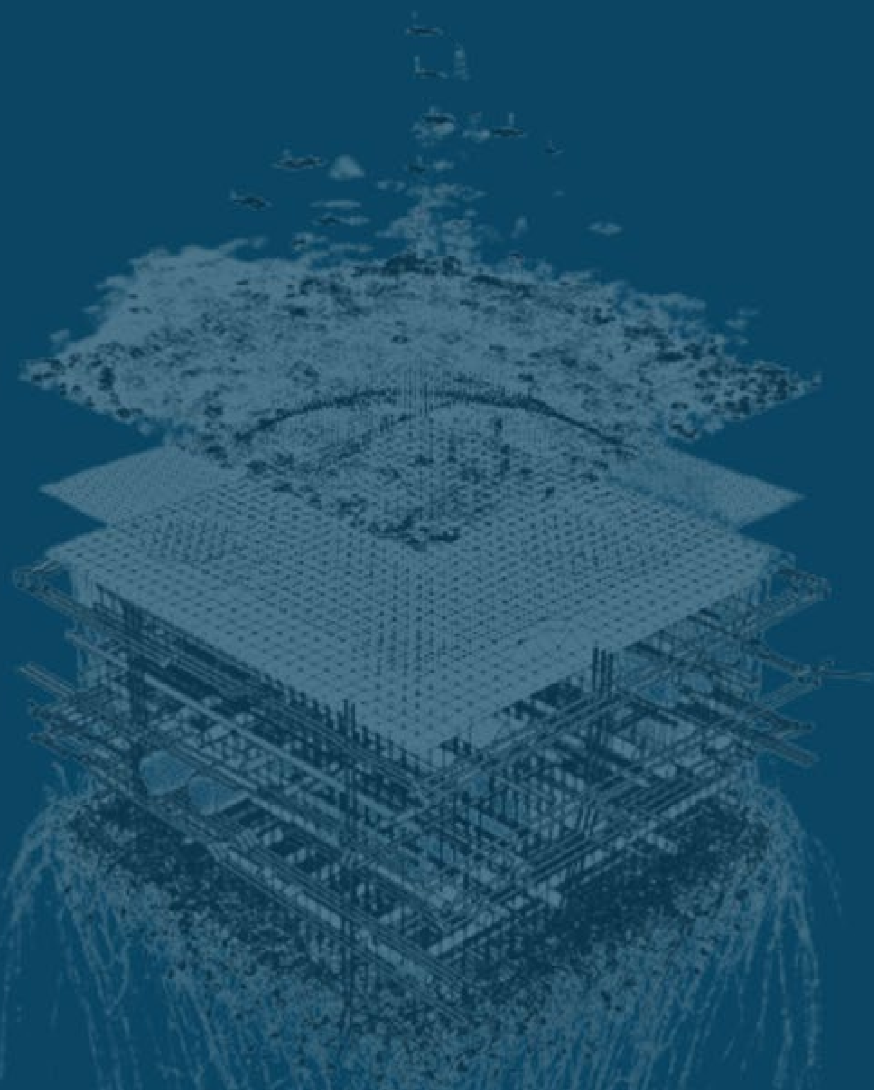
Engineering Resilience in Disaster Risk Management for Sustainable Development



World Federation of Engineering Organizations
Peruvian Engineers Association

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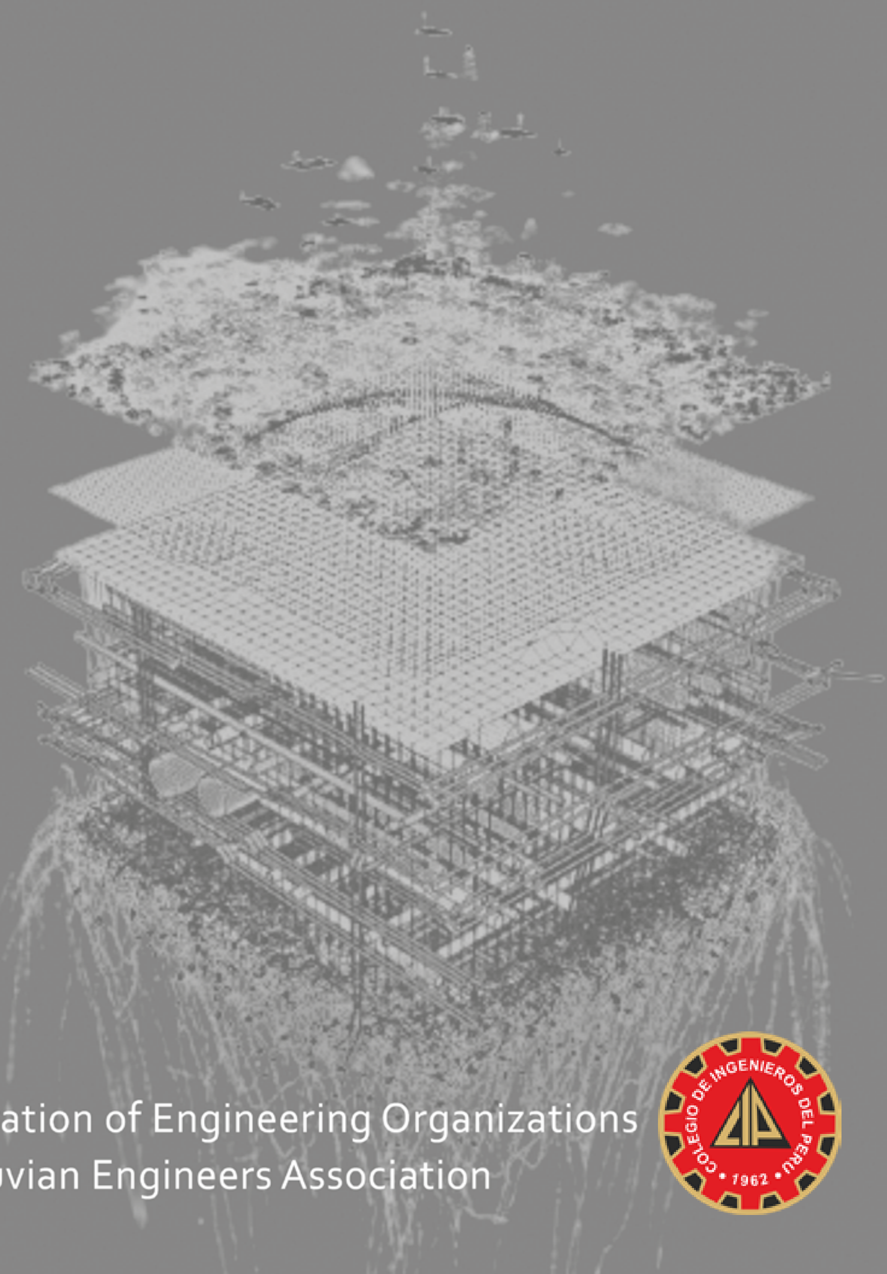

