ENHANCING DISASTER RESILIENCE OF PACIFIC ISLANDS THROUGH INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

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I dedicate this work to my parents, Marston Mataava “Mak” Porter and Wilma “Ma” Banse Porter.

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ABSTRACT

Recent disaster management (DM) practices have demonstrated that the impacts of disasters can be minimized by purposeful planning, integrating and utilizing Information Communication Technologies (ICT) at all phases of the DM cycle (ITU, 2003; UNISDR, 2015). The use of ICT can help to collect accurate data, produce information to support operations and make better decisions for an overall effective disaster management system (DMS). It has long been recognized by Pacific Island Countries and Territories (PICT) that ICT is a tool for regional development to support economic growth, education, health and disaster management, but they also recognize the need for ICT to have a complete life cycle designed for sustainability within the Pacific Region (ASTBS, 2021). Regional and territorial investments in ICT for disaster management (ICT4DM) have had varying results in sustainable implementation, integration and effectiveness (UNESCAP, 2020). This research explored successes and challenges in integrating ICT for disaster management (ICT4DM) in PICT focusing on: (1) institutional, (2) cultural (3) technical, and (4) political capacity gaps based on two case studies, the 2009 Tsunami in American Samoa (2009 TAS) and the 2022 Hunga Tonga-Hunga Ha'apai Eruption and Tsunami (2022 HTHH).

This research study is organized in three parts: Part 1: Where we've been – Case Studies – 2009 TAS and 2022 HTHH; Part 2: Where we are: US Deployed ICT4DM in the Pacific via the Pacific through Radio and Internet for the dissemination of hydro-meteorological and hydrological information (RANET Network) and; Part 3: Where we're heading: Capacity Gaps, Elements of Resilience and Lessons Learned. The objectives of this research are: (1) To inventory US deployed ICT4DM in the Pacific through the RANET Network 2006-2022; (2) To identify cultural, institutional, political and technical factors influence the use and implementation of ICT in disaster management; and (3) To establish what challenges and opportunities for the planning and ICT4DM.

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GLOSSARY OF ACRONYMS

AM	Amplitude Modulation
ASC	American Signal Corporation
ASDHS	American Samoa Department of Homeland Security
ASTBS	American Samoa Territorial Broadband Working Group
ASTCA	American Samoa Telecommunications Authority
ATS	Applications Technology Satellite
AusAID	Australia Agency for International Development
AWIPS	Advanced Weather Interactive Processing System
BGAN	Broadband Global Area Network
BLAST	Broadband Linking American Samoa Territory
BoM	Australia Bureau of Meteorology
CAP	Common Alert Protocols
CEDS	American Samoa Comprehensive Economic Development Strategy
COVID-19	Coronavirus disease
CRS	Console Replacement System
CS	Cable Ship
DELTA	Distance Education, Learning and Telehealth Applications
DM	Disaster Management
DMO	Disaster Management Organizations
DMS	Disaster Management System
DRR	Disaster Risk Reduction
DSS	Decision Support System
EMS	Emergency Medical Service

EMWIN	Emergency Managers Weather Information Network
EOC	Emergency Operations Center
ESF	Emergency Support Functions
FFA	Forum Fisheries Agency
FM	Frequency Modulation
FTTP	Fiber-to-the-Premise
GEONETCast	Global Network of Satellite-based data dissemination systems
GIS	Geographical Information System
GOES	Geostationary Operational Environmental Satellite Program
GPS	Global Positioning System
HF	High Frequency
HRIT	High-Rate Information Transmission
HTHH	Hunga Tonga-Hunga Ha'apai Eruption and Tsunami
IAO	International Activities Office
ICT	Information and Communication Technology
ICT4D	Information and Communication Technology for Development
ICT4DM	Information and Communication Technologies for Disaster Management
IOC	Intergovernmental Oceanographic Commission
ITU	International Telecommunications Union
JCSAT	Japan Satellite Systems Inc.
LTE	Long-Term Evolution
MEIDECC	Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications
MHEWS	Multi-Hazard Early Warning System

NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NEMC	National Emergency Management Committee
NEMO	National Emergency Management Office
NEOC	National Emergency Operation Committee
NGO	Non-Governmental Organization
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
NRC	National Recovery Committee
NWS	National Weather Service
NZAID	New Zealand Agency for International Development
O3b	satellite constellation in Medium Earth orbit
OFDA	Office of US Foreign Disaster Assistance
PEACESAT	Pan Pacific Education and Communication Experiments by Satellite
PICTs	Pacific Island Countries and Territories
PITD	Pacific International Training Desk
PREP	Pacific Resilience Program
PRH	Pacific Region Headquarters
PTWC	Pacific Tsunami Warning Center
RA	Regional Association
RANET	Pacific Radio and Internet Technologies for the dissemination of hydro-meteorological and Climate-related information
RAPIDCast	Remote Asia Pacific Information Dissemination Broadcast
RICS	Rural Interconnectivity Systems

RQ1	Research Question #1
RQ2	Research Question #2
RUS	Rural Utility Services
SBD	Short Burst Data
SES	Société Européenne des Satellites
SIDS	small island developing States
SITAR	Synoptic, Incremental, Transactive, Advocacy and Radical planning
SMS	Short Messaging System
SOS	Save Our Ship
SPREP	Secretariat of the Pacific Regional Environment Programme
SSDM	Sustainable Smart Development Model
TAS	Tsunami in American Samoa
TASI	Telecommunication and Social Informatics Research Program
TCC	Tonga Communications Corporation
TCS	Tonga Cable System
TEMCO	Territorial Emergency Management Coordination Office
TGS	Tonga Geological Service
TIPG	Telecommunication Information Policy Group
TMS	Tonga Meteorological Service
TNDMO	Tonga National Disaster Management Operations
TOP	Territorial Operational Plan
TSDF II	Tonga Strategic Development Framework 2015-2025
UCAR	University Center for Atmospheric Research

UCEDD	University Center of Excellence for Development Disability
UH	University of Hawaii
UHF	Ultra-High Frequency
UK	United Kingdom
UMS	Tonga Unified Messaging Systems
UN	United Nations
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VHF	Very High Frequency
VOIP	Voice Over Internet Protocols
VSAT	Very Small Aperture Terminal
WFO	Weather Forecast Office
WMO	World Meteorological Organization

CHAPTER 1 - INTRODUCTION

This chapter covers:

- *Introduction to the research problem*
- *Scope of research*
- *Significance of the study*
- *Organization of chapters*

Recent disaster management (DM) practices have demonstrated that the impacts of disasters can be minimized by purposeful planning, integrating and utilizing Information Communication Technologies (ICT) at all phases of the DM cycle (ITU, 2003; UNISDR, 2015). The use of ICT can help to collect accurate data, produce information to support operations and make better decisions for an overall effective disaster management system (DMS). ICT is considered necessary to enhance adaptation capacity, support feedback, ensure information access, enable active participation, reduce vulnerability and build the overall resilience capacity of communities (Aydin et. al, 2015). Much research has focused on building individual and community resilience and how agencies coordinate during disasters, while less research has explored planning for disasters and the integration of ICT within in that process in Pacific Island Countries and Territories (PICT).

The research and practicing communities have continuously explored the links among ICT, disaster risk reduction (DRR), disaster or emergency management, climate change, and local and global developments, to identify ICT-grounded strategies for effective disaster mitigation, preparedness, response and recovery (Firdhous, M. F. M., & Karuratane, P. M. 2018; Mohan & Mittal, 2020; UNISDR, 2015;). ICT for DM (ICT4DM) is encompassing of the technical means to observe, provide knowledge, collect, process and analyze data, and communicate information to various stakeholders, decision makers, and the general public so that appropriate actions and decisions are made to lessen the negative impacts of disasters (Hameed, 2007; Sá & Virtudes, 2017). Various types of ICT used in DM include communication-based systems (e.g., radio, media, satellite radio, mobile phones, HF radios, internet, social media, etc.), information-based systems (remote sensing technologies, geographic information system, geo-positioning systems); decision support systems (DSS), and resource management systems (e.g., assets inventory management system). This dissertation defines ICT4DM as satellite commnication based systems used for hydro-meteorological, geological and disaster management operations (DMOs). This qualitative study further limits the review of ICT4DM to systems and technologies deployed to PICT by the United States (US) through the Radio and Internet for the dissemination of hydro-meteorological and hydrological information (RANET Network).

Building resilient PICT means a consideration for local context and understanding of culture and traditional knowledge in the development, design and implementation plans. The concept of resilience in context of Pacific Islands cultures, centers around the idea of self-reliance in the face of hardship without being overly dependent on outsiders. Although each Pacific culture is unique, in general the notion of self-reliance is not based on the individual, but rather on the notion of kinship ties, the "*aiga*" or family (Alefaio, 2020). ICT is a tool that can enhance those ties and connections within the context of disaster management. This research pulls from ICT4DM experiences in the 2009 Tsunami in American Samoa (2009 TAS) and the 2022 Hunga Tonga-Hunga Ha'apai Eruption and Tsunami (2022 HTHH) highlighting cultural, technical, political and institutional capacity gaps and lessons learned for planning.

1.1 Statement of Problem: The Search for Resilience through ICT

Disasters and hazards can occur at any time. The Pacific Region is prone to many disasters and experience a wide range of vulnerabilities to hazards such as tropical cyclones, earthquakes, tsunamis, floods, landslides, droughts, and volcanic eruptions. Frequent disasters have devasted the region causing over $1.07B USD in economic losses between 2011-2020 and affecting over 5 million people (Australian Aid, 2021). The PICT are a variety of political status, independent nations, commonwealths and trust territories. Their geographical isolation, small population size, remoteness, limited resources, and economic vulnerabilities contribute to the ongoing dependency on humanitarian, external and federal assistance, aid and ICT to mitigate, plan and respond to disasters (Fletcher et. al, 2013). It has long been recognized by Pacific Islands that ICT is a tool for regional development to support economic growth, education, health and disaster management, but they also recognize the need for ICT to have a complete life cycle designed for sustainability within the region (ASTBS, 2021). Investments in ICT4DM have had varying results in sustainable implementation, integration and effectiveness (UNESCAP, 2020).

In 2012, the Sustainable Smart Development Model (SSDM) was launched by the International Telecommunications Union (ITU) to support development (ICT4D) and disaster management (ICT4DM) through ICT. The SSDM framework encourages the dual use of ICT to address challenges in development and disaster management through strategic implementation of ICT resources, network and services to support communities and organizations, and facilitate collective action, decision making and timely response (ITU, 2018; ITU, 2022). The key areas of the SSDM are: Policy, Regulation and Advocacy; Infrastructure and Technologies; Financing, Partnerships and Business Models; Resources Mobilization and Innovation. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has since build upon that framework and the need to scale up broadband internet capacity for the effective use of technological innovation and harness technology to address disasters and major challenges. Despite these advancements and adoption of models, there are still many challenges and gaps ranging from policies and governance; undefined roles and responsibilities; lack of capacity of local disaster management offices to properly operate and maintain equipment; lack of interoperable systems; lack of comprehension of impact; misinformation; incompatible and non-unified standards; cognition and collaboration; and adaptation based on community needs (Bharosa, Lee & Janssen, 2010; Aydin et. al, 2015). The gaps are many and this research explored some of the gaps of the integration of ICT in DMS in PICT.

This dissertation explored elements of resilience through ICT and its role in building and supporting critical infrastructure, enabling stronger disaster governance, facilitating effective public service delivery and disaster coordination through the SSDM value chain logic model. The SSDM value chain logic model is a road map to ensure that the integration of ICT in development and disaster management would yield favorable outcomes such as resilience, coping and recovery. Furthermore, the review of the identified case studies, the 2009 TAS and the 2022 HTHH, portrayed how the disruption in ICT compounded the impacts and increased challenges locally regionally with regards to response and recovery.

Specifically, this research is an exploratory investigation of ICT4DM in DMOs in the Pacific with a specific focus on satellite communications and impacts on disaster resilience at an operational and institutional levels. This dissertation acknowledges the fact that there is a great diversity of ICT4DM utilized by the DMOs community at large, however the emphasis here is on the perspectives of IT staff / personnel on systems appropriate and historically effective in PICT settings. Furthermore, the ICT4DM covered here are those that support basic data and product access for meteorological services, as well as systems designed for dissemination of information from, or communication between, meteorological services, emergency management entities, and remote communities.

Preliminary findings show that the gaps in the relationship between ICT and disaster management are part of wider systemic challenges in PICT compounded by high costs; lack of good utility and public services; lack of economies of scale; lack of technical expertise; outdated regulatory environment; limited opportunities for improvements and of interest to this study, the lack of access to ICT4DM (Fletcher et. al, 2013). In this study, I demonstrate that improving one of these factors alone will not be effective in the managing of disasters, but rather an integrated approach of two or more will contribute to enhancing community resilience in the Pacific Region. While much research focuses on how individuals respond and recover following disasters, fewer have looked at elements of resilience through ICT. This study sought to identify patterns of political, cultural, institutional and technical drivers within the complexity of DMOs.

1.2 A Regional Approach for ICT4DM

While PICT experiences similar economic difficulties and development constraints to those of developing countries generally, PICT and other small island developing States (SIDS) have their own peculiar vulnerabilities and characteristics. Wider systemic economic challenges, their geographical remoteness and isolation, limited resource pool, and exposure to global environmental and economic challenges, including a wide range of impacts from climate change and more frequent and intense disasters tend of overwhelms local capacities beyond available resources (United Nations, 2022; Pacific Community, 2016). These circumstances impose significant costs on service provision in education, economic development, social welfare, health, disaster management, travel and communication and have limited the growth of important industries that support development and growth within island communities. Improvements in ICT technology and services can provide increasing opportunities for PICT to overcome these circumstances by reducing costs; barriers of distance; improving service delivery across islands and communities; improving local workforce knowledge and skills; sharing data; maximizing the economic growth island-wide and regionally; and working more effectively together.

The Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management 2017-2030 is a voluntary non-political regional framework that supports coordination and action on a number of key issues including the adoption and implementation of ICT initiatives for climate and disaster resilient developments. The adoption of ICT at all levels contributes substantially to the achievement of Sustainbale Development Goals (SDGs) or Global Goals for PICT. Seventeen (17) SDGs were adopted by the United Nations in 2015, as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. PICT and other SIDS have prioritized on several SDGs including climate actions and sustainable development through ICT to achieve their sustainable development. ICT is included under goal 9 (Build resilient infrastructure, promote sustainable industrialization and foster innovation) of the sustainable development goals. One of the targets under this goal is to significantly increase access to information and communication technology and strive to provide universal and affordable access to internet in least developed countries by 2020 (Pacific Community, 2016).

In a region inundated with disasters, the management of these events has emerged as a highlight for cooperation and engagement with regional and international partners. The need to prepare for future disasters underscore the importance of building upon a foundation of cooperation and engagement, with a focus on disaster resilience, mitigation and the localization of planning, response and recovery actions. Coordination of activities in relation to disaster management has been supported through many initaitives including ICT4DM projects and implementations. Through the Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management 2017-2030, PICT are able to work together with each other and with regional organizations to share information, warnings and operational guidance in relation to disaster management. A coordinated approach to share knowledge, data and resources is critical to enhancing our ability as a region to manage disasters and learn from disasters.

1.3 Scope of Research

The enhancement of disaster management and ultimately community resilience from ICT involves complex interactions between the technology, people and local context. The purpose of this qualitative study is to explore elements of resilience, capacity gaps and identify potential opportunities for ICT to support infrastructures, enable stronger disaster governance, effective decision support, public service delivery and disaster coordination within DMOs in the Pacific Islands. This study takes particular interest in aspects of culture and place, institutional and governance, and technical functionality that influence the use and implementation of ICT for disaster management and ultimately enhance the resilience capacity of American Samoa and Tonga. Specific examples will be reviewed including the 2009 Earthquake and Tsunami in American Samoa (2009 TAS) and the 2022 Hunga Tonga-Hunga Ha'apai Eruption and Tsunami (2022 HTHH).

The outcomes of this study are meant to benefit disaster planners and researchers to better understand the role of ICT4DM and how these tools can connect to local context, formulate better policies and make informed decisions. The community at large will also benefit from enhanced capacity for disaster resilience through access to accurate and better information and data. Finally, the outcomes of the research would benefit all stakeholders interested in understanding the role of ICT in the management of disasters.

1.4 Research Questions

This research addressed the following key research questions:

1. What cultural, institutional, political and technical factors influence the use and implementation of ICT in disaster management in PICT?

This question identifies elements specific to institutional capacity including governance, standards, procedures, technical factors that make the use and implementation of ICT in disaster operations challenging or not challenging.

2. How does disaster management related-ICT affect disaster resilience in Pacific Island communities?

This question addresses insights and possible variations in capacity among PICT. It addresses planning implications of ICT4DM given the uncertainties in planning and capacity gaps. Understanding similarities and differences, and where there are gaps, past and present strategies to cope, provides a pathway toward identifying points of intervention, which can eventually inform, improve and enhance resilience.

The objectives of this research are:

1. To inventory US deployed ICT4DM in the Pacific through Radio and Internet for the dissemination of hydro-meteorological and hydrological information (RANET) 2006-2022.
2. To identify cultural, institutional, political and technical factors influence the use and implementation of ICT in disaster management.
3. To establish what challenges and opportunities are there for the implementation and integration of ICT4DM

1.5 Significance of Study

Planning is "intervention", meaning to intentionally alter the existing course of events through alternatives, implementation and evaluation (Campbell & Fainstein, 1996). Over the years, planning theorists have reframed discussions and set a new direction in planning theory to incorporate concepts of inclusiveness, collaboration and the integration of local context (Fainstein, 2000; Mercer, 2007 and 2010; Burby, 1999). This new discourse aims to find a balance between indigenous and western knowledge that would help reduce vulnerabilities to environmental hazards in SIDS (Mercer, 2007). This research contributes to discussions on ICT, disaster management, and building resilience in the context of small island communities. To an extent, this study also contributes to discussions on place-based planning in the context of exploring elements and factors that contribute to the successful integration of western and traditional approaches to resource management and action strategies in disaster management

(Alexander, 2013; Galliano and Loeffler, 1999). This research also contributes to the wider conversation of rational-technical decision-making and process-based solutions involving multiple stakeholders.

1.6 Organization of Chapters

The chapters of this dissertation is organized in the following manner:

Chapter 2 provides a review of literature relevant to the dissertation topics. It includes disaster governance, sustainable smart development, knowledge to action, planning with uncertainty and information and communication technology (ICT) management. It links theoretical concepts to the selected case studies, and includes a proposed logic model as an alternative approach to enhancing resilience through ICT4DM.

Chapter 3 describes the methodological approaches applied to this study to answer the key research questions. Methods include secondary literature review, semi-structure interviews, logic model and case studies.

Th research is organized in three parts:

Part 1: Where we've been – Case Studies – 2009 TAS and 2022 HTHH;

Chapter 4 discusses the two case studies selected and lessons learned with regards to ICT4DM. The two case studies are the 2009 Tsunami in American Samoa and the 2022 Hunga Tonga Hunga Haapai Eruption and Tsunami.

Part 2: Where we are - US Deployed ICT4DM in the Pacific via the RANET Network and Findings – Capacity Gaps and Elements of Resilience

Chapter 5 presents an inventory of US deployed ICT4DM in the Pacific Region. While there are many ICT4DM available in the region, this study focused particularly on systems deployed through the RANET program from 2006 - 2022.

Chapter 6 contains the summary of the semi-structure interviews identifying what cultural, technical, political and institutional capacity gaps exists with the deploymenet of ICT4DM.

Part 3: Where we're heading: Planning Recommendations and Future Outlook

Chapter 7 contains recommendations and key takeaways for planning and ICT4DM.

CHAPTER 2.0 - LITERATURE REVIEW - ICT AND DISASTER MANAGEMENT

This chapter covers and overview of literature relating to:

- *Concepts of Sustainable Smart Design Model (SSDM) Value Chain, Knowledge to Action, ICT Management, Planning with Uncertainty and Good Governance*
- *A proposed ICT4DM Value Chain*

Disasters are disruptions to the functioning of a community as a whole causing widespread losses that exceed its capacity to cope using locally available resources. Disasters can overwhelm the capacity of a community requiring a reevaluation, enhancement or intervention to process, roles and responsibilities, implementation and actions; and an understanding of the role of local overarching political, technical, cultural and institutional capabilities. A disaster is the result of a combination of hazard, conditions of vulnerability and insufficient capacity to reduce the negative consequences of a risk (Ahren & Rudolph 2006; Birkmann 2007; Tierney 2012; Wisner, B. et. al, 2004). Quarantelli (1981) proposes principles of disaster planning as a continuous process to reduce unknowns, evoke action, understanding risk based on knowledge, conducting outreach and education activities and drills, not control. This dissertation adopts the definition of disaster management (DM) as described by Dilley et. al (2005) in Natural disaster hotspots: A global risk analysis, as the systematic 'unending' process using administrative, decisions, organization, operational, technical, cultural skills and capacities to implement policies, strategies and coping capacities of a community to lessen impacts of hazards and related environmental and technological disasters.

