Institution: University of Huddersfield		
Unit of Assessment: UoA 13		
Title of case study: Improved capacities and standard operating procedures for tsunami early warning in Indian Ocean countries		
Period when the underpinning research was undertaken: 2014 - 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof Richard Haigh	Professor of Disaster Resilience	1st September 2014 – present
Prof Dilanthi Amaratunga	Professor of Disaster Risk Reduction	1st September 2014 – present
Dr Nuwan Dias	Research Assistant / Fellow	4th May 2016 – present
Period when the claimed impact occurred: September 2017 – December 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Recent tsunami events have demonstrated the challenges in detecting and evaluating a tsunami threat, and the importance of communicating timely and accurate warning information to communities at risk. Research carried out by the University of Huddersfield in Indonesia, Sri Lanka, Myanmar and the Maldives established critical areas of capacity and processes for effective tsunami early warning and identified recommendations for improvements to early warning processes. The research has resulted in significant changes to: policy decisions on how tsunami preparedness is managed and assessed in 28 countries in the Indian Ocean region; priorities for capacity building of national agencies responsible for tsunami early warning; and, improved national processes and practices for tsunami early warning in Indonesia and Sri Lanka that are protecting coastal communities at risk. The extensive reach of the impact extends to 28 Indian Ocean countries and is helping to protect many of the estimated 800 million people that live in coastal areas surrounding the Indian Ocean. It covers the wide range of agencies responsible for tsunami early warning at the regional, national and local levels, including the UN agency responsible for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), officially mandated national contact points, national and local government agencies responsible for disaster management, as well as meteorology services, emergency services and the media. The underpinning research and impact won the UK 2019 Newton Prize for Indonesia.

2. Underpinning research

Around the world, tsunami threat remains high. Scientists have warned that climate change will result in more tsunamis. 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). The 2018 tsunami events in Indonesia have reaffirmed the challenges in detecting and evaluating a tsunami threat, as well as in communicating timely, accurate warning information to communities at risk.

There has been considerable progress and improvement in the IOTWMS that has been developed since the devastating 2004 Indian Ocean tsunami. However, the UN coordinating agency for the IOTWMS has formally recognised that much remains to be done to ensure dissemination of effective warnings and to prepare communities to act upon them.

Previous research has focused on disparate elements of the upstream and downstream warning chain, including technical studies to develop regional detection and monitoring infrastructure, and local studies on evacuation. The underpinning research is novel in focusing on the interface arrangements between upstream detection of a tsunami threat, and the downstream response. This interface is where regional tsunami threat information is evaluated by countries at the national or local levels, and decisions are taken on evacuations and what warning information is to be issued to local communities at risk. It typically involves 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.

Although the detection infrastructure and warnings are shared between countries, standard operating procedures (SOPs) for processing and issuing warnings vary greatly at the national and subnational levels. This is due to the wide variation of technical capacities, legal

frameworks, and socio-cultural factors across the 28 states that surround the Indian Ocean. The SOPs outline the tasks to be conducted as part of the routine operation of the system, define the roles of different stakeholders at different times and facilitate decision-making.

Haigh and Amaratunga have been working with the UN agency responsible for the IOTWMS since 2010, the Intergovernmental Oceanographic Commission of UNESCO's (IOC-UNESCO) Intergovernmental Coordination Group (ICG-IOTWMS) – in short IOTWMS. Since 2014, Haigh and Amaratunga worked with a University of Huddersfield team of post-docs (including Dias) and doctoral researchers, and led a series of research projects to study the interface arrangements of tsunami early warning and ways to improve SOPs. The projects were run in conjunction with external partners, including IOTWMS, who facilitated access to related government agencies and end users for data collection and dissemination of findings. It also included academic partners in several Indian Ocean countries, who contributed to empirical data collection and analysis (University of Colombo, Sri Lanka; Institute of Technology Bandung, Indonesia; Maldives National University, Maldives; University of Yangon, Myanmar).