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Editors:

José Macharé O.

Lizett López S.

Peruvian Engineers Association

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Engineering Resilience in Disaster Risk Management for Sustainable Development

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Edited by:

Av. Arequipa 4947, Miraflores

Telephone: 01-4456540. Email: decano@cip.org.pe

Maison de l'Unesco 1, rue Miollis 75015, Paris, France

Telephone: +33145684847. Email: secretariat@wfeo.org

Prepared by members of the WFEO Committee of Disaster Risk Management (CDRM) and five invited co-authors.

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Editors: José Macharé O. & Lizett López S.

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FOREWORD

Engineering: contributing to more effective risk management to enhance resilience to disasters

Every year millions of people are affected by disasters that claim lives, cause severe infrastructure damage, and exacerbate the poverty conditions of the most vulnerable. From 2000 to 2019, disasters claimed 1.23 million lives, affected 4 billion people worldwide, and led to 2.97 trillion USD economic losses.

In recent years, climate change has amplified extreme weather events leading to an increasing number of weather-related disasters. A reality reflected in the numbers: Over the last twenty years, the overwhelming majority (90%) of disasters have been caused by floods, storms, heatwaves and other weather-related events, while more than 50% of mortality by natural hazards are caused by geological hazards such as earthquakes and tsunamis.

Biological hazards also disrupt lives, as COVID-19 has shown. Although these hazards are included in the Sendai Framework for Disaster Risk Reduction for the 2015-2030 period, the world was unprepared for the pandemic. Therefore, it is time to act decisively on biological hazards by applying a multidimensional risk management approach, as we do for other hazards.

Therefore, Disaster Risk Reduction (DRR) is increasingly on the agenda of the UN System. While the Sendai Framework for Disaster Risk Reduction 2015-2030 is the roadmap for DRR, other global agendas, including the Sustainable Development Goals, the Paris Climate Agreement and the New Urban Agenda, have targets that cannot be attained without DRR.

The contributors to the present publication come from all over the world. Members of the World Federation of Engineering Organization's (WFEO's) Committee for Disaster Risk Management represent engineers' global voices specializing in disaster risk reduction.

The publication tackles the complex challenges of DRR. It describes the cascading effect of the natural phenomenon, the damage to the physical system, and the impact on the social and economic system. Furthermore, the publication provides us with how engineering can help to build resilient technical, economic and social systems, which demonstrates that engineering has an enormous role in infrastructure and data management and land use, capacity building, and policies.

Young engineers, in particular, can learn from the experiences of the experts who have contributed to the present monograph. For instance, readers will learn the importance of devising construction codes adapted to local conditions for greater resilience and engaging with communities living in disaster-prone areas who face difficult decisions, such as restricting or prohibiting construction in floodplains and along certain coastlines.

UNESCO operates at the interface between natural and social sciences, education, culture and communication, playing a vital role in building a global culture of resilience. UNESCO assists countries in capacity building for management of disaster and climate risk, mainly supporting the Member States on 1) early warning systems; 2) safe critical infrastructures; 3) UNESCO designated sites risk prevention; 4) using Science, Technology and Innovation such as Artificial Intelligence and big data; 5) built environment; 6) risk governance; 7) nature-based solutions and 8) post disaster response. In addition, UNESCO fully utilizes the knowledge and experience of engineering in our DRR interventions.

For instance, UNESCO has been implementing a three-year project since 2020 in Latin America and Caribbean countries, making the built environment more resilient to earthquakes.

The project is developing technical guidelines for engineers and masons – including those without a background in structural engineering – on assessing risks and constructing and retrofitting buildings to resist an earthquake. Structural engineering is the crucial element of this project. However, the project also includes the public policy element to ensure that all target countries develop risk-informed policymaking and 'build back better' from past damages.

In conclusion, I commend the authors, as well as the Colegio de Ingenieros del Perú (Peruvian Engineers Association), which hosts WFEO's Committee for Disaster Risk Management, for having so generously devoted their time and expertise to the preparation of this publication and, in doing so, contributed to advance the cause of sustainable development.