ICT can be defined as the discipline concerned with technology and other aspects of collecting, managing, processing and distributing and communicating information (Hameed, 2007). Figure 1 summarizes the applicability of ICT in the various stages of DM. ICT is an integral part of the disaster management cycle and can also be used to support the following activities:

- Mitigation – ICT can be used for spatial and geographic information in mitigation planning and assist to identify appropriateness of land-use, resources, and development plans; improve forecast modeling.

- Preparedness – ICT may be applied to improve strategies, evacuation planning and exercises, and outreach, learning and awareness of disasters.
- Response - ICT is a foundation of multi-hazard early warning system; coordinate response, alert target groups, provide impacts, and communication in affected areas
- Recovery – ICT is needed for damage assessment, evaluation and monitoring.

The growth of studies and research in ICT4DM have slowly increased over the last decade (Sood & Rawat, 2021). Aman, Irani & Liang (2012) examined the use of ICT in disaster management, and identified the following categories where ICT technologies are used:

- Communication - Technologies for communication among first-responders, victims and the public, and information creation, dissemination and validation.;
- Event Detection and Assessment - Technologies used for disaster prevention, early response and damage mitigation.;
- Warning - Technologies used to alert the public of potential dangers.; GIS Supported Collaboration - Map-based technologies to help in collaboration.;
- Decision Support - Technologies to aid in decision making.; Training - Tools used in training of first responders for emergency response activities.;
- Navigation - Technologies that assist in navigating to/from affected areas.; and
- Evacuation - Technologies used to assist in evacuating affected areas or areas.

To address the research questions of this study, this chapter will review the relevant literature in reference to characteristics of disaster governance, sustainable smart development, knowledge to action, planning with uncertainty and information and communication technology management. This study will discuss the links each of these theoretical concepts in the application to selected case studies, and the proposed logic model as an alternative approach to enhancing resilience through ICT4DM.

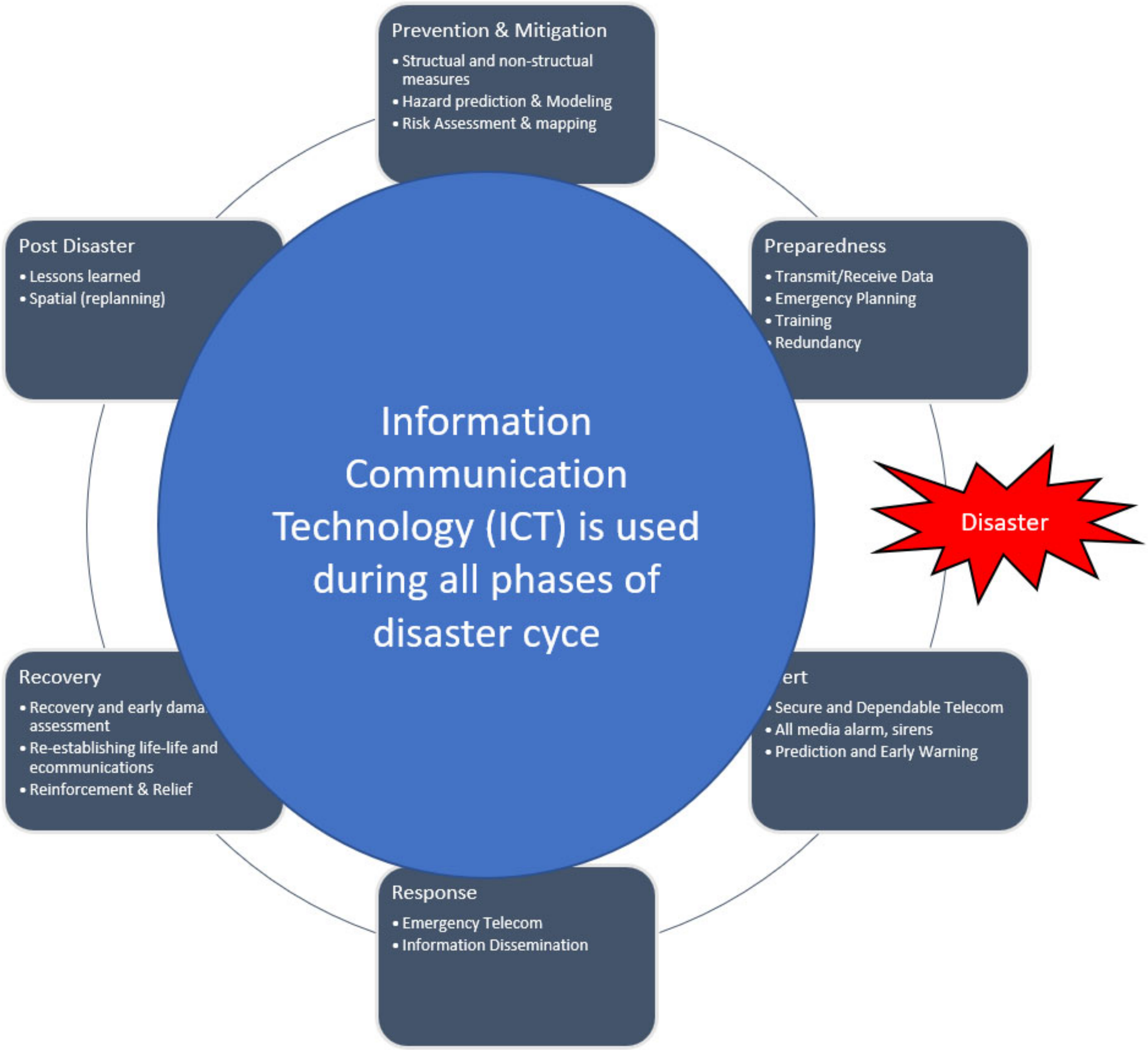

Figure 1 Application of ICT in DM Cycle (Author's adaptation)

2.1 Sustainable Smart Design Model (SSDM) Value Chain

In 2012, the International Telecommunications Union (ITU) launched the Sustainable Smart Development Model (SSDM) to support development and management of disasters through the use and integration of ICT. The SSDM encourages the multi-use of ICT to address challenges in development and disaster management through strategic implementation of ICT resources, networks and services to support communities, facilitate collective actions, decision making and timely response (ITU, 2018). There are four key areas of SSDM: (1) Policy, Regulation and Advocacy; (2) Infrastructure and Technologies; (3) Financing, Partnerships and Business Models; and (4) Resources Mobilization and Innovation. The goal of the SSDM is to explore innovative and collaborative ways to harness ICT for the benefit of all. It also aims to show the soci-economic and financial benefits of investing in ICT through successful implements for development and disaster management (ITU, 2012). The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has since build upon the SSDM framework and the need to scale up both structural and non-structural approaches for the effective use of technological innovation and harness technology to address disaster and major challenges. Non-structural mechanisms are policies, capacity developments, outreach and training, knowledge and traditions can all lessen the vulnerability of communities to disasters. Structural solutions are solutions relating to physical infrastructure such as the ICT units and transport system.

The SSDM model requires an integrated approached involving three key elements: people (whether individuals or entities); policy (whether national, regional or international) and technology. This process can only be performed with an active and committed participation and cooperation from a wide cross section of stakeholders. The SSDM ICT4D Value Chain (Figure 2) describes the relationship among resources, activities and the desired outcomes of the ICT interventions (Kivunike, F., Ekenberg, L., Danielson, M. & Tusubira, F, 2014). The ICT4D value chain offers four main domains:

- ***Availability***: implementation of an ICT4D initiative turns the inputs into a set of tangible ICT deliverables; typical among which might be a telecentre or mobile phones. Again, assessment can focus on either the delivered resources and/or the delivery process.
- ***Uptake***: the processes by which access to the technology is turned into actual usage; also noting that key concerns around this process and its ability to contribute to development have related to the sustainability of this use over time, and – for various innovations that are prototyped – the potential or actuality of scaling-up. In practice, usage indicators are more often assessed than the various uptake processes.

- ***Impact***: which can be divided into three sub-elements:
    - *Outputs*: the micro-level behavioral changes associated with technology use.
    - *Outcomes*: the wider costs and benefits associated with ICT.
    - *Development Impacts*: the contribution of the ICT to broader development goals.

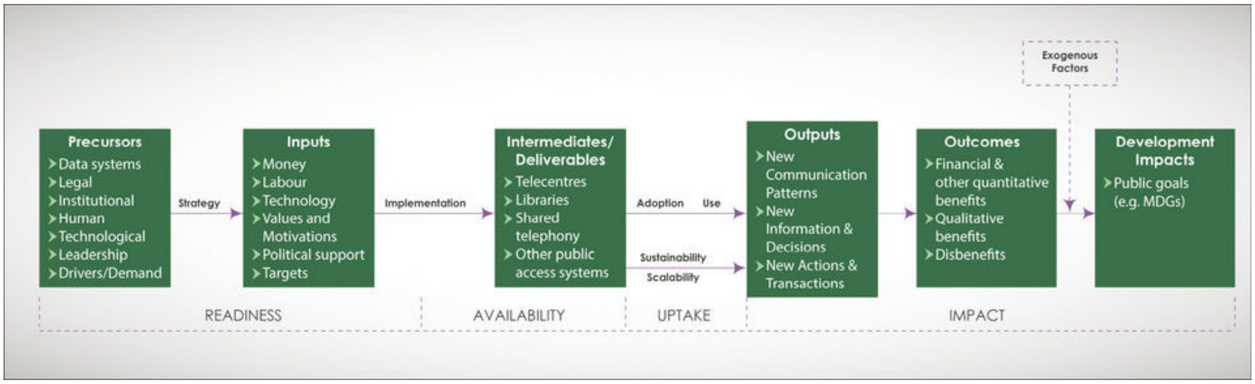

*Figure 2. ICT4D Value Chain (*Kivunike, F., Ekenberg, L., Danielson, M. & Tusubira, F, 2014*)*

2.2 Knowledge to Action

Planning theory should lead to more effective practice and therefore should include both a philosophical approach and a practical application (Friedman & Hudson, 1971). Planning links knowledge to actions (Friedmann & Hudson,1974; Friedmann, 1987; Hudson, 1979). In Hudson's *Comparison of Current Planning Theories* (1979), he presented a simple scheme that organized planning theories into five groups, Synoptic, Incremental, Transactive, Advocacy and Radical planning (SITAR). Synoptic planning is a continuous cycle of planning to understand an issue, assess planning measures, implement and evaluate alternatives. Incremental planning breaks up planning processes into smaller, manageable phases versus larger efforts needed for comprehensive planning. The goal of transactive planning is shared learning from people's experiences. The fundamental values of advocacy planning in the planning process are those of social justice and equity (Davidoff, 1965). Davidoff (1965) argued that planning is about people and the outcomes of planning has different benefits and costs to each of the groups involved in the planning decisions. Radical planning seeks to manage development in an equitable and community-based manner. Hudson (1979) acknowledges the gaps in SITAR and proposes a mixed approach in order to ensure that planners respond to the diversity of problems and settings so that appropriate actions are taken given the best information and resources available. In comparison, Friedmann (1987) identified social reform, policy analysis, social learning and social mobilization as categories to classifying planning theory. Friedman's planning tradition of social reform occurs naturally as a result of the lack of existing structures, for example after a disaster. Planning that emerges by necessity is only a temporary fix, as time progresses, knowledge increases and becomes available, prior planning pays off. With added knowledge, values are re-considered and priorities change.

When it comes to disaster, its impacts can be minimized by purposeful planning to identify appropriate interventions such as the integration of ICT4DM. The use of ICT can help to collect accurate data, produce information to support operations and make better decisions for an overall effective DMS.

2.3 ICT Management

ICT has made incredible leaps in utility, applications and capacity. Disaster governance, sustainable smart development, knowledge to action, planning with uncertainty need effective information management and communication systems to build a common understanding of information and knowledge and make informed decisions. Effective use of ICT helped government agencies to cope with, and respond to the multiple disasters and ongoing recovery demands. Graber (2003) suggests that for effective management to occur, there must be structure and emphasized that technology, information, and professional and organizational relationships played critically important roles in that structure. Bardach (1998) emphasized that the successful management of ICT requires good communications processes among people to be embedded in interpersonal relationships and also in multiple connection mechanisms. Primary communication systems as well as backup systems are required to keep all agencies and communities connected and updated in order to support one another in unexpected events. The content of the information needs to be aggregated into a common knowledgebase for all parties involved in order to support accurate and timely decisions, especially during a state of emergency.

The revolutionary potential of ICT lies in their ability to instantaneously connect vast networks of individuals and organizations across great geographic distances, and facilitate fast flows of information, capital, ideas, people and products. The constraints of being in a fixed location and time for interaction has been reduced with the availability of internet and mobile devices. ICT enhances our ability to interact but does not by itself create social capital or cooperation (Fountain, 2001).

2.4 Planning with Uncertainty

Inappropriate processes and technologies lead to ineffective or harmful results (Christensen,1985). A critical planning task is recognizing and addressing uncertainty. Actual problems vary in uncertainty over means (technology) and ends (goals). If people agree on what they want and how to achieve it, then certainty prevails and planning is rational application of knowledge. If they agree on what they want but do not know how to achieve it, then planning becomes a learning process. If people do not agree on what they want but know how to achieve alternatives, then planning becomes a bargaining process. If people agree on neither means nor ends, then planning becomes part of the search for order in chaos (Christensen, 1985). The limitations of decision making for organizations operating under uncertainty have spurred researchers to explore means of reformulating the concept of problem-solving capacity (Comfort, 1997).

2.5 Good Governance and ICT

Governance is generally defined as the ability of a governing authority to make and enforce rules to deliver public services (Fukuyama 2013). The governance structure of a community includes both formal and information constraints such as local customs and traditions, sanctions, codes of conduct as well as formal rules such as laws, constitutions, rights and policies (Ahren & Rudolph, 2006). Governance also involves decisions, negotiations, and different power relations between authorities. An integrated approach between key actors and authorities in public and private sectors; civil society both organized and organic; non-profit organizations; communities at a regional, national, local and village levels interacting to manage and reduce disaster related risks constitutes a community's governance structure for disaster management (Britton, 2012; Tierney, 2012; Nakagawa, 2004; Djalane, R. et. al, 2011). Disaster governance is necessary to ensure societies cope and recover from disasters through the exercise of political, economic and administrative authority as well as the inclusiveness of relevant stakeholders in the process (Nakagawa, 2004).

When studying governance, it is important to understand some of its fundamental operating principles such as accountability, transparency, participation, effectiveness, equity, security and representation (Wilde et. al, 2009). Various combinations of these normative, value-oriented, prescriptive principles help guide community governance. Arguably, when these principles are better realized in a disaster governance structure, the more prepared a community become to respond, recover, mitigate and adapt to hazards. Governing principles of accountability, participation, transparency and effectiveness are briefly discussed below.

2.5.1 Accountability

The concept of accountability can be applied to all whom are involved in the process of decision and policy making, including local and federal governments, village elders, community leaders, civil societies and private sector (Ahren & Rudolph, 2006; Baker, 2015). It involves an understanding and agreement on clear roles and responsibilities of key actors and stakeholders and a reporting, feedback or evaluative mechanism on projects, activities and actions conducted. Ahren & Rudolph (2006) further discusses accountability in relation to disaster management not only as an operating principle and a characteristic of the ultimate outcome of an action, but also the degree of responsiveness of governments and donors to the local context and the needs of the community, including ensuring that communities have control over the rebuilding process after a disaster.

Accountability involves improving processes, challenging power relations and claiming ownership (Wilde et. al, 2009). Accountability works in two different ways, downward and upward. Downward accountability is being accountable to the people, and upward accountability is being accountable to donors, funders or government. In disaster governance, downward approach is most critical, particularly to local communities affected by disasters. Quarantelli (1987) argues that successful disaster management requires activities across a range of phases, namely planning, response and recovery, with each requiring different involvement, participation, ownership and reporting mechanisms to and from multiple actors include government agencies, organized civil society, donors and communities. This allows for open communications to ensures that response, recovery, mitigation and adaptation efforts are considerate of all processes, rules, regulations and interventions as appropriate.

2.5.2 Participation

Disaster governance is nested within and influenced by various overarching societal governing systems. Participation of individuals, groups and organizations in the disaster governing process enables them to identify and share their needs, vulnerabilities and priorities and encourages awareness of available local resources, services, information and policies (Krumay, 2015; Wilde et. al. 2009). Participation of local communities and stakeholders in the design and implementation of policies can mobilize their commitment, ownership and cooperation to a greater extent than to a top-down approach, the imposition of directives (Pal & Shaw 2017; Zurita et. al, 2015). This makes plans, actionable and responsive to the needs of the community. In addition, local expertise and traditional knowledge can be obtained and incorporated and used to facilitate suitable disaster planning, response and recovery. By taking an integrated multi-sectoral approach to disaster governance, participatory work is well placed to deal with the complexity of disasters and the diverse of factors affecting people's vulnerability (McEntire, 2001, 2003). For participation to be efficient, it is necessary to thoroughly design a politico- administrative structure that is appropriate to guide an effective implementation strategy. Participation includes the concept of subsidiarity (Jones et. al, 2014).

2.5.3 Transparency

There are several pieces to being transparent. Transparency refers to when the process of decision making and potential outcomes and impacts are made know to those who will be affected by the governance policies and practice; that the information for decision making is accessible, available and understandable; and that any decisions taken and their enforcement are in compliance with established rules and regulations. Transparency is required in order to hold communities accountable for their actions as well as decision makers for their policies. Better information can also act as an incentive for people to participate in collective action and at the same time facilitates the spread of innovation and technical change (Crook & Manor, 1994; MaCalister-Smith 1985). Transparency plays a fundamental role in the prevention of corruption that may otherwise divert resources, information, aid and other materials during disasters. The sharing of data and creating open networks and systems promotes transparency and ensure that wide range of actors participate and contribute to building the resilience of communities.

2.5.4 Effectiveness

Good governance means that the processes implemented to produce favorable results meet the needs of local communities and stakeholders, while making the best use of resources – human, technological, financial, natural and environmental – at its disposal. Effectiveness in disaster governance can be measured in timeliness and responsiveness of key disasters; un-wasteful use of resources as well as the resilience of a community.

2.6 A Proposed ICT4DM Value Chain

The concepts described in section 2.5 of this study are critical to enhancing the resilience of island communities through the successful integration of ICT4DM in DMO. As discussed in sections 2.1, the ICT4D value chain offers four main domains: Availability, Uptake and Impact. As the elements of smart sustainable development, knowledge to action, planning for uncertainty, ICT management and good governances are introduced into the SSDM ICT4D value chain, it yields the outputs that result in the effective us of ICT4DM. This dissertation proposes the following ICT4DM value chain described in Figure 3. The proposed logic model adopted the precursors and inputs of ICT4D and expands the intermediates to address the multi-purpose use of ICT as required by SSDM. Recalling that SSDM was established by ITU in 2012 to encourage the multi-use of ICT for development and disaster management.

This dissertation narrowed its approach and organized findings based on the outputs of the proposed ICT4DM value chain.

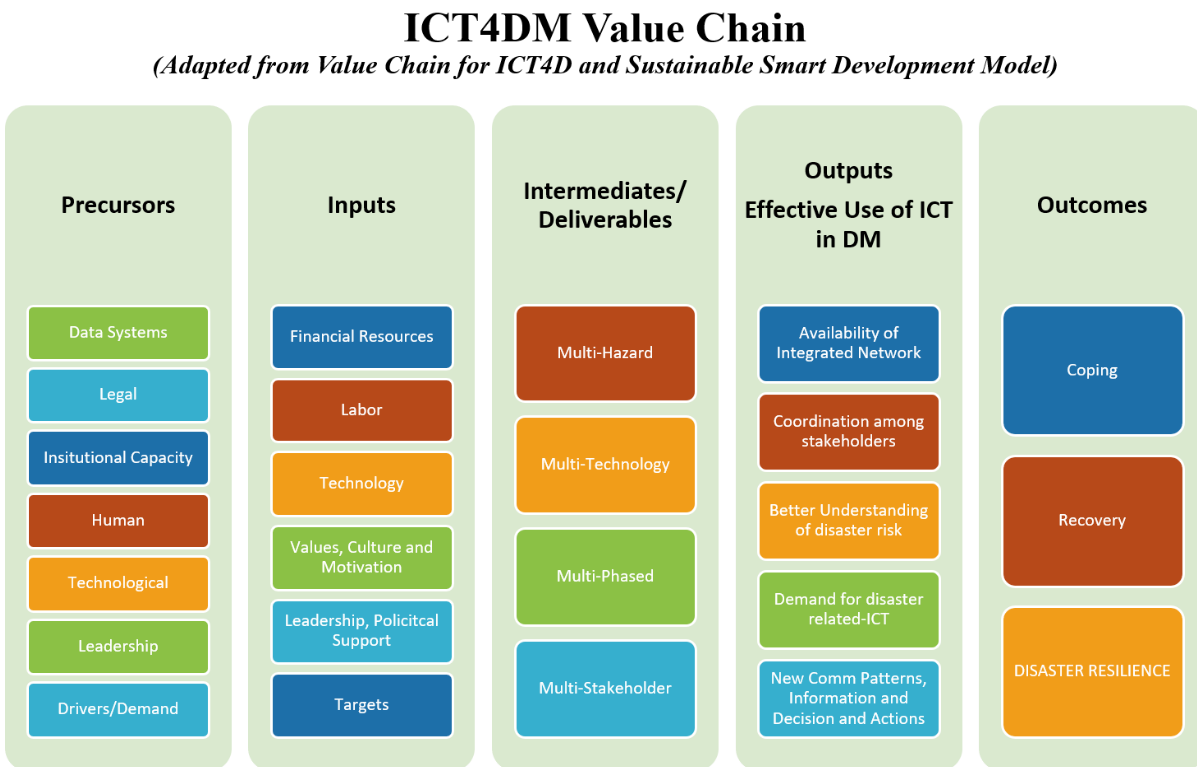

Figure 3. ICT4DM value chain used in this study. Author's adaptation of ICT4D incorporating elements of disaster governance, sustainable smart development, knowledge to action, planning with uncertainty and information and communication technology management.