IOTWMS invited us to undertake research to define the interface concept and identify key areas of capacity in the interface arrangements for tsunami early warning, which Haigh and Amaratunga led as principal investigators on research grants G1 and G2. This involved using the conceptual analysis method to review the literature and develop a conceptual framework of nine core concepts in tsunami early warning [3.1]. This formed the basis for Haigh and Amaratunga to lead a detailed empirical study of the interface arrangements in the Sri Lankan tsunami early warning system, including a documentary analysis of international and national guidelines and reports from previous simulation exercises and tabletop exercises, followed by key informant interviews with representatives from eight Sri Lankan government agencies. Thematic analysis was used to provide a detailed understanding of capacities in Sri Lanka that determine the effectiveness of the interface arrangements for tsunami early warning. These findings were validated in focus group discussions with Sri Lankan government representatives and international experts in tsunami early warning systems identified through IOTWMS. This resulted in a detailed analytical framework of eleven critical areas of capacity for the interface arrangements of tsunami early warning that could be tested in other countries [3.2], including decision making, defining of actors, the level of centralisation, standardisation, technical and human capacities, spatial and socio-cultural factors, vertical and horizontal coordination, formal and information communication, and evaluation. It also resulted in a series of recommendations and follow up studies to improve the Sri Lankan interface arrangements for early warning, including a synergised SOP to better define responsibilities and improve coordination [3.5].

The analytical framework developed in Sri Lanka provided the basis for Haigh and Amaratunga to lead further detailed empirical studies of IOTWMS members states: Indonesia [G3], and Maldives and Myanmar [G2]. Haigh and Amaratunga led the research team and developed the overarching research strategy. They worked with in-country research partners who collected and analysed the empirical data, including documentary analysis and key informant interviews. The cross-case analysis was carried out by Haigh and Amaratunga using individual country reports. These findings are recorded in a series of research papers, including the interface arrangements in Indonesia [3.3], a comparative analysis of tsunami early warning governance arrangements at the interface in Indonesia and Sri Lanka [3.4], and a comparative analysis of tsunami early warning interface arrangements in Indonesia, the Maldives, Myanmar and Sri Lanka [3.6]. The analyses identify the current status of the four countries against eleven areas of capacity in the analytical framework, as well as shortcomings in the end-to-end warning chain and SOPs.

The excellence of the underpinning research has been recognised by Haigh and Amaratunga winning the Newton Prize for Indonesia in 2019, along with Harkunti Rahayu, their Indonesian counterpart, for the 'best research / innovation that promotes economic development and social welfare' (see section B4), awarded by the UK's Department for Business, Energy and Industrial Strategy (BEIS), Newton Fund and Global Challenges Research Fund (GCRF).

G1. University of Huddersfield QR / GCRF 3_AMARATUNGA, £162,118.
G2. CABARET (Capacity Building in Asia for Resilience EducaTion), €993, 340, Erasmus+ EAC/A04/2015, 573816-EPP-1-2016-1-UK-EPPKA2-CBHE-JP.
G3. Institutional Links Grant No. 261824838 with ITB, Indonesia, UK Newton Fund, £116,820.

3. References to the research

References are published in reputable journals in engineering [3.1, 3.6], disaster risk [3.2] and governance [3.4] fields, and were subjected to double-blind peer review. 3.3 is in an edited book by Springer, and was subjected to double-blind peer review. 3.5 is in an IEEE conference Proceedings that was subject to double blind peer review.