Dr. Shamila Nair-Bedouelle
Assistant Director General
UNESCO Natural Sciences Sector

PROLOGUE

I am very pleased to witness the launch of this booklet - Engineering resilience in disaster risk management for sustainable development, edited by the Standing Technical Committee for Disaster Risk Management (CDRM) of the World Federation of Engineering Organizations (WFEO). The World Federation of Engineering Organizations (WFEO), consisting of more than one hundred of national and international member organizations, is the world's largest comprehensive engineering organization and represents engineering community in the global agenda of sustainable development.

The natural disaster risk reduction (DRR) is an integrated issue dealing with economic, social and environmental dimensions and all Sustainable Development Goals (SDGs), a serious issue dealing with billions of lives of people and trillions of US dollars of economic lost as well as social and economic inequalities. Just as Mr. António Guterres, UN Secretary General, pointed out in his message to the launch of the third IPCC report on April 4, 2022, “We are on a fast track to climate disaster: Major cities under water, unprecedented heatwaves, terrifying storms, widespread water shortages. The extinction of a million species of plants and animals. This is not fiction or exaggeration”. Recognizing the importance and integrated nature of DRR and its ever-growing threat to humankind and the planet, WFEO established the Standing Technical Committee for Disaster Risk Management (CDRM) in 2009, hosted by our Japanese member from 2009-2017, and then hosted by our Peruvian member since 2017. This booklet, written by 18 authors from 11 countries of different continents, is an outcome of CDRM's work in recent years.

This booklet provides a comprehensive perspective of the disaster risk management, from land use planning, resilient infrastructure systems, data and information management to capacity building and institutional framework and public policies, with many case studies showing how science, technology and engineering solutions could help people in both developed and developing countries to manage the disaster risk together with proper institutional framework and public policies. The booklet has not only given strong warnings to the importance and seriousness of the problems and challenges, but also showcased good engineering practices and provided clear messages of the way forward.

Hereby, I congratulate Mr. José Macharé, Chair of CDRM and the authors for their excellent work. I trust this booklet and its rich references will help readers to know more about disaster risk management comprehensively and help young engineers to be better prepared for disaster risk management in their engineering practices, to accelerate the delivery on the SDGs and to engineer a more resilient, inclusive, prosperous and sustainable future of the world.

Dr. GONG Ke

President of World Federation of Engineering Organizations (2019-2022)

PREFACE

It gives me great pleasure to provide an introduction to this important publication. I was a founding member of the WFEO Committee for Disaster Risk Management and have been involved in its activities except for my time on the WFEO Executive Board. The application of engineering to the assessment and management of natural disaster risks to infrastructure assets, has been an important part of my professional career. The contributions to this important document bring together expertise from around the world and is a wonderful example of the power of WFEO in being a forum for engineering that can inform and educate engineers and policy makers around the world.

The release of this document is both very timely and relevant. The United Nations Sustainable Development Goals include the imperative to mitigate the impact of natural disasters. The role of engineering approaches and solutions is central to achieving these Goals. The *United Nations Global Sustainable Development Report*[1], recognizes science and engineering as one of four levers to accelerate sustainable development. In particular, with increasing urbanization, sustainable cities that are resilient to natural disasters are recognized as one of six pathways that can accelerate transformation for sustainable development.

Resilient infrastructure in urban and peri-urban environments are also important. While retrofitting ageing infrastructure is critical in many developed countries, there is also an important opportunity to use the latest approaches, such as those described in this document, for more resilient, green and sustainable solutions in less developed countries. Engineers will be needed to design, develop and implement solutions for these challenges.

I am sure that the comprehensive information that has been presented in this document and the associated references that provide a wealth of additional information will support engineers around the world. The systems and approaches described in this document, present diverse examples from Japan, India, the Philippines, New Zealand, Peru and Chile, to name a few, and represent the result of experience of experts who have lived through and informed the preparation for and responses to natural disasters in their country. The expert contributions of these engineers, will, no doubt, build capacity to understand approaches to natural disaster risk management for rare events, especially for young engineers who may nnot have the experience of events such as earthquakes and tsunami that can have devastating consequences. The case studies and examples in the book will no doubt, assist in developing systematic engineering approaches for sustainable development that leaves no one behind.

Dr. Marlene Kanga
WFEO Immediate Past President

1 https://sustainabledevelopment.un.org/content/ documents/24797GSDR_report_2019.pdf

About the World Federation of Engineering Organizations (WFEO) and the Committee on Disaster Risk Management (CDRM)

The World Federation of Engineering Organizations (WFEO) is an international, non-governmental organization representing the engineering profession worldwide. Founded in 1968 by a group of regional engineering organizations, under the auspices of the United Nations Educational, Scientific and Cultural Organizations (UNESCO) in Paris, the WFEO brings together national engineering organizations from some 100 nations and represents more than 30 million engineers from around the world.

WFEO represents engineering at the highest international levels, at the United Nations and its related agencies, is the Co-Chair of the Science and Technology Group among the Major Group of Stakeholders at the United Nations.

The technical activities of the Federation are carried out by 10 Standing Technical Committees, which cover particular areas of Engineering and Technology. One of these committees is the Committee on Disaster Risk Management (CDRM).

The CDRM was established at the WFEO General Assembly held in December 2009, Kuwait. The committee was hosted by the Science Council of Japan and the Japan Federation of Engineering Societies (JFES) for a period of eight years (2010-2017). CDRM currently executes its mandate through its headquarters at the Peruvian Engineers Association (Colegio de Ingenieros del Perú-CIP) based in Lima, Peru.