CHAPTER 3.0 – RESEARCH DESIGN AND METHODOLOGY

This chapter aims to provide the following:

- *Research Design and Questions*
- *Selection of cases*
- *Unit of analysis and observation*
- *Data Collection*

This research is an exploratory investigation of ICT4DM in DMOs in the Pacific with a specific focus on satellite communications and impacts on disaster resilience at an operational and institutional levels. This dissertation acknowledges the fact that there is a great diversity of ICT4DM utilized by the DMOs community at large, however the emphasis here is on the perspectives of IT staff / personnel on systems appropriate and historically effective in PICT settings. Furthermore, the ICT4DM covered here are those that support basic data and product access for meteorological services, as well as systems designed for dissemination of information from, or communication between, meteorological services, emergency management entities, and remote communities. A mixed methods approach was used to gather perspectives and information sourced from literature, semi-interviews, discussions and meetings (Figure 4). Portions of this research was also conducted as part of my ongoing work with the University of Hawaii Telecommunications and Social Informatics Research Program (UH TASI), where I have served in various roles since 2014. See Chapter 5 for further details. The UH TASI serves as the equipment hub for disaster communication systems deployed by the US to meteorological and disaster management offices in the Pacific Region. The UH TASI is also the secretariat of the Pacific through Radio and Internet for the dissemination of hydro-meteorological and hydrological information (RANET Network).

The objectives of this research are:

1. To inventory US deployed ICT4DM in the RANET Network 2006-2022
2. To identify cultural, institutional, political and technical factors influence the use and implementation of ICT in disaster management

3. To establish what challenges and opportunities there are for the integration of ICT4DM in PICT DMO

This chapter includes the following sections: 1) research design; 2) research questions; 3) selection of cases; 4) unit of analysis and observation; and 5) data collection.

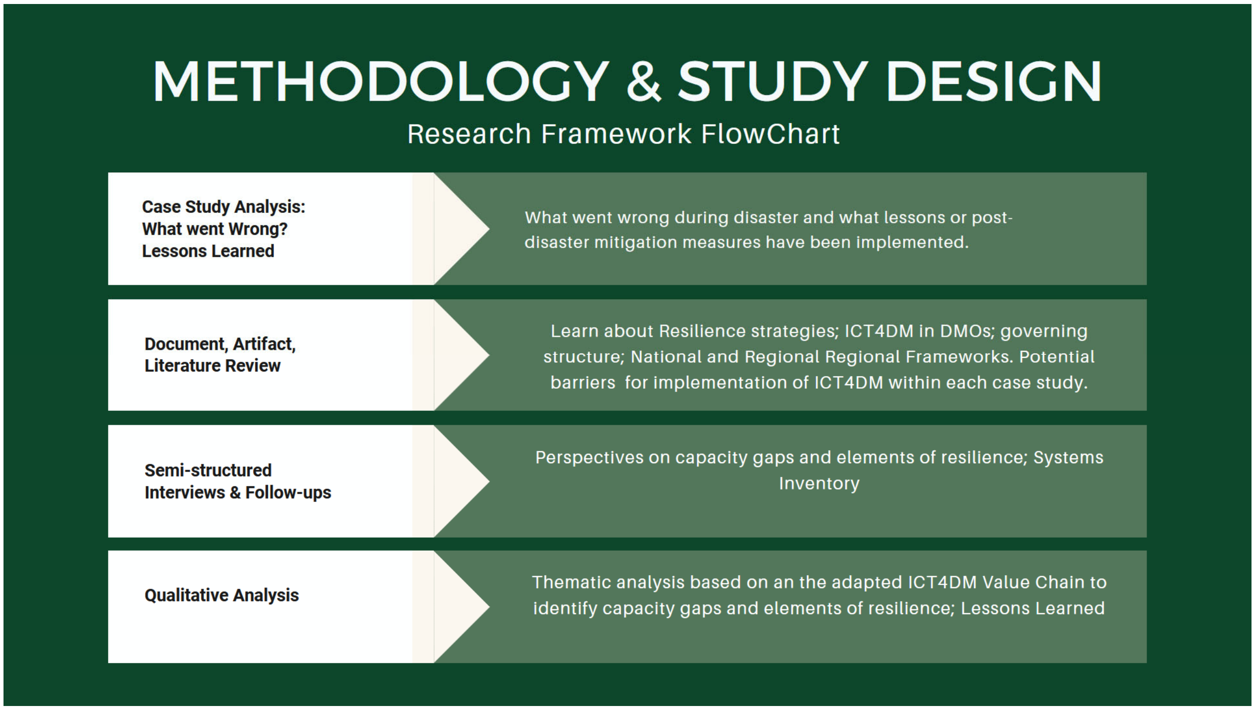

Figure 4. Research Framework Flow Chart.

3.1 Research Design

The research approached the research in three parts: (1) Part 1: Where we've been – Case Studies – 2009 TAS and 2022 HTHH; (2) Part 2: Where we are: US Deployed Communications ICT4DM in the Pacific via the RANET Network and; (3) Part 3: Where we're heading: Capacity Gaps, Elements of Resilience and Lessons Learned.

Part 1 required a thorough review of existing artifacts, reports, news articles, publications and other related documentation. The case study approach sought to identify the positive and negative factors that influence DMOs during each event and to identify lessons learned. The case study method also allows for the investigation of ICT4DM in differing settings. Semi-structured interviews were used primarily for Parts 2 and 3.

The purpose of this study is to review the use of ICT4DM and its role in improving disaster resilience based on the elements of the ICT4D value chain addressing Development Impacts through a logic model. This study will take a particular interest in aspects of culture and place, institutional and governance, and technical functionality that may influence the use and implementation of ICT for disaster management and ultimately enhance the resilience capacity of small islands. Specific case studies reviewed as part of this study is the 2009 TAS and the 2022 HTHH.

3.2 Selection of Cases - 2009 TAS and 2022 HTHH

An exploratory case study research examines a set of actors bounded in time and place and the contextual materials describing the events (Creswell, 1998). According to Creswell (1998), case study requires gathering extensive materials from multiple sources of information to provide an in-dept picture of the case. Denzin & Lincoln (2000) added that case studies structure the problem, issues, and lessons learned. Case studies allow for the investigation and comparison of the e-resilience of ICT4DM in different settings. The case studies selected for this research is the 27th September 2009 tsunami in the American Samoa (2009 TAS) and the 15th January 2022 volcanic eruption and tsunami in Tonga (2022 HTHH). The cases were selected to demonstrate the value of ICT4DM on resilience at a local, national and regional level and illustrate the overall resilience of communications in the Pacific Region. This study seeks beyond a two-dimensional analysis, but also the relationships among cases. This study identifies lessons learned and provide practical incremental solutions among the key actors within the cases. The cases selected seeks to identify the cultural, technical, institutional factor that influence the integration of ICT4DM and overall, the e-resilience of the organizations. For example, the tsunami events in American Samoa in 2009 and the 2022 event in Tonga share many similarities and differences in disaster communications such as the need for multiple redundancy; failure is local telecommunication systems; and need to under risk and vulnerabilities. Understanding more of the systems and the interactions among actors will also inform the functions of scalable management, governance and policies.

3.3 Unit of Analysis and Case Studies

The unit of analysis is the organization. The unit of observation are the network and technical systems personnel responsible for maintaining and management ICT4DM. While the unit of analysis and observation are at a local level, the lessons and implications are at a country level. This may be viewed as the formal systems implemented to manage disasters officially and the systems that are temporarily introduced to assist in the management of disasters. In each case, the study focused cultural, political, technical and institutional capacity gaps and opportunities for improved implementation. The unit of observation are information technology (IT) personnel including but not limited to network analysts, systems administration, technicians and operators. Table 1. Outline of Case Studies, Actors and Analytical Frameworks

The study adopted the Smart Sustainable Development Model (SSDM) value chain as the foundation of: preliminary research, secondary data inventory, primary data collection, data analysis, data interpretation and strategic recommendation. The SSDM ICT4DM value chain is based on the standard input-process-output model, linking resources in order to systematically analyze the stages of an ICT intervention. The adapted SSDM ICT4DM incorporates characteristics and elements of disaster management as discussed by (Kivunike, F., Ekenberg, L., Danielson, M. & Tusubira, F, 2014).

Table 1. Outline of Case Studies, Actors and Analytical Frameworks		
	Case 1: 2009 Tsunami in American Samoa	**Case 2: 2022 Tsunami in Tonga**
Primary Actors	• Department of Homeland Security • NOAA/NWS WSO Pago Pago • Emergency Operations Center	• Tonga Meteorological Service • Tonga Geological Services • Tonga National Disaster Management Operations
Other Actors	• Pacific RANET Working Group • University Center for Atmospheric Research (UCAR) • University of Hawaii Telecommunication and Social Informatics Research Program (UH TASI) • Regional Experts • American Samoa Office of Disaster Assistance and Petroleum Management • University Center of Excellence for Development Disability (UCEDD) • American Samoa Territorial Broadband Working Group	• Pacific RANET Working Group • UCAR • UH TASI • Regional Experts • Emergency Telecommunications Experts
Analytical Framework	• Legal structure and authority of DOM • Training Programs and Capacity Building • Outreach and risk communication • Emergency Management Plans • Context of operations • Use of ICT4DM	• Structure of Authority • Responsibility and Coordination • Outreach and risk communication • Training and Capacity Building • Use of ICT4DM

3.4 Data Collection

3.4.1 Semi-Structured Interviews

Semi-structured interviews were designed and constructed from preliminary analysis of archival reports, national level plans and reports; and many discussions and meetings over the years. I conducted interviews and follow-up calls to gather in-depth information about ICT4DM from key organizations involved in disaster planning and response in American Samoa and Tonga. The discussions and interviews were conducted as part of my work with UH TASI and the RANET Pacific Working Group which consisted of technical and network operators and staff from all over the Pacific DMO. Specific to this dissertation and its objectives, the interviews and follow-ups were conducted May 2021 to February 2023.

3.4.2 Secondary Methods

In the initial phase of this study, an extensive review of reports, documentation, literature other surveys were completed to firmly structure the research questions and unit of analysis. This review would become the foundation of the answers of both research questions, particularly identifying the capacity gaps and solutions. However, in-depth discussions were held to further understand the complexity of operations.

3.4.3 Thematic Approach

Data analysis followed a thematic approach. The elements of resilience for this study adopts key indicators identified by ITU (2022) and the World Meteorological Organization (WMO) described in Table 2.

Table 2. Guiding Interview Questions		
Element of Resilience	Guiding Interview Questions	Research Question
Availability of Integrated Network	• What disaster-related systems were implemented in the Pacific Islands over the last 20 years? • What cultural, institutional and technical factors influence the implementation of ICT in disaster management?	#1
Infrastructure readiness	• What were the barriers and enablers to the use of ICT systems in disaster management? • Describe your institutional readiness for the deployment of ICT in disaster management today? • What are potential implications of unmanaged, ungoverned, unregulated, poorly financed ICT systems in disaster management?	#1
Improved Institutional Capacity	• Describe your institutional readiness for the deployment of ICT in disaster management? • What activities in disaster management do you apply ICT (with a focus on mitigation, planning, response and recovery processes and activities)? • How effective ultimately is the use of ICT in DM in your organization/agency/ department/ministry? • What has been the role of donor countries like US in the deployment of disaster related-ICT systems in the Pacific?	#1, #2
Better understanding of risk	• What design elements would enable successful adoption of ICT for disaster management in your organization/agency/department/ministry? • What lessons learned from your operational use of ICT in disaster management can inform community actions toward resilience?	#1, #2
Coordination among stakeholders	• To what extend is local context and cultural understanding integrated in ICT-based initiatives for disaster management? • What elements are most important to enable the successful integration of ICT in your current operations today?	#1, #2

3.5 Analysis and Interpretation

Information obtained from review of documentations and archives were critically examined and summarized for analysis and discussions. Information obtained from semi-structured interview and survey were also analyzed and compared with the theoretical references, indicators selected and best practices.

PART ONE - WHERE WE'VE BEEN

CHAPTER 4.0 – CASE STUDIES

This section aims to provide the following:

- *What went wrong during the 2022 Hunga-Tonga-Hunga Haapai volcano eruption and tsunami (2022 HTHH) and 2009 Tsunami in American Samoa (2009 TAS)*
- *An overview of disaster management in American Samoa and Tonga and;*
- *Lessons Learned from these two case studies – 2022 HTHH and 2009 TAS*

This chapter summarizes what went wrong and lessons learns in the context of the 2022 HTHH and the 2009 TAS. In many aspects, island communities are underserved in areas of health, education, economic development and ICT. However, there are also numerous opportunities to learn from island communities (Kim & Freitas, 2018). Specifically, this chapter will approach the research questions from the technical perspective network operators, technicians, systems administrators and developers of ICT4DM deployed to support disaster communications in DMO.

4.1 CASE STUDY 1: Hunga-Tonga-Hunga Haapai 2022 Volcano Eruption and Tsunami

The 2022 Hunga Tonga-Hunga Ha'apai eruption and tsunami has been described as a classic example of complex, cascading and compounding disaster (Fakhruddin & Sing, 2022). The volcanic eruption generated a tsunami that destroyed many critical infrastructures including the undersea fiber optics cable connecting Tonga to domestically and to the world. At the time of the eruption, Tonga was also under COVID-19 restrictions with travel border closure and all pandemic protocols in place including a three-week quarantine. Despite the crisis of the volcanic eruption, the Government of Tonga did not ease up on the restrictions and agreed to "contactless" aid and response.

4.1.1 What went wrong?

Tonga is an archipelago of over 150 islands and over 100,000 people. Tonga's total land area is dispersed between 15 degrees and 23 degrees South latitudes and 173 degrees and 177 degrees West longitudes. On January 15, 2022, the Tonga Geological Services (TGS) recorded one of the largest eruptions of the Hunga-Tonga-Hunga-Ha'apai underwater volcano, blasting steam, ash, and sulfure dioxide to record heights, killing four people (one foreign national in Tongatapu and three local residents from Ha'apai). The eruption created a boom heard as far north as Alaska and generated local tsunami waves rising as high as 15m (49ft). The tsunami waves hit the west coast of Tongatapu Islands, 'Eua, and Ha'apai Islands. It also triggered a tsunami that destroyed homes on nearby islands before crossing the ocean to the coasts of Japan, North and South America. The localized event did not receive deep ocean observations until after the tsunami waves hit the coastline of Nukualofa. The tsunami generated 6-9.5ft/1.98-2.9m waves above sea level. The first wave arrived at 5:32pm local time and the highest recorded wave reached shores at 5:50pm. Wave run-up was between 49ft/15m and 65ft/20m above sea level in some areas, with inundation reaching 1640ft/500m inland at Nomuka, Ha'apai and 19688ft/600m inland at Mango, Ha'apai. The Tongan Meteorological Service (TMS) reported that the tsunami completely damaged all resorts in 'Eua and nine major resorts in the Tongatapu islands and Nuku'alofa, and estimated that around 160 homes were seriously damaged or destroyed. Within the Tongan Islands, an estimated 84,000 people or more than 80 percent of

Tonga’s population, were impacted by the volcano’s eruption. Over 70 earthquakes (magnitudes 4.4-5.0) continued occurring until February 4th, 2022, which continued to devastate the emergency management system in Tonga.

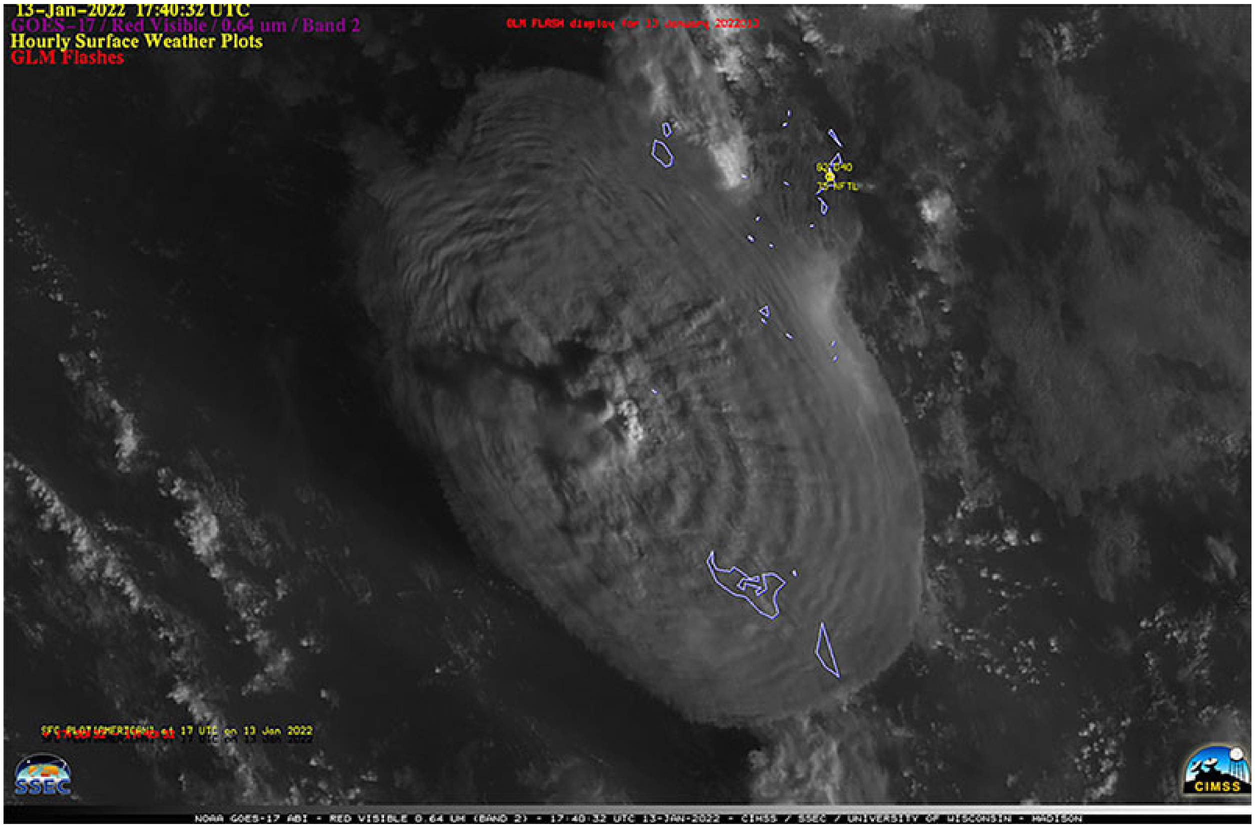

Figure 5. A massive eruption plume rising above Hunga Tonga-Hunga Ha’apai captured by the GOES-17 satellite (NOAA). Source: Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Space Science and Engineering Center (SSEC).

For the last decade, Tonga has relied on a single submarine fiber optic cable for global communcations for the last decade. The Tonga Cable System (TCS), operated by Tonga Cable Ltd, terminates in Nukualofa and connects the Friendly Isles globally via Fiji. From Nukualofa, the TCS has interisland spurs linking to the outer islands of Tonga. The cable is part of a network of 19 subsea cables that crisscross the South Pacific. This is also Tonga’s primary connection for phone and internet connectivity. The 2022 HTNN eruption caused severe disruption to communmications from and to Tonga when it cause the 827km (513mi) cable to rupture in two location - about 37 km (22.9mi) offshore from Nuku’alofa, and a second cut in the domestic cable was situated at 47km (29.2mi) offshore. This made it difficult for emergency services and Tonga government officials to communicate and for local communities to determine aid and recovery needs. The government of Tonga immediately identified telecommunications as one of two priority areas in the response.

Reconnecting Tonga proved a challenging, due to the need for a contactless disaster response approach to reduce risk of COVID-19 transmission. Restoring communications to Tonga is vital for monitoring the volcano and critical to support humanitarian aid organizations as they provide much needed medical assistance and emergency supplies to Tongan citizens. Immediate efforts to repair the TCS were activated by local officials and international response agencies. The priority was to restore off-island communications services to the main island of Tongatapu, which would cover roughly 80 percent of bandwidth needs for response and recovery. Figure 6 indicates the location of the two locations at where the cable was severed.

