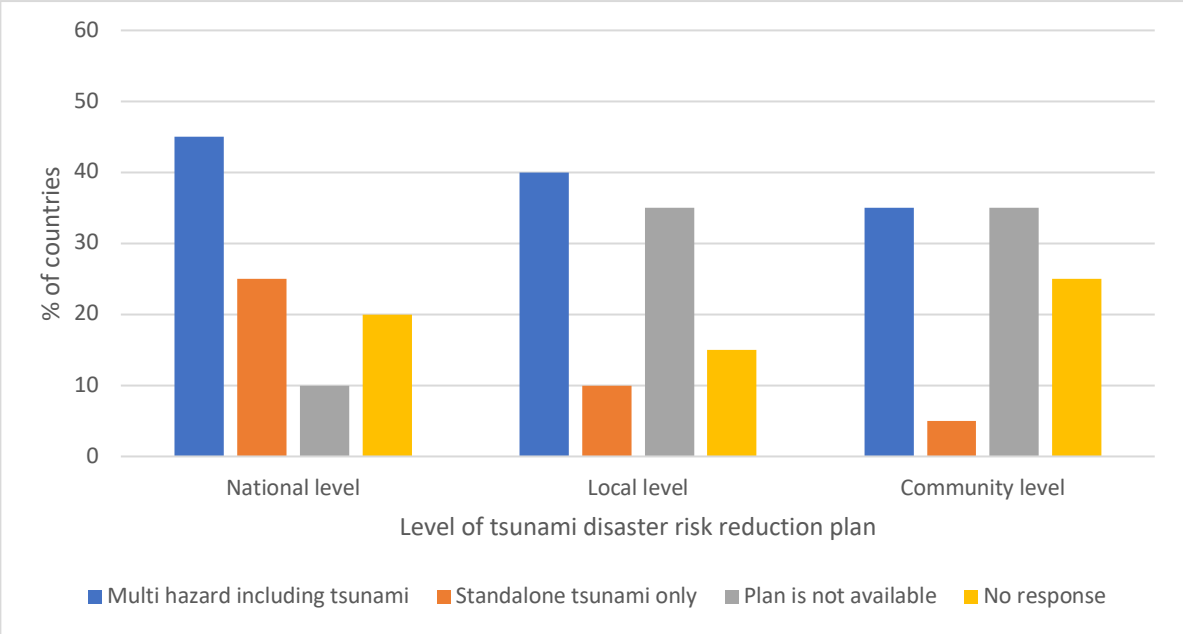

Figure 24: Availability of national, local and community level tsunami disaster risk reduction plans during preparedness phase

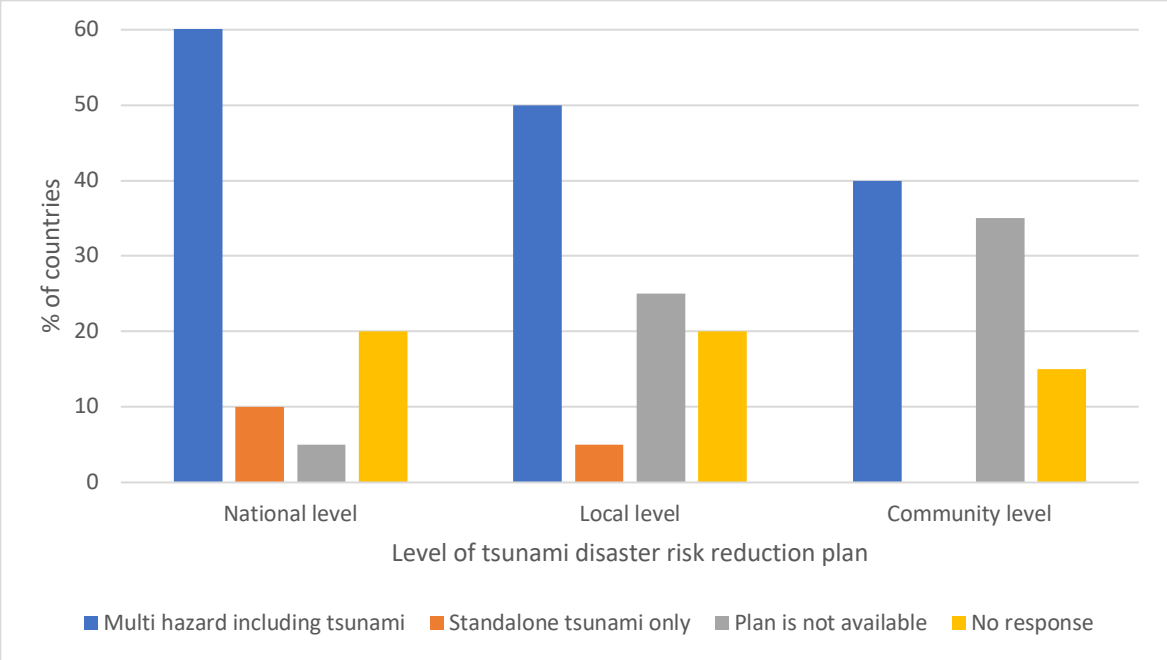

Figure 25: Availability of national, local and community level tsunami disaster risk reduction plans during emergency response phase

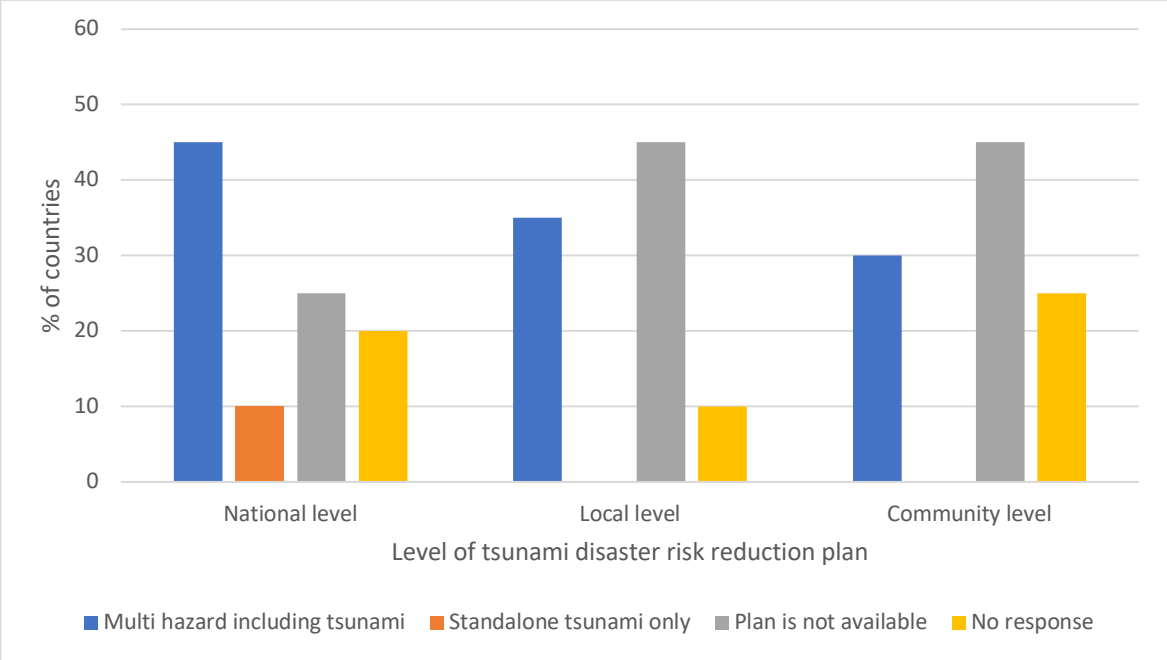

Figure 26: Availability of national, local and community level tsunami disaster risk reduction plans during rehabilitation and reconstruction phase

All countries (100%) reported that their tsunami disaster risk reduction plans are based on hazard and/or risk assessments.

Guidelines

Countries were asked to confirm the availability and type of national tsunami guidelines they have, including whether it is multi-hazard or standalone, and which phases of the disaster management lifecycle it addresses, from prevention and mitigation, through to preparedness, emergency response, and rehabilitation and reconstruction (Figure 27).

The responses indicate that 17 of the 20 countries (85%) have some form of national tsunami guidelines. At the prevention and mitigation phase and preparedness phase, there is a mix of standalone guidelines and those that address tsunami as a part of a multi-hazard guideline. At the emergency response phase and rehabilitation and reconstruction phase, they predominantly address tsunami as a part of national multi-hazard guidelines.

65% of countries have national tsunami guidelines have address the preparedness phase and emergency response phase, whereas only 50% of countries address the prevention and mitigation, and rehabilitation and reconstruction phases.

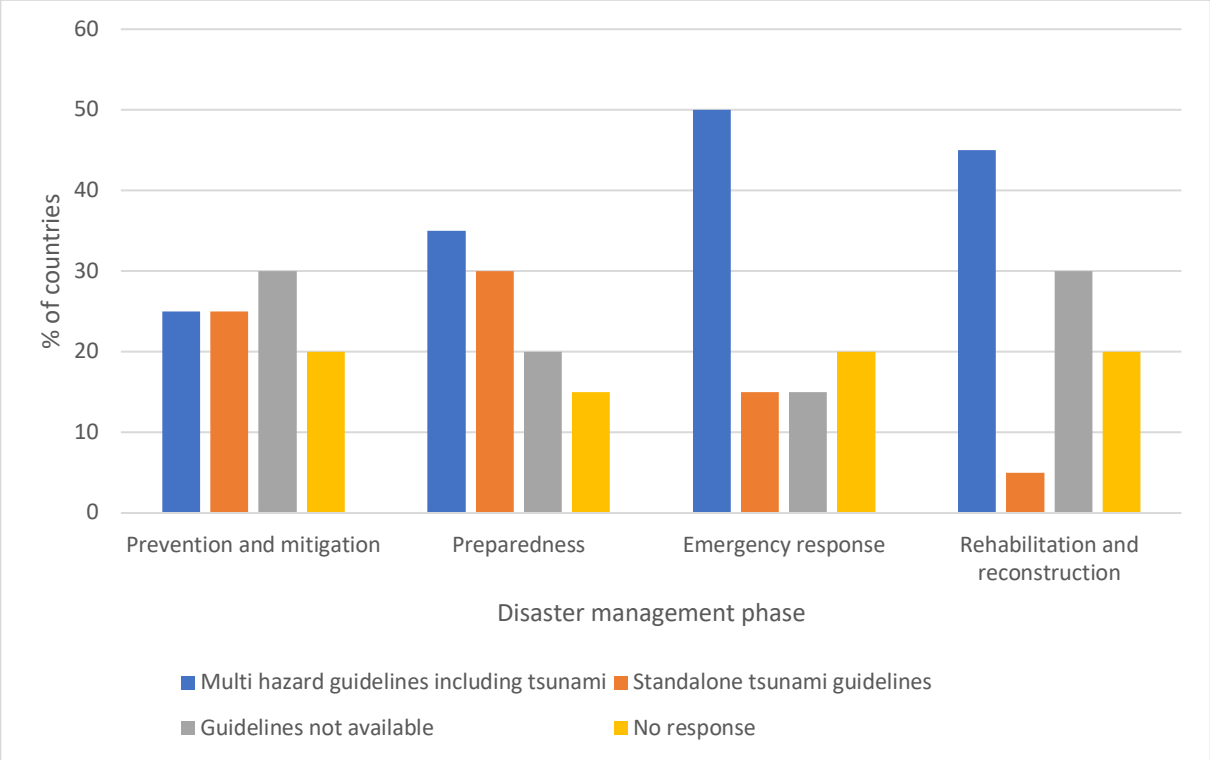

Figure 27: Types and phases of national tsunami guidelines

Using the same approach, countries were asked to confirm the availability and type of local tsunami guidelines they have, including whether it is multi-hazard or standalone, and which phases of the disaster management lifecycle it addresses, from prevention and mitigation, through to preparedness, emergency response, and rehabilitation and reconstruction (Figure 28).

The responses indicate that 16 of the 20 countries (80%) have some form of local tsunami guidelines. Across the disaster management phases, the majority address tsunami as a part of multi-hazard guidelines. 55% of countries have local tsunami guidelines have address the emergency response phase. They are not as commonly found in other phases, including preparedness (45%), prevention and mitigation (40%), and rehabilitation and reconstruction (35%).

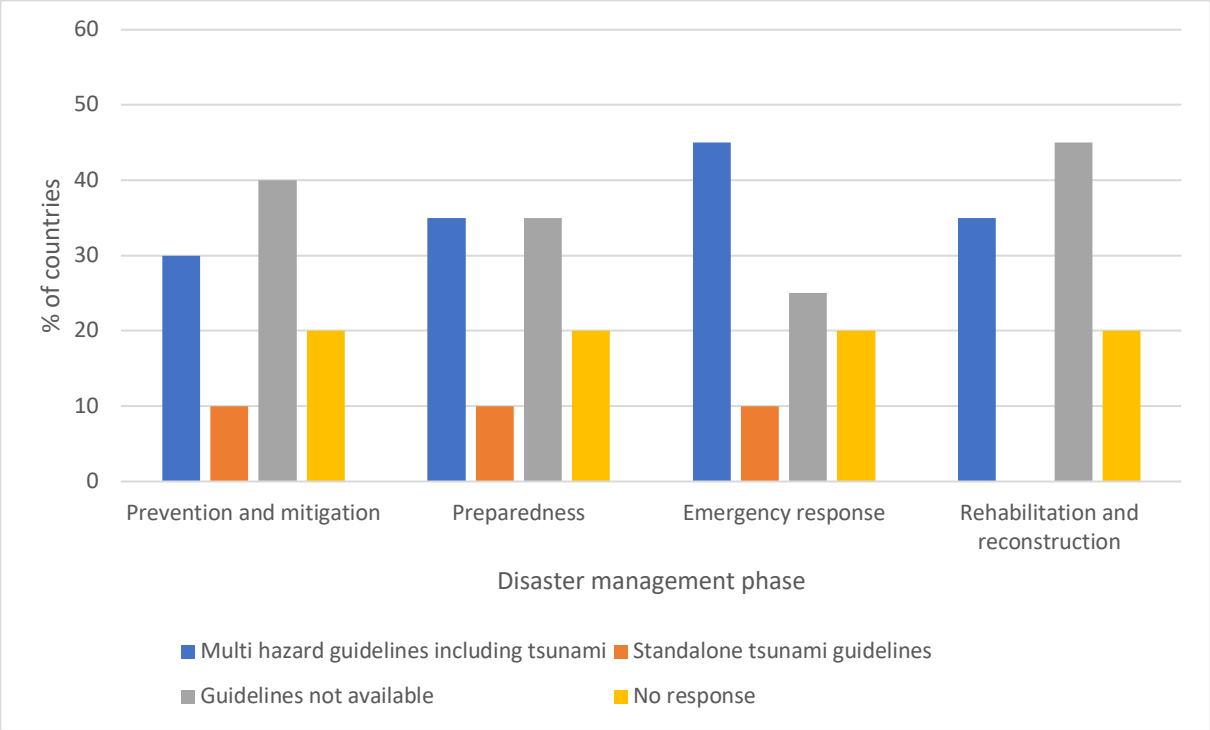

Figure 28: Types and phases of local tsunami guidelines

3.4. Detection, warning and dissemination

Detection and warning

All countries (100%) reported that they have a national capability to assess and/or receive potential tsunami threat information and advise / warn their coastal communities.

Countries were asked to confirm the type of data used for the coastal forecast zones (CFZ) of their coastline to determine national threats (Figure 29). 45% of countries relied solely on the data provided by the IOTWMS Tsunami Service Providers (TSPs) to identify CFZs, while 45% of countries used TSP data and their own threat assessment data. 5% of respondent countries relied solely on their own threat assessment data.

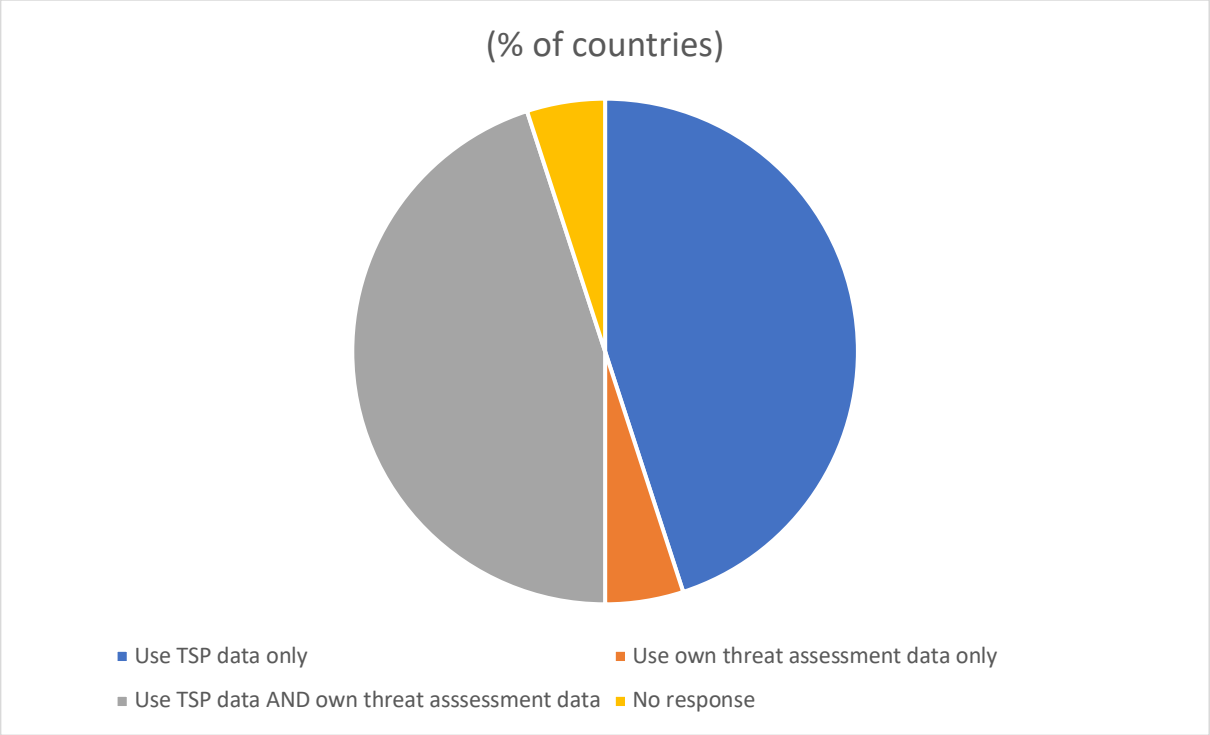

Figure 29: Data use for the Coastal Forecast Zones (CFZ) of a country's coastline to determine national threats

90% of respondent countries reported that the organisation responsible for assessing and/or receiving potential tsunami threat information operates 24x7. Comoros reported operating 12 to 15 hours per day, and Iran is currently looking to move towards 24x7 operations.

Countries were also asked to confirm what type of infrastructure is available to enable 24x7 operations. Computers and the internet were reported by 100% of respondents, while landline telephones and mobile phones or cell phones were reported by 90%+ of respondents. Fax, GTS and UPS were also widely reported (70%+). Satellite phones and VSAT were reported by 25% of respondents or less.