CDRM mobilizes and coordinates a network composed of engineers linked to the public, private and academic sectors from different parts of the world. CDRM activities are developed to support the implementation of the global disaster risk reduction initiative, the Sendai Framework for Disaster Risk Reduction 2015-2030 through engineering. Likewise, the CDRM will direct efforts to contribute to the Sustainable Development Goals (SDGs).

About the Peruvian Engineers Association

(Colegio de Ingenieros del Perú-CIP)

The Peruvian Engineers Association (Colegio de Ingenieros del Perú-CIP) is an association of professional engineers constituted on the basis that it is prescribed by the Political Constitution of Peru and it is also created by Law.

CIP represents the professional engineers of Peru in all its specialties, at the end of the year 2021 it had about 280 thousand members, taking into account all those who were registered from the beginning.

Our association is maintained with its own resources, has 28 headquarters throughout the Peruvian territory, and is also a member of several international organizations, such as WFEO, UPADI, FEIAP, COPIMERA, APEC INGENIEROS and Pacific alliance.

CONTENTS

INTRODUCTION

The purpose of this booklet is to address Disaster Risk Management as an integral part of *building resilience* in a community to cope with the stressors due to natural hazard events, and specifically the engineering contribution towards it. It is not the intention of the booklet to address man-made events, although human actions may take part in the origin of complex events, and are mentioned in some sections. The stressors could be sudden shocks such as an *earthquake*, or slow chronic variations such as *climate change*.

Resilience is defined as the capacity of a society to cope, as a system, with stressors related to its development by withstanding, adapting, and recovering related to their impacts.

1. The Characteristics of Disaster Risk

Based on the intensity and duration of a hazard event, extent of damage to various parts of the community system varies. The natural hazards considered here are:

- Earthquakes - Geologic phenomena
- Tsunamis - Geologic phenomena - cascading
- Landslides – Geologic phenomena – cascading
- Volcanic Eruptions – Geologic phenomena
- Severe Wind -Storms – Weather related
- Floods – Weather /other causes
- Droughts – Weather related
- Fires/Wildfires – accidental/manmade/resulting from other hazards such as earthquakes
- Climate Change impacts – Weather related

Except for climate change and droughts, the hazards listed above are occurrences of natural hazards that can be determined probabilistically, although the probability of occurrence for each type of hazard is different. Fire related hazards do not have defined probabilities. Some hazards such as large-magnitude earthquakes are low probability events with high consequences. Natural hazards could cause significant damage to physical civil infrastructure systems and paralyze community functionality. Essential services such as hospitals and fire services could be severely damaged compromising their functions when they are needed the most.

Climate change effects require separate considerations. First, they increase the occurrence of weather extreme events, which are becoming stronger and more frequent. In addition, its effects degrade the land surface and increase the susceptibility of many regions to landslides, flows, and their consequences. This booklet does not attempt to address all climate related effects, specifically.

Many damaging earthquakes have resulted in fires as *cascading subsequent events.* In fact, in the 1906 San Francisco, USA earthquake, data shows that more losses were caused due to fires following the earthquake than the earthquake event itself. Similarly, landslides could occur after severe storms resulting in unstable slopes. These are also considered as cascading events. In frequent hazard events such as hurricane, the damage could be equally devastating, mostly to residential structures, however, it may be limited to a small area. The fundamental difference between the two events is that in earthquake, no warning is given whereas in hurricanes, sufficient warning is available. The consequences of various hazards are shown in figure 1.