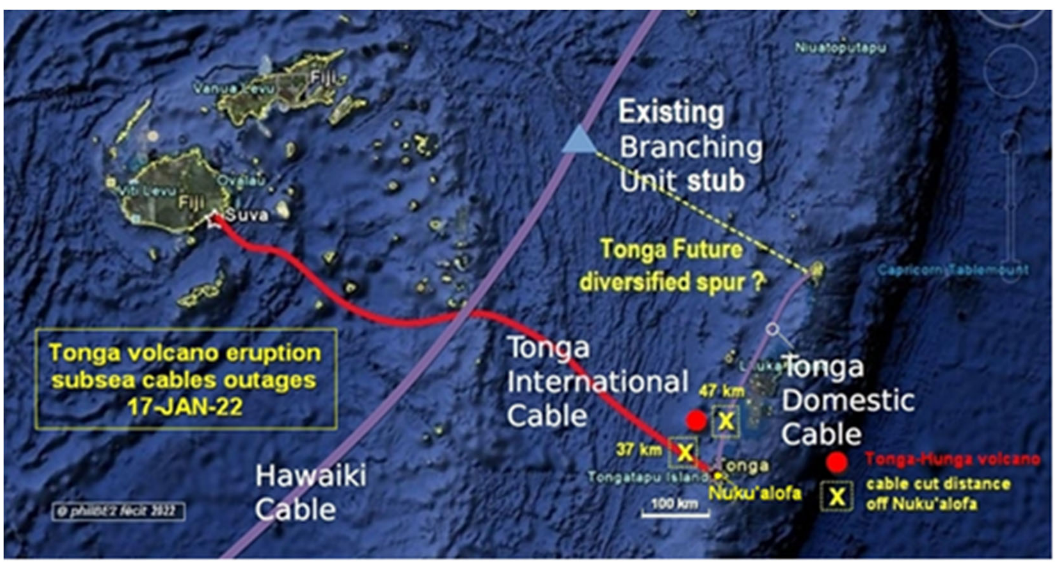

Figure 6 Cable cut points after the HTHH. Image source: @philBE2 on Twitter

The CS Reliance vessel was dispatched from Papua New Guinea (PNG), located over 4000km (2400m) away to repair the cable. The CS Reliance had to travel to Samoa to collect supplies before making its way to Tonga to start repair. By February 22, 2022, more than 5 weeks after the eruption, the international section of the undersea communications cable was repaired. Data, SMS, and voice services provided by the two national providers in Tonga—Digicel and the Tonga Communications Corporation (TCC)—became available on Tongatapu. However, according to various Emergency Telecommunication Cluster Reports, communication with the outer islands of Tonga remained a challenge as the domestic section of cable had not been repaired. Sourcing and manufacturing the cable needed to complete the repair of the domestic line could take up to a year. In the interim, microwave and satellite links are providing connectivity to the outer islands. Figure 7 illustrates broad view of reconnection efforts and type of communications available and planned in Tonga.

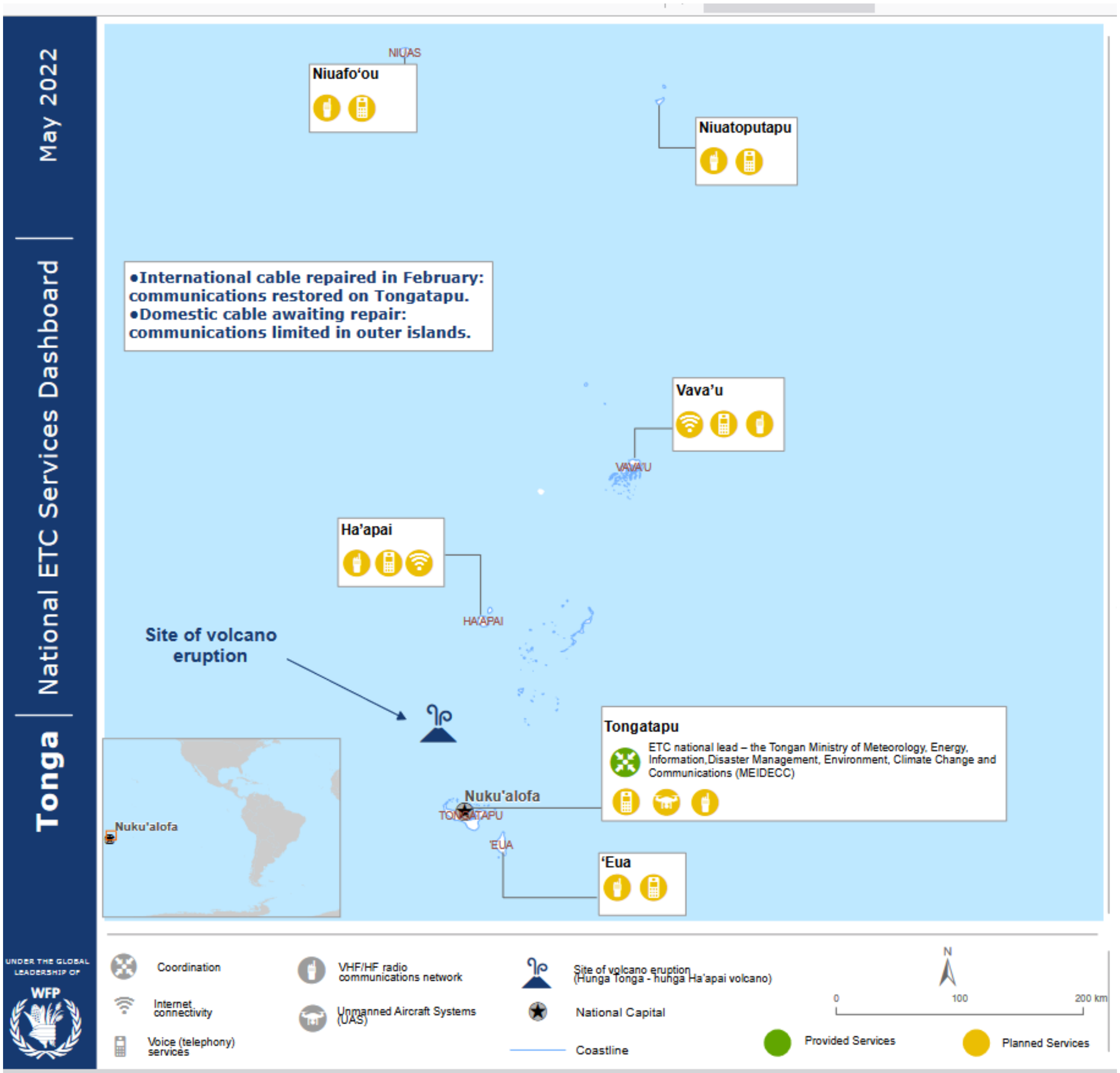

Figure 7. May 2022 Reconnecting Tonga Map. Source: UN Emergency Telecommunication Cluster.

4.1.2 Disaster Management in Tonga

The Emergency Management Act 2007 provides the legal framework for all emergency and disaster risk managements policies, procedure and programming in Tonga. The National Disaster Council (Cabinet) is the highest governing body with three national committees providing governance support: the National Emergency Management Committee (NEMC), the National Emergency Operation Committee (NEOC), and the National Recovery Committee (NRC). Agencies involved in emergency and disaster risk management in Tonga possess a range of capabilities and perform various roles and responsibilities across the 'policy and preparedness', 'emergency response', and 'relief and recovery' phases. The Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) is responsible for climate resilience and disaster risk management and leads emergency telecommunications response in Tonga (Government of Tonga, 2021). Figure 8 outlines DM in Tonga. The National Emergency Management Office (NEMO), embedded within MEIDECC, serves as a secretariat for emergency committees and responsible for the coordination of risk reduction and emergency management activities in Tonga.

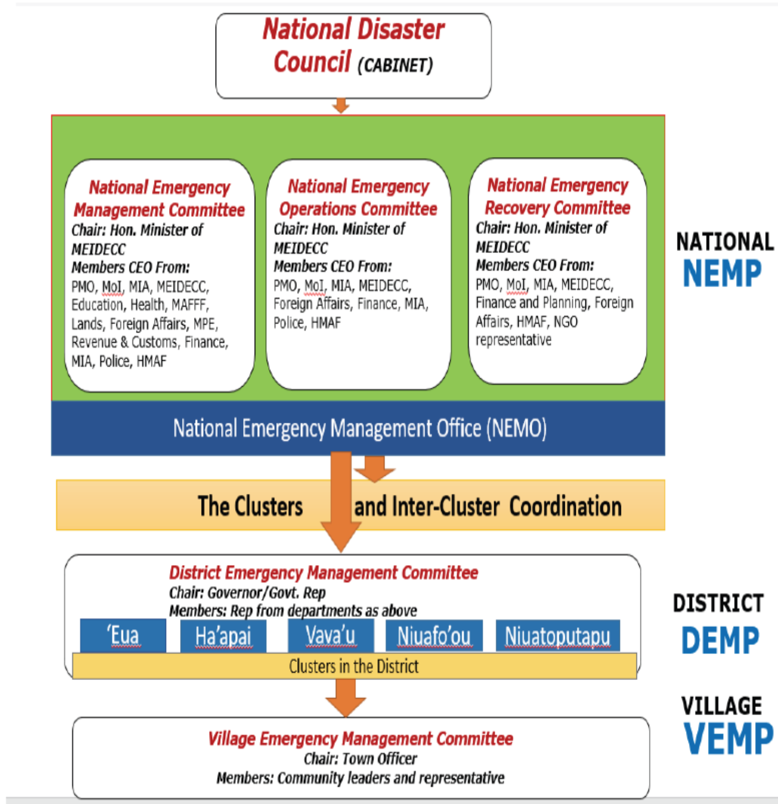

Figure 8. Disaster Governence Structure in Tonga. Source: Tonga Strategic Roadmap for Emergency and Disaster Risk Management 2021-2023

The Government of Tonga identified improving its multi-hazard early warning system as a priority under the Tonga Strategic Development Framework 2015-2025 (TSDF II) and National Emergency Management Plan. MEIDECC has made significant mandate in disaster risk reduction from policy and standard operating procedures development and adoption for the National Emergency Coordination Center, tropical cyclone procedures, a national tsunami plan, and improved forecasting and disseminating capabilities through various mediums. The country has a good early warning system with capable leaders, scientists and staff in both the Tonga Meteorological Service (TMS) and the TGS (Government of Tonga, 2015).

International and regional programs contribute to strengthening Tonga's multi-hazard early warning system through early warning and preparedness, and mainstreamed disaster risk and climate change in development planning, technological and financing. Programs like the Pacific Resilience Program (PREP) of World Bank provides comprehensive and integrated assistance to the Government of Tonga with institutional and regulatory strengthening, capacity building and implementation support, and modernization of the observation infrastructure, data management systems, forecasting and warning systems. The Pacific Radio and Internet Technologies for the dissemination of hydro-meteorological and Climate-related information (RANET) network, detailed in Chapter 5 also provides and supports the deployment of ICT4DM technologies to support national DMOs in Tonga.

4.1.3 Lessons learned for enhancing Tonga's e-resilience

The 2022 HTHH volcanic eruption and tsunami is a prime example of how fragile critical infrastructures such as the global submarine cable network is, and how easily it can go offline. It has also highlighted how dependent communities have become to technology and broadband and how quickly we become paralyze without it. To build the resilience of a community, diverse and accessible communications need to be in place including more satellite-based systems and technologies. This is also the second major submarine cable cut for Tonga. In 2019, the TCS was damaged and Friendly Isles was without internet service for about two weeks. As a result, the Tonga government sought to establish a backup geostationary satellite system through a company called Kacific1. However, at the time of the 2022 HTHH, a dispute between the Tongan government and the Kacific1 company is under arbitration in Singapore.

4.1.3.1 Redundancy

The failure of essential services from critical infrastructure during disasters can impact populations by disconnecting and hindering their ability to respond and recover from an event. Critical infrastructure failures cause domino effects across communities and therefore crucial to understand to better prepare and design mitigation, response and recovery tactics. Enhancing e-resilience also means enhancing the capacity of people to be able to cope with service outages (Fakhruddin, Fluckman & Bardsley, 2021).

4.1.3.2 Strengthen Broadband Infrastructure

Tonga has the ability to provide alerts and early warning notifications through communications systems such as internet, radio, HF/VHF, email and phone calls. Significant effort has gone into building and enhancing Tonga's Multi-Hazard Early Warning System

(MHEWS) by developing policies, providing opportunities for training, integrating local and traditional knowledge, and the implementations of communication technologies. However, there is much systematic process and guidelines for early warnings and the dissemination of information to ends users that are in progress. For example, Tonga has adopted as one of its outcomes the institutionalization of the UN Cluster System. In addition to the Cluster System, Common Alert Protocols (CAP) has been at the forefront for policy and systems development for a Tonga Unified Messaging System (UMS). A UMS leverages multiple channels of communications originating from a single distribution point (Government of Tonga, 2021). The system integrates with multiple mediums and media to deliver and disseminate the message. It allows systems to interlink with the messaging broker to write, publish, subscribe, and disseminate warnings though all media. Many countries have adopted CAP as the warning standard. This could be made available to the National Emergency Management Office and TMS as a software package contextualize with local characteristics and designed to activate early warnings for all hazards.

A significant gap identified as part of the review process is the absent of formal binding agreements between the Tonga Government National Emergency Management Office, TMS and communications service providers for disaster alert messaging. This is a challenge all around in the ability to communicate among agencies, between agencies and with the general public. During an event like the 2022 HTHH or any disaster, this can create confusion between roles and responsibilities for disseminating emergency information. In addition, there is no policy to eliminate costs for end users for information relating to an emergency such as text message notifications and alert messages. Absent of a formal policy, costs are accrued by both the carrier and the users.

4.1.3.3 Effective Risk Communication

Understanding risk requires data to be analyzed, information and messaging created and communicated at a level that people can understand. Risk communication is a critical part of reducing risk and increasing resilience. Effective communication through impact-based forecasting is critical for communities to understand risks and take appropriate actions.

4.1.3.4 Community preparedness

Public education and awareness of risks, vulnerabilities and reduction efforts is essential. It is not enough to send a message. Messages must be crafted and delivered in various modality such as campaigns, social media and community mobilization, considering the needs of specific audiences – must be generated for specific types of hazards. In the case of the 2022 HTHH, an awareness program on natural warning signs would be useful. Impact-based early warning systems and anticipatory action related activities will further enhance the community capacity and resilience.

4.1.3.5 Conclusion

The devastating 2022 Hunga Tonga-Hunga Ha'apai eruption and tsunami in Tonga provides many lessons for the future. Certainly, it has highlighted that resilience to natural hazards requires integrated risk management – from hazard identification and risk register, hazard warnings and risk communication – to prepare for hazard events and respond when an event occurs. The risk and improvement to both structural and non-structural communications is also highlighted. Risk communication is ensuring that people understand the message and that the safest actions are taken. It is also important to hold open and public conversations about disasters and planning for uncertainty, complicated decisions, trade-offs, and responsibilities which are often overlooked as a part of disaster planning.

4.2 CASE STUDY 2: 2009 Tsunami in American Samoa

4.2.1 What went wrong?

On September 29, 2009, a magnitude 8.1 submarine earthquake occurred along the Tonga Trench subduction zone in the Samoan Islands region. It generated a tsunami that hit the coastline of American Samoa within 15 minutes, before an official warning could be issued; wave heights of up to 46ft/14m were recorded in American Samoa, Samoa and Tonga killing 149 across the 3 countries. In American Samoa specifically, 34 people were killed and hundreds were injured. The combination of the earthquake, tsunami, and flooding resulted in a devastating amount of damage on the island of Tutuila, with most of the damage caused by the tsunami. A total of 241 homes and one school were destroyed, 3,058 homes and four other schools were damaged. Loss of power affected the operation of water and sewage treatment facilities and broadband (USACE, 20212).

Reports indicate that immediate evacuation occurred due to previous education, local leaders who signaled danger, community outreach and knowledge of previous tsunami. The manmade sub-components of communications critical infrastructure often failed. Land based infrastructure, such as overhead telephone and power lines, were impacted, rendering television and telephone land lines inoperable. On-island mobile capacity was overwhelmed and phones were jammed. The primary early warning alert system radio station transmitted warnings, but went down shortly after the power plant. New ultra-high frequency (UHF) two-way radios allowed key officials and agencies to communicate during the tsunami.

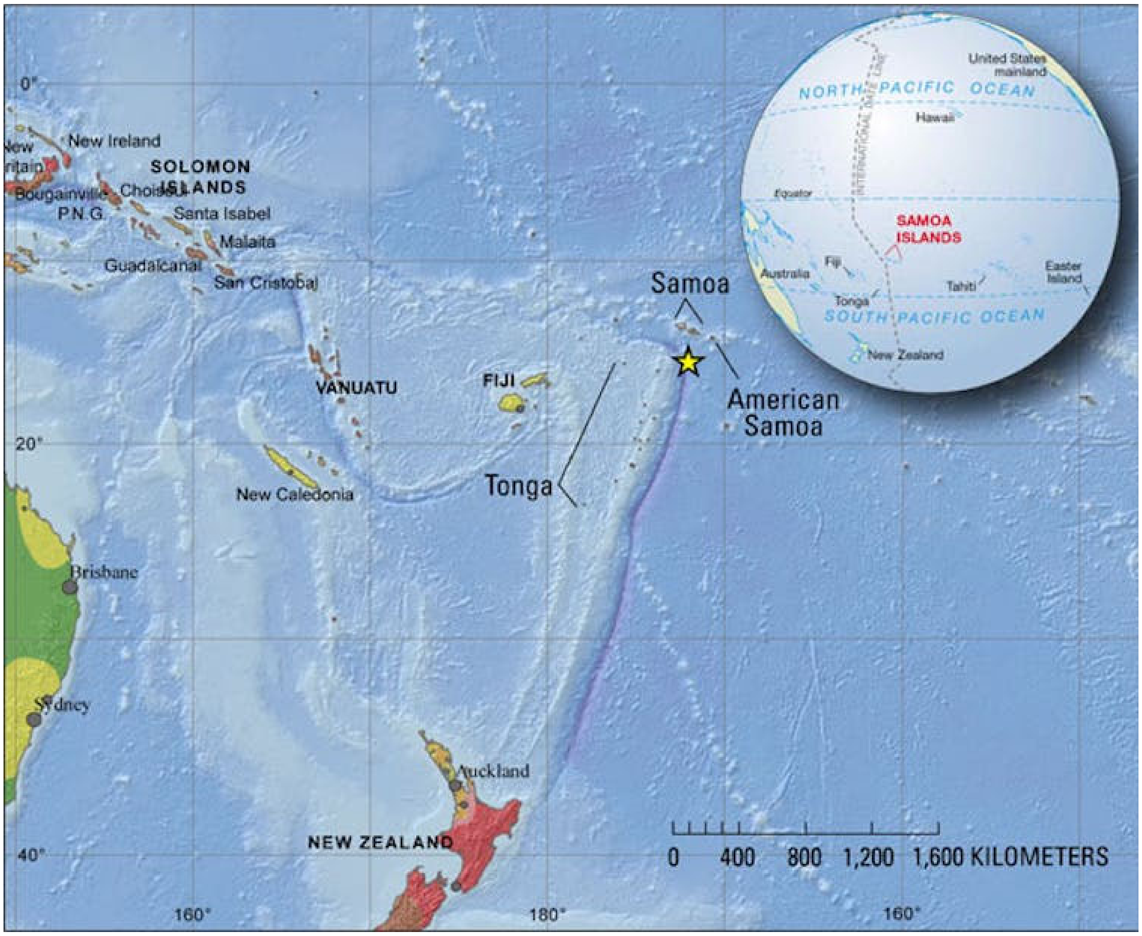

Figure 9. Regional view of American Samoa and Tonga

4.2.2 Disaster Management in American Samoa

American Samoa comprises five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u) and two atolls (Rose Atoll and Swains Island) covering 75 square miles in the South Pacific Ocean. An unincorporated and unorganized territory of the United States of America (US) – American Samoa is the furthest US land to the east and south of the equator. Major economic activities in American Samoa include government services, tuna canning, and tourism. Government activities account for one-third of total employment, and tuna canning accounts for another one-third. The remaining one-third of employed workers are in the secondary economy, consisting mainly of retail and service enterprises. Agriculture has potential as a growth market; however, it is currently mostly for home consumption. The current population of American Samoa is 55,312. Over 90% of the population resides on Tutuila Island. American Samoa is about 2,300 miles southwest of Hawaii, over 4,100 miles southwest of San Francisco, and 1,600 miles northeast of New Zealand. Figure 9 presents a regional view of American Samoa and Tonga.

American Samoa utilizes the Incident Command and Unified Command structures as the framework for disaster management. It operates according to 15 Emergency Support Functions (ESFs) that carry out coordination and completion of response and recovery activities. The American Samoa Department of Homeland Security (ASDHS) is the central coordinating agency for the American Samoa Government with Federal, State, Tribal, Non-Governmental Organizations, and religious denominations in response to Natural or Man-Made Disasters through its Emergency Operations Center (EOC). Disaster planning in American Samoa uses an all-hazards approach. All-hazards planning is based on the premise that the consequences of disaster are similar regardless of the hazard, and most of the functions performed during a disaster are not hazard-specific. The ASDHS provides disaster and technical assistance through the Territorial Emergency Management Coordination Office (TEMCO) and serves as the custodian of the tsunami siren alert system, cybersecurity, dissemination of public warnings, birth and death certificates, divorce records and other sensitive decrees. The TEMCO is charged with the responsibility of maintaining a territorial plan of emergency management, known as the Territorial Operational Plan (TOP).

