Chapter 51: A cross case analysis of the upstream-downstream interface in the tsunami early warning systems of Indonesia, Maldives, Myanmar and Sri Lanka

Dias N.[1], Haigh R.[1], Amaratunga D[1]., Sakalasuriya, M. [1]
[1]Global Disaster Resilience Centre, University of Huddersfield, United Kingdom

*Correspondence: n.dias@hud.ac.uk

Abstract

The 2004 Indian Ocean tsunami and more recent tsunami events in Indonesia have demonstrated the challenges in detecting and evaluating a tsunami threat, and the importance of communicating warning information to communities at risk. Early warning for tsunami is faced with the dilemma of time verses uncertainty due to short response times, and obvious limitations of technology and currently available scientific knowledge. Previous studies have also revealed a need for better governance, including a more strategic approach focusing on stronger integration of tsunami early warning into national and local disaster management and other public and private sectors. This chapter describes research carried out in Indonesia, the Maldives, Myanmar and Sri Lanka to better understand current tsunami early warning systems. The four countries are linked to the region wide Indian Ocean Tsunami Warning and Mitigation System. The chapter builds on the results of four national level studies to carry out a cross case analysis of the upstream-downstream interface arrangements in tsunami early warning. This is the period where the tsunami warning decision is taken at the country level, the warning information is disseminated, and an evacuation order is issued. The analysis focuses on nine critical aspects of capacity at the interface, including: decision making mechanism; clearly defined actors; centralised vs decentralised approach; standardisation of interface arrangements; technical capacity; human capacity; spatial and sociocultural aspects; vertical and horizontal coordination; and, formal and informal communication mechanisms. The results provide insights into the operationalisation of the interface arrangement in each country, as well as the technical, social, economic and political dynamics that shaped their establishment and current functioning.

Keywords- Tsunami early warning system; Governence; Institutions; Capaci ties; Warning dissermination; Evacuation

51.1. Introduction

The recent tsunami events in Indonesia have again demonstrated the challenges in detecting and evaluating a tsunami threat, and the importance of communicating warning information to communities at risk.

This chapter describes research carried out in Indonesia, the Maldives, Myanmar and Sri Lanka to better understand current tsunami early warning system (TEWS) arrangements and to establish priorities for capacity building in the Indian Ocean region. It builds on the results of four national level studies to carry out a cross case analysis of the upstream-downstream interface arrangements in TEWS. The results of this analysis provide important insights into the different socio-politico contexts of each country, and the similarities and differences in their approaches to tsunami early warning.

The chapter begins with an introduction to the threat posed by tsunami and some of the challenges in developing an effective early warning system that can protect communities. It goes on to introduce a conceptual framework that details the key areas of capacity that underpin effective tsunami early warning and that can be used to better understand existing tsunami early warning arrangements. The underpinning fieldwork in four countries is briefly described, followed by the methodology for a case-oriented cross case analysis. The second half of the chapter presents the results of the analysis against the key areas of capacity and discusses the implications for capacity building in the Indian Ocean region.

51.2. Background

Around the world, tsunami threat remains high. According to the INFORM Risk Index 2019, the disaster risk index for tsunami is the highest of all hazards in Indonesia (9.6), the Maldives (8.9) and Sri Lanka (8.2).

Some scientists have also warned that climate change will result in more tsunamis. It is widely accepted that climate change increases the frequency and magnitude of different types of disaster due to natural hazards, as well as the risk and vulnerability levels of communities. However, the subject of linkages between climate change and tsunami inundation is an emerging area of research. It is increasingly recognised that rising sea level induced by climate change could significantly increase the level of tsunami hazard to coastal land areas (Shao et al., 2019, Li et al., 2018). One of the other hypotheses is that tsunami like water waves can be caused by oceanic impacts such as seismic, landslide or volcanic geophysical events, that are potentially increased in number and size with climate change (Gusiakov et al., 2009).

Among the potential sources of tsunami, those generated by tectonic plate movements (resulting from seismic activities) have a large impact on the land areas, and hence results in large loss of lives and damage (Lockridge, 1990, Escaleras and Register, 2008). However, the nature of such tsunamis allows for systems that warn

and alert exposed communities well before the tsunami impact so that people can evacuate and find shelter (Kamigaichi, 2004, Titov, 2009).