3.1 Sakalasuriya, M., Amaratunga, D., Haigh, R., and Hettige, S. (2018) A Study of The Upstream-downstream Interface in End-to-end Tsunami Early Warning and Mitigation Systems" International Journal on Advanced Science, Engineering and Information Technology. Vol. 8, No. 6. http://dx.doi.org/10.18517/ijaseit.8.6.7487

3.2 Haigh, R., Sakalasuriya, M., Amaratunga, D., Basnayake, S., Hettige, S., Premalal, S. & Jayasinghe Arachchi, A. (2020) The upstream-downstream interface of Sri Lanka's tsunami early warning system, International Journal of Disaster Resilience in the Built Environment, 11(2), PP 219-240. https://doi.org/10.1108/IJDRBE-07-2019-0051

3.3 Haigh, R., Sakalasuriya, M., Amaratunga, D., Rahayu, H., Wahdiny, I. (2021) An analysis of the Interface in Indonesian tsunami early warning and mitigation system, In: Andri N.R. Mardiah, Mizan B.F. Bisri and R Olshansky (Eds) Post-Disaster Governance in Southeast Asia: Response, Recovery, and Resilient Societies, Springer. [DELAYED OUTPUT]

3.4 Sakalasuriya, M., Haigh, R., Hettige, S., Amaratunga, D., Basnayake, Rahayu, H. (2020) The governance, institutions, community and power within the interface of tsunami early warning system: a comparison of Indonesia and Sri Lanka, Politics and Governance (ISSN: 2183–2463) 2020, Volume 8, Issue 4, Pages 432–444. https://doi.org/10.17645/pag.v8i4.3159

3.5 Dias, N., Amaratunga, D., Haigh, R., Premalal, S. and Basnayake, S. (2019) Societal Impact of the Research Study on Governance of Upstream-Downstream Interface of Tsunami Early Warning - The Case of Sri Lanka, 2019 From Innovation to Impact (FITI), Colombo, Sri Lanka, 2019, pp. 1-6. https://doi.org/10.1109/FITI49428.2019.9037636

3.6 Dias, N., Amaratunga, D. and Haigh, R. and Sakalasuriya, M. (2021) A cross case analysis of the upstream-downstream interface in the tsunami early warning systems of Indonesia, Maldives, Myanmar and Sri Lanka, In: Amaratunga, D., Haigh, R. and Dias, N. (Eds) Multi-Hazard Early Warning and Disaster Risks, Springer. [DELAYED OUTPUT]

4. Details of the impact

The research has resulted in significant changes to policy decisions on how tsunami preparedness is assessed, regional policy for capacity building, and improved national processes and practices for tsunami early warning that are protecting coastal communities at risk. The extensive reach of the impact extends to 28 Indian Ocean countries and the wide range of agencies responsible for tsunami early warning at the regional, national and local levels, including the international body responsible for the IOTWMS, national and local government agencies for disaster management, meteorology and emergency services, and the media.

Changes to regional policy decisions on how tsunami preparedness is assessed by ICG-IOTWMS as an international agency

In September 2017, Haigh and Amaratunga were formally appointed as expert members of the IOTWMS working group that is responsible for assisting, developing and strengthening the overall capacity and capability of member states in tsunami risk assessment and mitigation, community awareness and preparedness [5.1].

During a series of IOTWMS meetings held in Hyderabad, India in July 2018 [5.1] and Jakarta, Indonesia in September 2019, presentation of the detailed cross-country comparisons in Indonesia, Sri Lanka, Maldives and Myanmar [3.4, 3.6] resulted in interface arrangements being formally recognised by the IOTWMS, and assessed in the national reports of the 28 member states each year. Dr Srinivasa Kumar Tummala, Head of Secretariat, IOC UNESCO ICG/IOTWMS [5.3], summarised the contribution of this work: *"This work led to the identification of critical areas for improvement by member states, as well as comparisons across countries with different risk profiles, demographics and legal frameworks"*.

The work is now being embedded in regional guidelines that are being issued by the IOTWMS. Dr Srinivasa Kumar Tummala [5.3] confirmed: *"The research on the upstream-downstream interface arrangements is being embedded in an Intergovernmental Oceanographic Commission Technical Series guide on Governance of the upstream-downstream interface in tsunami early warning, which includes the results of the cross-country analyses and a self-assessment tool*

that can be used by countries to continuously evaluate their capacities, for distribution across 28 member states. The guide is being developed through Working Group 1 Tsunami Risk, Community Awareness and Preparedness".