Table 3. American Samoa Primary Agency Listing and Emergency Support Function		
ESF #	**Emergency Support Function**	**Primary Agency/Organization**
1	Transportation	American Samoa Department of Public Works (DPW)
2	Communications	American Samoa Telecommunications Authority (ASTCA)
3	Public Works & Engineering	American Samoa Department of Public Works (DPW)
4	Firefighting	American Samoa Department of Public Safety Fire (DPS-FIRE)
5	Emergency Management	American Samoa Department of Homeland Security-Territorial Emergency Management Coordinating Office (ASDHS-TEMCO)
6	Mass Care, Housing and Human Services	American Samoa Department of Education (DOE)
7	Resource Support / Logistics	American Samoa Office of Procurement (OP)
8	Public Health and Medical Services	American Samoa Medical Authority (LBJ Hospital) American Samoa Department of Public Health (DOH)
9	Urban Search & Rescue	American Samoa Department of Public Safety- FIRE (DPS-Fire)
10	Oil and Hazardous Material Response	American Samoa Department of Public Safety- Fire (DPS-Fire)
11	Agriculture and Natural Resources	American Samoa Department of Agriculture (DOA)
12	Energy	American Samoa Power Authority (ASPA)
13	Public Safety and Security	American Samoa Department of Public Safety – Police (DPS-Police)
14	Long Term Community Recovery	Office of Disaster Assistance and Petroleum Management (ODAPM)
15	External Affairs	American Samoa Office of Public Information (OPI)

Table 3. American Samoa Primary Agency Listing and Emergency Support Function. Source: American Samoa Territorial Operations Plan

4.2.3 Broadband in American Samoa

American Samoa has been at the forefront of regional broadband development and enhancement for the last three decades. In 1997, the ASG established the ASG Distance Education, Learning and Telehealth Applications (DELTA) Consortium to coordinate and develop a public service telecommunication and ICT infrastructure for the Territory. In 1998, the ASG created the American Samoa Telecommunications Authority (ASTCA) by Executive Order under the authority granted to the Governor and applicable sections of the Federal Communications Act of 1934, as amended, and the Telecommunications Act of 1996. The telecommunication industry in American Samoa continued to grow with the American Samoa Cablevision and BlueSky Communications entering the market for cable television, long-distance, mobile, and Internet services. By 2002, the American Samoa Comprehensive Economic Development Strategy (CEDS) acknowledged the need for an industry with higher productivity levels. Such higher productivity would be the result of better-educated, better-trained workers, a more efficient class of managers, and capital investment in new technology. For the next 20 years, efforts emerged to support the growth and development of American Samoa's broadband physical infrastructure and related initiatives.

4.2.4 Lessons from 2009 Tsunami – Building American Samoa's e-resilience

4.2.4.1 Prioritizing Disaster Communications, a function of e-resilience

Like many remote locations, broadband was intermittent, slow, expensive and of poor quality in American Samoa. The 2009 tsunami continues to highlight the need to prioritize investment in ICT in general for improving operations and transactions in American Samoa, especially in disaster communications. Communications during emergencies incorporate a wide range of measures to manage risks within communities and the environment. It encompasses the information disseminated by the government, responders, disaster managers, and other media.

In 2015, the US Department of Agriculture's (USDA) Rural Utility Service (RUS) funded the Broadband Linking American Samoa Territory (BLAST), installing fiber-to-the-premise (FTTP) infrastructure connecting all homes and businesses to the local fiber-optic network. American Samoa invested over $90 million in BLAST to replace its copper infrastructure with a fiber-optic network capable of delivering high speed, voice, video, data and cellular backhaul service throughout its islands of Tutuila, Aunu'u, Ofu, Ta'u, and Olosega. American Samoa further capitalized on BLAST upgrades by replacing the Territory's 2G network with 4G LTE (long-term evolution) technologies. The ASG followed BLAST with a $30M investment to launch the Hawa`iki Submarine Cable (Hawa`iki Cable) in 2018, connecting American Samoa to the global community via the availability of 200+ Gbps off-island bandwidth capacity. The Hawa`iki Cable is a 15,000 kilometer (9320 miles) high-capacity underwater cable connecting Australia and New Zealand to the mainland United States, American Samoa, and Hawai`i. These investments enable an ecosystem for digital innovations to thrive, positioning American Samoa for e-Resilience.

4.2.4.2 Maintaining Broadband Infrastructure to Support Disaster Response and Recovery

Damaged or overwhelmed communication systems was identified as a challenge to critical infrastructure in the American Samoa Tsunami Study conducted by the US Army Corps of Engineers (2012). In order to quickly and effectively respond to emergencies, disasters, and pandemics, American Samoa must upgrade, expand and build solid resilient broadband infrastructure rather it be fixed, wireless, satellite or other short burst technologies. Since the 2009 tsunami, American Samoa has since adopted FirstNet which allows Law Enforcement and Emergency Medical Services (EMS) specific band devices dedicated to First Responders and will prioritize these users during traffic congestion.

The tsunami siren alert system must also be kept up and maintained with ongoing continuous testing. As of this study, the tsunami siren alert system is 90%, largely due to the collaborated effort of AS Power Authority, AS Telecommunications, and AS Homeland Security while the Department is coordinating closely with American Signal Corporation (ASC), and the arrival of equipment and spare parts, to rehabilitate long standing sirens that are due routine maintenance (siren heads, solar panels, batteries, etc.) from deterioration from natural elements since the loosening of travel restrictions into American Samoa. However, at the time of the event, the tsunami siren alert system was not operational.

4.2.4.3 Risk Communication

The Weather Service Office (WSO) in Pago Pago, in conjunction with the Pacific Tsunami Warning Center (PTWC), is responsible for providing tsunami watches and warnings for American Samoa. However, WSO Pago Pago was not authorized to release official tsunami warnings, and communication with the PTWC, the official notification group, was hampered after the earthquake; the WSO's decision to send out an "unofficial" warning caused some confusion for residents. Subsequent to the tsunami, the WSO was given the authority to release official tsunami warnings. However, at a local level, the functions of public warnings and alerts rest with the local Department of Homeland Security. This calls for a review and better integration of WSO into existing DM operations in American Samoa.

4.2.4.4 Education and Outreach

The importance and effectiveness of public education programs was highlighted by this event, as the majority of survivors were saved by their decision to self-evacuate. Reports indicate that immediate evacuation occurred due to previous education, local leaders who signaled danger, community outreach and knowledge of previous tsunami. Village mayors and schools participated in evacuation training and drills that came into action during the tsunami. It was discovered that planning needed to take into consideration barriers to evacuation in planning evacuation routes. Some residents had difficulty getting to high ground because of rivers, mangrove swamps, landslides or fences that separated them from the most direct evacuation routes; others did not have the ability to evacuate due to special needs. It was also recommended that emergency plans and warnings be short, precise, and recorded in English and Samoan.

4.2.4.5 Conclusion

The 2009 TAS certain have left us with many lessons. American Samoa had already been aware of deficiencies with its emergency alert system; although it had begun implementing improvements, there had not been sufficient time since they were identified to get them all in place. More priority must be given to the importance of communication infrastructure overall and systems and technologies to support actions and decisions. Certainly the 2009 TAS also highlighted the need for integrated disaster management approaches, community involvement and ongoing education and public outreach.

PART 2 – WHERE WE ARE

CHAPTER 5.0 – US DEPLOYED SATELLITE COMMUNICATIONS IN THE PACIFIC THROUGH RANET 2006-2022

This chapter aims to provide the following:

- *Satellite Communications in the Pacific Region*
- *Advantages and Disadvantages of Satellite Systems*
- *RANET Deployed Communication ICT4DM to the Pacific*

The role of ICT4DM in enhancing community resilience in the Pacific region has long been recognized. Leadership over the years have adopted collective visions, program investment plans, outlook plans, regional frameworks to mitigate disasters by strategizing together on ways to mainstream sustainable development, implement SSDM initiatives - multi-hazard preparations, multi-phased approaches and prevention strategies, multi-technology and multi-stakeholder solutions – and implement solid institutional infrastructures for communications and early warning systems (ESCAP, 2019). The reality is, each island country and territory are focused on national and sectoral issues and priorities, rather than adopting a regional approach to addressing disaster management challenges with ICT. For instance, there were ideas to set up a consortium among Pacific Island countries to collectively purchase bandwidth at a cheaper rate; to build a pool of technicians to be deployed for routine maintenance or post-disasters, or use regionally owned satellites like TongaSat to provide satellite services, but these ideas never materialized.

Satellite communications have been transforming and enabling innovative approaches to many regional challenges in the Pacific since the late 1970s. It was an accessible, faster, cheaper and higher-quality way to connect globally to support development. At one point (1970 – 2000) in the history of ICT in the Pacific Region, satellite was the primary international connection between the islands and the world. However, with numerous submarine fiber optic cables now commissioned in the region, satellite communication shave become secondary and used for backup and redundancy.

This dissertation acknowledges the fact that there is a great diversity of ICT4DM utilized by the DMOs community at large, however the emphasis here is on systems more appropriate and historically effective in PICT. Furthermore, the systems covered here are those that support basic data and product access for meteorological services, as well as systems designed to for dissemination of information from, or communication between, meteorological services, emergency management entities, and remote communities. This chapter focuses on *Where We Are* - provides a short summary of ICT4DM deployed through the Pacific RANET Network.

5.1 Satellite Communications in the Pacific Region

Between the late 1970s and 1990s, Intelsat was the primary commercial satellite used in the Pacific region for communications. Other commercial satellite service providers like short-lived SES New Skies, Iridium, Eutelsat, JCSAT, entered the market in the 1990s forward, and by 2010 forward, O3b, KACIFIC, and many other satellites the new players for high-bandwidth capacity and lower cost satellite connection. Specific to public service including DMO, a satellite communication experiment using decommissioned US weather satellites also started in the 1971, through a program called the Pan Pacific Education and Communication Experiments by Satellite (PEACESAT) at the University of Hawaii at Manoa. PEACESAT is known today as the Telecommunication and Social Informatics Research Program (UH TASI), who manages the Pacific RANET Network.   Over that period of time as well, a significant number of fiber optics submarine cables were laid across the Pacific offering a tremendous amount of bandwidth and a shift in the use of satellite communications for many island communities. While satellite communications are no longer the primary medium to provide connectivity in the region, it is still very much a critical component of DMO operations, evident of cases studies reviewed. Table 4 provides the current usage of satellite in the Pacific by DMOs.

Table 4 Satellite Communications in Pacific DMO		
Country	**Use**	**Purpose**
American Samoa	Secondary	Redundancy
Cook Islands	Primary	International/Domestic Connection/Redundancy
Fiji	Secondary	Redundancy
French Polynesia	Secondary	Redundancy
Federated States of Micronesia	Secondary	Redundancy
Guam	Secondary	Redundancy
Kiribati	Primary	International/Domestic Connection/Redundancy
Marshall Islands	Secondary	Redundancy
Nauru	Primary	International connection/Redundancy
New Caledonia	Secondary	Redundancy
Niue	Primary	International connection/Redundancy
Palau	Secondary	Redundancy
Papua New Guinea	Secondary	Redundancy
Samoa	Yes	Redundancy
Solomon Islands	Yes	International/Domestic connection
Tokelau	Yes	International connection
Tonga	Yes	Redundancy
Tuvalu	Yes	International/Domestic Connection/Redundancy
Vanuatu	Yes	Redundancy

Table 4 Satellite Communications in Pacific DMOs Source: Author's consolidation based on semi-structured interviews, ESCAP (2019) and review of various documents.

5.1.1 Advantages of Satellite Communications in DMOs

Satellite communications have many advantages that are ideal for usage in DMOs:

- ***Wider coverage:*** Satellite technology has the ability to cover large areas. The Pacific islands, being isolated and spread over a million square millions of ocean satellite technology is an ideal because of its ability to cover large areas. It can be broadcasted to an arbitrary number of points within its coverage area – point-to-multipoint coverage. Its services are not affected by the relief of the terrain;
- ***Multiple radio frequency bands:*** Satellite communications operates on a variety of radio frequency C-band, Ku-band, Ka-band, L-band). This means voice, video and data connections can be transmitted or received over multiple channels.
- ***Rapid Implementation and Installation:*** Satellite antennas can be installed and moved rapidly during a disaster. It can also be installed quickly to and from various locations as needed. Once the satellite is in position, an antenna can be installed and communications may be established within a few days or even hours; Mobile communications can be easily achieved with a satellite system because of its flexibility in interconnecting mobile vehicles
- ***Mobility:*** Satellite communications has the advantage of the quality of transmitted signals and the location of the antennas. The sending and receiving of information is independent of distance, and it is often the only way to connect remote small islands.
- ***High Bandwidth Connectivity:*** Satellite technology is able to provide high bandwidth connectivity through O3b satellites;

5.1.2 Disadvantages of Satellite Communications

Satellite communications are also at a disadvantage for several reasons:

- ***Costly Service and Maintenance Fees:*** Satellite communications is highly unaffordable and costly to maintain for many Pacific Islands. They are expensive because satellite communications require specialized equipment and mechanical components for both on earth and in orbit in space. These main components result in high fees for satellite communications. High-capacity connection (O3b services) have been adopted in many

Pacific islands, including American Samoa, Cook Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, and Vanuatu. Some countries have reported that capacity can cost up to $300,000 USD to maintain and is unsustainable for the small operations. In addition to bandwidth costs, the antennas are also high valued equipment and costly to repair. As seen in the 2022 HTHH, satellite technology parts were not readily available and accessible in country or even in the region and had to be transported from other continents.

- ***Unreliability:*** Different factor influence the reliability of satellite communications such as the radio frequency used, obstructions (trees and leaves), antenna alignment, atmospheric conditions and space weather can all cause interference of the signal, impacting the overall operations of the satellite.
- ***Slow Speeds:*** Compared to broadband internet via fiber optics, satellite communication is slow. The average download speed tends to be around 1Mbps if there is no interference.

5.2 The Radio And Internet Technologies For The Dissemination of Hydro-Meteorological And Climate-Related Information (RANET Network)

The Radio and Internet Technologies for the Communication of Hydro-Meteorological and Climate-Related Information (RANET) initiative is a collaborative effort of DMOs, national hydro-meteorological services, non-governmental organizations (NGO), and academic institutions, technology champions and communities. The concept of RANET began in the late 1990s with various DMO agencies and the African Center of Meteorological Applications for Development in the late 1990s. By 2001 the program had begun setting up networks and working with a number of communities globally. RANET aims to make weather and climate information available to rural and remote populations, which are often among the most in need of environmental forecasts, observations, and warnings. While significant advances have been made in the ability to predict and observe our environment, much of this valuable information remains inaccessible to those outside major cities. By 2003, RANET expanded to the Pacific Region.

5.2.1 RANET in the Pacific

Prior to the wide availability of broadband internet, DMOs in the Pacific were heavily relied on a landline teleprinter network called the Aeronautical Fixed Telecommunications Network to transmit observations data and receive weather bulletins. When internet became available, DMOs switched to using dial up connectivity to send observation data via email. This became an issue for many islands due to the lack of resources both on the service provider and the user side. Internet service providers (ISP) oversubscribed available capacity; there were ongoing technical problems within ISPs; exposure to viruses and cyber threats; connectivity was expensive; and messages were not delivered on time or failed all together to be delivered. Many DMOs also did not have the financial capacity to support robust internet service, and little capability to reach the most remote areas in the region. The lack of availability of power, technical resources contributed to the lack of adoption. In efforts to enhance the capacity of DMOs to support operations during disasters, RANET was explored as an option for sustainable ICT4DM to be adopted for the Pacific.

By 2003, a RANET Pacific Steering Committee was formed to immediately asses and identify options for implementation of RANET in the Pacific to support weather and disaster management operations. It should be noted that while RANET began as a technical network of communication systems, it is also a collaborative network with principles of operations centralizing around people. The RANET Pacific Steering Committee adopted the following principles – collaboration with and with the approval of the communities and technical communities, associated services, and stakeholders; build upon existing community strengths and systems; encourage local ownership and use of communication systems for multiple purposes such as distance learning, telehealth, community outreach; and to build upon and augment existing networks and means of communications.

The RANET Pacific Steering Committee initiated demonstration projects to implement high-frequency (HF) radio digital email and satellite digital email. HF Email is a two-way communication capability to send and receive email via a HF radio. This design takes into account existing HF radio networks already operational within DMOs and the familiarity of staff with operating HF networks. By 2006, the network was in full swing with pilots in Vanuatu, Niue, Cook Islands, Tokelau, Kiribati, Tuvalu, and by mid late 2000s, the network was operational with rebroadcast FM Radio Stations, solar power and a number of community users.

The core systems were funded by United States Agency for International Development Office US Foreign Disaster Assistance (USAID/OFDA), NOAA, the Australia Bureau of Meteorology and Australia Agency for International Development (AusAID); the New Zealand Meteorological Service; New Zealand Agency for International Development (NZAid); UK Meteorological Service; UNESCO IOC and others. However, significant in-kind support, in-country and local resources, and donation of commercial services makes RANET what is truly is, a network of people. The region had undergone restructuring in many aspects of regional, donor and allied support and unfortunately, several funding streams were no longer available to support RANET. The regional steering committee with multi-lateral representation also underwent changes and become the RANET Pacific Working Group of volunteers. To present date and time of writing, the US has continued to sponsor the development, upgrade and expansion of RANET systems through different over the years.

5.2.1.1 University of Hawai`i Telecommunications and Social Informatics Research Program (UH TASI)

Formerly known as the Pan Pacific Education and Communication Experience by Satellite (PEACESAT 1968-2012) / Telecommunication Information Policy Group (TIPG), the principal purpose of PEACESAT is to support and promote development in the Pacific Region through public service telecommunications, using decommissioned weather satellites. Between 1971 to 1985 (16 years), the PEACESAT program used the first series of retired NASA satellites, ATS-1 NASA and between 1987 to 2012, transitioned to using the NASA GOES series to provide public service voice, video and data to support health, education, disaster management, policy and economic development in the Pacific Islands. The University of the South Pacific Net (Disaster Education Network of the University of South Pacific) and the Forum Fisheries Agency (FFA) were the major users of the PEACESAT network. PEACESAT offered free satellite network, not only for telephone communications but also the very first data and video transmission in many of the FFA member countries.

By the early 2000s, the PEACESAT/TIPG program evolved and expanded its services from being a network architect and operator of technology to a focus on applications and delivery of services via improved broadband services. PEACESAT rebranded itself to the Telecommunications and Information Policy Group (TIPG) with a focus on applications, building and implementing training and capacity building programs in rural and remote communities and in Hawaii and the Pacific Islands. TIPG would later become UH TASI who objective functions are to conduct, facilitate and support basic and applied research into ICT policy, regulation, technology systems and applications and share its knowledge through education, training, workshops, and other program activities. Today, TASI's areas of research include distance learning, telehealth, disaster management, and Health Information Technology and its application in rural and remote communities within Hawaii and the Pacific Island economies.

5.2.1.2 RANET Pacific Working Group

In 2014, the UH TASI entered into an agreement with the NOAA/NWS Office of International Affairs to re-launch the Pacific International Training Desk (PITD) to support training in meteorology and messaging and the upgrade and expansion of RANET systems. UH TASI was in a position to support the equipment and training needs for given its history of using weather satellites and capacity building partnerships in the region with the PEACESAT network. The PITD began in 2001 as two-month, one-on-one internship at the WFO Honolulu, and was eventually trimmed to six weeks. Training was expanded in 2010 to include two trainees from a single country at a time, as well as including participants from RA II member countries, such as Vietnam, Cambodia, Indonesia, and Malaysia. Participants came with a wide variety of knowledge, abilities, and educational and vocational backgrounds, from directors to observers.

The PITD is supported by the NOAA/NWS International Activities Office (IAO) and Pacific Region Headquarters (PRH), and hosted by the NWS Honolulu and Guam Forecast Offices. The training curriculum covered a range of general topics including stability, satellite interpretation, numerical weather prediction, tropical weather analysis and forecasting. The content was also highly tailored, individualized, and practically relevant; the curriculum was primarily focused on enabling participants to prepare and disseminate local forecasts for their home area of responsibility   The extensive hands-on component of training made use of tools and operational aids available to each country, and in nearly all NMHS offices, this was limited to weather information publicly available online, because South-Pacific NMHS did not have integrated data and forecast systems and are limited by extremely narrow bandwidths.

The PITD is structured differently from the National Centers for Environmental Prediction (NCEP) international desks in terms of the education and experience of the participants, the length of training, and operational products. The mission of the PITD, however, is similar - to build capacity in the meteorological services of Pacific Island nations. This is accomplished through online prerequisite modules on fundamental meteorology, a four-week on-site analysis and forecast training program at the NWS Forecast Offices, and ultimately in-country workshops on advanced and specialized topics. Significant recent milestones include a complete program review and redesign. Administration was restructured and formalized, the curriculum was standardized and assessments were developed, and additional training components were added, notably in communications systems such as RANET Chatty Beetle, RAPIDCast, Short Messaging System (SMS) messaging, and web development. The PITD site in Guam was launched to serve the Weather Service Offices in the Freely-Associated States in the Northwest Pacific, with fifteen participants from the Federated States of Micronesia, the Marshall Islands, and Palau completing the program since its opening in 2016.