Tsunami early warning systems (TEWS) have long been identified as the single most important and effective mechanism that can be used to predict tsunamis and hence minimise the consequent damages (Basher, 2006, de León et al., 2006). The main objective of TEWS is to alert the vulnerable communities about the potential tsunami risk and provide guidance for protection, and if necessary for evacuation (Cecioni et al., 2014, IOC/UNESCO, 2015).

At the time of the IOT on 26 December 2004, the region did not have a TEWS. The tsunami resulted in the loss of over 230,000 lives and the displacement of over 1.6 million people around the Indian Ocean, with estimated economic losses of US$14 billion (UNESCO-IOC, 2019). The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) was formed in response. After 8 years of international collaboration and development, facilitated and coordinated by the UNESCO Intergovernmental Oceanographic Commission, the IOTWMS became fully operational in 2013 with Tsunami Service Providers (TSPs) established by Australia, India and Indonesia.

For all the progress and improvement at the detection end of the tsunami early warning system that has been developed since the 2004 IOT, in 2014 the ICG/IOTWMS formally recognised that much remains to be done to ensure dissemination of effective warnings and improve the preparedness of communities to respond to such warnings. At the ten-year anniversary event held to commemorate the IOT (UNESCO-IOC, 2014), it was stressed that there is a need for better governance, including a more strategic approach focusing on stronger integration of tsunami early warning into national and local disaster management and other public and private sectors, and a stronger client orientation for tsunami warning services.

The complexity of the challenges for TEWS was reaffirmed by the Central Sulawesi Tsunami (September 2018) and Western Java and Southern Sumatra Tsunami (December 2018), which both caused widespread damage and loss of life in Indonesia. The summary statement from a ‘Lessons Learnt’ symposium after these events (UNESCO-IOC, 2020) highlighted that TEWS are faced with the dilemma of time verses uncertainty due to short response times, obvious limitations of technology and currently available scientific knowledge. It also identified a low level of public knowledge related to a near-field tsunami risk, lack of capacities of disaster management offices to deal with nearfield tsunamis, lack of proper evacuation plans and related infrastructure during tsunami emergency, poorly implemented/ineffective spatial planning, and policy related issues.

As these reviews of previous tsunami events and their responses indicate, the challenges for tsunami early warning are varied, from the need for timely and accurate monitoring, detection and evaluation of the hazard threat, to the dissemination of risk information and preparedness of communities at risk. This reflects the full spectrum of an end-to-end tsunami warning and mitigation system, as was set out in the original implementation plan for IOTWMS (UNESCO, 2011).

The end-to-end system is usually defined in terms of the upstream and downstream, as documented in official technical documents and previous studies (UNESCO, 2011; de León, Bogardi, Dannenmann, & Basher, 2006). The upstream mechanism typically starts at the regional level, where an earthquake is detected, and the risk of a tsunami is forecasted. Once the warning information is received by a national authority, warning information is processed and disseminated within the country. The downstream mechanism is where the warning information and evacuation order is disseminated to the relevant authorities and general public, and if necessary, communities are relocated. Typically, the downstream mechanism continues until the risk of the tsunami is alleviated (Bernard & Titov, 2015).

Previous studies have usually focused on disparate elements of the upstream and downstream warning chain, including technical studies to develop regional and national detection and monitoring infrastructure, and local studies on evacuation infrastructure. However, this chapter will focus on more recent research into the challenges at the interface between the upstream and downstream of tsunami early warning. The interface in the context of TEWS is a relatively new concept and was not well defined in previous research. A study by Sakalasuriya et al (2018) identified the interface as the period where the tsunami warning decision is taken at the country level, the warning information is disseminated, and an evacuation order is issued. They found this stage of early warning to be especially challenging and poorly understood. This is due to it involving a wide array of jurisdictional agencies and response partners, including regional tsunami service providers, tsunami national contact points, and a range of sub-national emergency operational centres and related actors. They also noted the socio-politico complexities in the interface arrangement, due to the wide variations across the twenty-eight countries in the IOTWMS, including their levels of tsunami threat and exposure, types of governance and institutional arrangements, levels of human and technical capacities, and social context.