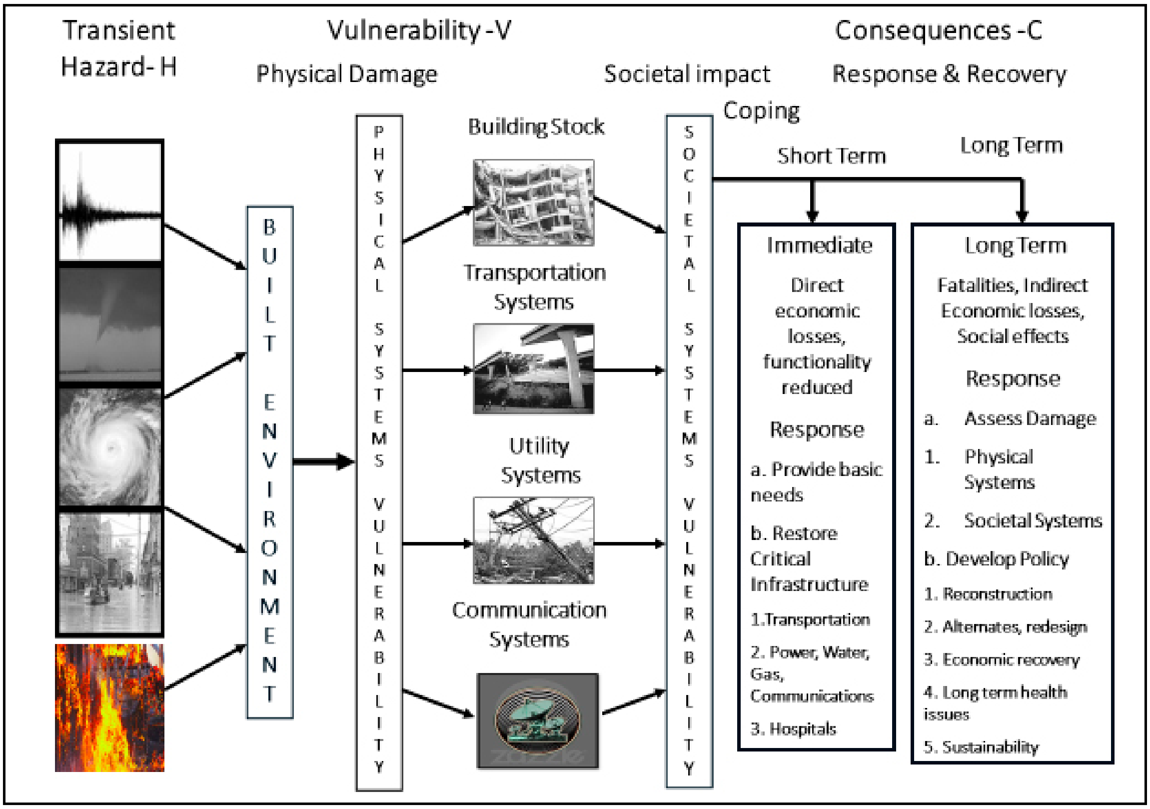

Figure 1. Consequences of Hazards

To manage the disaster risk, a community needs to develop *resilience* through the collective action of all stakeholders in an integrated cohesive fashion.

2.The Characteristics of a Community System

When a community is subject to a hazard event, it is faced with the *Disaster risk* which is a function of hazard, exposure, and vulnerability. This risk is normally expressed as a *probability of loss of life, and injury and destroyed or damaged assets* that impacts the community functionality. Thus, a community is interested in minimizing the loss of daily functionality. A community is defined here, as a large complex system that in a broad sense is comprised of three sub-systems: *technical systems (built environment), economic systems, and social systems.* These sub-systems are interdependent and interact with each other within an organizational constraint *forming a unified whole* to make-up a community.

The three component systems noted above are linked with each other and need to act interdependently in an integrated and synergistic way for providing acceptable level of community resilience so that it cannot only withstand the disaster event, but successfully recover from it quickly and grow back in its normal fashion or better. A brief description of each system is given below:

The Technical systems comprise all built environment and are thus *static* in nature regarding a hazard. Their overall behavior and resilience to an external event such as a natural hazard is built-in during design and construction-based on the prevailing codes and regulations, at the time. *Land use planning and Infrastructure systems* fall in this category.

The *Economic systems* comprise economic and financial institutions and are quasi-static, as some financial institutions, such as stock and bond markets can respond to a hazard dynamically depending on the circumstances while others such as banking institutions are not able to change their behavior. The overall *economic system thus can be considered as a quasi-static* one. *Institutions by their nature* can be considered *a part of the economic systems.*

The *Social systems* essentially comprise services, various networks, and societal organizations, and are *dynamic* in nature as they determine their response to a hazard depending on the circumstance and modify it, if necessary. Such behavior may be different from hazard to hazard and even different to the same hazard at a different time because of behavior modification based on the previous experience. Thus, social systems are dynamic in nature. I*nformation management, and capacity building, fall in the social systems category.*

Overarching all three systems is the *organizational system* as it determines the level of functionality of each system during a hazard event (figure 2). Generally, this system is also static and cannot change quickly for response to the hazard. *Early warning systems and public policies* can be considered as parts of the organizational system.

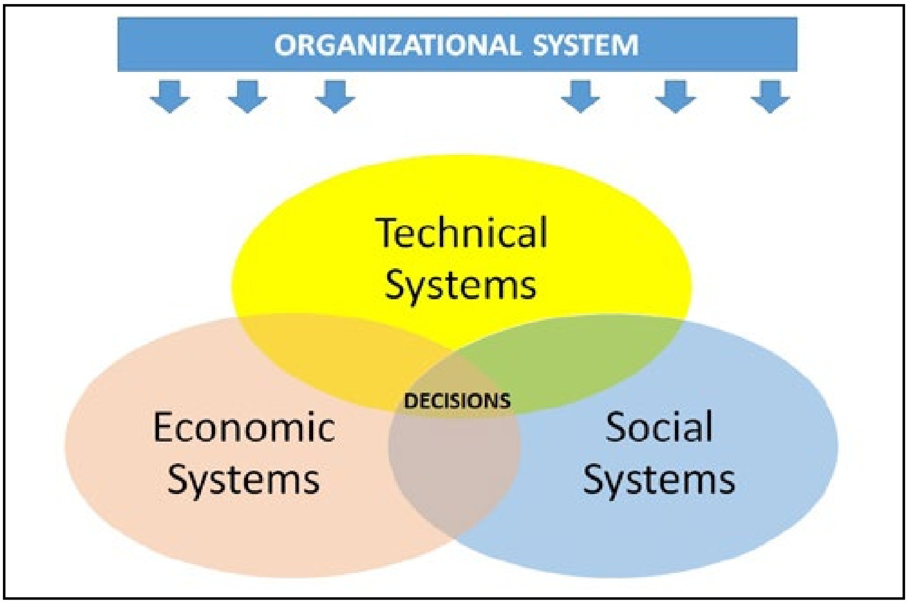

Figure 2. Community as a complex System

All these systems need to act together synergistically to minimize the damage due to a hazard. The overall behavioral outcome is difficult to *predetermine* thus making the community system a *complex system*. The decision-making considering all the stakeholders is arduous and difficult. Overall interaction among systems and decision-making is schematically shown in figure 2.