5.3 Technology Deployed through Pacific RANET Working Group 2006-2022

The following section describes RANET satellite technologies deployed to the Pacific Region to support DMOs through the RANET Pacific Working Group. This dissertation acknowledges the fact that there is a great diversity of ICT4DM utilized by the DMOs community at large, however the emphasis here is on systems more appropriate and historically effective in PICT. Furthermore, the systems covered here are those that support basic data and product access for meteorological services, as well as systems designed to for dissemination of information from, or communication between, meteorological services, emergency management entities, and remote communities.

5.3.1 HF and VHF Networks

Despite being an old technology, it is reliable when operated correctly, and it allows easy cross operation with other organizations and entities, such military and coast guard / search and rescue units. While some upkeep issues have arisen, a lot of this is associated with training for hub and station operators. With support from USAID, AusAID, and NZAID, RANET has over the years supported the deployment of HF and VHF digital networks. These support search and rescue operations, remote communication, and data collection. In the northern Pacific the network went through a refresh in the last few years. Figure 10 provide a diagram of HF and VHF network connectivity.

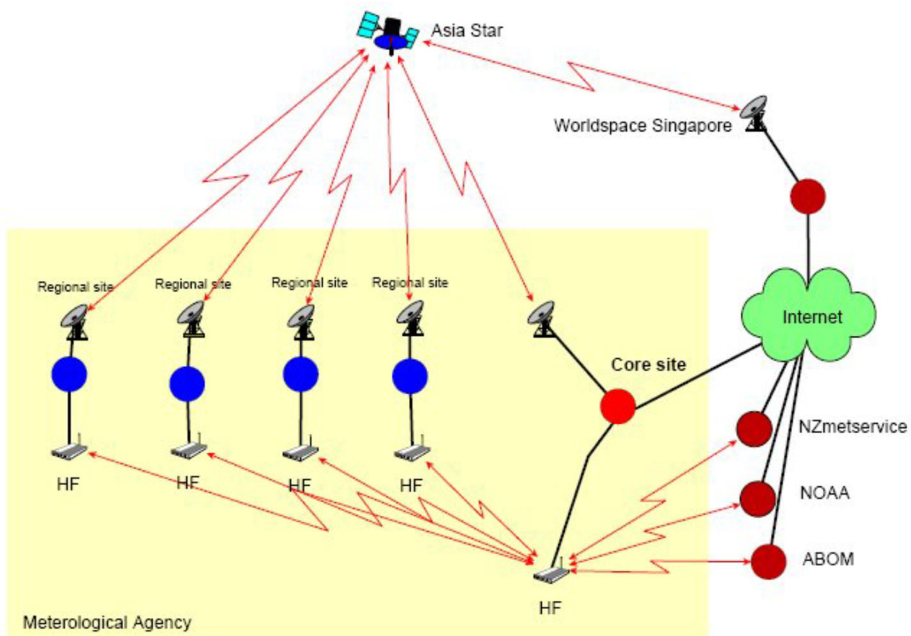

Figure 10. HF and VHF Network. Source: Pacific RANET Working Group.

5.3.2 Chatty Beetle

Chatty Beetles are a two-way text messaging systems designed for remote applications where there is no other communication means, or where it is unreliable, or where simple notification is required. It is also designed to provide weather alerts to remote locations where communication options are limited via Iridium Short Burst Data (SBD). It serves as a "heads up" alert device to give communities basic alerts of potential hazards. Also, it supports two-way messaging, allowing operators to provide status reports and other field observations. Messages are sent and received from each terminal through the Iridium Satellite. The RANET gateway reads the message, interprets its routing info and any special commands (e.g. alert level), then sends it back to intended terminal. With this device, early warnings of climate change, weather, and hydrometeorological events can be disseminated to remote locations in areas with limited connectivity in order to save lives and minimize losses. Figure 11 illustrates a chatty beetle connectivity flow.

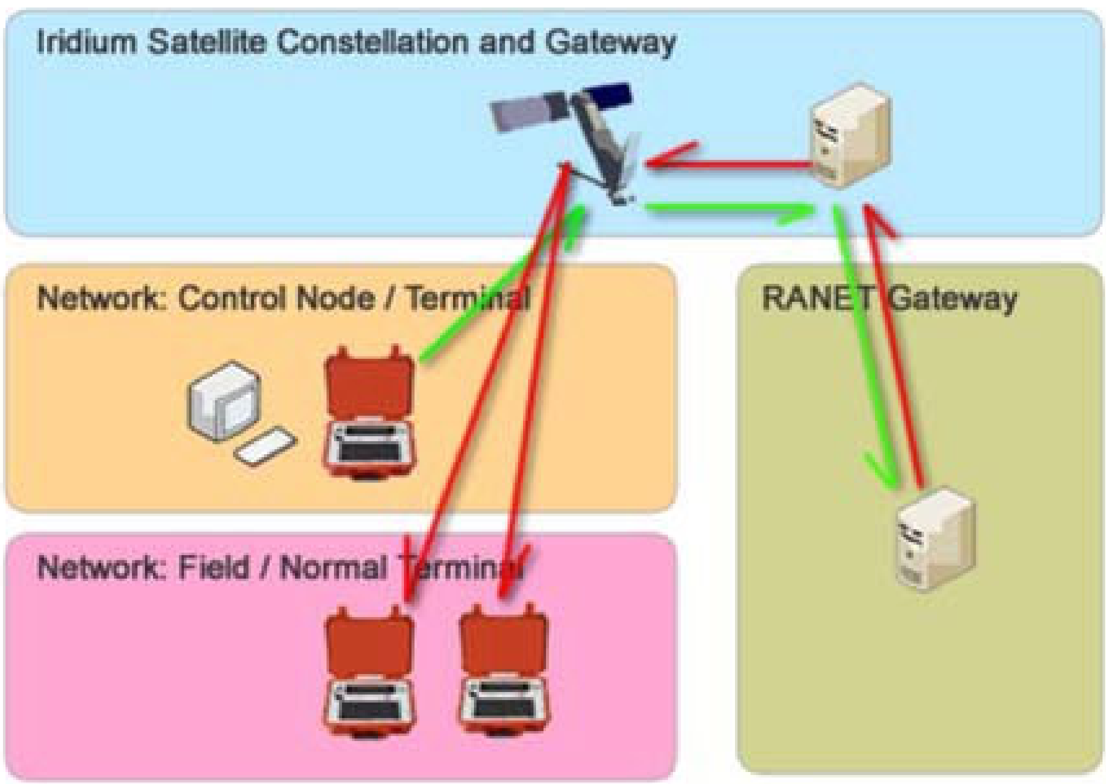

Figure 11. Chatty Beetle Connectivity Diagram. Source: Pacific RANET Working Group

The concept for the Chatty Beetle came from discussions the RANET Pacific Steering Committee had with Pacific Islands Disaster Managers. There was no way to wake up residents in remote islands in the middle of the night to warn them that a tsunami was approaching. The RANET Team developed a ruggedized platform using Iridium Short Burst technology for the harsh, humid conditions in remote Pacific islands. HF are turned off at night to conserve power, and satellite dishes and large antennas are stored to prevent damage from the impacts of tropical cyclones. This has resulted in improved services and timely receipt of weather and climate forecasts and warnings.

The US has deployed over 100 Chatty Beetles to the Pacific since 2003 throughout the Pacific Region in countries including: American Samoa, Australia, and Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Kiribati, New Zealand, and Republic of the Marshall Islands, Republic of Palau, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. Table 5 includes a list of units per country. UH TASI is responsible for the deployment and maintenance of the Chatty Beetles since 2012. This includes the troubleshoot of hardware and software errors.

Table 5. Chatty Beetles Deployed to Pacific Region	
Chatty Beetles	**Total Units in Country**
Australia	5
American Samoa	3
Chuuk, FSM	1
CNMI	2
Cook Islands	0
Fiji	4
French Polynesia	0
Guam	3
Kiribati	7
Marshall Islands	19
Nauru	0
New Caledonia	0
Niue	4
Palau	2
Papua New Guinea	0
Federated States of Micronesia	8
Samoa	3
Solomon Islands	8
Tokelau	0
Tonga	10
Tuvalu	15
Vanuatu	2
Yap, FSM	2
TOTAL	**98**

Table 5. Chatty Beetles Deployed to Pacific Region Source: Author's consolidation based on semi-structured interviews and review of various documents.

5.3.3 Emergency Managers Weather Information Network (EMWIN) / High Rate Information Transmission

The EMWIN system is direct service that provides users with weather forecasts, warnings, graphics, and other information directly from NOAA / NWS utilizing the GOES West and East satellites. The GOES EMWIN relay service is one suite of methods to obtain these data and display the products on the user's personal computer. The HRIT service **p**rovides broadcast of low-resolution GOES satellite imagery data and selected products to remotely located user HRIT terminals. Table 6 includes the list of EMWIN and HRIT units deployed to the Pacific Region.

Table 6. EMWIN Deployed to Pacific

Country	Description
American Samoa	EMWIN Only
Cook Islands	HRIT and EMWIN
Fiji	HRIT and EMWIN
Kiribati	HRIT and EMWIN
Marshall Islands	HRIT
Nauru	EMWIN Only
New Caledonia	-
Niue	HRIT
Palau	-
Papua New Guinea	HRIT and EMWIN
Federated States of Micronesia	HRIT
Samoa	HRIT
Solomon Islands	HRIT
Tokelau	-
Tonga	EMWIN/HRIT
Tuvalu	HRIT
Vanuatu	HRIT

Source: Author's consolidation based on semi-structured interviews and review of various documents.

5.3.4 Remote Asia Pacific Information Dissemination BroadCast (RAPIDCast)

The Pacific region is known to have remote populations separated by vast distances. Communications in the Pacific are often expensive yet not a robust service, and there is a recognized need to have basic meteorological alerts and routine weather information received on a regular basis and to have it disseminated to major Pacific Island cities and remote communities alike. RANET responded to this need. The RAPIDCast has the simple goal of providing remote areas of the Pacific with access to warning, agricultural, and related information. One of the potential solutions was RAPIDCast. RAPIDCast is a KU Band satellite broadcast service for the Pacific region, and it is designed to deliver alerts and notifications, as well as routine forecast and related information to rural and remote islands.

RAPIDCast originally started as a 3-year pilot / demonstration project with funding provided by USAID/OFDA in partnership with NOAA NWS (IAO, PR HQ) and Australia BoM. RANET began testing and refining the RAPIDCast broadcast project in 2011. The broadcast project uses a low cost 1.2-meter ground station to receive data. The RAPIDCast system is modeled, in part, off of the GEONETCast system. In late 2012, a site was successfully setup and tested at the UH TASI. The program confirmed that the ground station configuration would work with 15 ground stations ready for the Pacific. It was anticipated that RAPIDCast would begin broadcasting a Pacific sub-set of EMWIN. RANET expects to work with both NOAA and JMA to get appropriate satellite imagery products. For RAPIDCast RANET will also utilize the regional satellite data requirements, related surveys, and will consult with regional partners, such as SPREP and WMO experts, to identify content to place on the broadcast. See Figure 12 for a RAPIDCast network model.

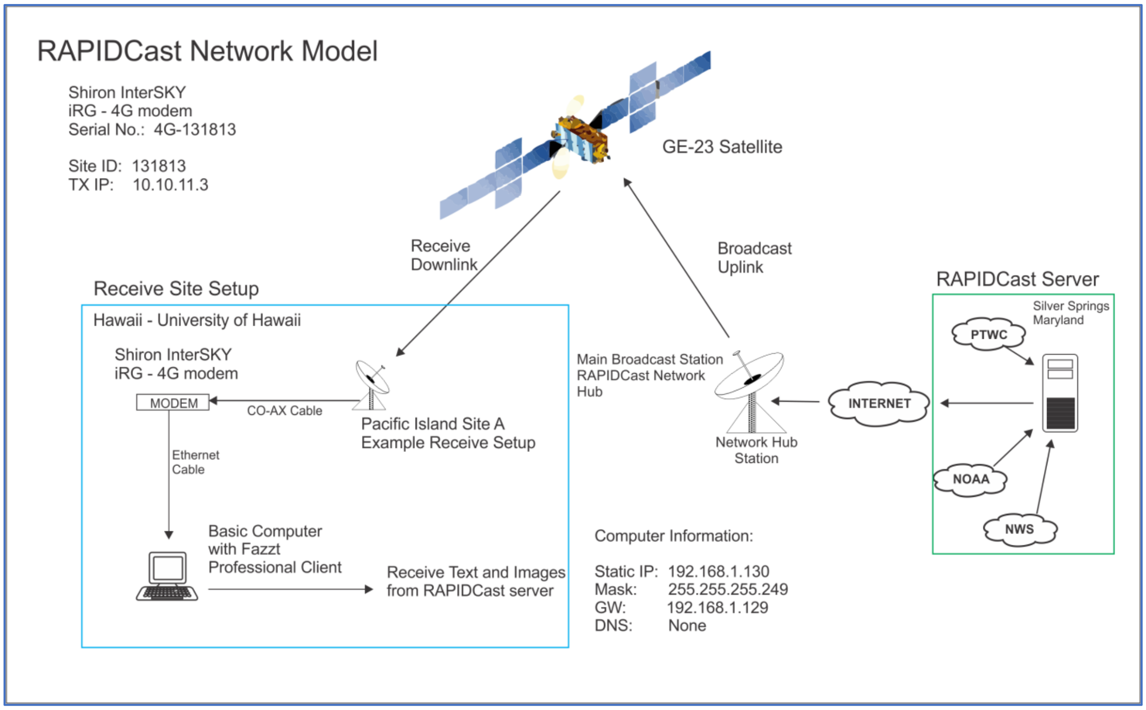

Figure 12. RAPIDCast Network Model. Source: Pacific RANET Working Group

5.3.5 Delorme inReach Satellite Communicators

The Delorme inReach SE is a two-way messaging device that works anywhere in the world. It allows for the use of SMS text messages, can trigger an SOS warning, and gives the ability to share and track your movements, drop locations and share these coordinates with others. InReach operates on the Iridium satellite network which includes 100% global coverage. It can be used on land, sea or in the sky. The inReach handheld devices are designed to be outdoors and to withstand rugged terrain. They are portable and hand-held devices that are durable and water resistant (water rating of IP67). The inReach device has the ability to trigger an SOS alert and receive delivery confirmation of the SOS at any time. This alert will connect with GOES emergency monitoring. This emergency monitoring is available 24/7 search and rescue monitoring center This device offers 100% global Iridium coverage. The iridium satellite network covers the entire globe meaning there is no place the inReach device will be without coverage. Messages can be sent from the device to an email address or through SMS text messaging. There is also the option to send messages from one inReach to another. SMS availability depends on the country's providers and satellite plan. The device will make a noise alert when it receives a message. Continuous tracking of your GPS location, which includes elevation land and speed with others. The user interface on the home screen shows an option to share your location. Your current location can be sent to any of the contacts synced to the device, or a contact you enter manually. The inReach device can pair with Bluetooth enabled smartphones including both Android and iPhone models. Through the Earthmate app, there is access to downloadable maps including NOAA charts and color aerial images. Messages can be pre-set and sent through the app, or typed out on the mobile device. Your GPS location can also be shared through this app. Syncing a smartphone with the app can import contacts to the inReach device.

5.3.6 SMS Alert Watch

The RANET SMS Alert Watcher began shortly after the 2004 Indian Ocean tsunami. It receives messages from the Pacific Tsunami Warning Center (PTWC) and pulls out key information --such as earthquake magnitude, timing, message type, and location – to be sent as a 140-character SMS (text message) to mobile subscribers. In short it operates as a heads-up system alerting users to seek more detailed information from the PTWC and other authoritative sources. Subscribers are limited to professionals such as national watch authorities or emergencies managers. In October 2014, the service stopped due to significant message format and terminology changes with the PTWC released messages. The hope is to restart the service with new features, as well as the ability of national points of contact to assign and manage users via a web interface.

CHAPTER 6.0 –FINDINGS - CAPACITY GAPS & ELEMENTS OF RESILIENCE

This section aims to provide the following:

- *Inventory of communication systems utilized in weather and disaster management operations*
- *Summary of the technical, cultural, institutional and political challenges to integrating ICT4DM*
- *Role of ICT4DM in building disaster resilience*

Planners play a critical role in identifying capacity gaps in communication ICT4DM and advocating for approaches that make technology usable and operational within organizations and communities. Planners can also be a valuable link between disaster management operations and ICT4DM developers by understanding workflow processes, local context, serving as a technical advisor and facilitator to bridge systems and technologies, and users. Planners working in the Pacific Islands must be aware the capacity gaps and ways disaster management through external aid and donors may sometimes hinder planning, integration and e-resilient of ICT4DM at the local level. E-resilience is defined in this dissertation to mean enhancing the capacity of people to be able to cope with service outages and technology failures. Elements of resilience such as self-organization, self-governance, new communication patterns, integrated networks at the local level emerge with the failure of structural and non-structural planning and infrastructure. To achieve smart sustainable development and resilience, one must address the root cultural, technical, institutional, and political gaps associated with the integration of ICT4DM.

This chapter summarizes the main findings, conclusions and capacity gaps within the context of the 2009 TAS and the 2022 HTHH. In many aspects, island communities are underserved in areas of health, education, economic development and ICT. However, there are also numerous opportunities to learn from island communities (Kim & Freitas, 2018). Specifically, this chapter will approach the research questions from the technical perspective network operators, technicians, systems administrators and developers of ICT4DM deployed to support disaster communications in DMO.

6.1 Research Question #1 (RQ#1): What cultural, institutional, political and technical factors influence the integration of ICT in disaster management operations in PICT?

The advancement of ICT4DM has significantly improved services in all phases of disaster management, however, to effectively integrate technology into DMO, it requires a mixture of cultural, institutional, political and technical interventions to succeed. It also requires coordination between multiple stakeholders, such as governments, private sector, civil society, academia, media agencies and volunteers. ICT4DM is not only about the technology, but it is also about the people and process. ICT4DM is about identifying needs, gaps and capacities and assessing which technologies will enhance DMO capacity and meet objectives. Assessments may also find that ICT4DM are not required to effect change and achieve goals in building community resilience. There are many factors that challenge the implementation of ICT4DM, evident of the 2009 TAS and 2022 HTHH.

To address the first RQ1, a baseline of communication ICT4DM currently deployed in the region was derived from interviews and an updated assessment done as part of my work with the Pacific International Training Desk. The general inventory of communications systems used in disaster management operations, inclusive of hydro-meteorological and geological operations is summarized in Table 7 and 8.

Table 7. Primary Systems of Communications in DMO in PICT (Source: RANET Working Group Survey August 2022)

Capability	**Primary Communication ICT4DM for DMO in PICT**
Voice	Mobile, Voice-over-IP, Amateur radio – VHF, UHF, HF Radio
Video	Broadband internet via fiber
Data	Broadband internet via fiber, Microwave satellite communications
Text-based communications	Email, Apps (WhatsApp, Viber, Messenger), SMS

- For voice capabilities – Mobile and VOIP technologies are primary and Amateur radio – VHF, UHF or HF Radio remain the primary form of voice communications in many remote islands absent of mobile networks and high-speed broadband internet connectivity.
- For text-based communications, email is the primary form of communicating with other partners to coordinate DMO and to disseminate information to the general public. Secondary is texting via application like WhatsApp, Viber, Messenger and wireless texting via mobile network.
- For data capacity, broadband internet via fiber optics is the primary form of transmission and receipt for many of the main islands with microwave satellite communications connecting remote island communities.
- For video, Zoom is the most popular application for video conference.