The remainder of this chapter draws upon the findings of a region-wide study into the interface of TEWS. The main study was designed to understand the operationalisation of the interface arrangement in each country, and analyse the technical, social, economic and political dynamics that shaped their establishment and current functioning. These national analyses have been recorded on the interface arrangements in Indonesia (Haigh et al, 2021), the interface arrangements in Sri Lanka (Sakalasuriya, 2018, Haigh et al, 2020; Dias et al, 2020), and a comparative analysis of tsunami early warning governance arrangements at the interface in Indonesia and Sri Lanka (Sakalasuriya et al, 2020). This chapter extends these earlier analyses to present a cross case analysis of the upstream-downstream interface arrangements of the TEWS in Indonesia, Maldives, Myanmar and Sri Lanka.

51.3. Conceptual framework

This chapter's analysis is built upon the conceptual framework established for the region wide study. A literature review was undertaken in order to understand the state of the art related to TEWS and establish a basis for data collection and analysis. This literature review led the authors to construct a conceptual framework that consists of nine components. This framework was used as the foundation for data collection in four countries, as well as the analysis and reporting of the results. The nine components in the framework are: decision making mechanism; clearly defined actors; centralised vs decentralised approach; standardisation of interface; technical capacity; human capacity; spatial and sociocultural aspects; vertical and horizontal coordination; and, formal and informal communication mechanisms. A more detailed description of this conceptual framework is presented in Sakalasuriya et al. (2018). Aspects related to disaster governance and politics are further elaborated in Sakalasuriya et al. (2020).

51.4. Methodology

After a preliminary desk study described in Sakalasuriya et al. (2018) and Sakalasuriya et al. (2020), the TEWSs of four countries were selected as case studies, namely those of Indonesia, Maldives, Myanmar and Sri Lanka. These countries are all member states of the common regional warning system, the IOTWMS. These were chosen based on the variations in criteria that affect the operationalisation of TEWS such as administrative system, extent of (de)centralisation, and proximity and exposure to tsunami threat, and recent experience. During the 2004 IOT, Indonesia and Sri Lanka were the two worst affected countries in terms of deaths, disappearances and destruction, whereas the losses of the Maldives and Myanmar were much less (NOAA, 2019a). Indonesia is the only one of these countries to have faced a significant tsunami threat since 2004 and since the establishment of IOTWMS (NOAA, 2019b). All four countries have extensive coastlines that are potentially exposed to a tsunami threat. Indonesia has approximately 6,000 inhabited islands. Sri Lanka is an island nation, while the Maldives comprises 26 atolls. Myanmar has an extensive coastline but also over 4 miles of land borders. The four countries are very different in terms of geographic and demographic features, and also provide very different social and political contexts. For example, the Sri Lankan TEWS operates on a more centralised basis while the decision making in Indonesia is decentralised to local governments (Hettiarachchi and Weeresinghe, 2014, Spahn et al., 2010). There is evidence that administrative and political systems in Maldives and Myanmar also tend to be centrally operated (Faizal and Laking, 2013, Howe and Bang, 2017). These many differences provide an interesting context for comparison and wide ranging challenges for an effective early warning system.

As required by the nature of the areas being studied and based on the research questions to be addressed it was decided to use a qualitative research approach for

the study. The region wide study was directed by a main academic team and supported by in-country teams in Indonesia, Maldives, Myanmar and Sri Lanka. After an initial literature review, data collection guidelines were developed by the academic teams, which were adapted into context specific tools by the country teams. Documentary analysis, semi structured interviews of key informants and focus group discussions (FGDs) were used for data collection regarding each phase of the TEWS. The data was analysed using content analysis. The findings were further validated through FGDs held in the countries with the participation of stakeholders and experts before being compiled into reports by the country teams. The final country reports were used to develop the publications and policy briefs, and to provide recommendations to national warning organisations in respective countries. The cross-case analysis presented in this paper is based on the reports and was led by the main academic team. In addition to country reports, the 2018 Status report on 'Capacity assessment of tsunami preparedness in the Indian ocean' (IOC, 2020) is used as documentary evidence for this paper. The comparative analysis is based on the conceptual framework described in section 3. The case-oriented cross case analysis method was used during the data analysis, which allows researchers to explore and explain the similarities and differences between the cases (Ragin, 2004, Khan and VanWynsberghe, 2008). This method was also deemed viable given the limited time frame of the research and the nature of the data collected by different research teams in the case study countries. The data from each country were mapped into the conceptual framework, and the similarities and differences among cases were explored.

51.5. Results and Discussion

51.5.1. Decision making mechanism

Sri Lanka and the Maldives have a central decision-making mechanism where a significant role is played by national level institutions.