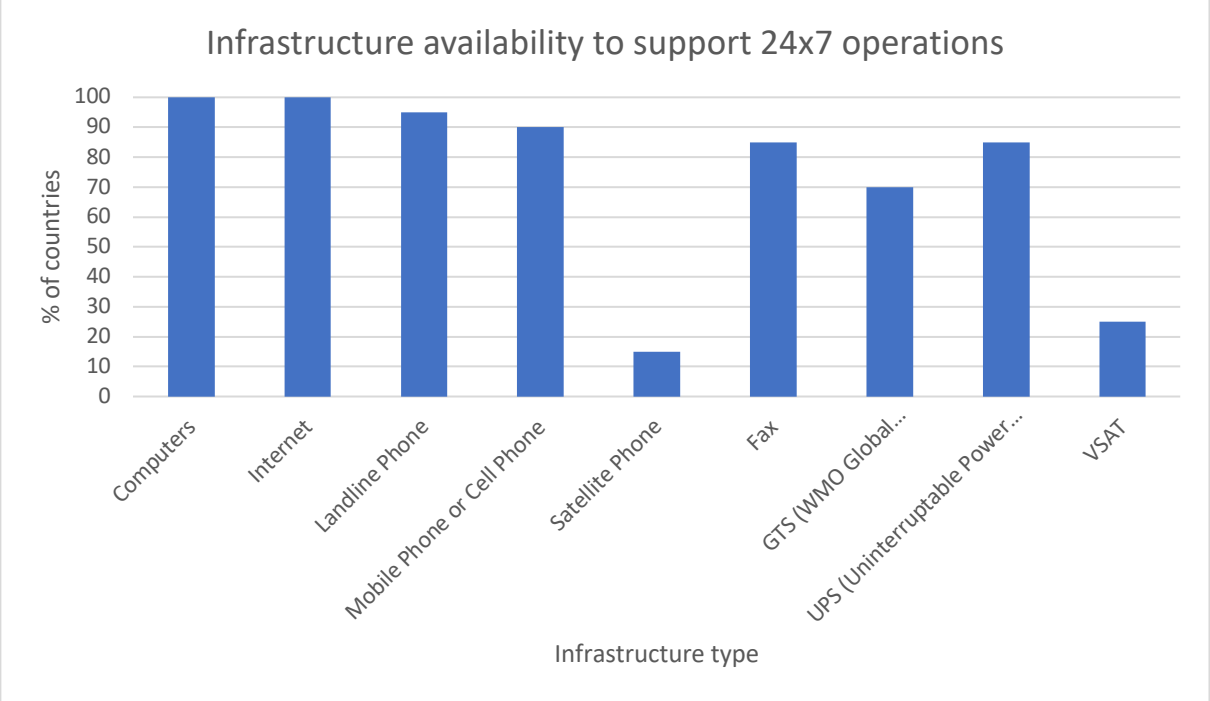

Figure 30: Infrastructure availability to support 24x7 operations

Countries were asked to report the level of tsunami threat forecast information produced by the responsible organisation (Figure 31). 90% of countries reported producing national level threat forecast information, while 70% of countries produce local level information. 6 countries (30%) reported producing ocean-wide information. 80% of countries reported producing multiple levels of tsunami threat forecast information.

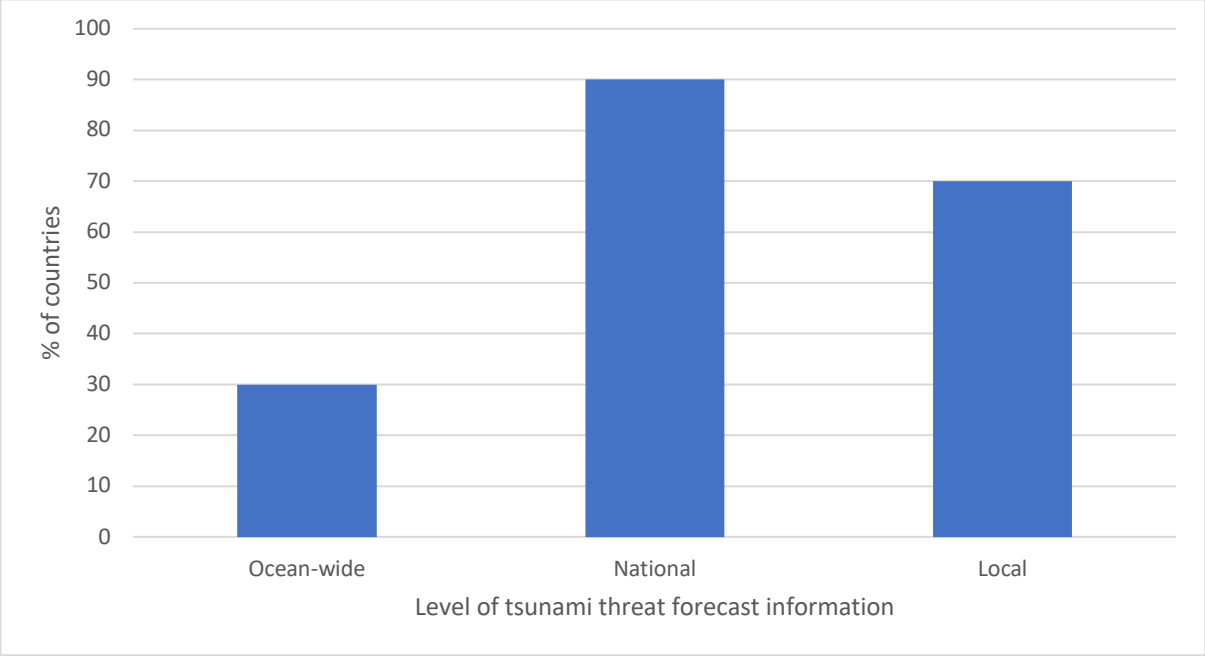

Figure 31: Level of tsunami threat forecast information is produced by the responsible organisation

Countries were also asked about their access to national or international seismic networks, and access to national or international sea level networks.

90% of respondent countries reported that the responsible organisation has access to national or international seismic networks. These ranged from a national seismic network, to the California Integrated Seismic Network (CISN), the USGS Network, Seedlink, RIMES, TSPs, Real-time seismic data from the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and IRIS.

65% of respondent countries reported that the list of broadband seismometers operated by their country is listed accurately in the IOTWMS seismic database. Two countries reported that stations had been added to their network when compared to the database listing.

85% of respondent countries reported that they have access to national or international sea level networks.

85% of respondent countries reported that the list of sea level stations operated by their country is listed accurately in the IOTWMS sea level database.

Countries were also asked about other observing networks operated by them and used for tsunami early warning (Figure 32). 55% of countries reported that they operated no other observing networks, and one country did not provide a response (5%). 15% of respondent countries reported operating GNSS/GPS, and a further 15% reported operating coastal radars. 15% of respondents identified other observing networks they operate, including DART Buoys and HF Radars.

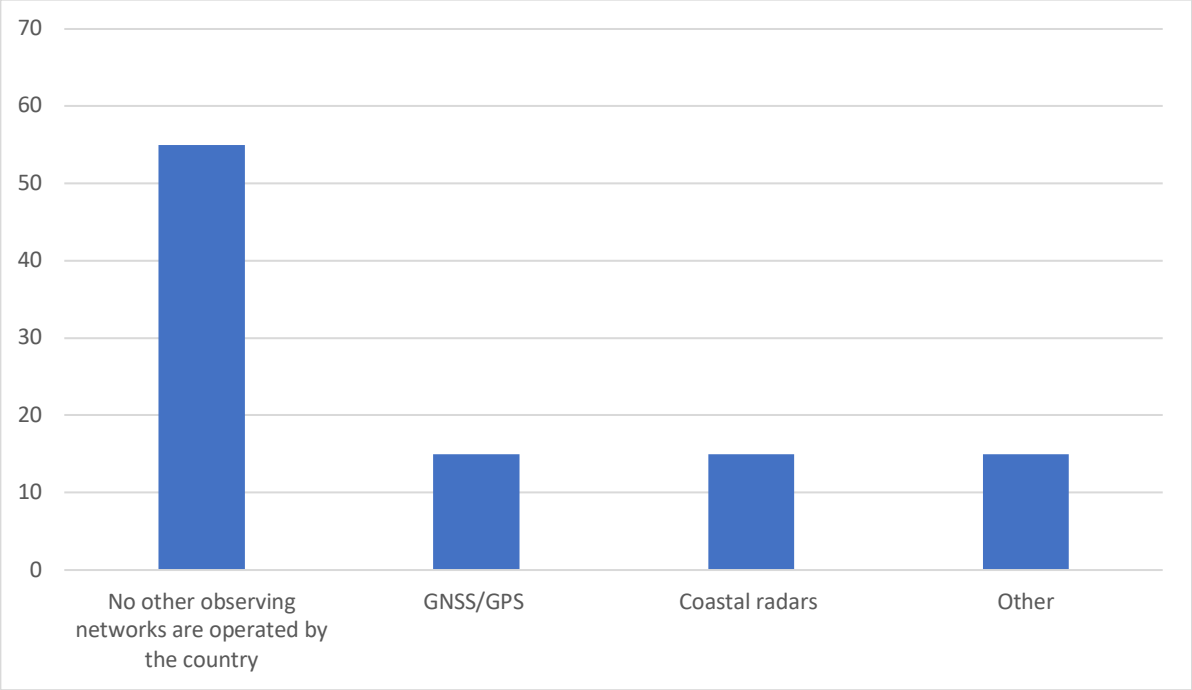

Figure 32: Other observing networks operated and used for tsunami early warning

Countries were asked to report on their capacity to analyse real-time seismic and sea level data for tsunami threat, their capacity for tsunami modelling to support generation of threat forecasts, as well as the software tools they use to support these.

65% of respondent countries reported having the capability of analysing real-time seismic and sea-level data for potential tsunami threat. Software tools used for this purpose varied greatly across the countries. Examples included: SeisComP3, JISView, Linuh, OTPAS (Operational Tsunami Prediction and Assessment System), Toast, Antelope, SeisAn, CSDP-IAS (Seismic data Analysis), Tide tool, Bulletin Hydra, and in-house developed applications for analysis of sea-level data.

60% of respondent countries also reported having the capability for tsunami modelling to support generation of threat forecasts, although 2 of these countries identified that their current tools are not adequate for accurate threat forecasts. Software tools used varied across the countries. Examples included: ComMIT, WINITDB, TSUNAMI, TSUCAT, OTPAS, TOAST, easywave, Mhras, TUNAMI, COMCOT, MOST Model, Geoware proprietary software, In-house developed application which uses TUNAMI-N2 and ADCIRC models.

80% of the respondent countries reported that the organisation responsible for identifying a potential tsunami threat also issues national tsunami watches, advisories, alerts and/or warnings.

Countries were also asked to report on their participation in communication tests and drills. 95% of respondent countries reported that their country's NTWC and/or TWFP participated in the 6-monthly communications tests conducted by the IOTWMS TSPs. Timor-Leste reported that it did not participate.

19 of the respondent countries (95%) reported that their country's NTWC and/or TWFP participated in the Tsunami Drill (e.g. IOWave) conducted in the inter-sessional period. Pakistan reported that it did not participate.

Countries were also asked to report on any recent experiences of tsunami, specifically those that occurred after 2004.

20% of respondent countries reported that they were impacted by a Tsunami after the 26th December 2004 event. However, Indonesia was the only country to report damage/losses from events, including Mentawai (2010), Aceh (2012), and Palu (2018).

Australia reported that although there was no major damaging tsunami affecting it, there were two noteworthy ones. The 17 July 2006 Java event generated a very localised impact to Steep Point of Western Australia (WA) where a camp site was destroyed and evidence of inundation to 200m inland. No tsunami warning was issued. A field impact assessment survey was subsequently conducted. Tide gauge observations along the Western coasts provided little clue to this very localised impact. For the 11 March 2011 Japan event, JATWC issued a National No Threat Bulletin to Australia for this event. A few tide gauges in Australia recorded tsunami waves up to 55cm. Unusual currents and waves were noted at Port Kembla and Sydney Harbour. Several swimmers were washed into a lagoon at Merimbula NSW although inconclusive whether due to tsunami. Overall the impact to Australia is minor.

India reported that there was no event which generated a major tsunami. However, on 11 April 2012 twin events (M 8.5 & M 8.2) generated a minor tsunami, and NTWC-India issued appropriate bulletins for those events.

Dissemination

Countries were asked to report on how their tsunami information (warning, public safety action, etc) is disseminated (Figure 33). Email is used in all countries, while 95% of countries use SMS and television. Telephone, fax, websites and radio were also widely used to disseminate tsunami information (85%). Social media, sirens, police/military and public alert systems are used in 50% or more of respondent countries. Less common methods (40% or less) include megaphones, VHF radio, VPN and door-to-door warnings.

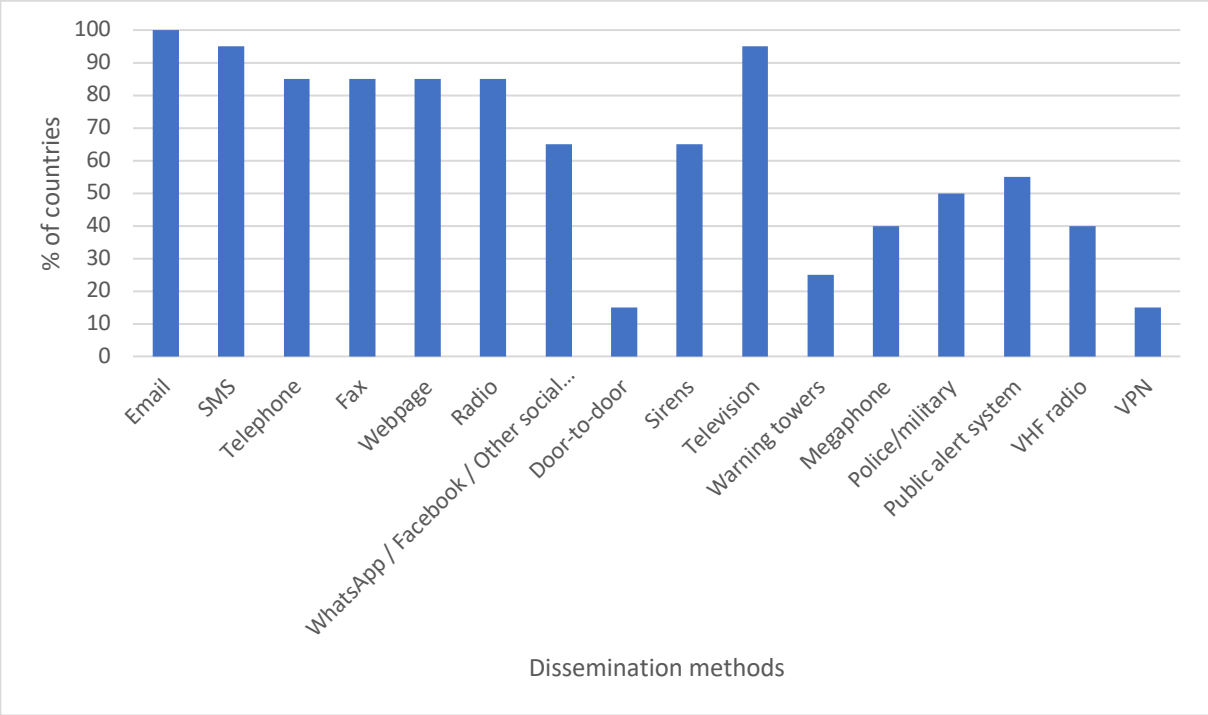

Figure 33: How tsunami information is disseminated

3.5. Public awareness, preparedness and response

Standard operating procedures

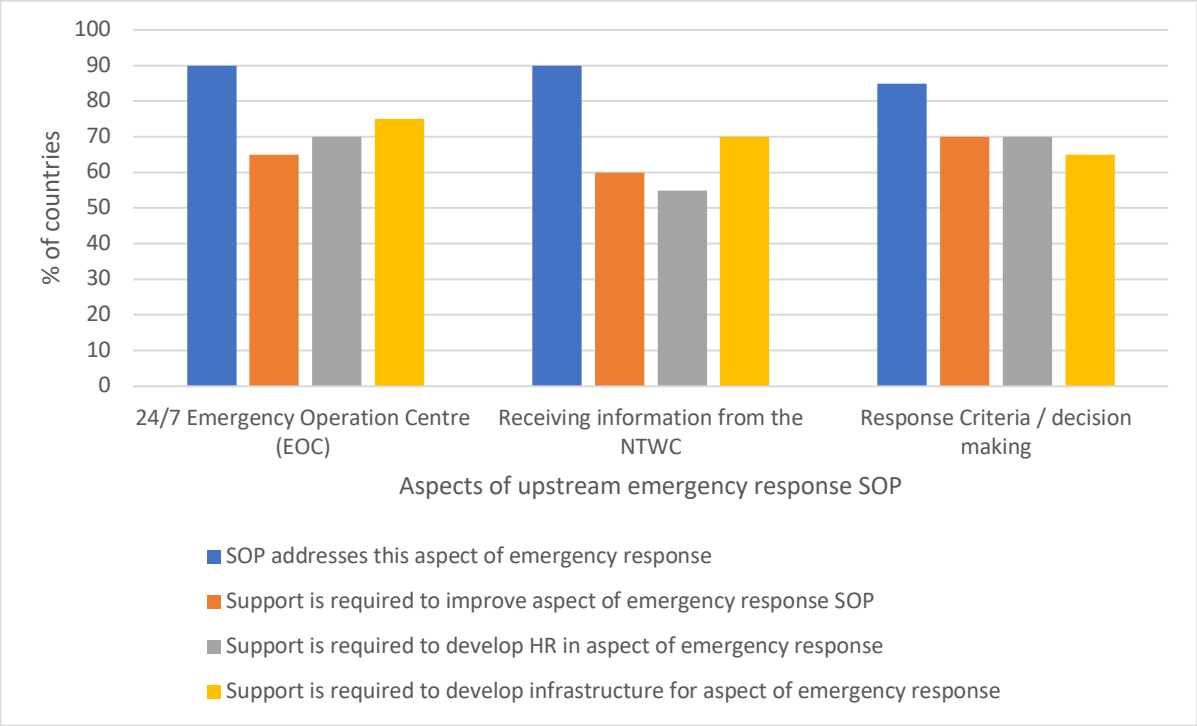

Figure 34: Support required to develop upstream emergency response SOP

Countries were asked to report on the availability of standard operating procedures (SOPs) for emergency response during the upstream stages of tsunami early warning (Figure 34).

The responses indicate that most countries have SOPs that address the operation of a 24/7 emergency operation centre (90%), receiving information from the NTWC (90%) and response criteria and decision making (85%). However, many countries also require support to develop SOPs in all three aspects (60 – 70%). Similarly, they also require support to develop human resources in these areas, especially 24/7 emergency operations and response criteria / decision making (70%). Support to develop infrastructure across all three aspects is also required in many countries (65 – 75%).