Changes to regional policy on capacity development of national agencies in 28 Indian Ocean countries linked to the UNESCO ICG/IOTWMS

Haigh and Amaratunga were asked to guide implementation of a survey for capacity assessment of tsunami preparedness in the Indian Ocean region, informed by the analytical framework described in section 2 [3.2]. They developed the capacity survey tool that in November 2018 was issued, by the IOTWMS, to the officially mandated national tsunami contact points of all 28 Indian Ocean member states. Haigh and Amaratunga also led the survey analysis, which was formally published as an IOTWMS Status Report on Capacity Assessment of Tsunami Preparedness in the Indian Ocean 2019 [5.2].

Dr Srinivasa Kumar Tummala [affiliation listed previously], highlighted the significant contribution of this work [5.3]: *"The 2018 assessment identified capacity gaps and future support requirements in the broad areas of a) policies, plans and guidelines; b) risk assessment and reduction; c) detection, warning and dissemination; and d) awareness preparedness and response. The results of this survey and their research on capacity areas for tsunami preparedness is informing the ICG/IOTWMS capacity building and training programme that targets the twenty-eight member states of IOTWMS"*.

The reach of the research impact has thereby extended to informing regional policy for capacity building of the officially mandated disaster management and meteorology agencies that are responsible for tsunami early warning in Australia, Bangladesh, British Indian, Ocean Territory, Comoros, Djibouti, France, 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, and Yemen.

Improved national processes and practices for tsunami early warning in Indonesia and Sri Lanka

The research recommendations that emerged from the studies in Sri Lanka and Indonesia [3.2, 3.3, 3.5] have resulted in changes and improvements to their national processes and practices for tsunami early warning. This includes improvements to SOPs that identify and coordinate the responsibilities and actions of different agencies involved in early warning at the national level, as well as training and evaluation to support their implementation.

In her support for the research receiving the 2019 Newton Prize for Indonesia, Professor Dwikorita Karnawati, Chair of IOTWMS and Director General of the Indonesian National Agency of Meteorology, Climatology and Geophysics, confirmed that [5.4], *"The research has helped us to carry out a comprehensive assessment of tsunami preparedness in Indonesia and other countries in the Indian Ocean, allowing us to improve our standard operating procedures"*. The research is therefore helping to protect many of the 800 million people, who the UNESCO-IOC Indian Ocean Tsunami Information Centre estimate to live in coastal areas surrounding the Indian Ocean.

As a result of the Sri Lanka interface study [3.2, 3.5], a newly updated and documented cross agency and synergised SOP [5.5] for the Sri Lankan tsunami early warning system was developed and formally adopted in Sri Lanka, and tested at a periodic, region wide exercise for evaluating the readiness, and where Haigh and Amaratunga were appointed by IOTWMS as official international observers (IOWave in October 2018 and October 2020) [5.6], as well as at a tabletop simulation exercise in 2019 [5.7].

The impacts of the research and changes to SOPs are confirmed by Mr Sunil Jayaweera, Director of Preparedness Planning at the national disaster management agency in Sri Lanka [5.8]: *"Their research has helped us to identify and address limitations in our tsunami early warning system, including unclear communication protocols and inadequate organisational coordination. This has resulted in changes to the SOPs to help workers carry out complex routine operations involved in receiving regional dissemination and warning information,*

evaluating against pre-defined criteria, and disseminating and enacting the response through other agencies".

The impact of the work is further confirmed by Dr Sarath Premalal, Director General, Department of Meteorology, Sri Lanka [5.9]: *"This revised SOP has achieved improved efficiency, quality output and uniformity of performance in Sri Lanka, while reducing miscommunication and failure to comply with country regulations"*.