The Department of Meteorology (DoM) and the Disaster Management Centre are the key national authorities in Sri Lanka. DoM receives warnings from the TSPs and issues them to the DMC, which has the decision-making authority for issuing evacuation orders. Both DoM and DMC are under the Ministry of Disaster Management. A concern identified in the Sri Lankan tsunami decision-making mechanism is the use of personal contacts with the Ministry to agree on decisions, rather than following formal decision-making procedures and guidelines (Haigh et al., 2019).

The Maldives also has a central decision-making mechanism similar to Sri Lanka, whereby the Maldives Metrological Department (MMS) receives warnings from the TSPs and issues them to the National Disaster Management Authority of Maldives (NDMA). The NDMA, as the national decision making body, issues the orders for evacuation to relevant bodies including the island councils. A problem encountered with the Maldivian decision-making process is a confusion in

identifying the difference between warning information and evacuation orders. This appears to occur due to the MMS issuing warning information directly to the general public while also issuing warning information to the NDMA for decision making. As a consequence, people often identify MMS information as evacuation orders and they start to evacuate themselves (Shadiya et al., 2019).

Indonesia and Myanmar have a similar decision-making process, which is partially decentralised. Both national and local institutions are involved in the decision-making process.

In Indonesia, the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG), Indonesian National Board for Disaster Management (BNPB), Local Disaster Management Organisation (BPBD), and the local mayor's office are involved in the tsunami early warning process. There is a clear hierarchy from BMKG as an information provider and decision-maker to provide warning information to the relevant authorities. The actual evacuation order is taken at the local level by the Mayor and with the support of the local disaster management organisation. This reflects a wider decentralisation of government across all government sectors of Indoensia. Although this can be seen to empower local level decision making, it has also resulted in some different practices at the local level. There are concerns that local level actors may not have the capacity and experience to make such critical decisions. There is now recognition that there is a need to strengthen guidelines for local political actors (Rahayu et al., 2019).

In Myanmar, the Department of Meteorology and Hydrology receives information from TSPs and issues them to the Department of Disaster Management (DDM). But, the responsibility of the DDM is only to convey the message to regional, district, town and village level government administrative department/disaster management bodies. The decision to issue the order for evacuation is taken by these administrative department/disaster management bodies at different levels, depending upon pre-defined emergency status levels and associated criteria. A concern with this approach is the time taken for decision making. Different levels of general administration department (GAD) need to be consulted. If one level is unable to handle the situation, it is passed on to a higher level and these practices consume a considerable amount of time (Aung et al., 2019). Tsunami threats are sudden onset events, which typically afford anything from a few minutes to a few hours to issue warning information to communities at risk. This is very different from, for example, a typical cyclone, which is usually forecast several days before the event. It illustrates the need to tailor decision making processes to reflect the amount of time available from a hazard being detected, to when it directly impacts communities at risk.

51.5.2. Clearly defined actors

All four countries have clearly defined National Tsunami Warning Centres (NTWCs) and National Disaster Management Organisations (NDMOs) in their

TEWS. This reflects standard roles as defined by regional guidelines provided by the IOTWMS.

They also have defined actors for downstream operations as well. For example, Sri Lanka has identified roles for the Department of Fisheries, Ministry of Health, The Tri-forces (Army, Navy and Air Force), Police, the Transport Board, District Disaster Management Offices and Grama Niladaris (the lowest administration level of Sri Lanka).

Although these actors are identified, a key issue identified in all four countries is fragmented coordination among them (Aung et al., 2019, Haigh et al., 2019, Rahayu et al., 2019, Shadiya et al., 2019).

This is especially challenging in the Maldives, where there is a need to coordinate operations at an island level. The Maldives has a population of approximately 530,000 people spread across 200 inhabited islands, grouped in clusters, or atolls. They also have very little experience of tsunami events. The island level authorities do not have adequate knowledge of their roles and responsibilities in the early warning mechanism (Shadiya et al., 2019).

Similar to Sri Lanka and the Maldives, Indonesia has designated interface institutions but, there are issues in the coordination mechanism. The Service Guidebook for Ina-TEWS is the principal document prepared to guide all the stakeholders with-in the Ina-TEWS. There are gaps in the clarity of the guidelines given in the service guide book. For example some roles that are evident in practice, do not appear in the guidance (Rahayu et al., 2019).

The situation in Myanmar is even more complex. As detailed in section 5.2, the evacuation decisions are taken by GADs at National, Regional, District, Town and Village Committees depending on the emergency level There are twelve working committees under each level and the coordination mechanism among these levels is not documented or demonstrated in Myanmar's TEWS (Aung et al., 2019).