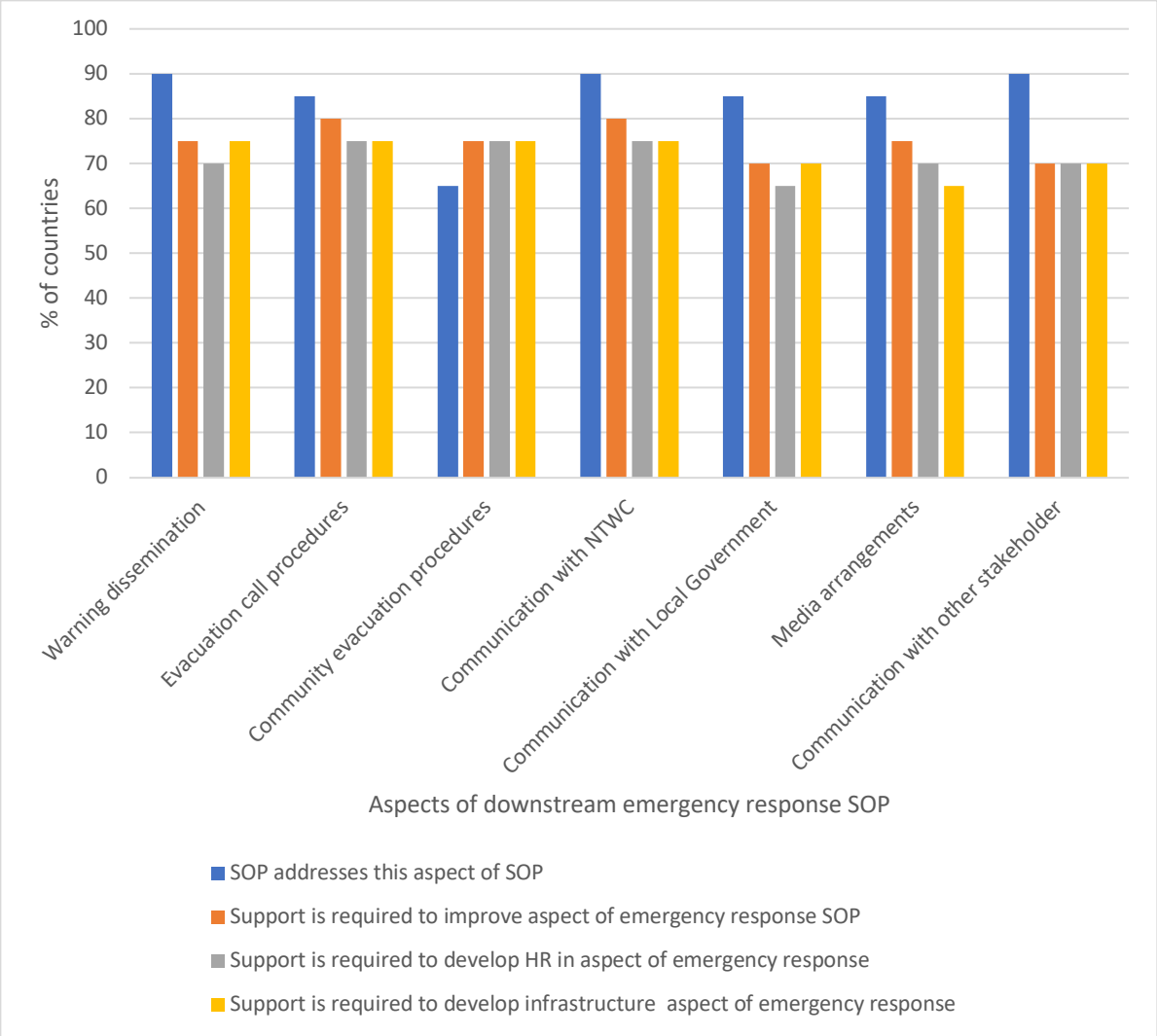

Figure 35: Support required to develop downstream emergency response SOP

Using the same structure, countries were also asked to report on the availability of standard operating procedures for emergency response during the downstream stages of tsunami early warning (Figure 35).

The responses indicate that most countries have standard operating procedures that address warning dissemination, communication with the NTWC and communication with other stakeholders (90%), evacuation call procedures, communication with local government and media arrangements (85%). Community level evacuation SOPs are only available in 65% of countries.

However, despite widespread availability, many countries also require support to develop SOPs in all seven aspects (70 – 80%). Similarly, they also require support to develop human resources in these areas (65 – 75%). Support to develop infrastructure across all seven aspects is also required in many countries (65 – 75%).

95% of the countries surveyed indicated their willing to share SOPs with IOTIC and other countries.

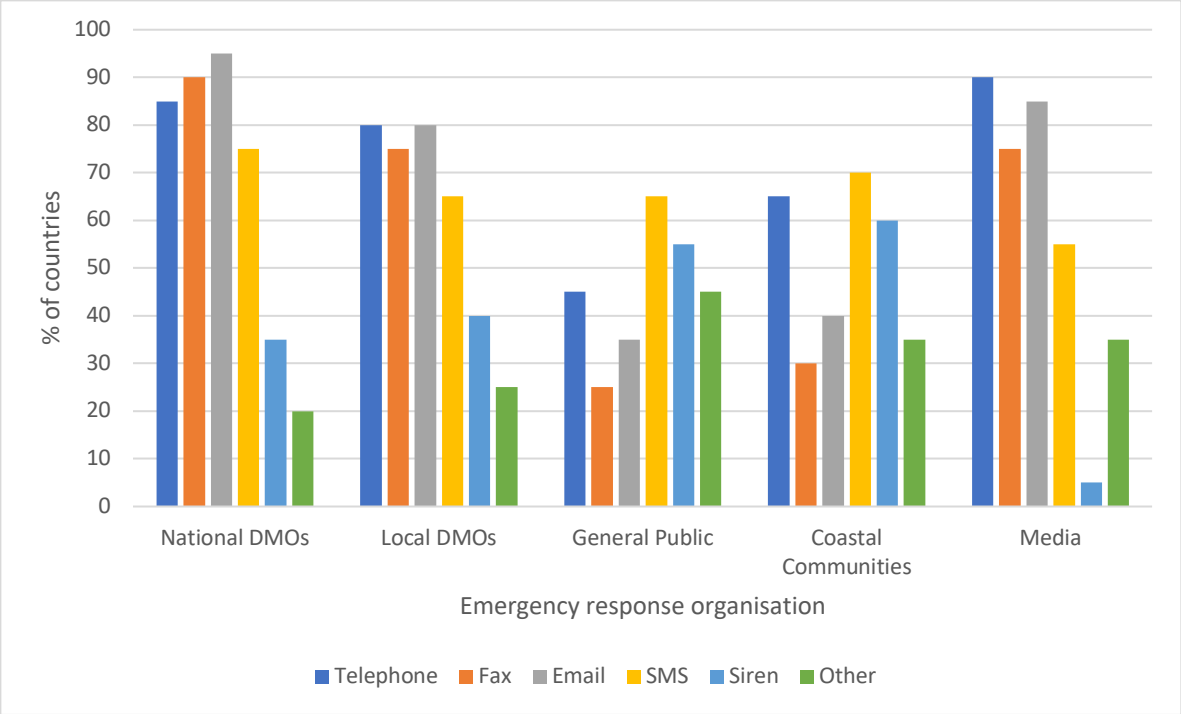

Figure 36: Communication methods for emergency response

Respondents were asked to confirm the communication methods used for communicating with emergency response organisations (Figure 36).

For National DMOs, telephones, fax, email and SMS are all widely used in many countries (75% or more). The situation is similar for Local DMOs (65% or more).

For communicating with the media, the telephone, fax and email are the main methods (75% or more).

Unsurprisingly, the pattern of responses for the general public and coastal communities is similar, with SMS and sirens used widely (55% or more), but telephones also widely used for communicating with coastal communities (65%), but less so for the general public (45%).

Other communication methods mentioned by countries included websites, social media, radio, dedicated applications, broadcast alert systems, and television.

Evacuation infrastructure

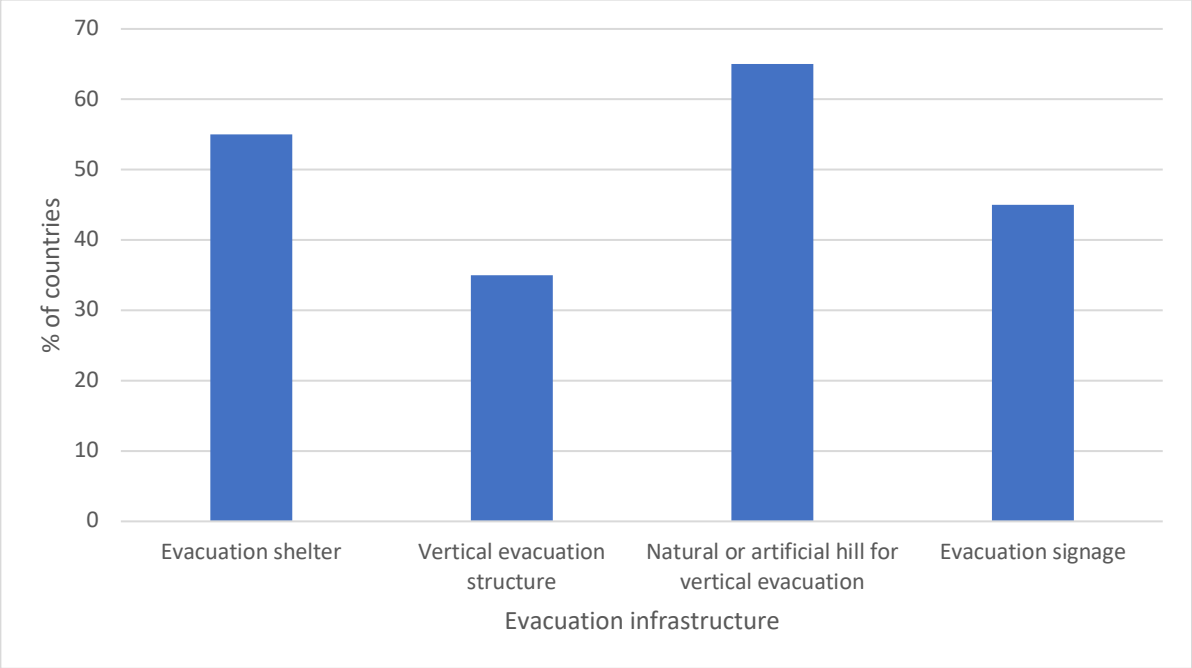

Figure 37: Evacuation infrastructure

Respondents were asked to indicate the availability of four different types of evacuation infrastructure in their country.

Natural or artificial hills for vertical evacuation are the most widely available evacuation infrastructure, identified by 65% of the countries. Evacuation shelters are available in 55% of countries, whereas, less common are evacuation signage (45%) and vertical evacuation structures (35%).

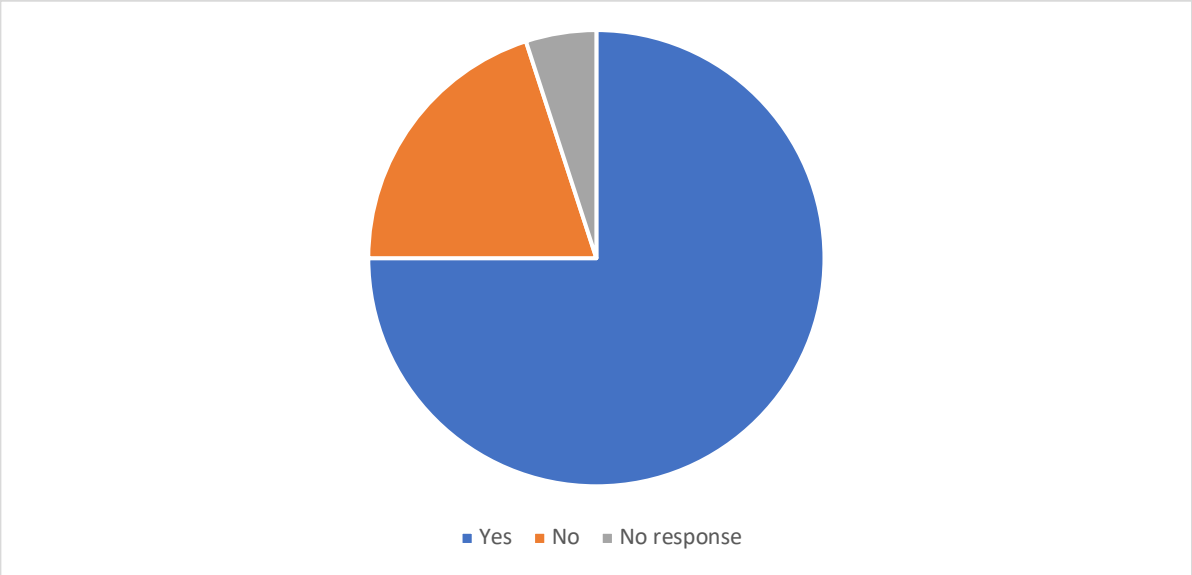

Figure 38: Integration of evacuation infrastructure into evacuation plan

A large majority of the respondent countries (75%) reported that their evacuation infrastructure is integrated within their evacuation plan (Figure 38).

Tsunami exercises

65% of respondent countries reported that they have tsunami exercises incorporated within their national policies and 80% have tsunami exercises incorporated within national guidelines.

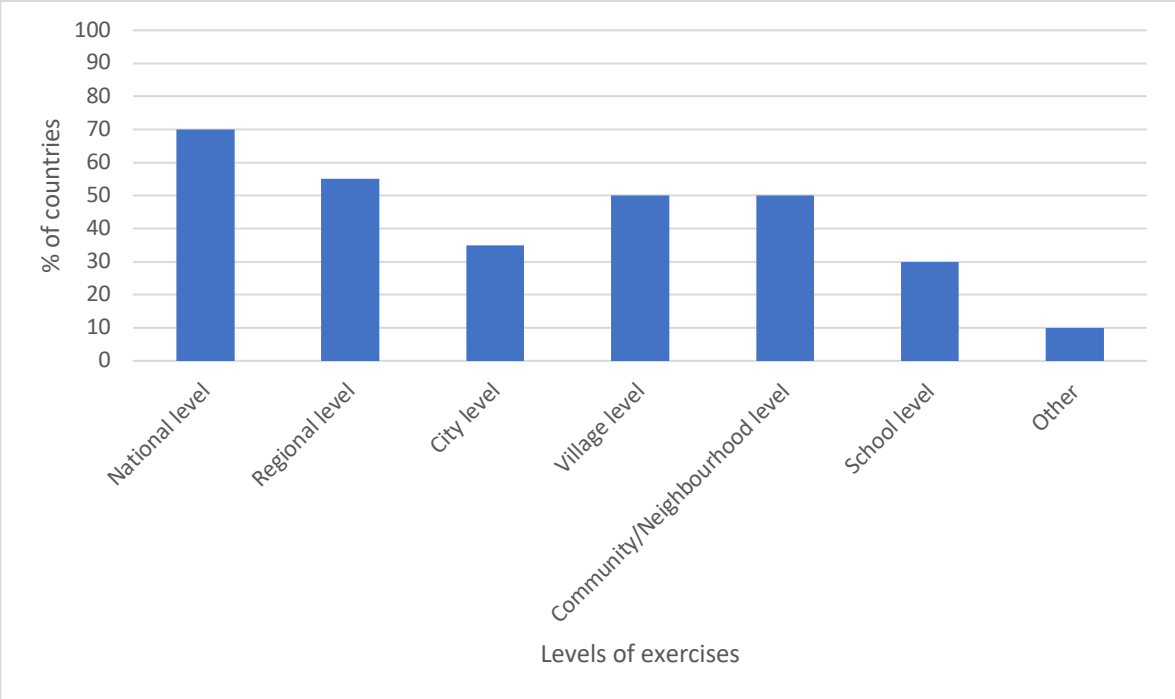

Figure 39: Levels of tsunami exercise conducted

All 20 respondent countries reported conducting tsunami exercises at one or more levels during the inter-sessional period.

Exercises are conducted at the national level within 70% of countries and at the regional level in 55% of countries. Village and community level exercises are conducted in 50% of countries. Other levels are less common, including the city (35%) and school (30%).

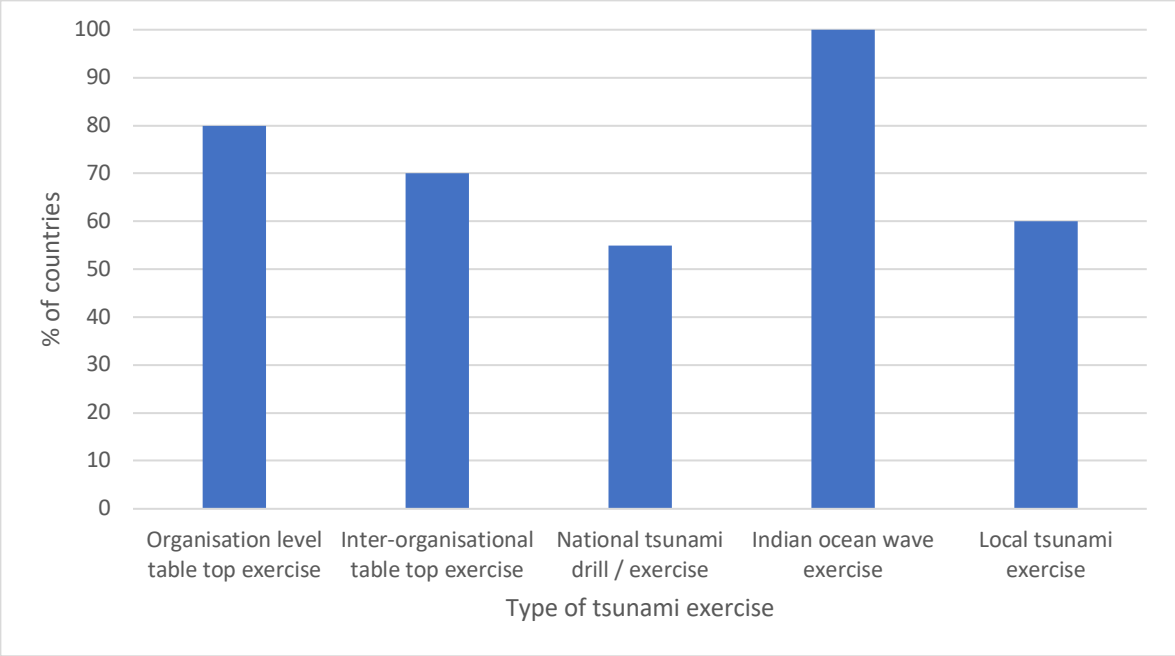

Figure 40: Types of tsunami exercise conducted

Countries were asked to report on the type of tsunami exercise activities that have been undertaken in their countries (Figure 40) during the inter-sessional period (between ICG Meetings).

100% of respondent countries reported that they took part in the Indian Ocean Wave exercise. Table top exercises were also widely undertaken, both within organisations (80%), and also as inter-organisational exercises (70%).

Local tsunami exercises were undertaken by 60% of respondent countries, which was slight more than at the national level (55%).

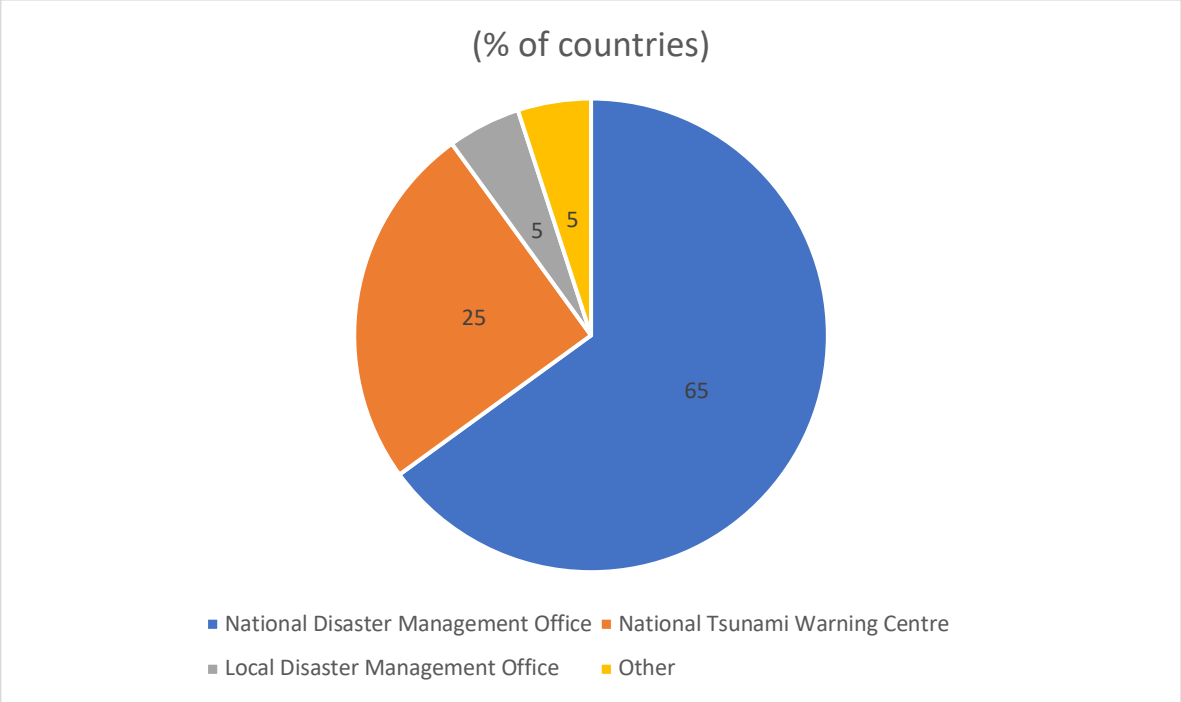

Figure 41: Organisation responsible for tsunami public awareness programmes

Countries were asked to identify the organisation responsible for tsunami public awareness programmes in their countries (Figure 41). In a majority of countries, the National Disaster Management Office takes responsibility (65%), but the National Tsunami Warning Centre (25%) and Local Disaster Management Office (5%) were identified by some countries. One country reported that is the responsibility of multiple organisations, including the NDMO, LDMO, NTWC and international organisations.