Table 8. Communication-based ICT4DM used for DMO in Pacific

(Source: RANET Working Group Survey August 2022

Table 8. Communication Systems used for disaster management in the Pacific	
County	**Communications Systems**
American Samoa	• Internet – Broadband, microwave, undersea fiber optic, O3B satellite • Mobile • Landline • Chatty Beetles • AWIPS • NOAA Weather Radio • FirstNet • Amateur radio – VHF, UHF or HF Radios • Social Media • Radio – AM/FM • Satellite systems – EMWIN, HIMAWARI
Cook Islands	• Amateur radio – VHF, UHF or HF Radios • EMWIN • Broadband Internet • Social Media • Satellite systems – EMWIN, HIMAWARI
Federated States of Micronesia	• Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system • Social Media • Satellite systems – EMWIN, HIMAWARI
Fiji	• Amateur radio – VHF, UHF or HF Radios • Chatty Beetles • Satellite Phones • Broadband Internet • Social Media • Satellite systems – EMWIN, HIMAWARI
Guam	• Internet – Broadband, microwave, undersea fiber optic, satellite • Mobile • Landline • Chatty Beetles • AWIPS • NOAA Weather Radio • Social Media • Radio – AM/FM • Satellite systems – HIMAWARI
Kiribati	• Amateur radio – VHF, UHF or HF Radios

	• Internet • Social Media • Satellite systems – EMWIN, HIMAWARI
Marshall Islands	• Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system • Social Media • Satellite systems – EMWIN, HIMAWARI • VSAT, BGAN • RICS
Nauru	• Telephony – Landline, Mobile • Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS
Niue	• Amateur radio – VHF, UHF or HF Radios • Internet • Satellite systems – EMWIN, HIMAWARI
Palau	• Amateur radio – VHF, UHF or HF Radios • NOAA Weather Radio
Papua New Guinea	• Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS • Satellite Phones - Iridium •
Samoa	• Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS • VSAT • Chatty Beetles • Mobile / Landlines • SMS • Mobile Applications
Solomon Islands	• Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS • Internet – DSL
Tokelau	• Amateur radio – VHF, UHF or HF Radios • Internet – Satellite RICS • VSAT
Tonga	• Amateur radio – VHF, UHF or HF Radios • Chatty Beetles • VSAT, BGAN • Satellite Phones - Iridium • Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS

Tuvalu	• Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS • Amateur radio – VHF, UHF or HF Radios • Chatty Beetles
Vanuatu	• Amateur radio – VHF, UHF or HF Radios • Internet connectivity – fiber optics, digital microwave systems, satellite system, RICS

Further to the inventory of communication ICT4DM, RQ1 solicits the challenges and gaps in policies, technology, culture and institution to the integration of ICT4DM. Figure 13 provides an illustration of the capacity gaps gathered during the course of this dissertation through semi-structured interviews. It highlights some of common and similar challenges that hinder the integration of communication ICT4DM in DMO, evident of the two events discussed. As stated earlier in this chapter, ICT4DM is not only about the technology, but are also about the people and process. The responses are not just about the technology or the technical specifications, but about elements of culture and the capacity of the community as a whole. This becomes apparent in the responses of the technical personnel interviewed.

A view of ICT4DM Capacity Gaps in Pacific Disaster Management Operations

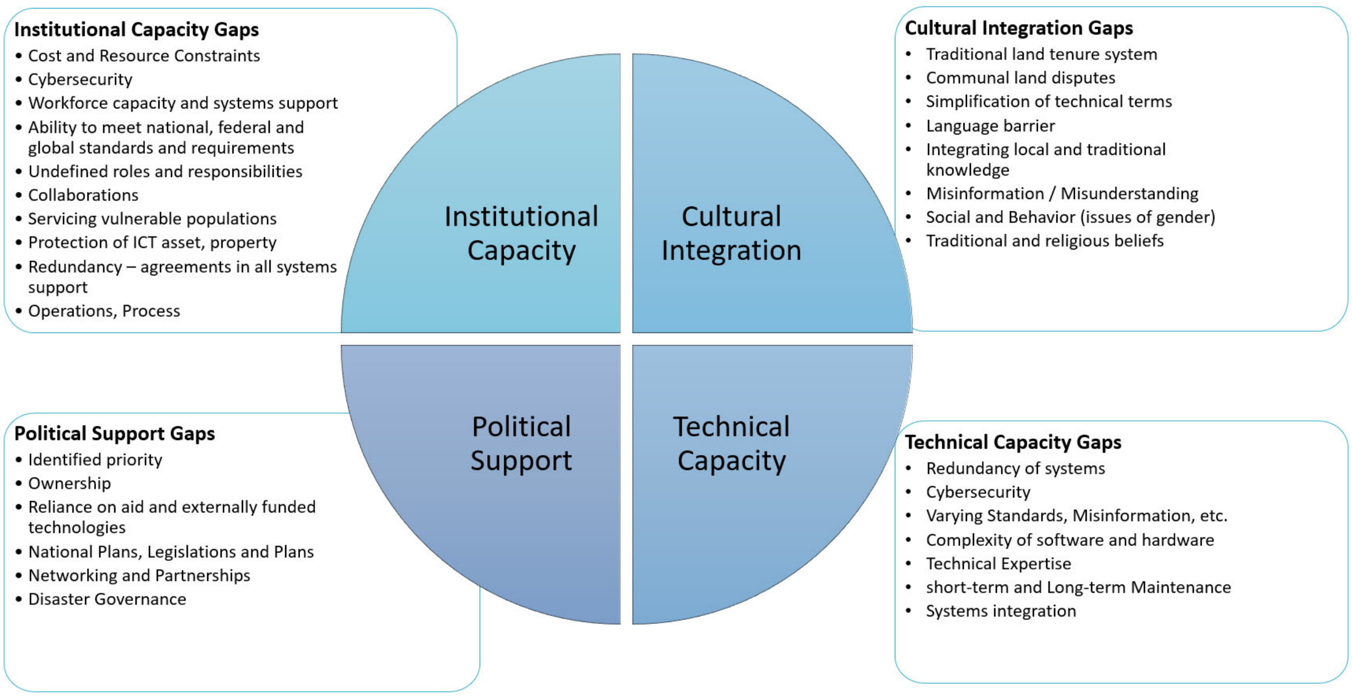

Figure 13 A view of ICT4DM capacity gaps in Pacific Disaster Management Operations based on semi-structured interviews. Author developed.

6.1.1 Institutional Capacity Gaps

Protection of ICT infrastructure against disasters: Short- and Long-term maintenance are ongoing issues in the Pacific Region. It is a combination of the availability, lack of, equipment parts and materials needed to maintain and upgrade system within the region. This also becomes an issue of supply chain and transportation. In addition to supply chain issues, there is also the need for funding for maintenance. US federal and external donor funded projects do not allow for the long-term maintenance of systems. While the SSDM addresses the need for multi-purpose and multi-function ICT4DM, there still exists a gap of long-term maintenance.

a. **Redundancy in all ICT4DM:** Redundancy is a topic covered across all areas of ICT4DM. The need for redundancy in the form of ICT4DM including communications systems, power utilities, information systems, off-site or remote systems, were identified as areas of critical needs and concerns. At an institutional level, the need for formal arrangements for alternative communications with outside sources/partners and with other countries was also shared. During the 2022 HTHH, while the Chatty Beetle satellite communications system was used immediately when both the off-island and domestic submarine cable was severed, other systems were inoperable and not maintained for various reasons (awaiting parts for repairs).
b. **Workforce capacity:** There is an ongoing need for qualified technical personnel who can assess functionality and maintain existing communication ICT4DM. Many of the local technical staff have received on-the-job training but no formal education or certification in ICT. The technical staff identified the need for training for systems and technical staff at all levels – introductory, intermediate and advance to support systems and networks for disaster management.
    - A related challenge to systems maintenance is the availability of vendors due to timezone differences. It is a seven-hour time difference between East Coast US and American Samoa and a 14-hour difference between US East Coast and Guam. This leaves little overlapping hours of operations to support the Pacific Region.
c. **Cybersecurity Policies:** An area of growing concern with having ICT4DM in operations in cyber threats. One interviewee jokingly said, weather data can become a weapon of mass destruction. In the instance that unwarranted access to weather and climate data can

be used to mislead people, it can become a weapon of destruction. With the rise of fiber optics and access to broadband internet, there is a need to cybersecurity policies and systems in place. Currently limited policies, regulations and laws governing ICT4DM is available in PICT.

d. **Administrative Burden and Access to funding:** There are a significant amount of funding available through external aids to procure communication ICT4DM such as Green Climate Funds, United Nation Development Program, Bi-lateral agreements, US federal grants, however, it is notable that many of the administrative and funding requirements are cumbersome and become administrative burdens to smaller DMOs. This not only discourages local communities from seeking assistance but also delays planning and recovery.

e. **Process to service vulnerable populations:** Interviewees acknowledge the lack of accessible ICT4DM, communications and services to reach all populations within their community including people with disabilities, bed ridden, and non-English speaking.

f. **Defined roles and responsibilities:** Throughout the region, countries have made significant progress in the development of their national disaster management plans, legislations and/or frameworks. American Samoa follows the Incident Command structure, while Tonga and Samoa follow the UN Cluster System. Regardless, these systems identify roles and responsibilities of each cluster or support functions.

6.1.2 Cultural Capacity Gaps

a. **Traditional and Communal Land ownership:** One of the most common issues discussed in relation to cultural factors impacting the integration of technology is that of traditional and communal land ownership. Customary lands often underpin Pacific societies' cultural and socio-political frameworks. In American Samoa, for example, where 94% of lands are under customary tenure, all chiefly titles are attached to customary lands (Tufele 2008; Stover 1999). Chiefs (Matai) of village clans are the legal owners of these lands, who owe fiduciary duties to the intended beneficiaries of the lands: villages, clans or extended families. The authority and power of Matai is, in part, determined by their control of these lands. Respondents reported the push back from matai(s) whose land were identified as sites to build antennas and other structures for communication ICT4DM. Many times, a cultural mediation process would have to be conducted in order to use communal land to install antennas or other equipment. This causes the delay in projects. Other interviewees described experiences in which an antenna installation was halted due to land disputes between families in the village in which the equipment is installed in. This hindered the process of implementation for many months.

b. **Systems Technical Jargon and Linguistics:** Language was identified as a barrier to integrating ICT4DM across all phases of disaster. Manuals, resource documents, websites are in English and a few translated in other languages. As a result, technical staff require additional support and time to translate and customize documents and resources for local use. Interviewees alluded to the need to communicate using simple English terms as well as finding between connections between science terminology and technical language. In addition to internal operations, interviewees also reflected that most products are disseminated in English language. In many of the local communities, English is a not spoken or spoken as a second or third language. This hinders the integration of all aspect of disaster management, not limited to ICT.

c. **Integrate Local and Traditional Knowledge - Who are we building these systems for:** ICT4DM systems design, models and implementations do not account for elements of local and traditional knowledge including environmental factors and externalities. Issues such as patterns of impact, frequency of events, important points and landmarks within communities, migration of wildlife were among some of the examples provided. One of the notable examples shared was that of the installation of siren system and antennas was in the path of bird migrations in American Samoa.

d. **Managing Misinformation and Building Trust:** Ensuring that data and information provided was accurate is one of the most challenging tasks for ICT4DM operators. By the time the information is received by the community, the message has changed so much causing chaos and misinformation. Building a reputable of being a reliable source of information and the authority of the message is an ongoing challenge. Communication ICT4DM assists to build that trust between organizations and the general public.

e. **Community Buy-In and Support:** Community Buy-in and support is key component of building resilience (Bracht & Tsouros 1990). Interviewees stressed the importance of community participation and community acceptance as an important social process to bring planned improvements in community life, services and/or resources.

f. **Environmental conditions and externalities:** Conditions such eroded equipment, rust from salt spray, coastal erosion, sea level rise was identified as factors that challenge the integration of ICT4DM. It is recommended that systems design should consider extreme climate- and weather-conditions when designing technology to be deployed in the Pacific Islands.

6.1.3 Technical Capacity Gaps

a. **Network Redundancy:** The failure of essential services from critical infrastructure during disasters can impact populations by disconnecting and hindering their ability to respond and recover from an event. Critical infrastructure failures cause domino effects across communities and therefore crucial to understand to better prepare and design mitigation, response and recovery tactics. Enhancing e-resilience means enhancing the capacity of people to be able to cope with service outages both at a technical and social levels. Communication ICT4DM has failed DMO in terms of internet outage, or computer malfunctioning during times of forecasting which resulted in forecasts being sent late or no forecast at all. However, ICT and communication systems are now improving with new computers and internet outages are slowly being improved, but a backup plan/communication tool is indeed in need.

b. **Short-term and long-term maintenance:** Short- and Long-term maintenance are ongoing issues in the Pacific Region. It is a combination of the standardizing technology, availability, lack of, equipment parts and materials needed to maintain and upgrade system within the region. This becomes an issue of supply chain, transportation and supply chain. This also speaks to the need to upgrade local networks and systems and ensure that its has the security requirements (cybersecurity, etc.) so that data and information remain correct and accurate.

c. **Climate-Proofing infrastructure and building more sustainable communities:** Design elements to fit environment such as stainless steel, battery operated with solar panels, water and salt-spray resistant and many others.

Complexity of software and hardware: The installation, troubleshoot, integration and maintenance of ICT4DM many times would require a certified technician or a specialist to be able to fix. This is unsustainable as it disrupts operations and creates inefficiencies.

d. **Placement of technology:** The need to be strategic about the placement of technology so that there is backup mechanism to activate them in case one trigger fails there is another way to activate the technology. For example, for automated siren systems that is triggered by a system, backup triggers can be installed at identified backup locations so that it is accessible to authorities when needed.

6.1.4 Political Capacity Gaps

a. **Political Motivation:** While ICT4DM is recognized as a valuable means for economic development and disaster management in the region, it is poorly reflected in the means of laws and leadership and administrative priorities. Recognizing ICT4DM as an established priority means improving operations, transactions and funding consistent with market forces and responsive to changes and fluctuations in the region.
b. **Significance of Comprehensive Plans, Legislations and Laws:** National plans should highlight the need to prioritize ICT for improving operations and transactions in the region, especially in disaster communications. Communications during emergencies incorporate a wide range of measures to manage risks within communities and the environment. It encompasses the information disseminated by the government, responders, disaster managers, and other media.
c. **Networking, Partnerships and Collaborations:** The gaps in collaboration within agencies impacts the ability of disaster management agencies to operate effectively.

6.2 Research Question #2 (RQ#2): How does ICT4DM impact disaster resilience in Pacific Island communities?

The foundation to addressing this question stems from the ICT4D value chain that centers around readiness, availability, uptake and impact. To guide the conversation of resilience and ICT in this paper, the following adapted logic model and illustrative markers was used. Community resilience through ICT4DM can be summed up in four principles: multi-hazard, multi-technology, multi-phased, and multi-stakeholder. Timely, predictable and effective information is much needed by government agencies and other humanitarian actors involved in rescue operations and decision-making processes.

ITU (2022) further explains each of the categories as quoted below:

- Multi-hazard: Natural hazards include earthquakes, cyclones, floods, mud slides, droughts, tsunamis, volcanic eruptions, and fires. For all disasters that follow natural hazards, ICTs play a critical role in facilitating the flow of vital information in a timely manner.
- Multi-technology: In building disaster resilience, the use of different information and communication technologies and networks, including satellite, radio, mobile networks and the Internet, that can contribute to enhance capacity and reduce vulnerability of people is highly encouraged.
- Multi-phased: ICTs are critical at all stages of disaster management: mitigation, preparedness, response and relief, recovery and rehabilitation.
- Multi-stakeholder: The local community, the government, the private sector, disaster management agencies, meteorological organizations, civil society, humanitarian agencies and international organizations should ensure access to ICTs to better coordinate disaster management activities. Partnerships are the best way to achieve this task.

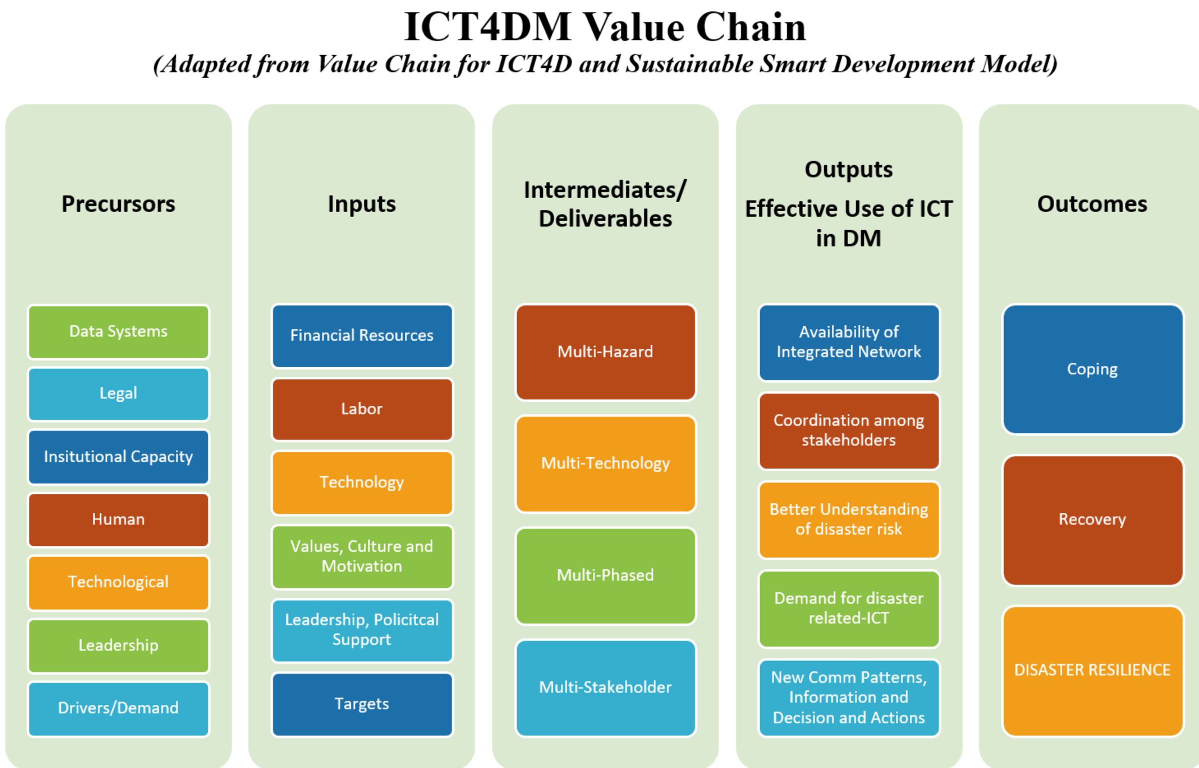

Figure 13. ICT4DM value chain used in this study, adapted from ICT4D value chain and SSDM.

Recalling RQ2, *how does ICT4DM impact disaster resilience in Pacific Island communities*, evident of the 2009 American Samoa Tsunami and the 2022 HTHH, the question is approached based on the outputs of the adapted ICD4DM. The added values of the lessons learned from these events will help communities to build back better with e-resilience. E-resilience is defined in this dissertation to mean enhancing the capacity of people to be able to cope with service outages and technology failures the connectivity, quality and stability of ICT4DM infrastructure and networks. Table 9 provides a summary of findings against identified elements of resilience based on the outputs illustrated in Figure 13.

Table 9. Database of Findings

Output			
Availability of Integrated Communication Networks	The 2022 HTHH and 2009 Tsunami in American Samoa highlighted the need to have an integrated communications network beyond the traditional modes of voice, video and data. This may include various forms of traditional communications and alerts within a community. American Samoa and Tonga in both events relied heavily on formal communications, mostly broadband-based communications for data transfers, email, online services, telephony, social media, mobile, radio, all of which failed during the two events. Relative to the availability of integrated communication networks, these elements of resilience were derived and identified as impactful and value added to build community resilience.		
	Element of Resilience	**Issue**	**Next Steps**
	• **Functional ICT systems** – Implementation of temporary and mobile communication systems for operations. The dependance on external aid or in instances where ICT systems are purchased based on funding requirements has led to 'mis-match' or non-functional ICT systems implementation.	• Funding requirements based on sponsor needs versus local situation • These systems become idle during events and at times are not functional.	How do we integrate the various assessments already completed to better identify functional ICT systems rather than re-do assessments?
	• **Robustness** – The ability of DMO/Met Offices to maintain its performance and characteristics during disaster. Fiber optics network was severed during the 2022 HTHH and communication systems were overwhelmed during both events, operations including data collection, reporting, and locally operated systems continued operations.	• Physical Preparedness – A similar problem is power failure in both events. • Institutional Capacity • Multi-Level Governance • Not enough capacity	For effective disaster risk management, an integrated system is indispensable, both in terms of communication channels as well as involving diverse groups of stakeholders.