Mr Sunil Jayaweera [affiliation listed previously], summarised the impact of our work in Sri Lanka [5.8]: *"In doing so, their research is helping us to protect from tsunami the approximate 5.1 million or 25% of the Sri Lankan population that lives within 1 km of the coastline".*

The reach of the research has also extended to the District (local) level in Sri Lanka, in terms of improved vertical and horizontal coordination of early warning agencies. Mr K. Sugunathas, Assistant Director of the Trincomalee District Disaster Management Unit confirmed that the revised SOPs and processes, and improved training provision from the Disaster Management Center in Sri Lanka, resulting from the work have [5.10], *"increased our coordination with other agencies, including the tri-forces, local disaster management officials and the private sector."* He added: *"The IOWAVE and tabletop simulation exercises have demonstrated the benefits of the new synergised SOP. Our officers now better understand tsunami alerts and related messages, and can relay more accurate warning information to our local people in a timelier manner. This will help us to better protect our local communities in case of a future tsunami".*

5. Sources to corroborate the impact

5.1. Minutes of the IOC UNESCO, ICG/IOTWMS Secretariat meetings in Jakarta (Sept '17) (see p1-6) and Hyderabad (Jun/Jul '18) (see p12-18, 21, 23) corroborating our membership of official working groups for regional capacity survey and reporting of our research.

5.2. UNESCO/IOC. 2020.Capacity Assessment of Tsunami Preparedness in the Indian Ocean –Status Report, 2018. Paris, UNESCO, IOC Technical Series No. 143 corroborating our engagement in the task team that designed and reported on regional capacity survey.

5.3. Supporting Statement from the Head of ICG/IOTWMS Secretariat, IOC UNESCO, Australia, corroborating our contributions to the regional capacity survey and identification of critical areas for improvement by member states, and embedding of our research in an official technical guideline & informing ICG/IOTWMS policy on capacity building & training.

5.4. Newton Prize article https://www.newton-gcrf.org/impact/news/protecting-coastal-communities-from-the-impacts-of-climate-change-project-wins-newton-prize-2019-for-indonesia/ & booklet that describes our winning of the Newton Prize for Indonesia 2019 and a supporting statement by the Chair of IOC UNESCO ICG/IOTWMS and Director General of Indonesian Meteorology agency (BMKG), corroborating our comprehensive assessment of tsunami preparedness in Indonesia and other Indian Ocean countries, and impact on Indonesian SOPs for tsunami early warning.

5.5. Updated SOP for Tsunami Early Warning in Sri Lanka (Mar '20) that reflects the impact of our work on national processes and practices for early warning.

5.6. IOC Technical Series 138 IOWAVE Indian Ocean Exercise Report 2018 (see p41-42, Annex XXX), Sri Lanka IOWAVE '18 Exercise Report and Sri Lanka IOWAVE '20 Exercise Report corroborating the testing and improved performance of revised SOPs in Sri Lanka resulting from our work.

5.7. 2019 Tabletop Exercise Evaluation Report - SOPs for the Tsunami Early Warning and Mitigation System in Sri Lanka (11th July 2019) corroborating the testing and improved performance of revised SOPs in Sri Lanka developed as a result of our work.

5.8. Supporting Statement from Director Preparedness Planning at the Disaster Management Centre, Ministry of Defence, Sri Lanka corroborating our impact on updating Sri Lankan SOPs for tsunami early warning and its effect in protecting coastal communities.

5.9. Supporting Statement from Director General, Department of Meteorology Sri Lanka, corroborating our impact on improved performance of SOPs for tsunami early warning.

5.10. Supporting Statement from the Assistant Director of the Trincomalee District Disaster Management Coordinating Unit, Sri Lanka corroborating our impact on local SOPs for tsunami early warning, and improved coordination of local agencies in Sri Lanka.