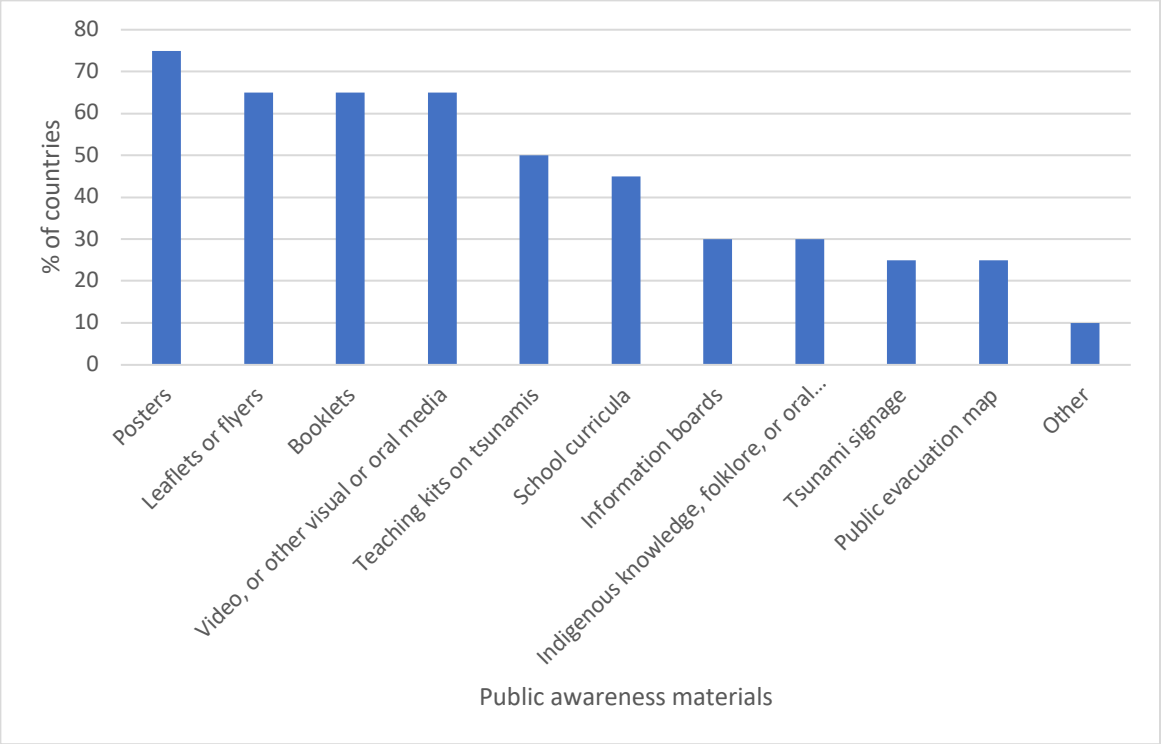

Figure 42: Types of public awareness materials

Countries were also asked to identify what tsunami related education and awareness materials they have developed and use (Figure 42). Posters (75%), leaflets and flyers, booklets and video/oral media (65%) were identified by the majority of countries. Education materials such as teaching kits (50%) and school curricular (45%) were also used in many countries. Less common were the use of information boards, indigenous knowledge, signage and public evacuation maps. Australia and Singapore both commented that dedicated websites with educational material had been developed.

95% of the respondent countries confirmed that they are willing to share these education and awareness materials with the Indian Ocean Tsunami Information Centre (IOTIC) and other countries.

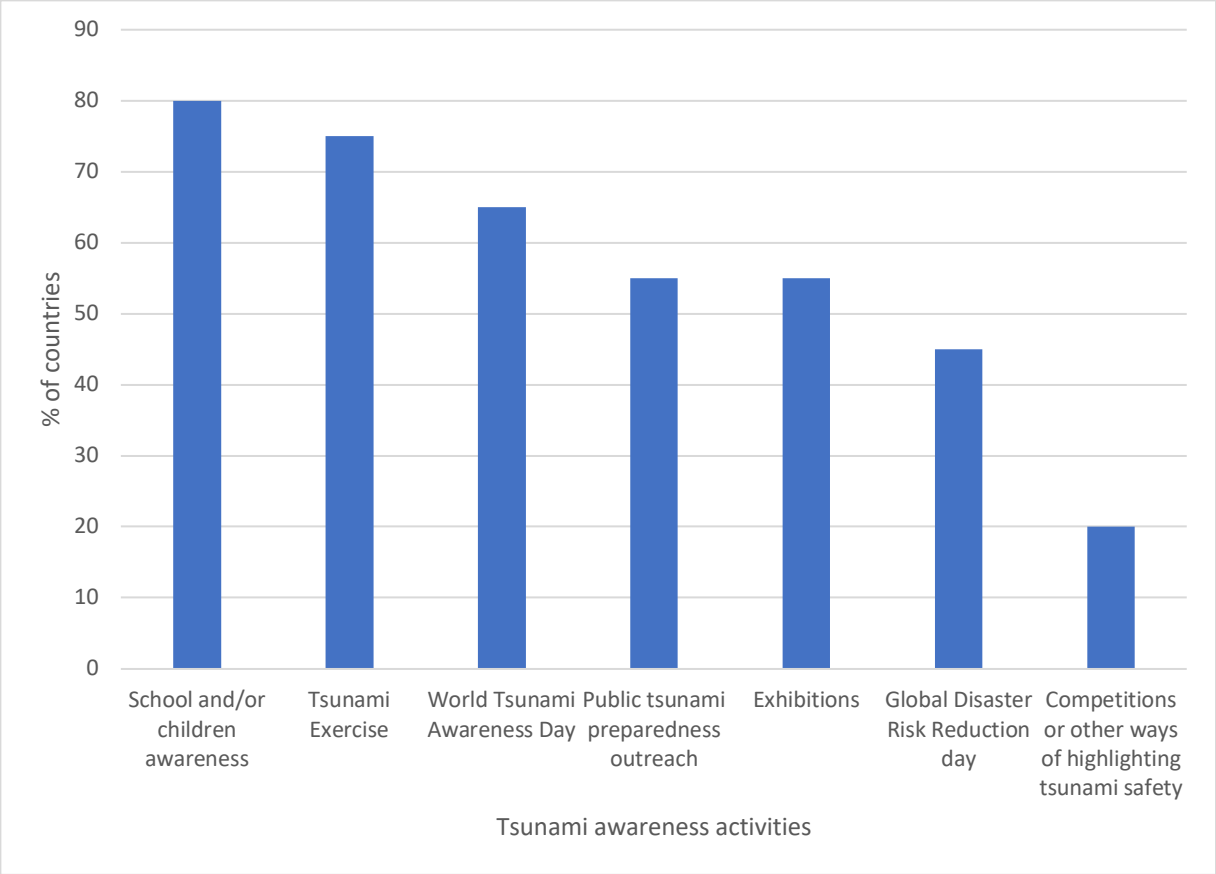

Figure 43: Types of public awareness activity

Countries were asked to confirm whether or not they carry out a range of public awareness activities (Figure 43). The responses varied greatly across countries. School and child related awareness activities (80%) and tsunami exercises (75%) are the most widely carried out across respondent countries. A majority of countries also carry out preparedness outreach activities and exhibitions (55%), whereas less than half the countries participate in Global Disaster Risk Reduction Day (45%) or carry out competitions or similar to highlight tsunami safety (20%).

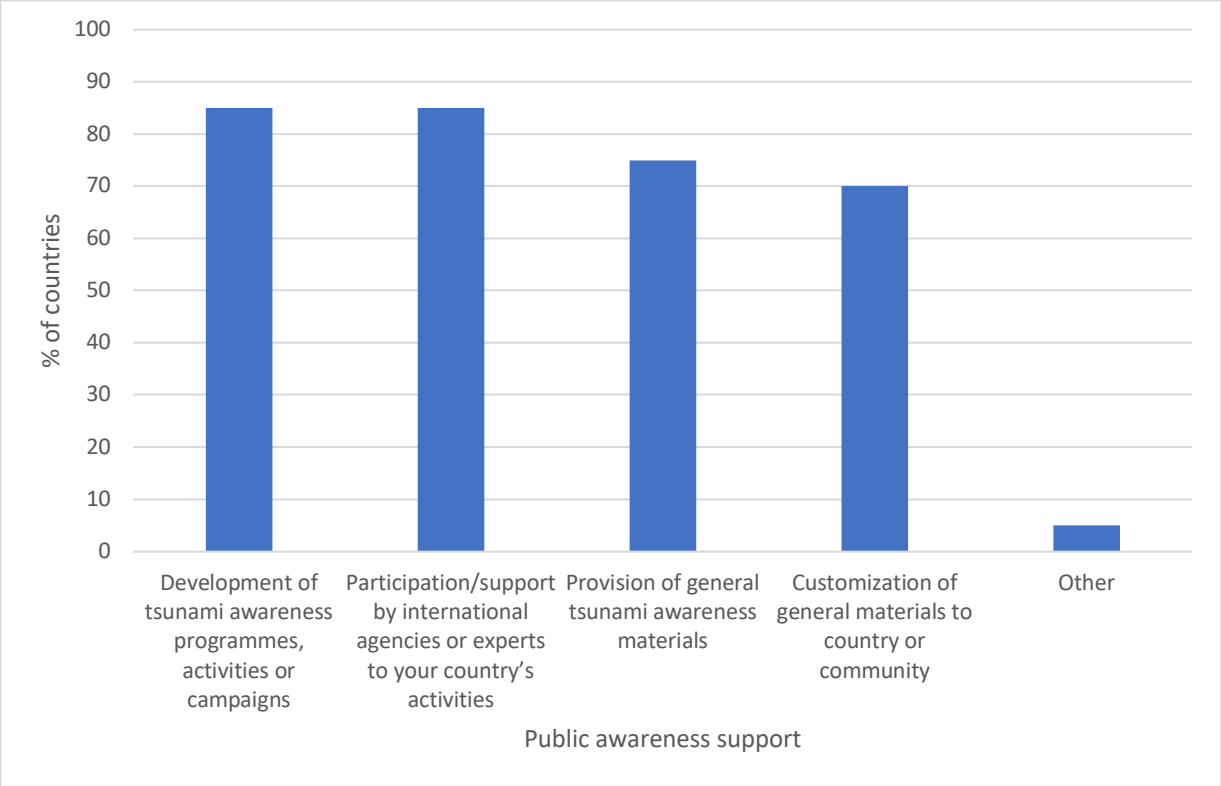

Figure 44: Support required for public awareness activity

Countries were asked to indicate any areas in which they required support from the IOTIC to develop or enhance public awareness in their country (Figure 44). Support was requested by the majority of countries for all four areas of public awareness provision. Support in the development of tsunami awareness programmes, activities or campaigns, and participation by international agencies or experts were the most widely requested by countries (85%).

50% of the respondents also offered to support other Member States to develop or enhance public awareness. The type of support on offer included to provide experts or share their materials, and to conduct or support training activity.

35% of respondents confirmed that their countries are piloting the Indian Ocean Tsunami Ready (IOTR) initiative.

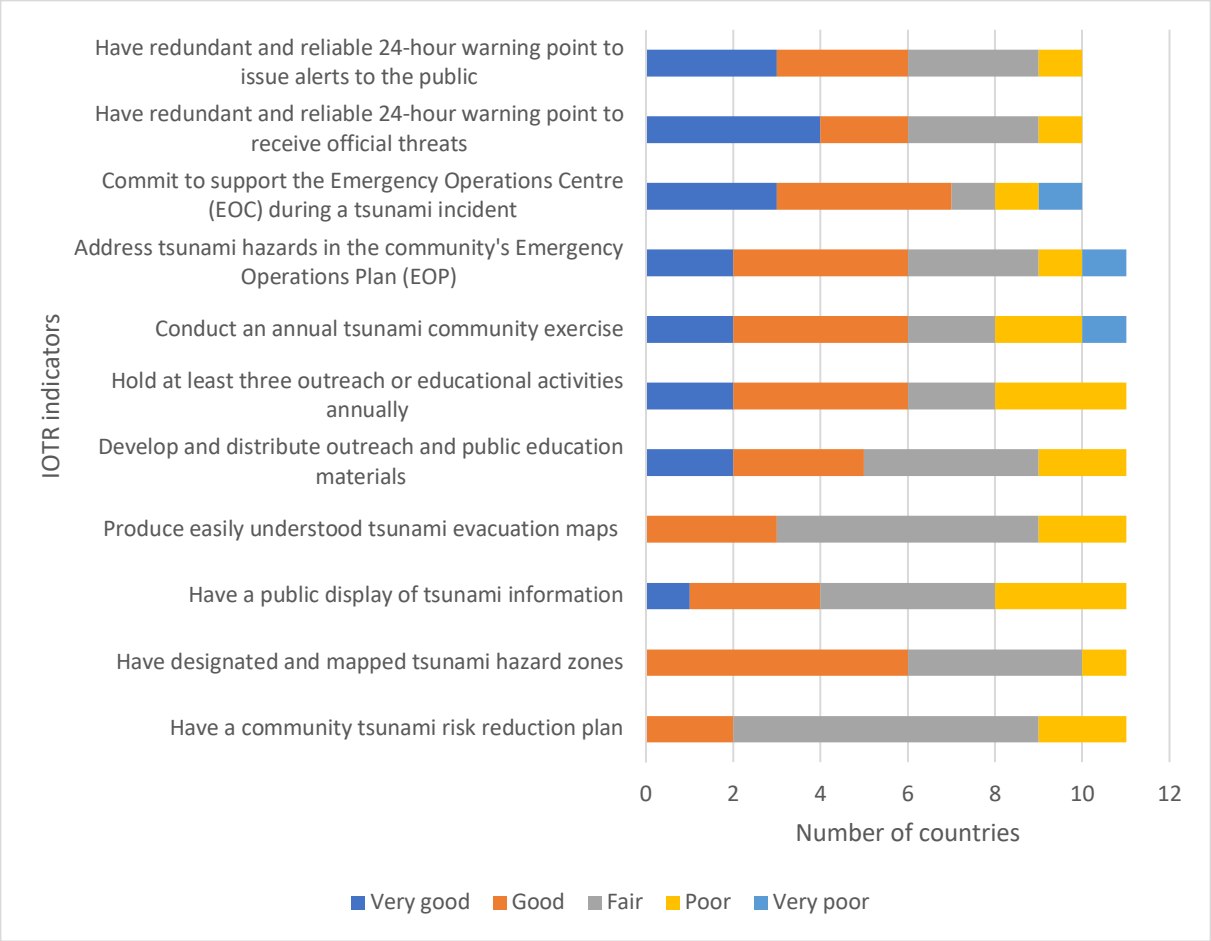

Figure 45: Performance against IOTR indicators

Countries that had communities who participated in the IOTR initiative were asked to provide a general ranking of their performance against the IOTR indicators, using the scale 1 (very poor) to 5 (very good) (Figure 45).

Performance varied greatly among countries, and between the eleven indicators. Performance in having redundant and reliable 24-hour warning points to receive information and alert the public were rated very good or good by 6 of the 10 responding countries, with no country rating as very poor. Commitment to support the EOC during a tsunami, addressing tsunami in a community's EOP, and conducting an annual tsunami exercise were also rated very good or good by 6 or more of the 10/11 responding countries. However, for each of these aspects one country rated themselves as very poor.

The weakest areas of performance included designated and mapped tsunami hazard zones (no countries were very good, 4 countries rated as fair, 1 as poor), and community risk reduction plans (no countries rated as very good, 7 countries rated as fair and 2 as poor).

3.6. Regional overview of existing capacity and additional support requirements

Sections 4.2 to 4.4 of this report have identified the current status of the end-to-end tsunami warning and mitigation system in the Indian Ocean. The findings are based on a sample of 20 countries that completed an online questionnaire survey. The survey instrument was developed by the "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP) and built upon existing survey and report templates (ICG national report, post-IOWave survey and post-event assessment survey).

The regional analysis is based on the survey findings from the following 20 countries:

Australia, Bangladesh, Comoros, France Indian Ocean Territories, India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Singapore, Sri Lanka, Tanzania, Thailand, Timor-Leste.

Section 4.5 of this report attempts to provide a baseline on the current status of the end-to-end tsunami warning and mitigation system in the Indian Ocean, as well as identify specific gaps and priorities for capacity development at the regional level. The section is structured around the three pillars, namely: Risk assessment & reduction, Detection, warning & dissemination, and Public awareness, preparedness & response.

3.7. Risk assessment and reduction

The survey revealed that all 20 countries participating in this survey (100%) conduct hazard assessments to understand the hazard threats to their territory. A large majority (90%) conduct this as a multi-hazard assessment including tsunami. 17 of the 18 countries that do multi-hazard assessments also include flooding (85% of total), 15 include cyclones (75% of total) and 14 (70% of total) include earthquakes. Less common hazards to be included are drought and landslide (55%), epidemics (35%) and volcanic eruptions (20%).

A range of different organisations are engaged or have responsibility to undertake these tsunami hazard assessments. 75% of assessments involve a national agency, 45% a national or local university, 40% a national or international consultant, and just 20% an international agency. 45% of tsunami hazard assessments involve multiple organisations.

It would appear that in many countries there is sole reliance on a national agency to carry out hazard assessments. There may be opportunity to increase engagement of other national, regional or international actors, such as research institutes and universities. Their expertise in areas such as hazard assessment would help to address some of the capacity shortcomings revealed at the national level. It would also help to strengthen the link between science, policy and action.

The level at which these assessments are carried out also varies greatly among countries, although given the wide variations in geographic area, population size and hazard threat among them, this might be expected. 65% of countries carry out the tsunami hazard assessment at a national level, 40% at the regional level, 45% at the city level and 30% at the village level (Figure 6). 50% of countries carry out hazard assessments at multiple levels.

The survey results reveal that countries draw upon a range of data types to support their tsunami hazard assessment, but that in many cases, this data is not publicly available. 17 countries (85%) identify two or more data types used to support their tsunami hazard assessment, while 3 countries did not identify any data types. Bathymetry and topography are the most widely used data to inform tsunami hazard assessment. 55% of the 20 countries use seismo-tectonic models, and 55% of countries also use infrastructure details. However, none of the data sources are widely available to the public. Land cover data was reported as available in 7 of the 13 countries that use it, whereas infrastructure data is publicly available in just 3 of the 11 countries using this data to inform tsunami hazard assessments. The rationale for not making data available was not examined within the survey and this might be explored in future studies. For example, it might be due to the cost of making it available, a lack of understanding on how this data could be used for the benefit of others, security, data protection or similar.

The number and type of products to emerge from the tsunami hazard assessment also varies greatly across the 20 respondent countries. The most common products (Figure 8) are inundation maps (80%) and hazard maps (70%). The other products are developed by less than 50% of countries.

The reason for such differences in the type of products produced by countries can partly be explained by the widely varying capacities to undertake such assessments. 45% of countries rate themselves as having very good or good capacity to undertake tsunami hazard assessments, while 35% of countries rate themselves as having fair capacity. 20% of countries rate themselves as having poor capacity.