• **Traditional forms of communications** – Interviewees stressed the importance of integrating local forms of communications not just the physical aspects but also oral traditions. The ringing of the bells (oxygen tanks), *pate* (wooden or bamboo drums) and 'apa (large tin containers or oil bins) remains an effective way of communicating pre-, during- and post-event in both instances. These traditions remain effective. In 2009, there was no early warning from the government for the American Samoa tsunami event. Villagers rang the bells in attempt to evacuate people.	• Innovative means to include traditional knowledge • Technology dependence	In both American Samoa and Tonga, what cultural practices do we want to prioritize and how can these lessons best be perpetuated in the future? How can warning system of local governments and villages be made efficient so that it can reach all residents?
• **Village-centric information dissemination** – Due to failed structural/ICT based communications, the dissemination of information was funneled through village councils.	• Dissemination of information were dependent on structural systems such as NOAA weather radio, radio, TV, internet, most of which failed.	Community involvement in planning, Ongoing relationship building Implement strategies to increase digital literacy
• **Consistency and Stability** – DMO/Met Offices remained connected through limited backup communications, local mesh network, peer-to-peer and cashe data. Traffic was prioritized by local carriers for disaster management, coordination efforts.	• Instability of ICT4DM systems and infrastructure • Consistency of information distributed were inaccurate, delaying response.	
• **Accessible Communication –** ICT systems used must be accessible and functional for users. Addressing accessible issues for vulnerable		

	populations including the elderly, people with disabilities were highlighted as failures in both events.		
	• **Affordability of broadband services** – The availability of an integrated communication network is also an issue of infrastructure affordability. Although fiber optics has improved the capacity and access to internet, costs remain a limiting factor. DMO/Met Offices have limited bandwidth to support operations. At the time of the event, DMO/Met Offices on average were paying up to $12,000/month for internet connectivity.	• Financial resource constraints	
	• **Redundancy of communication systems** - Extend to which components within a system are substitutable;	• Resource Spareness • Functional Overlaps and Interdependency • Resource Substitutability	
Coordination amongst stakeholders	The efficiency, sharing of data, dissemination of accurate information, and the role of stakeholders in mitigation, planning, response, recovery is critical component to building community resilience. These elements of resilience Value added Relative to the availability of integrated communication networks, these elements of resilience were derived and identified as impactful and value added to build community resilience.		
	Element of Resilience	**Issue**	**Next Steps**
	• **Self-Organization** –Ability of the system to independently rearrange its functions and processes in the face of an external disturbance, without being forced by the influence of other external drivers. In the aftermath of both the 2009 TAS and 2022 HTHH,	• Collaboration and Consensus-Building • Social Networks • Local Leadership and Trust	
	• **Improved quality and quantity of communicating –**Technological innovation improves and expands the outreach to communities and rural areas. Social media in not only an		

	effective tool for monitoring and engaging public discourse but also enables a cultural shift regarding		
	• **Need for disaster communication protocols at the village level**	• Communication failure	How to setup disaster communication protocol so that there is no confusion and to prevent duplication of efforts at the local level.
	• **Emergency Operation Center / Clusters at village levels –** Pulenuu or village mayor is central to DM and should be placed in a accessible location in the village.		
	• **Public-Private Coordination**		• Public-Private Coordination
Better Understanding of Disaster Risk	Understanding the probability of harmful consequences or losses (deaths, injuries, property, livelihood, economic activity or environmental damage) at a local level		
	Element of Resilience	**Issue**	**Next Steps**
	• **Culture of communication that values proper information management and inclusive information sharing** - The advancement of ICTs has made DM easier, but procuring the technology alone is insufficient-it requires a mix of political, cultural and institutional interventions, and coordination between governments, corporate sector, civil society, academia, media agencies and volunteers. ICT for DRR initiatives is more about people and processes than about the technologies.		
	• The ability of vulnerable communities to adequately prepare for these threats can drastically reduce casualties through timely planning and evacuation (Izumi et al., 2019).		

Demand for disaster related-ICT	Current telecommunications infrastructure is extremely vulnerable to disaster impacts. This is compounded by aging infrastructure, poor maintenance and reinforcement as well as the location of critical telecommunications infrastructure in hazard prone areas. These findings have been a constant theme noted in both the 2009 Tsunami in American Samoa and the 2022 HTHH eruption and tsunami. The demand for disaster related ICT and their e-resilience is pivotal to ensuring the DMO/Met service operations and the delivery of telecommunications services to all citizens, particularly in the wake of large-scale disasters.		
	Element of Resilience	**Issue**	**Next Steps**
	• **Multi-Hazard Early Warning System** - The significance of advance warning of approaching weather-related hazards cannot be overstated. This is of importance to the Pacific region in general countries given that a large percentage of the population resides in coastal areas. Early warning systems and their attendant inputs are essential tools for managing disasters operations.		
	• **New technology -** Improvements in forecasting capabilities and accuracy are obtained through the collection of wind data from doppler radar, streamflow and rainfall gauges, as well as automatic weather stations.		• Enhanced cooperation by formalizing agreements and frameworks between telecommunications sector and DMO/Met Service
	• **Multi-technology communication system** – During the 2009 tsunami, communication system was not working: neither telephone nor radio.	• Communication system failure	• Improve telecommunication system – how do we handle communications when systems are overwhelmed? Who monitors and reports the situation to relay message to

			emergency response team? • Implement FirstNet network – a system provided by local service provider and prioritizes traffic for First Responders.
	• The advancement of ICTs has made DM easier, but procuring the technology alone is insufficient-it requires a mix of political, cultural and institutional interventions, and coordination between governments, corporate sector, civil society, academia, media agencies and volunteers. ICT for DRR initiatives is more about people and processes than about the technologies.		
	• Information Systems and Platforms - climate risk information platforms and other decision support tools help guide DRR actions in sensitive sectors (e.g. agriculture) and prepare for other related hazards.		
New Patterns, Communications and Decisions and Actions	In DMO/Met service operations, there is a shift in online cloud, storage, broadband-based transmit/receipt capabilities. The public is also moving away from traditional modes of communications like radio and broadcast/cable television as the primary channels for news and information and more towards mobile technology, social media. The adaptation of ICT4DM must now find ways to communicate with the public however they receive information		
	Element of Resilience	**Issue**	**Next Steps**
	• **Learning** - Capacity of the system to generate feedback with which to gain or create knowledge, and strengthen skills and capacities necessary to experiment and innovate	• Capacity Building • New and Traditional Knowledge • Reflective Thinking	
	• **Equity** – The Pacific region increasingly recognizes the need to provide services to all	• DMO/Weather Services must ensure	

affected populations, even those with limited means, access and functional needs, or limited language and literacy proficiency.	its alerts are available and understood by everyone who faces threats. Additionally, they must find ways to help people in underserved areas or with limited resources to be able to provide timely and effective alerts to people in their jurisdiction.	

PART 3 – WHERE WE ARE GOING

CHAPTER 7.0 – PLANNING RECOMMENDATIONS AND FUTURE OUTLOOK

This chapter aims to provide the following:

- *Planning Recommendations*
- *Study Limitation*
- *Future Studies*

Policymakers and leadership can no longer ignore the use and benefits that communication ICT4DM brings to DMO. ICT4DM have become a central piece of infrastructure both as a means of communication and as embedded services in other systems, such as water, power transport, education, healthcare and disaster management. As such, disaster management planners should give specific consideration to ICT communications as a critical infrastructure. ICT policy and decision makers should take hazard risks and vulnerabilities more systematically and holistically, based on recent incidents and studies and analyses done in the region. In order for these technologies to deliver increased efficiencies and enhanced resilience, it must be planned from the beginning for networks to support disaster resilient applications and systems. Improving network interconnectedness in backbone infrastructure, including such concepts as peering and redundancy through meshed terrestrial networks, will greatly improve the capacities of these assets to provide enhanced disaster management. This chapter discusses planning recommendations and consideration for future studies in ICT4DM.

7.1 Recommendation for Planning

7.1.1 Recommendation #1: Integrate SSDM in DMO to ensure that planning designs and strategies are multi-hazard, multi-technology, multi-stakeholder, multi-phased.

ICT4DM have become essential to the effective management of all stages of the DM cycle and are widely used for: communicating and disseminating information; sharing information, promoting cooperation, and providing channels for open dialogue; teaching, learning, and raising awareness and training and skill and knowledge required by disaster managers; managing risks and impacts by utilizing available ICT4DM tools, including the Internet, phones, television and radio, to alert communities of impending disasters, coordinate response and rescue, and manage mitigation programs and projects; data collection and information exchange; databases and information systems to manage logistics during emergencies as well as for mapping, modeling and forecasting; and developing knowledge and decision support tools for early warning, mitigation and response planning.

The SSDM seeks to ensure that information and communication technologies are used for more than just development but also for disaster management with the aim of improving communities and lives (ITU, 2018). The limited financial resources, the technical and institutional capacity gaps and issues of supply chain are among some of the challenges that would make single-use ICT4DM a failure in many instances. Refurbishing and reusing existing ICT4DM infrastructure and integrating its use where necessary to supplement, support and strengthened DMO functions build organizational resilience through hands-on training and capacity building. Just as other systems and processes must be practiced and used regularly, so should ICT4DM to ensure existing protocol and equipment function well to inform decision making and action. This can also reduce the points of failure within DMO processes. There should also be better coordination among donors and grant funding to build upon existing ICT4DM appropriately and efficiently to avoid duplication of efforts. This is also an opportunity for donors and grant funding agencies to learn from each other and share lessons to incorporate elements of SSDM in projects and initiatives.

7.1.2 Recommendation #2: US agencies funding ICT4DM in the Pacific Islands should coordinate co-development of technologies and pilots for deployments with local users

> *"You know we're sitting on four million pounds of fuel, one nuclear weapon and a thing that has 270,000 moving parts built by the lowest bidder. Makes you feel good, doesn't it?" - Rockhound from the movie Armageddon, 1998*

There is an urgent need to build and replace infrastructure to ensure greater resilience to disasters as much of the critical infrastructure in American Samoa and Tonga are along the coastline. However, we must do so in a smart and sustainable manner. At all levels of funding global, bi-lateral, multi-lateral such as Green Climate Funds to US AID Participating Agency Program Agreements come many restrictions, conditions and provisions to receiving aid or grants to procure ICT4DM. Often times, these conditions are based on cost proposals versus the best technical solution. Within the US federal government, there are also many required procurement processes to purchase and implement ICT4DM projects. At the very least, all US agencies funding and deploying ICT4DM in the Pacific Islands should encourage the co-development of technologies and pilot projects, trainings, with Pacific users to incorporate best practices, capacity gaps and local knowledge. In addition, there also should be cohesion among US funded projects to ensure there is awareness and understanding of resources within communities prior to the deployment of ICT4DM. These efforts may seem related but altogether are somewhat disconnected from DMO who will need to operationalize ICT4DM.

7.1.3 Recommendation #3: Communications ICT4DM tools should be incorporated into planning curricula at all various levels of education

GIS and other information systems are well integrated as part of planning curriculum. However, there is an identified need to incorporate communication ICT4DM into planning curriculum. Systems Integrating a communication ICT4DM tools and processes curricula in a formal education setting, would mean ICT4DM becoming a core part of disaster planning education. The objectives of ICT4DM curricula would build on local and technical knowledge and capacities, and existing planning practices that have influenced technology integration in DMO. At an institutional level, disaster management and planning should complement each other and draw out the role of ICT4DM in planning. Incremental, physical and rational planning would also be a core component of the curriculum as ICT4DM rely heavily on physical infrastructure to function effectively. This would build a pool of planners who would have the background in planning but also the exposure, knowledge and perspectives on ICT4DM from an engineering, communication and social science perspective.

7.1.4 Recommendation #4: DMO should invest to build redundant infrastructure for communications

Redundancy is exhibited as the diversity of pathways (i.e., the multiplicity of pathways) and is critical for a system's capacity to adapt under changing environmental conditions arising from shocks and disturbances (Kharrazi et. al 2020). The need for redundant high-speed broadband internet capacity to support DMO cannot be stressed enough. The failure of essential services from critical infrastructure during disasters has significantly impacted DMO evident of the 2009 TAS and 2022 HTHH. It hindered communications, coordination and response and recovery. It also impacted people by disconnecting and hindering their ability to respond and recover from an event. Critical infrastructure failures cause domino effects across communities and therefore crucial to understand to better prepare and design mitigation, response and recovery tactics. Smart sustainable cities depend heavily on telecommunication infrastructure that is stable, secure, reliable and interoperable to support an enormous volume of ICT-based applications and services (ITU, 2018).

7.1.5 Recommendation #5: Strengthen enabling institutional environment and governing framework for ICT4DM

The appropriate use of ICT4DM enhances the effectiveness of the DMO, thereby safeguarding the infrastructure of the community and population (Harrison & Harrison 2008). Decision makers need to have access to high quality information, consistent data and capacity to use this information to inform planning. Uncertainties should be clearly communicated and valued, and there should be access to the tools needed to support decision-making under uncertainty. Elements of good governance, resilience and capacity approach can be used as a foundation to developing necessary legislative frameworks and governing structures for ICT4DM. Access to information should be complemented with the development of technical and institutional capacity to manage ICT4DM.

7.1.6 Recommendation #6: Country-level and operational plans should identify and prioritize ICT4DM as a core objective

American Samoa and Tonga have some of the most extensive and comprehensive disaster management and operational plans and strategies. While both recognize the value of communications ICT4DM, it is written in complimentary to the stages of DM rather than a core component of DM. This also means that ICT4DM becomes diluted and undervalued in planning processes. Understanding the value and prioritizing ICT4DM also means access to funding and technical support services. Tonga includes in its identified priority strategy for disaster management the improvement and implementation of multi-hazard early warning systems. Tonga has also adopted global frameworks for disaster management aligning for Sustainable Development Goals and many regional strategic frameworks for emergency and disaster management. American Samoa on the other hand, has a newly formed Office of Resilience that is working on a comprehensive disaster and climate adaptation plan. In a review of existing territorial plans for American Samoa, very little attention and focus in given to ICT4DM. The American Samoa Territorial Broadband Strategy (ASTBS), launched in 2021 acknowledges the need to prioritize ICT in general and addresses disaster management as part of critical services needed by the territory.

7.1.7 Recommendation #7: DMO should consider integrating disaster management planners into technical operations and the emergency operations centers.

ICT is a powerful lubricant for DMOs because appropriate ICT systems would make operations more agile (Tomasini & Wassenhove, 2009). However, without proper facilitation, it becomes an untapped resource. The role of a planner is often associated with community planning (non-operational) versus having a role within DMO and EOC. During an emergency crisis, disaster managers are often focused on managing, coordinating, and responding to the event; adding a planner into DMO might help them communicate, provide technical assistance, connect ICT4DM to DMO objectives and needs as well as community-level and social objectives that planners naturally consider in their line of work. Planners can also be integrated into the emergency operations center to support emergency support and recovery functions or cluster system. This would also require planners to be written into national and operational plans.

7.2 Study Limitation

This dissertation studied the barriers and enablers of ICT4DM based lessons on the 2009 TAS and the 2022 HTHH. The study conducted semi-structured interviews with technical personnel within DMO operations. A number of interviewees were not part of DMO during the studied events and others had a difficult time recalling specific processes relating to ICT4DM. There was conflicting data and information from the interviewees and their understanding of what had happened. To mitigate this, interviews were corroborated by official reports and archival news articles documenting the disaster events. The study population was a complexity. While the study aimed to focus on the technical personnel and their perspectives, there was continuous overlaps with other personnel including grants/funding management, program managers, and other administrative positions. Technical personnel included network operators, systems administrators, technicians, engineers, etc.

Time and timing added another complexity to this study. This study took place while there are still restrictions within island communities due to the COVID-19 global pandemic. Due to timing limitations, interviews were mostly conducted via Zoom.

Another limitation to this study is the cases study approach. The case study approach offers contextualized knowledge in order to understand what factors influence complex events and processes, key threats to external validity include the possibility that the cases are too specific and too standalone (George & Bennet, 2005). The external validity of the study may be limited to the Pacific Islands and therefore cannot be generalized for other island communities. However, it is my hope that this study has laid a foundation for further studies in the field of ICT4DM and disaster management in American Samoa and Tonga.

7.3 Future Studies

Planning offers more than a report or plan, but rather a course for knowledge to action and that allows the implementation successful DMO. Fundamentally, there is a lot to unpack in this study. One of the weaknesses of this dissertation is the fact that there were many variables. This study was from the perspective of technical support and it took pains to arrive to an understanding and definition of ICT4DM and its role in building resilience within the context of DMO. The contributions of this dissertation raise opportunities for optimizing ICT4DM for DMO. There is a need for more real-world experiences and lessons to be shared and incorporate into DM frameworks. There is also a need to consistently and constantly tie plans and frameworks to create comprehensive strategies to e-resilience within island context. There is also a need to better develop strategies for ICT4DM integration. Beyond the scope of this research, would be to further this work by regionalizing the study to include other US Pacific Islands.

APPENDICES

Enhancing Disaster Resilience in Pacific Island Countries and Territories (PICTs) through ICT

Semi-structured and Survey Interview Questions

Aloha, Talofa, Malo e lelei, Yakwe, Halo, Fakalofa atu, and in many tongues of the Pacific…hello.

My name is Hotavia Porter and I am a PhD student working on my dissertation at the University of Hawaii at Manoa. I am conducting a research study concerning disaster related-ICT systems in the Pacific Islands. Pacific Island Countries and Territories (PICTs) face repetitive Information and Communication Technology (ICT) systems failures during disasters, disrupting operations, communications and impacting response and recovery efforts at all levels. The investment in ICT systems and infrastructures for disaster management in PICTs have varying results for implementation, integration and effectiveness. The gaps are many and this research endeavors to explore areas of opportunities to improve, redesign and rehabilitate ICT in disaster management in PICTs that are technically, scientifically and culturally sound.

Faafetai for your sincerity!

Introductory Questions

- Please introduce yourself, your country, organization and your position/title.

Research and Interview Guiding Questions

- Where we've been - The evolution of disaster related ICT networks in the Pacific Region.
    1. What disaster-related network were implemented in the Pacific Islands over the last 50 years?
    2. Describe your institutional or regulatory framework for ICT in disaster management?
    3. Describe your institutional readiness for the deployment of ICT in disaster management?
    4. What has been the role of donor countries like Japan, US, New Zealand, Australia in the deployment of disaster related-ICT systems in the Pacific?
    5. What disaster-related network were most critical in your operations and why?
- Where we are – An inventory and assessment of current applications of ICT in DM in the Pacific Islands through the different stages of DM
    1. What ICT systems are implemented for disaster management in the Pacific Islands?
    2. What activities in disaster management do you apply ICT (with a focus on mitigation, planning, response and recovery processes and activities)?
    3. What were the barriers and enablers to the use of ICT systems in disaster management?
    4. Describe your institutional or regulatory framework today for ICT in disaster management?
    5. Describe your institutional readiness for the deployment of ICT in disaster management today? (What has changed?)
    6. What are potential implications of unmanaged, ungoverned, unregulated, poorly financed ICT systems in disaster management?
    7. To what extend is local context and cultural understanding integrated in ICT-based initiatives for disaster management?
    8. How effective ultimately is the use of ICT in DM in your organization/agency/ department/ministry?
    9. How does the use of ICT in disaster management in your organization translate to community actions in your context?

- Where we're heading – Expanding the application of ICT in disaster management (the current focus on ICT in disaster management has been to support hydrometeorological disasters, this section will explore application in other areas including pandemic)
    1. What design elements would enable successful adoption of ICT for disaster management in your organization/agency/department/ministry?
    2. What elements are most important to enable the successful integration of ICT in your current operations today?
    3. What lessons learned from your operational use of ICT in disaster management can inform community actions toward resilience?

University of Hawai'i
Consent to Participate in a Research Project
Dr. Karl Kim, Principal Investigator; Co-Investigator, Hotavia Porter
Project title: Enhancing Disaster Resilience in Pacific Island Countries and Territories (PICTs) through ICT

The purpose of this study to review US deployed communication-based ICT and their role in improving disaster resilience of PICT. This study will examine cultural, institutional, political and technical factors that may influence the use and implementation of ICT for disaster management in PICT. This study is conducted as part of a graduate research study at the University of Hawai'i at Mānoa Department of Urban and Regional Planning.

The one-on-one interview will consist of 15-20 open ended questions. It will take 45 minutes to an hour. The interview questions will include questions like, "Describe your institutional or regulatory framework for ICT in disaster management?" With your permission, I will audio-record the interview so that I can later transcribe the interview and analyze the responses. You will be one of about 20 people I will interview for this study.

Benefits and Risks: The survey will provide information to help understand the effectiveness of ICT in improving disaster resilience in PICT. There is little risk to you for participating in this research project. You may become stressed or uncomfortable answering any of the interview questions or discussing topics with me during the interview. If you do become stressed or uncomfortable, you can skip the question or take a break. You can also stop the interview or you can withdraw from the project altogether. There are no direct benefits to the participants from taking this survey.

Voluntary Participation: Your participation in this project is completely voluntary. You may stop participating at any time. If you stop being in the study, there will be no penalty or loss to you.

Privacy and Confidentiality: You will be asked to provide your name, position title, organization, email, and phone number as part of the interview process. Your contact information is for follow-up interviews and to share findings from the research. This information is voluntary and will be kept confidential and secure. All responses will be kept confidential in a secured database and will not be released publicly. The data will only be available to the research team and authorized users including the University of Hawaiʻi Human Studies Program. A summary of the data collected in the interviews will be available in reports and publications without personal identifiers and may be shared with individuals upon request.

Questions: If you have any questions about this study, please contact Hotavia Porter at 808-348-5653 hotavia@hawaii.edu. You may also contact my advisor, Dr. Karl Kim, at 808-956-7381, karlk@hawaii.edu. You may contact the UH Human Studies Program at 808.956.5007 or uhirb@hawaii.edu. to discuss problems, concerns and questions; obtain information; or offer input with an informed individual who is unaffiliated with the specific research protocol. Please visit http://go.hawaii.edu/jRd for more information on your rights as a research participant.

If you agree to participate in this project, please sign and date this signature page and return it to: Hotavia Porter hotavia@hawaii.edu

University of Hawai'i
Consent to Participate in a Research Project
Dr. Karl Kim, Principal Investigator; Co-Investigator, Hotavia Porter
Project title: Enhancing Disaster Resilience in Pacific Island Countries and Territories (PICTs) through ICT

Keep a copy of the informed consent for your records and reference.

Signature(s) for Consent:

I give permission to join the research project entitled, "*Evaluation of Services Provided via the Career Development and Counseling Program.*"

Please initial next to either "Yes" or "No" to the following:

____ Yes ____ No I consent to be audio-recorded for the interview portion of this research.

Name of Participant (Print): ____

Participant's Signature: ____________________________________

Signature of the Person Obtaining Consent: ____________________________

Date: ______________________

Mahalo!

2

Consent Form – version ___1

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