3. System Characteristics and Behavior

Overall, the community can be considered a dynamic system. A critical attribute of a *dynamic system that is responsive and adaptive*, is that it has feedback loops and various linkages among component systems, and it adjusts its behavior based on the type and frequency of the information received and processed through these loops.

It is to be noted that one sub-system namely the *Technical systems* and specifically, the civil physical infrastructure systems within it, are static and do not have feedback loops for behavior modification of these built physical systems. Linkages within the technical system are also predictive and are generally linear.

Socio-economic systems though, are dynamic and modify their behavior based on feedback. The linkages usually are non-linear and are not predictive. Herein lies the challenge of understanding the behavior of the complex community system as one integrated system. However, based on the needs of the community functionality, and existing coping capacity, all stakeholders need to take decisions to develop *resiliency that is considered acceptable*. The goal is to develop adequate capacity to minimize the hazard impact and maintain community functionality. These actions may vary in degree in different communities based on their specific needs and acceptable levels. Once an *acceptable community resiliency* is developed, a coping mechanism is inherently developed as shown in the diagram on figure 3, by a spring that has absorptive capability. For the subsequent damaging hazard event, this coping mechanism reduces the overall adverse impact on the community.

Codes and Regulations govern the design and construction of the physical engineering systems with the primary objective of protecting the health and safety of people. Thus, the specific provisions in the codes and regulations are written for ensuring the safety of the occupants as the primary concern, in building structures and not to limit the level of damage, so long as the building is safe to occupy or allow the occupants to evacuate safely. In case of bridges, provisions are written for safe travel across the bridge. Code provisions are also written to prevent the collapse of the structures. Thus, a *certain amount of resiliency is built-in in the physical systems that is given and cannot be changed.*

However, there are no specific provisions for limiting the damage of the non-structural components in buildings as they are not a part of the structural system designed to resist forces.

In infrastructure systems such as *transportation networks, utility systems and communications networks*, the damage due a hazard event will affect the functionality of the system itself and impacts the community significantly. The extent and duration of non-functionality and its impact on the socio-economic fabric of a community will depend on the location of damages, degree of redundancy in the system itself and the speed of restoration in infrastructure systems.

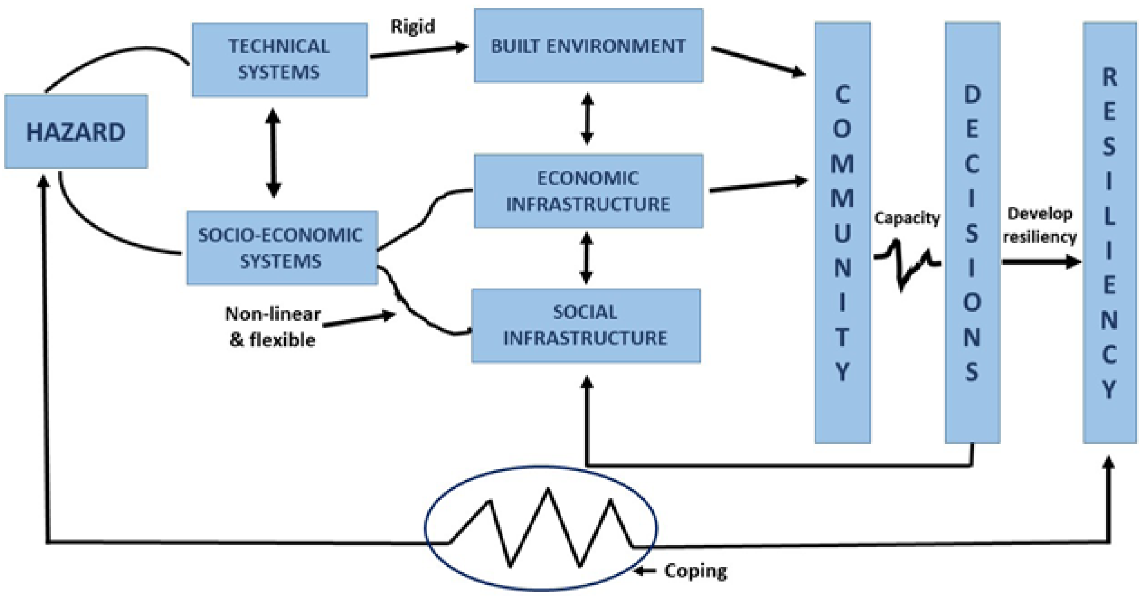

Figure 3. Linkages- Sub-systems

Economic systems depend on the functioning physical infrastructure, and on the reliability of communications networks that include cyber infrastructure which are generally globally connected. Many large business entities have alternate methods of restoring electric power with power generation units and can start functioning even if the workers cannot get to their offices. However, most functions are dependent on information and communications networks connected through satellites. It is the *damage to cell towers* that disrupts the functionality. Because some alternate methods are available to continue with limited functionality, economic systems are considered *quasi-dynamic.*

Societal systems can adapt to new situations in response to a hazard event. If the physical infrastructure is not working, people can assemble in smaller groups locally and render some services. Thus, their behavior changes to a different pattern than what is normally associated with them. This adaptation to the new circumstances makes the *societal systems dynamic in nature*, and since their behavior depends on a particular situation, the relationship of societal systems to other systems is non-linear as shown in figure 2.