51.5.3. Standardisation

In Sri Lanka, standard operating procedures (SOPs) are prepared by institutions such as MDM, DMC and DoM for their in-house use. A National Emergency Operation Plan (NEOP), which was developed by the DMC in 2015, provides some general guidelines on early warning and emergency response situations. However, these SOPs of different institutions are not formally integrated. The absence of a common guideline that can be followed by all stakeholders has created a lack of understanding among the individuals within the institutions. For example, there are disputes between DoM officers and DMC officers in understanding their roles, such as 'who contacts the regional TSP and the Ministry?' and 'who takes the final warning decision?'. Since this was revealed during this research study, an integrated SOP was developed by the key stakeholders. This integrated SOP was tested during the 2018 Indian ocean-wide tsunami (IOWave) exercise, further improved and later adopted (Amaratunga, Haigh, & Dias, 2019; Haigh & Amaratunga, 2018).

Indonesia holds the Service Guidebook for its TEWS as the principal document prepared to guide all the stakeholders. Further, there are guidelines available within the individual institutions, both at national and local levels. As stated in section 5.2, there are some gaps in the clarity of the guidelines given in the service guide book as some of the roles and responsibilities of key institutions are not clear (Rahayu et al., 2019).

Like in Sri Lanka, Maldives has developed a NEOP which provides certain general guidelines on early warning and emergency response situations. Besides this, SOPs are developed for the national level institutions, but these do not cover island councils who conduct the evacuation process (Shadiya et al., 2019).

The Department of Meteorology and Hydrology of Myanmar has a SOP for issuing a tsunami warning. As per the National Disaster Management Law 2013, all institutions related to disaster management should have their own SOPs and need to update them every 4 to 5 years (Aung et al., 2019, UNESCO/IOC, 2018). Although there are several guidelines and SOPs at the national and department level, they are not integrated into a single work plan for the operation. At the same time, the SOPs for local governments are not clearly defined in Myanmar (Aung et al., 2019).

51.5.4. Technical capacity

The findings of this study found that national level technical capacities of all four countries are at a broadly acceptable level, but that each has specific challenges, primarily at the local level.

Sri Lanka does not have adequate technical capacities at the district and local level to deal with emergencies. Also, this study identified a need to reconvene a national technical advisory committee for tsunami in Sri Lanka, which could provide on-going advice and guidance to relevant agencies and that can identify and address relevant research and technical gaps, and guide plans for capacity building (Haigh et al., 2019). This committee was originally established after the 2004 tsunami event, but over time had become dormant.

In Indonesia, the national level technical capacity is extremely high as the country is one of three regional TSPs that provide information for the whole IOTWMS. Downstream, the technical capacities are far less and it was found that tsunami warning dissemination was sometime disrupted due to the impact of an earthquake or a power outage (Rahayu et al., 2019).

The technical capacities of island councils in the Maldives also require improvement. For example, there is a need to provide satellite phones to all island councils. Currently, standard phones and social media groups such as ‘VIBER’ are in use to disseminate warnings to island councils which are easily overwhelmed in emergencies (Shadiya et al., 2019).

In Myanmar, the downstream warning dissemination modes are not clear. For example, it is not clear how the early warning information is communicated to the village level committees who decide to evacuate people. The lack of electricity in

most of the villages is also a critical technical issue and can prevent the dissemination of warning information to the village level (Aung et al., 2019).

51.5.5. Human Capacities

Similar to technical capacities, human capacities were also found to be generally acceptable at the national level, but more problematic at a sub-national level.

The key institutions of Sri Lanka and Indonesia are very well connected with relevant political bodies. In Sri Lanka, in case of an emergency and warning issuance, both the DMC and DoM inform the secretary of the ministry about the changing developments and the Secretary updates the Minister who informs the President. As the national disaster management institution, the individuals in DMC are under direct scrutiny and well-connected to political actors (Haigh et al., 2019).