The responses also indicate that all six areas of tsunami hazard assessment surveyed in this study require capacity improvement in at least some countries, but evacuation mapping was ranked as the highest priority for capacity improvement, followed by hazard mapping and inundation mapping.

The survey results also show that the capacity to offer training in these areas is already available across the Member States of the IOTWMS and that this could be used to develop those countries with poor or very poor capacity. For example, 40% of countries indicate very good or good capacity to give training on hazard mapping and inundation mapping, while 35% of countries indicate the same on evacuation mapping. For the other 3 areas, probabilistic tsunami hazard assessment, deterministic tsunami hazard analysis and field studies on tsunami impact, just 3 (15%) of the 20 countries indicate very good or good capacity. However, notably, the demand for capacity building in these three areas was also less.

The survey also asked countries to consider the extent and nature of tsunami risk assessments carried out. The results show that 16 of the 20 countries participating in this survey (80%) conduct tsunami risk assessments, and 15 of those are as multi-hazard assessments. All 15 countries that carry out multi-hazard risk assessments include tsunami, with flooding, cyclones and earthquakes considered by 50% or more of countries. Less common hazards to be included are epidemics and volcanic eruptions.

The organisation(s) responsible for carrying out tsunami risk assessments vary across the respondent countries. In 55% of countries a national agency is fully or partially responsible. National or local universities are at least partially responsible in 25% countries. A national agency or international consultant is at least partially responsible in 25% countries, while 20% countries indicated that an international agency is at least partially responsibleFigure 5. In 20% of countries, the tsunami risk assessment is the responsibility of multiple actors. As with hazard assessments, it would appear that in many countries there is sole reliance on a national agency to carry out hazard assessments. There may be opportunity to increase engagement of other national, regional or international actors, such as research institutes and universities. Their expertise in areas such as risk assessment would help to address some of the capacity shortcomings revealed at the national level. It would also help to strengthen the link between science, policy and action.

Of the 16 countries that carry out tsunami risk assessments, 11 conduct them at the national level, 8 at a regional level and 6 at a city level. Just 4 countries carry out village and/or community level risk assessments. 6 countries carry out risk assessment at multiple levels. These differences among countries may in part be explained by the variations in geographic area, population size and hazard threat among them, but other parts of the survey results, summarised below, indicate it is due to inadequate capacity.

The survey responses indicate wide ranging capacity to undertake tsunami risk assessment across the 20 respondent countries. 35% of countries rate their capacity as very good or good. 25% rate themselves as having fair capacity, and 35% of countries rate themselves as poor or very poor.

When asked to rate their priorities for capacity improvement across five levels of tsunami risk assessment, the responses indicate that all levels require capacity improvement in at least some countries. However, using a weighted response across the twenty respondent countries, city level risk assessment is ranked as the highest priority for capacity improvement, followed by village and community levels.

The wide-ranging capacities among countries may also explain the variations in the number and type of products developed from the tsunami risk assessment. A risk map is produced by 11 of the 16 countries (55% of all countries) that conduct tsunami risk assessments. Evacuation maps, guidelines and action plans are also produced, but each of them by less than half of the respondent countries that do tsunami risk assessments.

In contrast to hazard assessments, the survey results indicate there is limited capacity among the countries to give training and/or consultancy to other countries on the five levels of tsunami hazard assessment (national to community). For each level, there were no countries indicating very good capacity to deliver training on tsunami risk assessment. 30% of countries rate themselves as having good capacity to give training at the national level, and 20% at the regional and city levels. Only 15% of countries rate themselves as having good capacity to deliver training at the village or community level.

The survey revealed that 19 of the 20 countries (95%) have some form of national tsunami policy and the country without one commented that it is under development. A large majority address tsunami as a part of a multi-hazard policy. 90% of countries have a national policy have addresses the emergency response phase and 80% one that addresses the rehabilitation and reconstruction phase. 75% of countries have a national policy that addresses the prevention and mitigation phase and/or the preparedness phase.

Policies are less prevalent at the local level. The survey revealed that 15 of the 20 countries (75%) have some form of local tsunami policy, but 3 of the countries without commented that it is under development. For those countries with some form of local tsunami policy, the majority address tsunami as a part of a multi-hazard policy. Following a similar pattern to the national level, the emergency response phase has the highest number of local policies incorporating tsunami, with 75% of countries having one, whereas for each of the other phases, only 55% countries address tsunami, either as a standalone or multi-hazard policy.

The survey results reveal that 90% of countries have some form of tsunami disaster risk reduction plans, while 1 of the 2 without plans commented that they are under development. A significant majority of countries address tsunami risk reduction as a part of a multi-hazard plan, rather than as standalone plans.

Across all four phases of the disaster management lifecycle, availability of plans is significantly higher at the national level, followed by the local level. There is least availability at the community level. For example, at the emergency response phase, 75% countries have national level plans, while 55% have local and 40% have community level plans. This pattern is similar in all phases of disaster management.

Availability of tsunami plans is highest during the emergency phase. For example, the 75% of countries with national plans at the emergency phase, exceeds those during the prevention and mitigation phase (65%), the preparedness phase (70%) and the rehabilitation and reconstruction phase (55%). This pattern is replicated at the local and community levels, with availability at the emergency phase exceeding other phases.

All countries (100%) reported that their tsunami disaster risk reduction plans are based on hazard and/or risk assessments.

The survey revealed that 17 of the 20 countries (85%) have some form of national tsunami guidelines. At the prevention and mitigation phase and preparedness phase, there is a mix of standalone guidelines and those that address tsunami as a part of a multi-hazard guideline. At the emergency response phase and rehabilitation and reconstruction phase, they predominantly address tsunami as a part of national multi-hazard guidelines.

65% of countries have national tsunami guidelines have address the preparedness phase and emergency response phase, whereas only 50% of countries address the prevention and mitigation, and rehabilitation and reconstruction phases.

There is also widespread availability of guidelines at the local level, responses indicating that 16 of the 20 countries (80%) have some form of local tsunami guidelines. Across the disaster management phases, the majority address tsunami as a part of multi-hazard guidelines. 55% of countries have local tsunami guidelines have address the emergency response phase. They are not as commonly found in other phases, including preparedness (45%), prevention and mitigation (40%), and rehabilitation and reconstruction (35%).

Across policies, plans and guidelines, as well as national to local, there is a recurring trend of greater focus on tsunami within the emergency phase of disaster management. While the rehabilitation and

reconstruction phase may share many similarities with other hazards, the lack of tsunami specific focus for preparedness and the prevention and mitigation phases is more difficult to justify.

3.8. Detection, warning and dissemination

All countries (100%) reported that they have a national capability to assess and/or receive potential tsunami threat information and advise / warn their coastal communities.

45% of countries relied solely on the data provided by the IOTWMS Tsunami Service Providers (TSPs) to identify CFZs, while 45% of countries used TSP data and their own threat assessment data. 5% of respondent countries relied solely on their own threat assessment data.

90% of respondent countries reported that the organisation responsible for assessing and/or receiving potential tsunami threat information operates 24x7. Comoros reported operating 12 to 15 hours per day, and Iran is currently looking to move towards 24x7 operations.

The survey results reveal what type of infrastructure is available to enable 24x7 operations. Computers and the internet were reported by 100% of respondents, while landline telephones and mobile phones or cell phones were reported by 90%+ of respondents. Fax, GTS and UPS were also widely reported (70%+). Satellite phones and VSAT were reported by 25% of respondents or less.

90% of countries reported producing national level threat forecast information, while 70% of countries produce local level information. 6 countries (30%) reported producing ocean-wide information. 80% of countries reported producing multiple levels of tsunami threat forecast information.

90% of respondent countries reported that the responsible organisation has access to national or international seismic networks. These ranged from a national seismic network, to the California Integrated Seismic Network (CISN), the USGS Network, Seedlink, RIMES, TSPs, Real-time seismic data from the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and IRIS.

85% of respondent countries reported that they have access to national or international sea level networks.

Countries were also asked about other observing networks operated by them and used for tsunami early warning. 55% of countries reported that they operated no other observing networks, and one country did not provide a response (5%). 15% of respondent countries reported operating GNSS/GPS, and a further 15% reported operating coastal radars. 15% of respondents identified other observing networks they operate, including DART Buoys and HF Radars.

Countries were asked to report on their capacity to analyse real-time seismic and sea level data for tsunami threat, their capacity for tsunami modelling to support generation of threat forecasts, as well as the software tools they use to support these.

65% of respondent countries reported having the capability of analysing real-time seismic and sea-level data for potential tsunami threat. Software tools used for this purpose varied greatly across the countries. Examples included: SeisComP3, JISView, Linuh, OTPAS (Operational Tsunami Prediction and Assessment System), Toast, Antelope, SeisAn, CSDP-IAS (Seismic data Analysis), Tide tool, Bulletin Hydra, and in-house developed applications for analysis of sea-level data.

60% of respondent countries also reported having the capability for tsunami modelling to support generation of threat forecasts, although 2 of these countries identified that their current tools are not adequate for accurate threat forecasts. Software tools in use varied across the countries. Examples included: ComMIT, WINITDB, TSUNAMI, TSUCAT, OTPAS, TOAST, easywave, Mhras, TUNAMI, COMCOT, MOST Model, Geoware proprietary software, In-house developed application which uses TUNAMI-N2 and ADCIRC models.

The reason for such a variety of software tools being used for analysing data for tsunami threat or tsunami modelling was not explored within or explained by the survey results. However, the current situation may hinder the ability of the region to provide training and support for those countries that have inadequate capacity.

80% of the respondent countries reported that the organisation responsible for identifying a potential tsunami threat also issues national tsunami watches, advisories, alerts and/or warnings.

Countries were also asked to report on their participation in communication tests and drills. 95% of respondent countries reported that their country's NTWC and/or TWFP participated in the 6-monthly communications tests conducted by the IOTWMS TSPs. Timor-Leste reported that it did not participate.

19 of the respondent countries (95%) reported that their country's NTWC and/or TWFP participated in the Tsunami Drill (e.g. IOWave) conducted in the inter-sessional period. Pakistan reported that it did not participate.

Countries were also asked to report on any recent experiences of tsunami, specifically those that occurred after 2004. 20% of respondent countries reported that they were impacted by a Tsunami after the 26th December 2004 event. However, Indonesia was the only country to report damage/losses from events, including Mentawai (2010), Aceh (2012), and Palu (2018).

The lack of recent experience of tsunami events in many countries would appear to pose a number of threats to effective early warning, including loss of commitment, a reduction in priority level, difficulty in obtaining resources, lack of practical experience within agencies and their staff, and lack of experience or engagement among the public.

The survey results show how countries disseminate their tsunami information (warning, public safety action, etc). Email is used in all countries, while 95% of countries use SMS and television. Telephone, fax, websites and radio were also widely used to disseminate tsunami information (85%). Social media, sirens, police/military and public alert systems are used in 50% or more of respondent countries. Less common methods (40% or less) include megaphones, VHF radio, VPN and door-to-door warnings.

3.9. Public awareness, preparedness and response

The survey results reveal that most countries have SOPs that address the operation of a 24/7 emergency operation centre (90%), receiving information from the NTWC (90%) and response criteria and decision making (85%). However, many countries also require support to develop SOPs in all three of these aspects (60 – 70%). Similarly, they also require support to develop human resources in these areas, especially 24/7 emergency operations and response criteria / decision making (70%). Support to develop infrastructure across all three aspects is also required in many countries (65 – 75%).

A similar situation is revealed downstream. The responses indicate that most countries have standard operating procedures that address warning dissemination, communication with the NTWC and communication with other stakeholders (90%), evacuation call procedures, communication with local government and media arrangements (85%). However, community level evacuation SOPs are only available in 65% of countries.

Despite widespread availability, many countries also require support to develop downstream SOPs in all seven aspects listed above (70 – 80%). Similarly, they also require support to develop human resources in these downstream areas (65 – 75%). Support to develop infrastructure across all seven aspects is also required in many countries (65 – 75%).

Overall, despite SOPs being widely available for most aspects of upstream and downstream early warning operation, most countries are requesting further support to develop them, along with the associated human resources and infrastructure. The lack of community level evacuation SOPs in 35% of countries is also notable and significantly worse than other aspects that were examined in the survey. Encouragingly, 95% of the countries surveyed indicated their willing to share SOPs with IOTIC and other countries, which would provide a good basis for capacity building across the Member States.

Respondents were asked to confirm the communication methods used for communicating with emergency response organisations. For National DMOs, telephones, fax, email and SMS are all widely used in many countries (75% or more). The situation is similar for Local DMOs (65% or more). For communicating with the media, the telephone, fax and email are the main methods (75% or more).

Unsurprisingly, the pattern of responses for the general public and coastal communities is similar, with SMS and sirens used widely (55% or more), but telephones also widely used for communicating with coastal communities (65%), but less so for the general public (45%).

Other communication methods mentioned by countries included websites, social media, radio, dedicated applications, broadcast alert systems, and television.

Respondents were asked to indicate the availability of four different types of evacuation infrastructure in their country. Natural or artificial hills for vertical evacuation are the most widely available evacuation infrastructure, identified by 65% of the countries. Evacuation shelters are available in 55% of countries, whereas, less common are evacuation signage (45%) and vertical evacuation structures (35%). A large majority of the respondent countries (75%) reported that their evacuation infrastructure is integrated within their evacuation plan.

65% of respondent countries reported that they have tsunami exercises incorporated within their national policies and 80% have tsunami exercises incorporated within national guidelines. All 20 respondent countries reported conducting tsunami exercises at one or more levels during the inter-sessional period.

Exercises are conducted at the national level within 70% of countries and at the regional level in 55% of countries. Village and community level exercises are conducted in 50% of countries. Other levels are less common, including the city (35%) and school (30%).

100% of respondent countries reported that they took part in the Indian Ocean Wave exercise. Table top exercises were also widely undertaken, both within organisations (80%), and also as inter-organisational exercises (70%).

Local tsunami exercises were undertaken by 60% of respondent countries, which was slightly more than at the national level (55%).

In a majority of countries, the National Disaster Management Office takes responsibility (65%), but the National Tsunami Warning Centre (25%) and Local Disaster Management Office (5%) were identified by some countries. One country reported that is the responsibility of multiple organisations, including the NDMO, LDMO, NTWC and international organisations.

Countries were also asked to identify what tsunami related education and awareness materials they have developed and use. Posters (75%), leaflets and flyers, booklets and video/oral media (65%) were identified by the majority of countries. Education materials such as teaching kits (50%) and school curricular (45%) were also used in many countries. Less common were the use of information boards, indigenous knowledge, signage and public evacuation maps. Australia and Singapore both commented that dedicated websites with educational material had been developed. As with other aspects, nearly all respondent countries confirmed that they are willing to share these education and awareness materials with the Indian Ocean Tsunami Information Centre (IOTIC) and other countries.

Countries were also asked to confirm whether or not they carry out a range of public awareness activities. The responses varied greatly across countries. School and child related awareness activities (80%) and tsunami exercises (75%) are the most widely carried out across respondent countries. A majority of countries also carry out preparedness outreach activities and exhibitions (55%), whereas less than half the countries participate in Global Disaster Risk Reduction Day (45%) or carry out competitions or similar to highlight tsunami safety (20%).

Countries were asked to indicate any areas in which they required support from the IOTIC to develop or enhance public awareness in their country. Support was requested by the majority of countries for all four areas of public awareness provision. Support in the development of tsunami awareness programmes, activities or campaigns, and participation by international agencies or experts were the most widely requested by countries (85%).

50% of the respondents also offered to support other Member States to develop or enhance public awareness. The type of support on offer included to provide experts or share their materials, and to conduct or support training activity.

35% of respondents confirmed that their countries are piloting the Indian Ocean Tsunami Ready (IOTR) initiative. Although only seven countries indicated this involvement, 10/11 countries elected to answer the related questions on performance against the IOTR initiative.

Performance varied greatly among countries, and between the eleven indicators. Performance in having redundant and reliable 24-hour warning points to receive information and alert the public were rated very good or good by 6 of the 10 responding countries, with no country rating as very poor. Commitment to support the EOC during a tsunami, addressing tsunami in a community's EOP, and conducting an annual tsunami exercise were also rated very good or good by 6 or more of the 10/11 responding countries. However, for each of these aspects one country rated themselves as very poor.

The weakest areas of performance included designated and mapped tsunami hazard zones (no countries were very good, 4 countries rated as fair, 1 as poor), and community risk reduction plans (no countries rated as very good, 7 countries rated as fair and 2 as poor).

4. Current Status of Multi-Hazard Early Warning in Asia

This section seeks to further our understanding of intra and inter regional cooperation capacity needs for multi-hazard early warning in Asia. It sets out the current status of MHEW in Asia. The methodology underpinning this ananlsyis is

4.1. Hazard exposure in Asia

Table 3 presents the 20 deadliest natural hazards recorded during 1996-2015 across the globe. Of 20 recorded deadliest hazards, 10 are recorded from Asia and the Pacific region (CRED - UNISDR, 2016).

The most common natural hazards in Asia are: floods, earthquakes, landslides storms and extreme temperatures. The Nepal earthquake in 2015, the Japanese earthquake and tsunami in 2011, the Indian Ocean Tsunami in 2004, Myanmar's 2008 cyclone Nargis, Bangladesh and the Gorky Cyclone in 1991, and China 2008 earthquake are some of the deadliest natural hazards happened in Asia over the last two decades (Asian Century Institute, 2014). Even though incidents of tsunami are less frequent, its impact is massive. Tsunami has been identified as the deadliest hazard which is 16 times deadlier than any other ground movements (CRED - UNISDR, 2016). Storms are also a significant coastal hazard.

The Asia-Pacific region is one of the most disaster-prone areas in the world, with frequently occurring natural hazards including earthquakes, tsunamis, tropical storms, flooding, landslides and volcanic eruptions affecting millions of people every year (UNCHA, 2017). Some of the drivers behind these losses include: high population density, weak coping mechanisms and geographical features.

Table 3: 20 most deadly natural disasters (1996-2015)

Type of natural disaster	Country	Number of deaths	Year	Country category based on income
Earthquakes	Haiti	222,570	January 2010	Low
	Pakistan	73,338	October 2005	Lower middle
	India	20,005	January 2001	Lower middle
	Turkey	17,127	August 1999	Upper middle
	Iran	26,796	December 2003	Upper middle
	China	87,476	May 2008	Upper middle
Earthquake and tsunami	India	16,389	December 2004	Lower middle
	Sri Lanka	35,399	December 2004	Lower middle
	Indonesia	165,708	December 2004	Lower middle
	Japan	19,846	March 2011	High
Strom	Honduras	14,600	October 1998	Lower middle
	Myanmar	138,366	May 2008	Lower middle
	India	9,843	October 1999	Lower middle
Extreme temperature	Russian Federation	55,736	June 2010	Upper middle
	Spain	15,090	July 2003	High
	France	19,490	July 2003	High
	Germany	9,355	July 2003	High
	Italy	20,089	July 2003	High
Flood	Venezuela	30,000	December 1999	Upper middle
Drought	Somalia	20,000	2010-2011	Low

Source: CRED Disaster data, 2016 – region 6 countries are highlighted in yellow

4.2. Impact of hazards

Natural hazards killed more than 1.35 million people around the world during 1996-2015. More than half of the reported deaths are due to earthquakes, whereas the remainder are primarily due to weather and climatic related hazards (CRED - UNISDR, 2016). During 1996-2015, more than 749,00 earthquake deaths

were recorded in the world. Average mortality rate has been increased from 64,900 (1996 and 2005) to 69,800 (2006-2015) across all types of hazards. Similarly, average deaths per disaster also rose, up to 194 from 187 (CRED - UNISDR, 2016).

The Asian region faced many disasters in the first half of 2017 (CRED, 2017). The EM-DAT preliminary data shows that the death toll in Asia is remarkably high when compared to other regions. Table 4 illustrates the occurrences of natural hazards and their effects across continents in 2017.