Organization systems overarch Technical systems, Economic systems, and Social systems and are critical to operations for each of these systems. Unless an effective organizational system is in place, response to a hazard is uncoordinated and is not very cohesive or comprehensive. Some examples of such lack of organization system were evident in some damaging natural hazard events: e. g. *Kobe Earthquake, Japan (1995), Indian Ocean Tsunami (2004), Hurricane Katrina, USA (2005), and the Haiti earthquake, Haiti (2010). Due* to lack of organizational systems at many levels, hazards resulted in creating disasters in these events that could have been avoided.

4. Establishing a Resilience Strategy

The community needs to define the *acceptable level* of functionality in its systems, during and after a hazard event. This acceptable level may be different for different hazards because their impact and the duration are different for each event. For a frequently occurring flooding event, the community demands almost normal functionality as compared to a tornado event that is also frequent, but community demands another level of acceptance due the intensity and level of damage a tornado can instill.

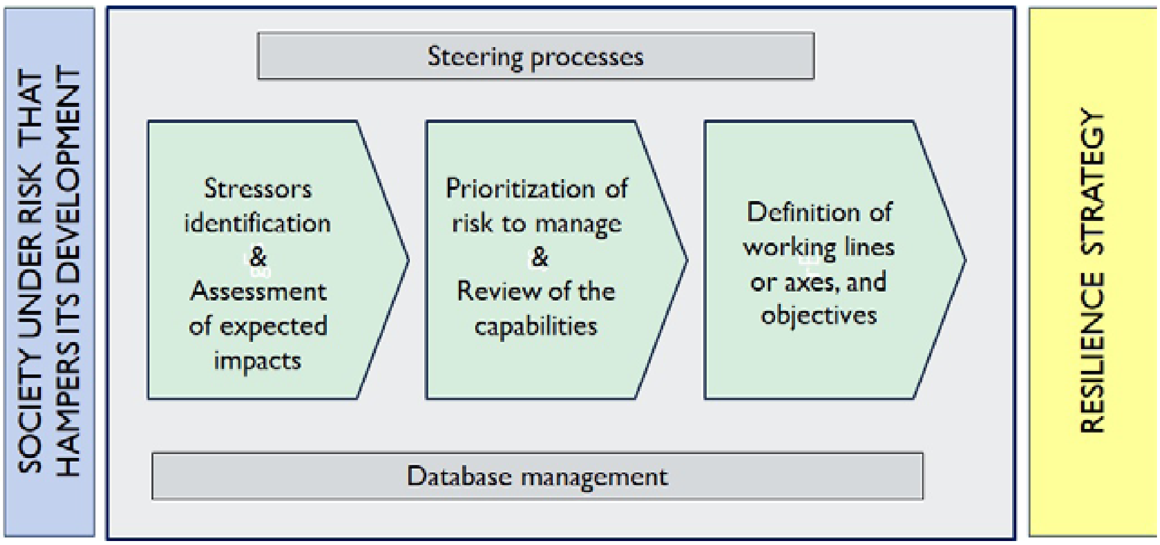

Figure 4. Resilience Strategy

The level of damage, as shown in figure 1 also varies depending upon the resilience available in each system. Some impacts are short-term and can be addressed immediately after the event; however, the long-term impacts such as business relocations need to be addressed with different solutions including policy related decisions. It is necessary and quite reasonable to develop different levels of resilience for different types of hazards considering their probabilities. A general approach to achieve such community resilience is shown in figure.4 above.

5.Disaster risk management processes within resilience strategies

Several processes are components of the disaster risk management (henceforth DRM) are embedded in those above mentioned for the resilience strategy.

Along this booklet, the concepts and terminology used are those widely agreed and gathered by the United Nations Office for Disaster Risk Reduction (UNDRR) and International Science Council Disaster Risk Reduction (UNDRR, 2020; 2021)

In a timeline, DRM processes apply before, during, and after a striking event. They are sometimes called pre-, syn-, and post-disaster actions. As most natural hazards are recurrent, with or without a defined periodicity, the timeline closes itself with each event, defining a *disaster cycle*. Thus, the period post-event X becomes the pre-event X+1.

Actions taken before a hazardous event are involved in the *prospective management,* and include the following processes:

a. *Risk assessment,* actions made to evaluate potential losses and damages estimated upon the probability of occurrence of an event of a given size, and on the vulnerability of a given system.

b. *Risk prevention*, actions aimed at avoiding the creation of new risk conditions. Adequate land use and building under standard codes are examples of them.

c. *Risk reduction,* actions directed to lower the risk level by reducing vulnerability with structural and non-structural measures. Examples of this are seawalls to protect port facilities (structural), or relocating exposed populations to higher areas (non-structural) when facing tsunami hazards. *Mitigation* measures are in often considered in this group; although they are more focused on the effects (loss and damage).

. Actions taken when the event is imminent, during the occurrence, and just after it are often grouped as *reactive management. They include:*

d. *Preparedness or Readiness*, to be ready to face the event and withstand its immediate impacts. It includes the early warning systems.

e. *Response or emergency attention*, to rescue trapped people; to provide first aid to affected people; to assist with food, water and shelter; to ensure eventual evacuation of some highly unstable zones. The *Relief* process is part of it.

f. *Rehabilitation or Recovery*, to reactivate lifelines: routes, energy, water and sewage, telecommunications and housing providing the basis to restart progressively the community activities.