In Indonesia, the Director-General of BMKG, Indonesia, is the head. An inspector and a main secretary are the two main leads under the Director-General, and the rest of the staff function under their guidance (Rahayu et al., 2019). Like DMC in Sri Lanka, BNPB is under the direct supervision of the President of the Republic of Indonesia

However, several stakeholders in the Sri Lanka TEWS, such as NARA (who is providing sea-level data), do not operate 24/7 as they do not have adequate staff. Also, DoM, as the NTWC of Sri Lanka often faces issues with its human resources due to the heavy workload and staff being stretched into several responsibilities. Also, some DMC staff carry a passiveness towards a potential tsunami as they lack up to date knowledge and awareness about the level of tsunami threat to Sri Lanka (Haigh et al., 2019). It was found that some staff had become complacent, most likely due to the country not experiencing a tsunami since 2004.

In Indonesia, there is a need to ensure provision of adequate training to the local Mayors, as they take the evacuation decision at local levels. Since the Mayor is a political actor, EOC specialists need to support and provide essential training to the mayors. The personnel at EOCs also need effective leadership skills to determine an evacuation order in the absence of the Mayor (Rahayu et al., 2019).

MMS as the NTWC of Maldives has a good human resource capacity. However, the NDMA needs for human resources for shift work as they sometimes limit their working hours due to non-availability of shift staff. Currently, when there is a yellow or a red alert, all the staff at NDMA are required to report for work, but, this can pose an extreme threat and a delay in decision making in case of an emergency. Further, it is was also evident that trained staff after 2004 Tsunami have now left their positions and the new staff have not received training on TEWS. The study did not reveal the human capacities within the island councils, which need further investigating (Shadiya et al., 2019).

The DMH of Myanmar, as the NTWC, holds an adequate human capacity, but, there is a lack of human capacity at the village level. As per Myanmar's TEWS when the alert level is number 5, the village level committees are responsible to take the evacuation orders and to pass it to the next level (town level) if they cannot

handle the situation. In order to take such a decision, as well as to decide the emergency level, they would require adequate training and knowledge on the early warning mechanism. In reality there is very little training or support at the local level (Aung et al., 2019).

51.5.6. Spatial and socio-cultural aspects

Hazard mapping is a key spatial aspect in improving the early warning mechanism. Indonesia and Sri Lanka have hazard mapped whole coastal regions, which is a major improvement in strengthening the TEWS of respective countries. However, it is noted that Myanmar needs to improve their hazard mapping as they have currently mapped only one village which is Aung Hlaing Village, Labutta Township, Ayeyarwady Region (UNESCO/IOC, 2018, Aung et al., 2019).
However, even when maps are available, they may not be fit for purpose. For example, in Indonesia the maps are available only at a macro scale, and as a result, they cannot be used for planning an evacuation at the local level.

Countries also have specific cultural challenges to overcome. In Sri Lanka, people in certain areas tend to believe and follow predictions from astrologers rather than follow scientific information from early warning authorities (Haigh et al., 2019). In the Maldives, some people in islands believe that a tsunami is a punishment from God and therefore there is no way to escape it. Accordingly, they do not follow the early warning information and orders (Shadiya et al., 2019). The Maldives also has a very high number of tourists per capita, many of whom would be unfamiliar with a tsunami threat and would be unlikely to have participated in any local level training or awareness raising. In Myanmar, many people are facing poverty and hunger, and these tend to take precedent over, for example, efforts to understand the early warning mechanism (Aung et al., 2019).

51.5.7. Ongoing evaluation

The IOTWMS organises region wide ‘IOWAVE’ exercises every other year to simulate tsunami warning processes. Most of the twenty eight countries in IOTWMS participate but it is not compulsory. They also tend to focus on national level processes, while participation downstream is minimal in most countries (Haigh et al., 2019, Rahayu et al., 2019, Shadiya et al., 2019). Twenty one countries also participated in a 2018 survey to assess tsunami preparedness, which has informed capacity building in the region (UNESCO/IOC, 2018). Countries are also encouraged to carry out national and local level simulation exercises, but these appear to be very ad-hoc and approaches differ greatly across countries. Indonesia for example, has conducted local level exercises in high risk areas since the 2004 event. At the time of the study, the DMH of Myanmar was also organising training courses for public awareness and knowledge sharing on disaster risk reduction to ensure the warnings reach the public (Aung et al., 2019).

51.6. Conclusion

Table 51.1 provides a summary of the findings to emerge from the study across the four countries. It also sets out some recommendations for capacity building that have emerged through the research.

The IOTWMS is a region wide system for TEWS and covers twenty eight countries. The guidance issued at the regional level has led to some commonalities across countries, such as the key roles of institutions and aspects of the SOP, especially the protocols between regional TSPs and national levels actors. However, this study has revealed important variations in how the system operates at the national and sub-national levels. These differences are not suprising as the contexts within which the TEWS operate are also very different.