Table 4: Impact of natural disasters during 2017

Continent	Occurrence	Number of deaths	Number of people affected	Economic loss ($ million)
Africa	38	635	50,966,253	2,489
America	32	654	7,639,426	8,700
Asia	60	1657	21,952,969	18,609
Europe	14	206	73,085	131
Oceania	5	10	9,907	2,422

Source: CRED, 2017

Compared to other regions, Asia records the highest number of death tolls, occurrences, number of people affected and economic losses. When compared to America and Europe, economic losses are also disproportionally higher in Asia.

4.3. Availability of MHEW in Asia

Early warnings have been identified as vital element in any disaster risk reduction strategies (UNISDR, 2015). They can be introduced to different types of natural hazards, for example, earthquakes and tsunamis (sudden-onset events) (Thomalla & Larsen, 2010), hydro meteorological hazards (flooding) (Basher, 2006), slow-gradual events (droughts) (cited in Pulwarty and Sivakumar, 2014Zia & Wagner, 2015). Hence, the introduction of MHEW would be more economical and efficient for regions which frequently suffer with multi-hazards. For example, MHEW is vital risk reduction mechanism for Asia since it faces many hazards. At the global level, the SFDRR too emphasises the necessity of enhancing availability and access to MHEW by 2030 within its seventh target.

Effective early warning systems consists with four elements: risk knowledge; monitoring and warning; communication and response capacity (WMO, 2016). In the context of Asia and the Pacific region, risk knowledge and monitoring & warning have reached to a high-level due to improvements in technology to assess hazards and risks and detection mechanisms. However, communication and response capacities still face challenges in many countries in the region (UN-ESCAP, 2015) (Dutta & Basnayake, 2018).

Early warnings are considered as a science initiative in Asia and the Pacific region. Hence early warnings are not properly integrated in policy and decision making in other related areas (UN-ESCAP, 2015) (Dutta & Basnayake, 2018). Although, some mandatory organisations have been established in the region to give early warnings, they suffer with many weakness and hence further improvements are nedded. Similarly, awareness among local authorities are not adequate on methods of dissemination of warning messages (Dutta & Basnayake, 2018). This creates difficulties in communicating end-to end warnings to needy communities (UN-ESCAP, 2015).

The project delivered 5 national reports to represent national perspective in terms of early warnings. National reports further reveal that some countries have knowledge to assess hazards but suffer with many limitations. For example, hazard assessment knowledge is available among experts in Sri Lanka but they suffer with limited availability of software and equipment. Another example from Myanmar shows the similar status as in Sri Lanka. Although Myanmar and Sri Lanka have developed risk maps for hazards, they are not adequate for different types of hazards as well as the maps are not area specific. In addition, human capacity limitations and geographical isolation, make hazard assessment a challenge in the Maldives. Furthermore, most of data in the Maldives are not up-to-date to conduct hazard assessments.

Table 5: MHEW in Asia

Evaluation of MHEW in Asia	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)
MHEW are important for coastal resilience	5.3	4.2	6.3	28.4	55.8
Current efforts in the region are sufficient	18.9	42.1	16.8	14.7	7.4
Available types of EW in the region are adequate	11.7	54.3	12.8	14.9	6.4
Regional capability is appropriate	10.6	39.4	21.3	20.2	8.5
Existing early warnings can reach "last mile"	11.8	44.1	19.4	18.3	6.5
MHEW has reached highest level of development	15.1	25.8	29.0	18.3	11.8
Improvements for MHEW is prioritised in Asia	5.3	23.4	20.2	31.9	19.1

From the regional expert survey,

Table 5 indicates the importance of MHEW for the region, but that its present status is not at the satisfactory level. Approximately 50% of expert respondents do not agree that there is satisfactory existing regional capacities to assess and or receive information, and advice or warn communities as appropriate. One another important finding of the survey is the difficulty of existing MHEW to reach the "last mile", the community who needs the most.

4.4. Regional cooperation

Regional cooperation can bring many benefits through sharing knowledge and costs incurred when developing and maintaining MHEW. In Asia and the Pacific, the immediate priority in the field of early warning is to improve people's access to timely and relevant warning information and to enable them to take life-saving actions early. To this end, the growing accumulation of people and wealth, especially in urban areas, require that continued investments in early warning be made and existing systems are updated.

Member countries in Asia and the Pacific region demand for a regional cooperation to share scientific knowledge & applications, as well as to share costs when dealing with trans-boundary hazards (UN-ESCAP, 2015a). As a result, some level of regional initiatives have been established after Indian Ocean Tsunami incident in Asia (Thomalla & Larsen, 2010). For example,

1. Establishment of Indian Ocean Tsunami Warning & Mitigation System (IOTWMS) in 2011 (Thomalla & Larsen, 2010),
2. Setting up of 24 tsunami warning centres in the Indian Ocean,
3. Increasing the number of sea level gauges from 4 to 100,
4. Increasing the number of deep ocean tsunameters for data sharing from 0 to 9 (UN-ESCAP, 2015a).
5. Indian Ocean Consortium was established to support the development of national components of the IOTWMS, through coordination mechanisms among governments, preparing national plans for tsunami warnings and creating links between regional efforts (IOC, 2008).
6. In the region, MHEWSs are in the process of further development and implementation. For example, the Severe Weather Forecasting Demonstration Project was introduced to fulfil the needs of MHEWSs as a regional project to strengthen capacities among high risk and low capacity countries (UN-ESCAP, 2015a).
7. Development of Key Performance Indicators in relation with the Sendai Framework Indicators (Joint discussion with TT-TWO)
8. Celebration of World Tsunami Awareness Day (Joint discussion with TT-TWO)
9. Tsunami Evacuation Mapping
10. Hazard Assessment- Inundation Modelling, evacuation mapping, response planning and exercising
11. UNESCO-IOC Tsunami Ready (UNESCO-IOC TR) Community- based tsunami recognition programme
12. Multi-Hazard Warning Approach
13. Marine & Ports Guidance
14. Structural Design Guidance for buildings that can be used as evacuation shelters (including vertical evacuation)
15. School Programmes
16. Presentation on TsuCAT (Tsunami Coastal Assessment Tool)

Despite the importance of regional cooperation for enhancing resilience especially among coastal communities, many challenges hinder their effective functioning. For example, uneven progress in early warning systems due to: high risk involvement, low capacities, types of hazards and lack of implementation on the last mile warning systems (Thomalla & Larsen, 2010; UN-ESCAP, 2015a). Specifically, in Asia and the Pacific region, unsatisfactory institutional arrangements (Thomalla & Larsen, 2010; UNDP, 2004), weak warning systems (Basher, 2006) and weak capacities (Adger et al., 2005) are prevalent. For example, early warning messages were not disseminated among coastal communities in Indonesia, Thailand and Malaysia during the Indian Ocean Tsunami incident in 2004 (Adger et al., 2005). Additionally, MHEWS is isolated from policy and decision-making process in the region. Hence, it is required to establish appropriate level of stakeholder partnerships.

Furthermore, dissemination of risk information among the most vulnerable communities, for an example, fishing communities, are limited (UN-ESCAP, 2015a). There are many other gaps hindering regional capacity development in Asia. For example, in terms of collecting and receiving warning messages, acquisition of real time data and requirement of equipment. Furthermore, training is identified as a necessary factor for handling data and overall MHEWSs in Asia (UNESCO-ICO; UN/ISDR/PPEW; WMO, 2005). In order to address these challenges, it is necessary to establish platforms for knowledge sharing in the region (Thomalla & Larsen, 2010).

In addition to above mentioned literature review findings, the report presents the findings of the regional survey results in assessing existing level of regional cooperation in Asia as presented in Table 6.

Table 6: Regional cooperation in Asia

Regional cooperation for MHEW	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)
Identification of key stakeholders	8.9	15.6	16.7	48.9	10
Availability of key stakeholder partnerships in Asia	8.9	13.3	22.2	48.9	6.7
Existing partnerships are effective in coastal resilience	6.8	35.2	18.2	31.8	8.0
Regionalism approach is available in Asia	10.1	21.3	21.3	36.0	11.2

It asked experts to consider the existing regional cooperation towards the development of MHEW in Asia in terms of key stakeholder identification, establishment of key stakeholder partnerships, their effectiveness and present level of regionalism approach. A clear gap has been found from the survey results showing that key stakeholder partnerships are available in Asia though, their level of effectiveness is not at the desired level. This reinforces the need to take actions to enhance effective operation among key stakeholder partnerships to improve MHEW in the region.

After identifying the level of effectiveness in existing MHEW in Asia, the survey explored the areas for further development of MHEW in Asia. Three aspects that have been identified through literature review were tested in the survey.

According to Table 7, more than 75% of respondents have identified the necessity for greater capacity development in the region. Similarly, innovations and training are also recopgnised as of high importance and requiring further improvement.

In addition to capacity development needs, innovations and training needs in the region, following aspects have been proposed by the respondents to an open-ended question: Integration of local people as stakeholders; Development of mechanisms for regional cooperation; Knowledge sharing and networking, Use of ICT and computer modelling; Mainstream into development planning; Emergency information systems for the public; Linkage between government disaster management units and universities and Disaster education and awareness building.

Table 7: Areas for further developing MHEW in Asia

Areas for further improvements in MHEW	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)
Capacity development	4.3	3.3	14.1	35.9	42.4
Innovation in MHEW	5.4	3.3	20.7	27.2	43.5
Training	4.4	2.2	11.0	30.8	51.6

4.5. Policies and institutional arrangements in Asia on MHEW

After assessing present status of regional cooperation in the region, the next section presents availability of policies at national and regional level to ensure effective operation of MHEW in the region. This section is based on a literature review, national reports and regional survey findings.

Asia Regional Plan for implementation of SFDRR

Asia Regional Plan for implementation of Sendai Framework for Disaster Risk Reduction 2015-2030 is a major initiative towards disaster resilience in Asia. Its objective is to guide and support the national implementation of the SFDRR by identifying priorities at regional activities to support national and local actions, enhance exchange of good practice, knowledge and information among governments and stakeholders, in addition to strengthening regional cooperation to support the implementation of the SFDRR. The plan contains a broad policy direction, a long term road map, a two-year action plan (Petz, 2014). Its guiding principle 2 emphasize the need for improving of multi-hazard risk assessment by its member countries. (AADMER, 2016).

User guide for National Tsunami Warning Centres (NTWCs)

The Indian Ocean region has a user guide for National Tsunami Warning Centres (NTWCs) and Indian Ocean Tsunami Warning & Mitigation System (IOTWS). This guide consists of several sections:

a. Access to tsunami threat and warning information
b. This section explains about bulletins issued by TSP and disseminates to NTWC and dissemination from NTWC to the public. It further explains the channels that can be used to disseminate warning and actors should be involved in disseminating warning. There is also a brief explanation about possible threat level given in the warning statement or bulletin.
c. System of regional tsunami service providers
d. This section explains the area of coverage and earthquake source zone, coastal forecast zones, detection networks, forecasting technique, operational procedures and products designated national contacts, and also IOTWS limitations.
e. Monitoring IOTWS performance
f. This section explains about monitoring IOTWS performance with key performance indicators. This monitoring can be done through communication test and IOWAVE exercises (Intergovernmental Oceanographic Commission, 2015).

The Asia –Pacific Plan of Action for Applications of Space Technology and Geographic Information Systems for Disaster Risk Reduction and Sustainable Development (2012-2017)

This plan aims at strengthening space technology applications and GIS for SDGs. In addition, to developing regional cloud base meta-data platform including remotes sensing data, baseline maps, statistics and big data. Regional Space Applications Programme for Sustainable Development (RESAP) has been implemented over the last few years. At its twentieth session, the Intergovernmental Consultative Committee on RESAP encouraged all member countries to provide guidance to the secretariat on the development of the Asia-Pacific Plan of Action for Space applications (2018-2030). It requested the secretariat to begin work on an initial draft. Since 2013, the implementation of RESAP has been guided by the Asia-Pacific Plan of Action for Applications of Space Technology and Geographic Information Systems for Disaster Risk Reduction and Sustainable Development, 2012-2017.

The International Centre for Water Hazard and Risk Management (ICHARM)

The International Centre for Water Hazard and Risk Management (ICHARM) was established by the Japanese government under the auspices of UNESCO as a part of the Public Works Research Institute (PWRI) in March 2006. Its mission is to serve as the Global Centre of Excellence for Water Hazard and Risk Management by, inter alia, observing and analysing natural and social phenomena, developing methodologies and tools, building capacities, creating knowledge networks, and disseminating lessons and information. The organization aims to provide assistance to governments and all stakeholders at global, national, and community levels in managing risks of water related hazards including floods, droughts,

landslides, debris flows, tsunamis, storm surges, water contamination, and snow and ice disasters (ICHARM, 2016).

ICHARM envision a Centre of Excellence housing a group of leading people, superior facilities, and a knowledge base. As a knowledge hub, it provides information/ knowledge of best national and local practices and further advisory services for policy making. It identifies three pillars:

a. Conduct innovative research: They engage in data collection, storage and sharing of water related disasters; engage in risk assessment; monitoring and predicting possible changes in water related disasters; proposal evaluation and adaptation policy ideas and supporting disaster risk management.
b. Effective capacity building: They support practitioners and networks who engage in water related hazards and risk management through provisioning of training. This helps in developing solution-driven practitioners and also developing local experts and institutions.
c. Efficient information networking: Their knowledge base with research findings contribute for better water related disaster risk management. They accumulate, analyse and disseminate through their networks and mainstreaming disaster risk reduction policies within institutional networks.

Regional Programme of World Meteorological Organization (WMO)

The WMO has identified six regions to support by identifying the needs of members, establishing requirements for regional networks, planning and monitoring progress; organizing regional subsidiary structures and promoting regional partnerships. Asia is named as Region II in this programme. The Programme specifically assists weather services at the national and regional levels towards the protection of life and property as well as in socio-economic development. They establish regional cooperation through provisioning a framework for the implementation of WMO strategies, policies and programmes after considering special requirements, capacities and priorities with in the region.

GSN in Indian Ocean Region

This is a cooperative partnership between IRIS and the U.S. Geological Survey (USGS), coordinated with the international community, to install and operate a global, multi-use scientific facility as a societal resource for Earth observations, monitoring, research, and education. They have more than 150+ stations across the world to provide free, real-time, and open access data. The stations of the GSN attempt to obtain the best possible recording capability, balanced with global geographic coverage. GSN instrumentation measures and records with high fidelity all seismic vibrations possible from high-frequency, strong ground motions near an earthquake to the slowest global Earth oscillations excited by great earthquakes. Seismology has been the primary focus in the creation of the GSN, but the infrastructure is inherently multi-use and can be extended to other disciplines. Several GSN stations currently incorporate microbarographs, GPS, Geomag, and Meteorological packages.

Climate Risk Early Warning Systems -CREWS

France, in collaboration with Norway, the WMO, UNISDR and the World Bank/ GFDRR (Global Facility for Disaster Reduction and Recovery), launched this coalition known as CREWS (Climate Risk Early Warning Systems) to strengthen and broaden the work of the international community in supporting early warning systems in vulnerable countries Further it aims to mobilize additional financing to support and enhance the actions which we are currently implementing, in order to try to fully cover the global population exposed to extreme climate events by 2020.

Program funding will contribute to narrowing the gap between priority needs in the developing countries and available funding. Implementing parties (WMO, GFCS, UNISDR, WBG/GFDRR) have complementary strengths and breadth of analytical, technical and operational knowledge. Proposed integrated approach by focusing on the MHEWS will help to address key systemic deficiencies including building long-term capacity and sustainability. Proposed partnership will improve donors' coordination on the ground, ensure complementarity and avoid overlap with other existing or future initiatives.

The CREWS initiative will strive to leverage and enable major investments to:

1. Strengthen the linkages between WMO global and regional centres for enhanced provision of technical and operational support to NMHSs and national early warning services and risk information, strengthen the NMHSs and their capacity to provide warnings and services and risk information
2. Improve the linkage between warning services and effective emergency management including local and national emergency plans and the use of risk information for risk reduction.

The expert survey reaffirmed the adequate availability of policies, programmes, plans and institutional arrangements for MHEW in many instances. 71% confirmed that there are policies, legislations and plans for the improvement and operations of MHEW in Asia. However, the survey further revealed that when experts were asked to rate the level of implementation and level of success of existing policies, programmes and plans in Asia, against a scale of very low to very high, over 80% rated it as being from very low to medium, as presented in Table 8.

Table 8: Level of implementation of existing policies, programmes and plans in Asia

Policies, legislations and plans for improving MHEW in Asia	**Very low**	**Low**	**Medium**	**High**	**Very high**
Level of implementation	12.3	28.4	43.2	14.8	1.2
Level of success	11.1	29.6	43.3	12.3	3.7

In addition to survey results, national reports too found similar results to the literature and survey findings. For example, all five countries have their policies, programmes and plans to address natural hazards. However, their level of implementation and success vary from one country to other.

For example, Policy documents are very much needed in the Maldives to guide stakeholders to design and implement national and global frameworks. Current policy documents such as Disaster Management Act and Maldives climate change policy framework have been very successful in terms of raising people awareness and changing people perception regarding disaster management. In contrast, a little knowledge is available among many interviewees from Sri Lanka regarding existing MHEW policies related to coastal hazards in Sri Lanka. However, there are some guidelines available for both national and district levels from 2006 onwards in Sri Lanka. In terms of success of these policies a moderate level of success is revealed from the national report from Sri Lanka.

According to the national report from Myanmar, their officers are knowledgeable about availability of laws and regulations related to hazards in Myanmar. However, they do not know exactly what these policies are all about. The report too highlighted another issue in implementation. For example, policies developed at the top level do not work well at local level. Hence, they demand very strict implementation procedures. Similar implementation issues are recorded from Indonesia. Indonesia has policies, legislations and guidelines related to disaster management. For example, successful implementation of Ina-TEWS was due to good collaboration and participation of all stakeholders. However, Ina-TEWS is interface and downstream area has implementation issues mainly at local level. The status in the Philippines is not different from other countries in Asia. They too have implementation issues in terms of organizational contexts and institutional capacities.

5. Developing more effective MHEW in Asia

This section considers the enablers and barriers for effective MHEW in Asia. The findings are based on the literature survey and regional survey results.

5.1. Enablers for MHEWS

The availability of effective early warning system is a vital element in disaster risk reduction efforts (UNISDR, 2015; WMO, 2016). For an effective early warning system, scholars have identified following elements:

Governance has been identified as one of the main factor that determine the level of effectiveness of MHEW in any context (Riley, 2016; Rogers & Tsirkunov, 2011; Seng, 2013). Governance ensures the involvement of different actors (governments, corporate sector, civil societies and experts) when making collective decisions under any uncertain situations (Renn, 2012).

Training too contributes to the development of any disaster resilience strategies: including capacity building, awareness raising (Alfieri et al., 2012; Chaimanee, 2006). It contributes for the operation and maintenance of EWS (Lauterjung, Münch, & Rudloff, 2010; WMO, 2011b, 2016). Training could be conducted through talks, conferences, radio and TV channels, short courses, school curricular, and producing training manuals (WMO, 2016).

Many member countries in the Indian Ocean have recognized the urgency for capacity development within ***local governments*** (Lauterjung et al., 2010; UNESCO-ICO; UN/ISDR/PPEW; WMO, 2005). Local authorities are aware of local hazards, their significance, local communities and their capacities (Scott & R.Few, 2016). Even though there are many issues and capacity gaps in local authorities, their importance is highlighted in any disaster resilience programmes (Malalgoda, 2014).