The highly dispersed, island populations of Indonesia and the Maldives pose a very different challenge to that of Sri Lanka or Myanmar. Also, while all countries were hit by the 2004 IOT, Indonesia has experienced multiple devastating tsunami since then and is more highly exposed to future events. It has invested heavily in early warning as a result and it appears to be a national priority. Due to the devastation experienced in 2004, Sri Lanka also made considerable effort to develop its TEW capability, but over time and as memories of the event recede, it is also clear that some of these capacities have faded. In contrast, the Maldives and Myanmar were not as badly impacted by the 2004 event. Other threats, such as climate change in the Maldives, or cyclones in Myanmar (especially after Cyclone Nargis in 2008) appear to have taken precendence. In the case of Myanmar, it appears that their very decentalised decision making structures have not been adapted to fit the specific challenges of a tsunami, which may need a decision to be taken in very limited time and with limited information.

Despite the many differences, a common challenge encountered across countries is the need to develop adequate capacities at the sub-national levels. The regional system focuses warning information on a central contact point at the national level. In all countries, most of the expertise and capacities is also focused on these national actors, especially the NTWC and NDMO. However, in all countries, a range of subnational actors are also involved in conveying warning information to communities at risk. It is therefore vital that these sub-national actors are provided with adequate capacities to fulfil their responsibilities. This is especially critical in countries like Indonesia and Myanmar, where decision making has been partially delegated to sub-national levels.

Looking forward, it is also evident that there is the potential for experiences to be shared across countries. The IOTWMS is using the input from this research and a 2018 capacity assessment of tsunami preparedness to inform capacity building and training efforts across the Indian Ocean region. As part of this, there will be opportunities for countries to share details of their approaches and learn from different contexts.

Table 51.1: *Comparison of countries against critical areas of capacity in the interface arrangements for tsunami early warning*

Areas of Capacity	Sri Lanka	Indonesia	Maldives	Myanmar	Similarities/differences	Gaps/issues	Recommendations
Decision-making mechanism	• Central • Significant institutions operate at the National level • Institutions are under the ministry	• Partially decentralised • Both national and local stakeholder institutions are involved • Clear hierarchy at national and local levels • Local mayor issuing the evacuation order	• Central • Significant institutions operate at the National level	• Mixed decision-making mechanism • Both national and local stakeholder institutions are involved • The decision to issue the order for evacuation is taken by administrative department/disaster management bodies in different administrative levels depending on the emergency status level.	• **Sri Lanka and Maldives**- centralized national level mechanisms from warning detection, decision making to dissemination • **Indonesia**- National mechanism for warning detection and to decide to warn the authorities (dissemination), but evacuation orders are taken at the local level • **Myanmar** - similar to Indonesia, detection and the decision to disseminate warnings taken at the Nation level, but, evacuation orders are taken by different administrative bodies (can be national or local depending on the emergency status level)	• **Sri Lanka**- Personal contact with ministry to agree on decision • **Indonesia**- Different practices at the local level in decision making • **Maldives**- Warning dissemination to the public by both MMS and NDMA, people are often confused in identifying the correct evacuation order • **Myanmar**- Time management for decision making as the process is so long	• **Sri Lanka-** Needs to follow formal mechanism in decision making • **Indonesia**- Clear guidelines to political actors on decision making at the local level is needed • **Maldives-** Provide awareness to people in differentiating dissemination information and evacuation orders • **Myanmar-** Clear policy guidance for decision making
Clearly defined actors	• Regulator- MDM • NTWC/TWFP- DoM • NDMO-DMC	• Regulator- BMKG • NTWC/TWFP- BMKG • NDMO-BNPB	• Regulator and NDMO- NDMA Maldives • NTWC- MMS	• NTWC- DMH • NDMO-DDM	• Defined actors in all four countries,	• Unclear roles and responsibilities • Discrepancies of actions	• Need to clearly refine roles of each actor
Standardisation	• SOPs prepared by MDM, DMC, and DoM for their internal use • Availability of NEOP	• Service guidebook- principal document prepared to guide all the stakeholders with-in the Ina-TEWS. • guidelines available within the individual	• NTWC and NDMO- SOP available • No SOPs for island councils	• NTWC-SOP available • All institutions related to disaster management should have their own SOPs and need to update them every 4 to 5 years.	• SOPs for national institutions in all four countries • NEOP plans are developed in Sri Lanka and Maldives • Service guidebook- principal document prepared to guide all the	• **Sri Lanka-** Some discrepancies in SOPs, SOPs of different institutions not formally integrated, absence of a common guideline • **Indonesia-** The roles of BNBP, EOC, and BPBD	• **Sri Lanka-** Need to use the DMC formally adopted synergised SOP to bring the coordination