Community as a vital stakeholder (UNISDR, 2015) become the target group of last mile warning message. When communities are aware of risk priorities, they are motivated to respond to early warning systems without waiting for warnings from the outsiders (IFRC, 2012; Thomalla & Schmuck, 2004). Absence of community representation could hinder the capacity of hazard responses (Haigh & Amaratunga, 2010; Malalgoda, 2014; Scott & R.Few, 2016). Communities to be informed on available safe options, escape routes, and mechanisms to avoid and minimize life and property damages (Rogers & Tsirkunov, 2011). Community participation is important to establish a culture of safety (Kadel, 2011), through successful communication and awareness campaign (Alfieri et al., 2012). Hence, a bottom-up approach is recommended for a community based effective early warning system (Thomalla & Larsen, 2010).

Similarly, ***education and awareness*** are considered as essential elements in an effective early warning system (Alfieri et al., 2012; Rogers & Tsirkunov, 2011) due to its ability of informing communities to respond correctly to warning information (Lauterjung et al., 2010).

Effective early warnings ensure preparedness measures towards risk reduction (Alfieri et al., 2012; Lauterjung et al., 2010). In this regard, scientific and technical information can be in cooperated (Alfieri et al., 2012). ***Technical and scientific*** information provide the basis for an effective EWS system (Lauterjung et al., 2010; WMO, 2016). For example, sound knowledge of meteorological or hydrological phenomenon provide the basis for predictions and preparedness measures (Rogers & Tsirkunov, 2011). Zia and Wagner Zia and Wagner (2015) are in favour of incorporating scientific findings into institutions' operating systems (Alfieri et al., 2012).

Risk information determines the sustainability of an effective EWS (Basher, 2006; Thomalla & Larsen, 2010; WMO, 2011a). Some countries maintain hydro meteorological data, climatological data, demographic data to support their disaster preparedness measures including development of risk maps (WMO, 2011a). Daily briefing, bulletins, special reports, websites and workstations are used in the process of formulation and dissemination of risk data. Sharing risk information within the region could deliver cost effective early warning system (UN-ESCAP, 2015a). For example, Indian Ocean Tsunami Early Warning Systems (IOTWMS)

has been able to share risk information and dealt with issuing warning messages to its member countries (UNESCO-ICO; UN/ISDR/PPEW; WMO, 2005).

An adequate allocation of ***resources and infrastructure*** help smooth functioning of any system. In Hong Kong, for example, early warnings are supported with an adequate level of transportation and communication network which help people to take necessary actions at the time of a disaster (Rogers & Tsirkunov, 2011). Governments allocate resources such as, aeroplanes, boats and other assets of armed forces and coast guards in the event of evacuation efforts (UN-ESCAP, 2015a). However, the share allocated for preparedness measures including early warning systems are insignificant when compared to post disaster recovery and relief efforts (Healy & Malhotra, 2009; Seng, 2013). This is because of the benefits are difficult to estimate in the event of preventing or minimizing the effects of a disaster (Rogers & Tsirkunov, 2011) and mostly early warning systems are funded and maintained by governments (WMO, 2011b, 2016) whose funding availability is limited to their budgetary capacities.

As mentioned earlier, global initiatives have emphasized the necessity of strengthening of MHEWS (UN-ESCAP, 2015a; UNISDR, 2015). Warnings are mostly issued by state agencies, for example, meteorological offices, disaster management centres and ministries to a particular geographical area (UN-ESCAP, 2015a; WMO, 2016). They are issued via fax, SMS, emails, telephones, the internet, radio, colored flags (WMO, 2016). One of the key factors for an effective EWS is the issue of warning messages to people who are marginalized and not involved in the development process with adequate time (Collins, 2009). Political leadership and commitment are too contribute to any DRR initiatives (Alfieri et al., 2012) inclusive of EWS (Basher, 2006). Political commitments support resource allocation and introduction of legal mechanisms. This has been progressed in the Asia-Pacific region. For example, the Government of the Philippines introduced a Zero Casualty policy after following the Typhoon Haiyan in 2013. It has shown a substantial reduction in terms of loss of lives and number of people affected from the Typhoon Koppu in 2015 (UN-ESCAP, 2015a).

Many international frameworks underline the significance of ***stakeholder participation*** (Alfieri et al., 2012; Rogers & Tsirkunov, 2011; UN-ESCAP, 2015a; UNISDR, 2005, 2015), and stakeholder partnerships (Rogers & Tsirkunov, 2011) for an effective EWS. This is because, no single institution could provide a fully comprehensive solution (Rogers & Tsirkunov, 2011). These partnerships could also bring expertise from wide range of disciplines. The Sendai Framework for Disaster Risk Reduction emphasises the integration of multi-hazard into development planning process across developed and developing nations. This could be achieved by establishing key institutions at national and local level (Alfieri et al., 2012).

Integration of disaster risk reduction into development planning enhance effectiveness of issuing warnings as well as effectiveness of resource allocation during an emergency situation (Alfieri et al., 2012). Along with the lessons learned in the disaster history, it is advisable to shift the region's urban governance system from response-recovery approach to a risk sensitive development approach (UN-ESCAP, 2015b). Because EWSs contribute in reducing loss of lives from disasters, it indirectly contributes in achieving sustainable development goals (Alfieri et al., 2012).

Other key elements of an effective EWS are, identifying future risks, monitoring hydro meteorological parameters, provisioning of archived and real-time data, conducting ***hazard mapping and analysis and forecasting*** their patterns (Rogers & Tsirkunov, 2011; WMO, 2011b, 2016). Monitoring and forecasting is useful for planning and preparedness measures (Rogers & Tsirkunov, 2011). Even though some advanced systems are in place in Asia for weather forecasting with longer lead-time, the EWS are issued with a very short notice specifically to the most vulnerable communities. Hence the UN-ESCAP has developed a regional corporation mechanism for flood forecasting in the trans-boundary river basins (UN-ESCAP, 2015a). For example, in Bangladesh the use of satellites for flood forecasting and warning system. Even though vertical and horizontal communication is an important element in a well-functioning EWS (Rogers & Tsirkunov, 2011; Thomalla & Larsen, 2010), there is lack of attention from operational contexts (Thomalla & Larsen, 2010).

According to Thomalla and Larsen (2010), effective ***communication*** ensures information transferring from national warning centres to affected communities.

Based on variables identified in literature review, a regional survey was designed to identify enablers that affect effective functioning of MHEW in Asia (the detailed research method applicable for this section is described in Annex 4).

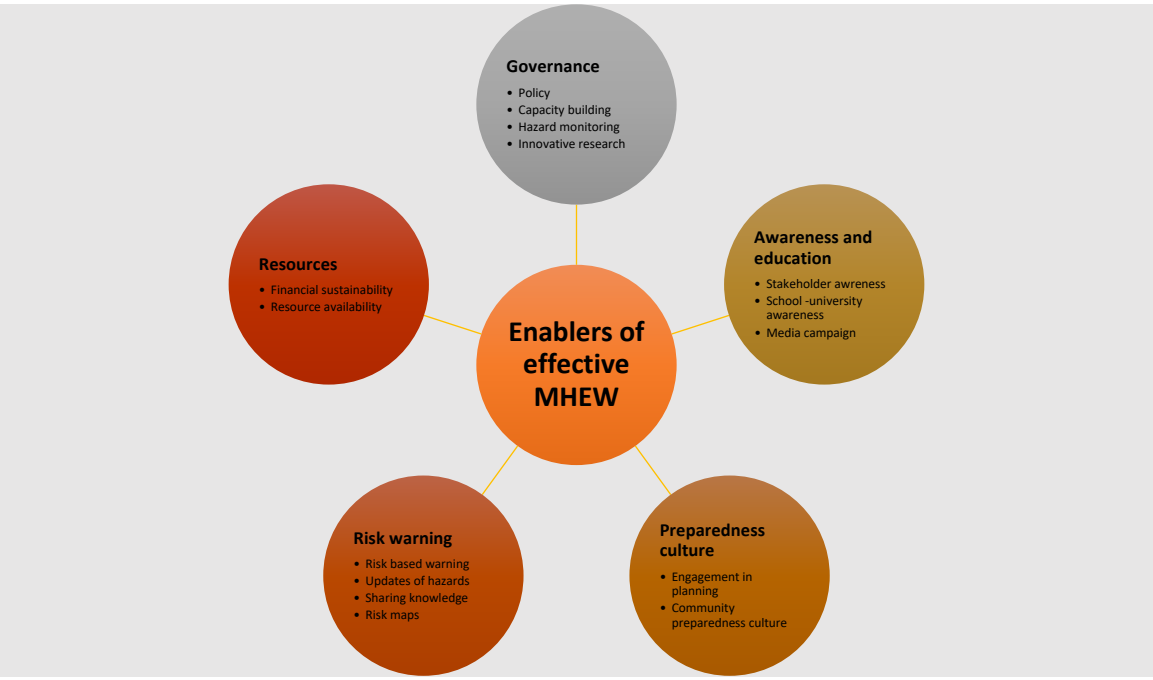

Figure 46: Enablers for effective MHEW

The survey findings were summarised and presented in Figure 46. Within the survey results five major categories have been identified[3]. The survey found that Risk warning (Category 1) is the main enabler for an effective MHEW. Asia needs more developed and improved systems to develop communication mechanisms to achieve the last-mile target.

The second category was named as ***Governance.*** Provision of capacity building, hazard monitoring feedback and innovations research based policymaking are related to enhance the quality of governance. Empirical evidences confirmed the importance of supportive policies for example, land use policies and disaster management policies for the success of early warning systems (Dutta & Basnayake, 2018; UN-ESCAP, 2015b). Capacity building is further identified as a critical factor for development of MHEW in Asia (UN-ESCAP, 2015b).

Category 3 has been named as ***Awareness and education***. Accordingly, stakeholder awareness is the highest important factor towards awareness and education. Similarly, school and university awareness and media campaign also increase the education and awareness as enablers. The Sendai Framework for Disaster Risk Reduction has emphasised the role of awareness and education towards resilience through effective EW (UNISDR, 2015; Zia & Wagner, 2015).

Fourth category was named as ***Community engagement***. Community engagement in planning has been revealed by the survey as an enabler. Moreover, creating a preparedness culture among community is similarly highlighted as an enabler. Their engagement in disaster preparedness and planning is strongly correlated with community culture. Community engagement has been highlighted as a crucial element in

[3] Higher correlation values demonstrate higher correlation between variables within a component. For example: Within Component 1; Risk Based Waning, Sharing Knowledge, Updates of hazards and Risk maps are highly correlated within this component. Based on their similarity or common characteristics, Component 1 can be named to represent the relationships among the highest correlated components. The first component is highly correlated with four variables; Risk based warning, Updates of hazards, Sharing knowledge and Risk maps. All these variables are positively related to effectiveness of MHEWS. For example, when risk based warning increases, the effectiveness of MHEWS increases. In addition, all these identified variables vary in the same direction. For example: increase of risk based warning also increases other three variables.

any disaster risk reduction strategy since they are considered as a key stakeholder (Haigh & Amaratunga, 2010; Malalgoda, 2014; Scott & R.Few, 2016).

The last category was named as ***Resources***. The regional survey revealed that financial sustainability of any early warning system is a significant concern among experts. This also links to the availability of adequate resources.

In summary, out of 41 factors identified as enablers for an effective MHEW in Asia, five categories are formed as: Risk warning; Governance; Awareness and education; Preparedness culture and Resources.

Based on national paper, inclusive and context specific disaster preparedness plans are the most highlighted enabler in the Philippines. Furthermore, dedicated policy and institutional frameworks, warning messages, technological systems for real time monitoring and forecasting, research outputs and multi-stakeholder partnerships are also significant enablers.

In the context of Indonesia, community knowledge and awareness, preparedness, warning procedures to cover last mile are the most significant enablers towards effective MHEW. In addition, collaboration and networking, early education and hazard monitoring and institutional arrangements are also identified.

Similar findings are reported from the Maldives since their main concern is on collaborative network between stakeholders as a primary concern.

Stakeholder cooperation, communication, and awareness are found to be significant in Myanmar too.

In Sri Lanka, community awareness, capacity development, data exchange and multi-stakeholder and multi-agency cooperation are found to be as the most significant enablers towards effectiveness of MHEW.

5.2. Barriers for MHEWS

The operational effectiveness of MHEW systems depends on many factors. Some factors are identified as barriers for effective use of EW. The following are identified as common barriers that prevent an effective multi hazard early warning system.

Lack of technology has been identified as a barrier for effective MHEW. Inability to assess accurate hazards, risks and detect threats, negatively affect the effectiveness of MHEW. This directly affects building knowledge and capacity of communities to act appropriately.

Lack of communication limited contact between forecasters and disaster managers, a state of affairs that prevents countries from creating effective end-to-end warning systems In addition, there are gaps in dissemination and communication of early warning information from national to local level in Southeast Asia. More awareness as well as capacity building programs are not operating at a satisfactory level in Asia (Dutta & Basnayake, 2018). Unreliable dissemination of warning messages to all concerned is also identified as a barrier.

Limited use of warning and risk information in various vulnerable sectors of the economy, including fishing and agriculture, despite the potential economic benefits (UN-ESCAP, 2015b).

Lack of response capacity elements in risk knowledge and monitoring and warning.

Lack of coordination affects the link between scientific community and policy makers. Early warning tends to be seen primarily as a science initiative, and thus it is mostly separated from policy and decision-making in other related areas, including disaster Management (UNESCAP, 2016).

Accordingly, the survey identified gaps / challenges for effective operation of MHEW in Asia. Survey results are presented in Figure 4. The detailed methodology is given in the annex[4]. As shown in Figure 47, three

[4] They were raised as ordinal scale measurement questions with five different scales as: strongly disagree=1 to strongly agree = 5. These data were similarly analysed using PCA to identify components that explains major barriers for an effective MHEW in Asia. Annex 8 presents all questions and identified components considering Eigen values. The reliability and sampling adequacy for questions were confirmed as shown in Annex 9.

main categories were identified as the barriers affecting effective MHEW in Asia: ***weak monitoring***; ***weak integration and cooperation***; and ***weak recognition***.

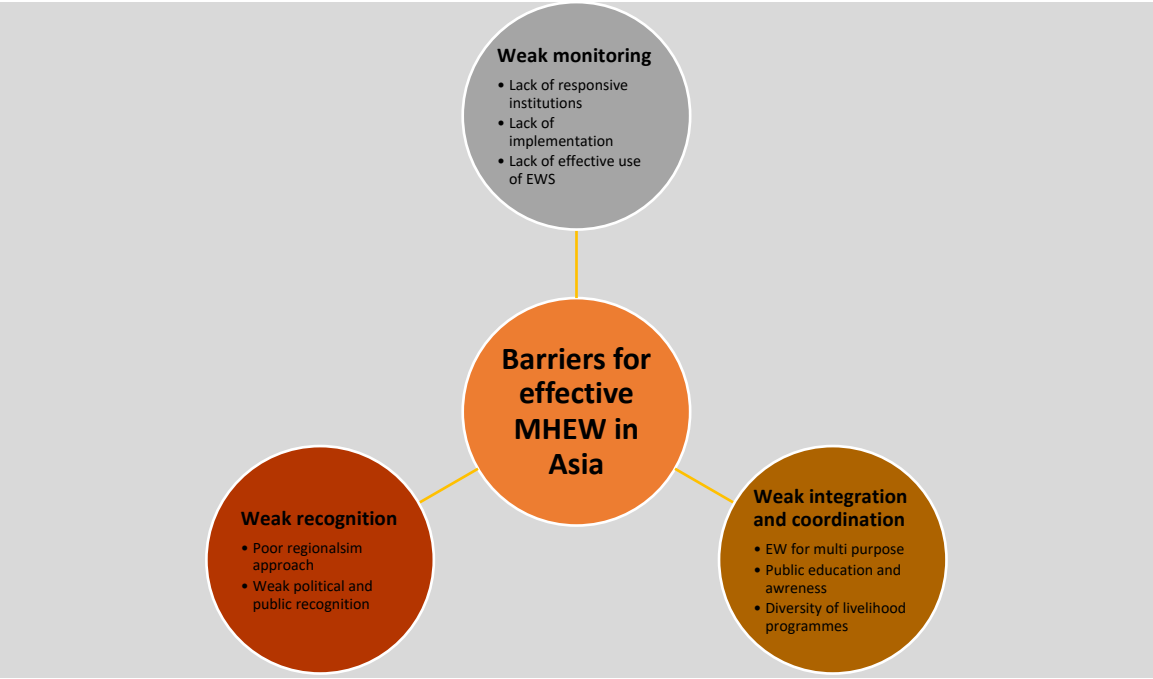

Figure 47: Barriers for effective MHEW in Asia

Category 1 demonstrate that ***monitoring*** will be weak when there is lack of responsive and innovative institutions for conducting research, education and implementation in the region. Survey revealed that lower the availability of these institutions, the effectiveness of MHEW cannot be achieved in Asia. Furthermore, lack of responsive institutions positively affects towards lack of implementation as well as use of EW effectively in Asia. This is because, governance along with strong leadership, legal frameworks and institutions enhance resilience capacities (Rogers & Tsirkunov, 2011). Hence, governance and institutional arrangements are considered as fundamentals to the development and maintenance of effective early warning systems (Riley, 2016; Rogers & Tsirkunov, 2011; Seng, 2013). However, survey findings show that there are still unsolved areas in the institutional arrangements and governance in Asia (Seng, 2013). In Sri Lanka and Indonesia for example, power struggles between government authorities significantly affect effective governance and hence monitoring (Thomalla & Larsen, 2010). Weak monitoring and weak institutional structures hinders the efficacy of distribution of warning messages. For example, most local authorities are not aware of the particular organization which issue warning messages (Dutta & Basnayake, 2018).

The second category is related to ***weak integration and cooperation*** is identified as a barrier for effective functioning of MHEW in Asia. It is found that early warnings are not integrated for multi-purposes in Asia. For example, EW are only limited to save lives despite of integrating with livelihoods. Further, public education and awareness on potential risks and importance of early warning advices at regional level is not at a satisfactory level in Asia. In Asia, diversity of livelihood choices of different countries is not effectively integrated. Present level of awareness and education within the Indian Ocean member countries is not at a satisfactory level (UNESCO-ICO; UN/ISDR/PPEW; WMO, 2005). According to Dutta and Basnayake (2018), integration of early warning systems into decision making in Southeast Asia is weak. They propose a strong coordination and integration mechanism to be developed in Asia to overcome these barriers.

The third category is related to ***weak recognition***. The survey identified that lack of collective actions towards the development of MHEW in the region. Hence, poor level of public and political appreciation or recognition for identifying vulnerabilities and their consequences in the region. A study by Alfieri et al.

(2012) concludes that political recognition at national level as well as regional level could enhance the effective use of early warnings in European region. These external political and legislative pressures may influence the effective use of early warning within countries.

The findings of both literature survey and regional survey are supported by findings of national reports. As indicated by regional survey, monitoring which is an element of governance and institutional arrangement, is a cross cutting issue in many countries in Asia.

Furthermore, communication barriers do exist in the Philippines, Indonesia and Myanmar.

Multi-stakeholder cooperation has been identified as an enabler in all five countries. However, they all have limitations in achieving the desired level of stakeholder cooperation towards effective MHEW.

6. Role of Higher Education Institutions in Capacity Building for MHEW

As set out in Section 2.4, Higher education institutions (HEIs) play an important role in the society. HEIs bear a profound, moral responsibility to increase awareness, knowledge, skills, and values needed to create a just and sustainable future. It prepares most of the professionals who develop, lead, manage, teach, work in, and influence society's institutions (Cortese, 2003).

According to Seidel (1991), HEIs have five main functions to the society:

- Providing education and training within a structure which combines research and teaching.
- Provide professional training.
- Responsible for carrying out research in a broad range of disciplines, including the increasing amount of interdisciplinary work, and linked to this, for training a constant supply of qualified people for all fields of employment.
- Play in regional development and developing international contacts.
- Fostering the intellectual and social development of society (Seidel, 1991)

HEIs also play an innovative role in knowledge-based societies and maximize capitalization of knowledge by establishing direct links and close integration with the industrial world (Esham, 2008). The UNISDR Science and Technology Conference on the Implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030 aimed to discuss and endorse plans that maximize science's contribution to reduce disaster risks and losses in the coming 15 years and bring together the diversity of stakeholders, producing and using disaster risk reduction science and technology (Aitsi-Selmi et al., 2016). Recent evidence of active involvement of HEIs in global policy making can be seen when making 2013 Global Assessment Report with more than 50 contributors from HEIs. Similarly, when developing Special Report on Extreme Events by the Intergovernmental Panel on Climate Change acknowledge the contribution of more than 200 representatives form HEIs (Holloway, 2015).

This implies that higher education has a role to conduct research, develop technology, and help reaching the community to create innovative MHEW. HEIs also can help society through training and capacity building. With broad range of disciplines and expertise, HEIs can contribute to the development of more effective MHEW, but in conjunction with other stakeholders.

Table 9: Level of involvement of HEIs in MHEW in Asia

Involvement of HEIs MHEW in Asia	Very low	Low	Medium	High	Very high
Expected level	2.7	12.0	24.0	33.3	28.0
Present level	25.3	20.0	36.0	14.7	4.0

Table 9 illustrates a clear gap between the expected level of involvement and their present level of involvement in the region. Although the HEIs are expected to contribute in the development of effective MHEW in the region, their present level of involvement is minimal, with 80% of respondents indicating a very low to medium level of involvement.

The regional expert surveyed suggested that HEIs have three major roles to be performed in developing MHEW. More than 84% confirmed that HEIs have a significant role to play in MHEW education as well as raising awareness. More than 87% confirmed role of HEIs in providing expertise knowledge and advocacy in strengthening MHEW. This could be achieved through conducting evidence-based research which supports in evidence-based policy making. They further engage in risk assessment with their expertise, skills and knowledge.

6.2. Capacity building

HEIs have a leading role in capacity building towards economic and social development. This is because higher education promotes income growth and hence, helps to alleviate poverty. It further contributes to labour productivity and entrepreneurial energy; strengthens civil society, and it promotes governance. Increasing globalization, information revolution and rapid expansion of new knowledge further emphasize the importance of effective higher education. They play a vital role in advancing human capacity and skills in disaster risk reduction strategies, engaging in disaster risk research and contributing to policy making at all levels (Holloway, 2015).

The national reports reveal that some leading HEIs in Indonesia offer and conduct education and research programmes relating to the dissemination of disaster information, including early warning systems, and they also conduct training programmes for government officers, NGOs and industry people. They also conduct research related to flood and weather forecasting for early warning to assist National Disaster Management Organization, to help develop the national system of MHEW in Indonesia.

6.3. Gaps in higher education within DRR context

However, HEIs face many challenges within research and innovation in disaster resilience: lack of research and innovation skills, lack of policy implementation, unclear/inadequate policies on research and innovation, and a heavy teaching workload are found as the major barriers in Asia (Liyanage et al, 2018). Most HEIs face challenges for example, funding limitations, limited courses and disciplined specific courses (Niekerk, n.d). Most HEIs limit their role in disaster risk reduction to the formal teaching approach which has disadvantages such as a lack of industry and community engagement, a lack of multidisciplinary teaching and learning provisions, a lack of flexibility in rapid responses to dynamic industry requirements and a relatively shorter period of student engagement (Siriwardena et al., 2013).

In addition to above literature, the national reports too revealed some common challenges among HEIs in Asia within disaster resilience context. The situation of HEIs in disaster resilience is still at the minimal level in many countries in Asia, for example, in the Maldives and Myanmar. Some frameworks developed in the Maldives did not recognise the role of HEIs within disaster resilience. They also identified a lack of demand for disaster management programmes in the Maldives. Another major barrier for HEIs in engaging in resilience education is lack of funding. For example, this has been evident in Myanmar. They also suffer from a lack of inter-ministerial cooperation and a lack of human resources.

The regional expert survey identified many capacity gaps within Asian HEIs, as presented in Figure 48. Funding and resources are the major barrier among HEIs. A lack of coordination with other institutions and gaps in knowledge were the also significant, as well as the lack of supportive policies and supportive political system.

Figure 48: Capacity gaps among HEIs in Asia

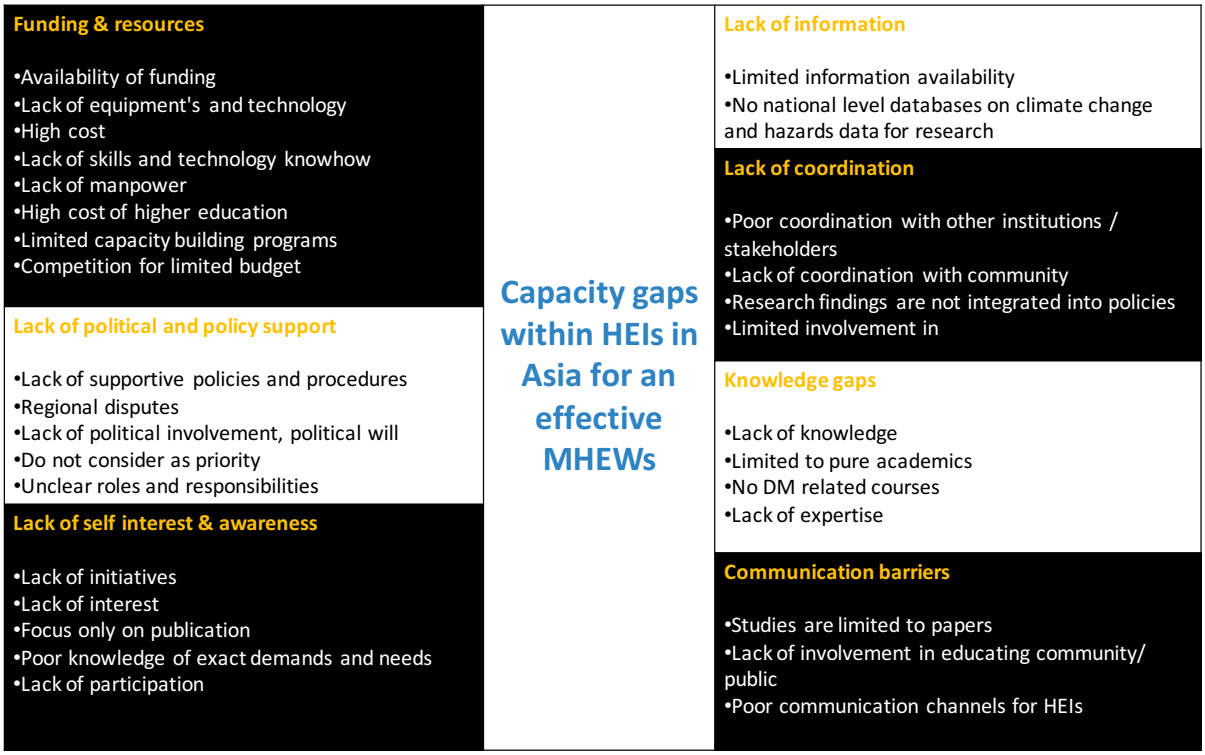

Figure 48 furthermore explains sub-elements under major categories. For example; lack of funding and resources refers to limited availability of funding, high cost in engaging in higher education, lack of human resources, lack of equipment and knowledge/ expertise, lack of skills, limited capacity building opportunities, and competition for limited budget allocation from governments.

The findings of the regional survey tend to reinforce the findings of national reports. For example, HEIs in Indonesia suffer from funding limitations and an underdeveloped research culture (technology and equipment).

Funding, inter-ministerial cooperation and human resources were identified as the major barriers among HEIs in Myanmar.

In the Maldives, there is a lack of demand for programmes. They also face a lack of knowledge among members of HEIs. Funding is also a major barrier in the Philippines. In some instances, where the government provide grants for conducting research, there are delays. A significant point highlighted within HEIs is the problem of "turfing" or competition between government agencies who are mandated to assess specific hazards and issue the "official" results. Universities that can perform similar research, but it is treated as supplemental information. HEIs in the Philippines also suffer with time limitation due to heavy teaching load and administrative work.

According to the national report of Sri Lanka, HEIs often face the challenge of overlooking their research findings in the policy formulation process. Poor attendance for disaster related programmes, and duplication of effort among institutions were also identified as problems. Other issues included a lack of exposure to disaster management for the local graduates, as well as inadequate resources, a lack of capacity to think beyond the main subject area.

6.4. Opportunities

Experts respondents at the regional level identified a series of prioritities to overcome these barriers. Specifically, they suggested the most important actions as increases in training and funding, the need to introduction new curricular on disaster related topics, greater efforts to promote research findings, a need to establish regional networks among HEIs, and greater involvement in policy formulation.

7. Conclusions and Recommendations

The Asia-Pacific region is regularly labelled as the most disaster-prone in the world due to a long history of both major catastrophic disasters and frequent small and medium-sized events. However, climate change, environmental degradation and other factors have resulted in a risk landscape for the region that is increasingly uncertain. Specifically, acute vulnerability to drought in so-called least developed countries, such as Myanmar, contributes significantly to the regional risk level.

This report has made clear the relationship between disasters, climate change and sustainable development clear. Climate-related hazards are particularly prevalent along coasts, which is where many Asian cities are located. Urban areas also concentrate risk. According to The Asia-Pacific Disaster Report, published biennially by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), a one-metre rise in sea level could displace 37 million people in Asia, while a three-metre rise would affect 90 million – along with the damage to the physical, economic and cultural capital of urban areas. Many of the region's urban population lives in informal settlements. People living informally will be the worst affected by disasters, because they lack access to basic services and security of tenure and do not have the voice or means to substantially improve their living conditions.

In order to address such disaster risk, this report has also stressed the important of effective, multi-hazard warning systems. Traditionally, many countries have been reactive to disasters experiencing significant losses in lives and livelihoods of their citizens. Adoption of the Hyogo Framework for Action (HFA) 2005–2015, and more recently, the Sendai Framework for Disaster Risk Reduction 2015-30, has led to a paradigm shift in disaster risk management, from emergency response to a comprehensive approach which also includes preparedness and preventive strategies to reduce risk.

Early warning systems are widely recognised as a critical life-saving tool for tsunami, floods, droughts, storms, bushfires, and other hazards. Effective warning systems are built upon four components: (i) hazard detection, monitoring and forecasting; (ii) analyzing risks and incorporation of risk information in emergency planning and warnings; (iii) disseminating timely and "authoritative" warnings; and (iv) community planning and preparedness.

The Sendai Framework for Disaster Risk Reduction 2015–2030 recognises the benefits of multi-hazard early warnings systems and enshrines them in one of its seven global targets: "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030".

The Sendai Framework urges a paradigm shift in the way risk information is developed, assessed and utilized in multi-hazard early warning systems, disaster risk reduction strategies and government policies. It states "in order to reduce disaster risk, there is a need to address existing challenges and prepare for future ones by focusing on monitoring, assessing and understanding disaster risk and sharing such information and on how it is created; strengthening disaster risk governance and coordination across relevant institutions and sectors and the full and meaningful participation of relevant stakeholders at appropriate levels". The Framework aims to achieve "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".

In order to support achievement of this goals, the CABARET project was established to promote international cooperation at the regional level, between Higher Education Institutes (HEIs) in Asia (region 6) and Europe, and among Asian HEIs themselves, to improve multi-hazard early warning and increase resilience among coastal communities. It has sought to build capacity, foster regional integration and cooperation through joint initiatives, sharing of good practices and cooperation among HEIs in Asia and Europe. It also set out to strengthen relations between HEIs and the wider economic and social environment through its focus on coastal communities, many of which are under severe pressure resulting from planned and unplanned development, population growth and human induced vulnerability, coastal hazards with increasing frequency and magnitude, and the impacts of global climate change.

This regional position paper is an attempt to engage users and beneficiaries, which increases the likelihood that the project can achieve a positive impact. This allows different audiences to have their input during the preparation and development phases, and not simply receive the results at the end. The specific problems to be addressed by CABARET are strategically important: Progress in MHEW is uneven across the Asian region, with some high-risk, low-capacity countries falling behind. Greater participation in regional MHEW will lower the cost, strengthen the sustainability and thus enhance the value for all members, as a single country would normally not be able to implement such a complex system without the cooperation of other countries and relevant regional and international organisations. Through improved regional cooperative mechanisms on MHEW, countries will be better able to share good practices, expertise and capacities in assessing risks, developing sustainable monitoring and warning services, creating proper dissemination and communication systems, and coordinating with communities to increase response capabilities. Higher Education, as a key actor in developing capacity and developing scientific knowledge, has an important role in improving this type of regional cooperation. Some of the key recommendations established through this paper include the following:

7.1. Improve capacities for tsunami preparedness

Hazard and risk assessments

50. Increase engagement of other national, regional or international actors in the carrying out of tsunami hazard and risk assessments
51. Increase the availability of publicly accessible data for tsunami hazard and risk assessments
52. Increase the capacity for tsunami hazard assessment, especially in the areas of evacuation mapping, hazard mapping and inundation mapping
53. Capitalise on the existing capacity in Member States for delivering training on hazard mapping and inundation mapping

54. Increase the capacity for city, village and community level tsunami risk assessments
55. Increase the capacity for developing products from tsunami risk assessments, such as risk maps, evacuation maps, guidelines and action plans

Policies, plans and guidelines

56. Provide support to increase availability of tsunami policies, plans and guidelines at the prevention and mitigation, preparedness, and recovery and reconstruction phases of disaster management
57. Provide support to increase availability of tsunami policies, plans and guidelines at the local level, either as standalone or as part of a multi-hazard approach

Detection, warning and dissemination

58. Provide support to increase the capacity for analysing real-time seismic and sea level data for tsunami threat
59. Provide support to increase the capacity for tsunami modelling to support generation of threat forecasts
60. Undertake a further study to examine whether there is a need for so many different software tools to be used to analyse data for tsunami threat or tsunami modelling
61. Increase the frequency of tabletop or similar tsunami warning exercises to review and test SOPs, and reduce the potential for complacency among countries that have not experienced a recent tsunami event

Public awareness, preparedness and response

62. Provide support for countries to improve their SOPs at the interface between upstream and downstream, including the operation of a 24/7 emergency operation centre, receiving information from the NTWC, and response criteria and decision making, as well as the associated human resources and infrastructure
63. Provide support for countries to improve their SOPs to address warning dissemination, communication with the NTWC, communication with other stakeholders, evacuation call procedures, communication with local government and media arrangements, as well as the associated human resources and infrastructure
64. Provide support for the development of community level evacuation SOPs
65. Capitalise on the willingness of countries to share their SOPs to share good practices across Member States

Evacuation infrastructure

66. Provide training and share Member States' experience of different types of evacuation infrastructure

Tsunami exercises

67. Provide support to incorporate tsunami level exercises into cities, villages, communities and schools

Public awareness

68. Provide training and share Member States' experience of different public engagement materials
69. Develop educational materials such as teaching kits, and encourage the incorporation of tsunami awareness into the school curricular
70. Raise awareness of the Global Disaster Risk Reduction Day and Tsunami Awareness Day

7.2. Improve capacities for MHEW

71. Significant efforts must be made to assure the adequacy of existing EW and communication of EW to reach "last mile" in the region.

72. Continuously evaluate and monitor the current status of existing early warning systems
73. Develop mechanisms for regional cooperation, including greater knowledge sharing and networking
74. Mainstream early warning into development planning
75. Increase disaster education and awareness raising
76. Develop inclusive and context specific disaster preparedness plans
77. Develop supportive policy and institutional frameworks
78. Develop technological systems for real time monitoring and forecasting
79. Increase multi-stakeholder partnerships, collaboration and networking

7.3. Increase engagement of HEIs in capacity development for MHEW

Education

80. HEIs should engage in capacity building among community through education, awareness and training
81. Develop more curriculum that address disaster risk reduction and resilience
82. Understand the needs to employers, including public authorities, NGOs and the private sector, to ensure that programmes for disaster risk reduction meet sector needs
83. Encourage students to conduct research in the area of disaster management, resilience and MHEW to facilitate evidence-based policy making
84. Incentives can be offered to encourage faculty to support capacity-building of stakeholders
85. Encourage the natural curiosity of students towards sciences in the midst of cultural expectations

Knowledge development

86. HEIs should be a place for training and technician incubators on disaster management in Asia
87. Build collaborations between HEIs and governments in conducting applied research
88. Deloading schemes are needed to allow faculty more time for research
89. Encourage relevant research with long term societal impact, fostering reflexive research attitude in young researchers
90. Provide an institutional environment that support trans disciplinary contextual research
91. Formulate and conduct research that integrates aspects such as long-term sustainability and resilience of communities as key focuses

Advocacy

92. Establish communication mechanisms between governments and HEIs to deliver outcome of evidence-based research
93. Create inter-ministerial cooperation
94. Give opportunities to more engage in local processes, as well as in international bodies and technical working groups
95. Academic staff should be trained to work with government organisations that have the specific mandates in the fields of MHEW and disaster resilience
96. Continuous dialogue is required among agencies to encourage better coordination, encouraging and supporting researchers to work with other stakeholders
97. HEIs should not be limited to evidence-based policy making but also need to create industry – HEI linkages for mutual benefits
98. Inter-HEI exchange (national and international) can be used as a way of increasing the role of HEIs in resilience education

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Annex 1: Regional survey methodology

A regional survey was conducted as part of the research strategy. The objectives of the regional survey were to explore the status of available MHEW systems, existing regional cooperation towards effective MHEW systems, and to identify the enablers and barriers that affect the effective operation of MHEW in Asia. The survey was also used to explore the role of HEIs in Asia towards disaster resilience and to identify any obstacles that affect their contribution towards resilience building.

The survey was developed based on a comprehensive literature review conducted by the research team and described elsewhere in this report. The review enabled the team to identify concepts and related theoretical background, and which could be tested through the survey instruments as a deductive approach. The initial questionnaire was distributed among CABARET members giving them opportunity to provide their feedback. The feedback was incorporated into the final regional survey instrument. The survey enabled the team to gather a large amount of data economically and efficiently. Survey strategies are commonly used in both descriptive and exploratory research studies (Saunders et al, 2016). It can also be linked with the deductive research approach where the theoretical facts are tested with empirical data.

The questionnaire survey instrument was launched using Survey Monkey instrument. The study launched the survey as a cross sectional data collection method during July-October 2017. The respondents were selected based on their experience and knowledge of working Asian disaster risk reduction, multi-hazard early warning systems, and early warning systems. In addition, the sample was selected to represent multi stakeholders for example, academics, practitioners, policy makers, private sector and non-governmental organizations. 136 responses were fully completed out of 199 survey responses collected.

The questionnaire survey consisted of closed ended and open-ended questions. The questions were designed as scale questions, ranking questions and dichotomous questions. The survey was comprised of 25 questions in total. Questions 2-4 were designed to elicit the respondent's profile, while Questions 6-7 were used to evaluate coastal hazards and the availability of early warning systems in Asia. Questions 8-9 were designed to understand the applicability of global initiatives in Asia. Questions 10-11 examined regional cooperation for MHEW in Asia, where the policy background in Asia was explored through Questions 12-13. Questions 14-17 were assigned to identify and evaluate enablers for an effective MHEW in Asia. Questions 18-19 were used to determine barriers for MHEW in Asia. Finally, questions 20-24 were designed to understand the role of HEIs and any barriers they face developing MHEW in Asia.

The study used a mixed method in data collection and data analysis. The data were analysed qualitatively and quantitatively using SPSS 23.0 version statistical software. The analysed data were presented in tables and graphs (pie charts and bar charts). Most questions were tested for statistical accuracy by conducting reliability and validity tests using Cronbach' Alpha and KMO and Bartlett test (to see the sample adequacy). Further, the study conducted Principal Component Analysis (PCA) to identify the commonalities among variables in identifying common themes. For example, to identify the main themes of enablers, the PCA was used and found with seven categories which were based on the PCA results.