		institutions, both at national and local levels			stakeholders with-in the Indonesian -TEWS.	were not specified as key warning conveyors and decision-makers in the regulations • **Maldives-** Island councils do not have SOPs to conduct evacuation • **Myanmar-** Several guidelines and SOPs at the national and department level, they are not clearly integrated into a single work plan for operation, SOPs of GADs not defined at each GAD level, severe delays in the decision-making process	• **Indonesia-** Clarity of the guidelines should be improved • **Maldives-** Needs to standardise evacuation procedure at island councils • **Myanmar-** Needs to standardise the decision-making process at the GADs, integrate all SOPs into a single work plan
Technical Capacity	• Better technical capacity at the National level • Inadequate technical capacities at the district and local level to deal with emergencies.	• Better technical capacity at the National level • Equipment for tsunami warning dissemination often dysfunctions, due to the impact of earthquake or power outage.	• Better technical capacity at the National level • Technical capacities of Island Councils should be improved.	• Better technical capacity at the National level • *Technical capacities of different levels of GADs are not revealed in this study*	• Better technical capacity at the National level in all four countries is a common feature	• Inadequate technical capacity at local levels is a common problem in all four countries • **Maldives** standard phones and social media groups such as 'Viber' in use to disseminate warnings to island councils, often jammed in emergencies • **Myanmar** Lack of electricity in most of the villages	• **Sri Lanka** needs a national technological advisory committee to revisit the capacity needs • **Maldives** required to provide satellite phones to all island councils.

						hinders downstream communication in emergencies.	
Human Capacity	• Politically well-connected with the key institutions • Better Human capacity at National level institutions • Regional and local level institutions do not operate 24/7 due to a lack of human capacity	• Politically well-connected with the key institutions • Local-level human capacity needs increasing • Mayor at local level take decisions on evacuation orders	• **MMS has the adequate human capacity** • NDMA more human capacity for shit work *Information on human capacity at Island staff were not clearly revealed from this study*	• DMH-well established human capacity • Local/village level decision makings capacity is not adequate	• Generally, in all four countries good human capacity at national level, local level human capacity needs improving	• **Sri Lanka-** DoM heavy workload for staff, DMC staff passiveness towards potential Tsunami • **Indonesia-** Wrong interpretation of warning due to lack of understanding in local level, Mayor's need proper training on early warning process, EOC personnel needs training on effective leadership skills to determine an evacuation order in the absence of the mayor. • **Maldives-** Trained staff have left from relevant positions, NDMA needs more staff for shift work • **Myanmar-** Lack of decision-making knowledge for local communities	• **Sri Lanka-** Staff training on potential Tsunami threat • **Indonesia-** Mayors require training and effective leadership skills • **Maldives-** Continuous training, to improve their knowledge on updated bulletin's new regional developments • **Myanmar-** Village level people's decision-making skills need to be improved as they take are supposed to local evacuation decision

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Spatial and socio-cultural aspects	• **Hazard maps** • All of the coast around Sri Lanka has been hazard mapped at the scale of 1: 50,000 by DMC	• **Hazard Maps- Done** major improvement	• **Hazard maps**- not clearly revealed from the study	• **Hazard Mapping**- need to improve hazard mapping in Myanmar	• Hazard maps are done in Sri Lanka and Indonesia. Myanmar need to improve them	• **Sri Lanka**- Predictions given by astrologers/people tend to believe these • **Indonesia** Hazard maps are available only on a macro scale, and as a result, they cannot be used for planning for evacuation at the local level • **Maldives**- Belief as God's punishment • **Myanmar**- Villagers struggle for their daily life and food, no intention to prepare for a potential hazard	• **Indonesia**- Further decentralisation and empowerment of local communities in terms of hazard mapping is required
Ongoing evaluation	• Participated IOWAVE 2018	• Participated IOWAVE since 2008	• Participated IOWAVE 2018	• *Information on this was not clearly revealed from this study*			

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