The *corrective management* comprises a series of actions taken between events, with long time spans in which one see the past disaster going away in time, but where one should also recognize that the next event may occur. The main process is the *Reconstruction (g)* that has to be always guided by the premise to *build back better.* To achieve the goal of providing a healthy and safe situation better than the previous one, correcting the weaknesses, new studies and zoning for land use, new building codes, and new risk assessment should be done, rejoining the prospective phase and closing the cycle.

For any DRM system to achieve the expected goals, besides the physical (equipment), normative (documents), and financial resources, it requires a highly performing human component. In this context, *Capacity Building,* especially for engineers, appears as a process that transversal to- and embedded in all the previously mentioned processes. It is aimed to ensure a high level in knowledge and skills to ensure the functionality of every component of the system.

Acknowledgements

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This section was prepared by Dr. Vilas Mujumdar, WFEO Distinguished Fellow, and CDRM Advisor, and Dr. José Macharé, CDRM Chair.

CHAPTER I
LAND USE PLANNING

Karel Vancura[a], Barbara Norman[b], Eric S.C. Ma[c], Hitomi Nakanishi[d]

[a] The Czech Association of Scientific and Technical Societies, Czech Republic, karlvancura@centrum.cz
[b] University of Canberra, Australia, Barbara.Norman@canberra.edu.au
[c] FHKIE, Hong Kong, ericma1986@yahoo.com.hk
[d] University of Canberra, Australia, Hitomi.Nakanishi@canberra.edu.au

1. Introduction

A city or local government area that has not implemented land use planning indicate hazardous behavior that might trigger a future catastrophe, at the local level only, but with huge consequences, e.g. in megacities. Regrettably such situations, even in the world of 21st century, continue to happen. As long as communities live more and more distant from nature, as they adapt their environment to live in, the need for land use planning and intelligent urban planning grows significantly. Nevertheless, land use plans or management systems are rather "static" in nature related to response to a hazard, as already indicated in the introduction chapter.

Land use plans, given usually by central authorities, guide engineers with help of codes and regulations in decisions on land and water use, how to use these resources of the environment in a most beneficial way, must go hand in hand with sustainable development. The increasing demand for land, coupled with a limitation in its supply, is a major cause of many conflicts over land use worldwide.

The aim of the chapter Land Use Planning is to provide to the public good examples of land use planning implementation cases from different parts of the world. An engineering background and knowledge is quite essential but it is only one point of view to carry out a proper land use management. It is also important that local people (communities and stakeholders) be involved in all steps of the planning process to make a successful land use plan. Such an approach, using local information, supported by environmental and engineering studies would also ensure local acceptability and can contribute to certain levels of resilience.

Such a land use plan in urban and peri-urban zones brings together consideration for both the physical development as well as the social characteristics of an area, city or country. GIS-based land use mapping (GIS) and related information is used to analyze the current pattern of development and serves as the framework for formulating how land (or city structure) will be used and developed in the future.

2. Case studies

2.1 Australia: wildfires, coastal floods and climate wise buildings

As the global temperature rises and other changes to the climate increase, Australia will face more frequent and severe events, such as extreme weather, fires and floods, and slow-onset events, such as, changing rainfall patterns, ocean acidification and sea level rise (Australian Government, 2021).

The Australia Government released an updated National Climate Resilience and Adaptation Strategy (October 2021). This Strategy comprises three core elements: (i) a new office to drive collaboration for adaptation; (ii) regular national risk assessment (5 years) in partnership with sub-national governments and sectors; and (iii) an enhancement of climate services to wider partners. This focus is on high-level information, assessment and review. It includes a lens into the built environment along the lines of working with the private sector and others to foster adaptation. It also includes a snapshot of the natural environment, the social considerations and the economic dimension.

However, land use planning in Australia is predominantly managed at the sub-national level of government, that is, states and local governments. The national government becomes involved only in cooperation with the states and local governments or through direct funding initiatives.

Managing disaster risk in Australia does involve the national government and especially with extreme events such as bush fires, floods, drought and storms. A valuable publication expanding on the governance arrangements for land use and disaster in Australia is detailed in a 'Land Use Planning for Disaster Resilient Communities' handbook (Australian Government, 2020).

This handbook summarizes the main spatial instruments and their potential role in disaster management – regional planning for regional centres incorporating regional risks, and strategic plans for new urban growth ensuring new development avoids lands with hazards, for example high wildfire risk or flooding, as well as local planning to provide guidelines for local decision making and finally structure plans that detail actions by sector.

The extreme events over the last five years have included fires, floods, drought, coastal storms, inundation and erosion. Coastal communities in particular face multiple climate risks with coastal storms, floods and bushfires. The cumulative impact of these events overlaid by two years of COVID have left these communities exhausted. Below are two case studies where communities have come together to recover and build a more resilient future – extreme wildfires and coastal inundation.

The 2019/2020 Australian fires 'resulted in the tragic loss of over 400 lives, 33 of them directly from the fires and 417 from smoke inhalation. Over 3000 homes and 7000 facilities and outbuildings were destroyed; 12.6 million hectares burned; and over 100,000 heads of livestock lost' (Norman et al., 2021a)). This national disaster affected nearly every Australian directly or indirectly; many of whom are still in the process of recovery (Norman et al., 2021b).

The policy response was a Royal Commission into National Natural Disasters Arrangements in Australia (2020) (https://naturaldisaster.royalcommission.gov.au/). The Royal Commission specifically recommended that 'Government measures will be necessary across land-use planning, infrastructure, emergency management, social policy, agriculture, education, health, community development, energy and the environment'. As a result of the Royal Commission' recommendations, sub-national governments with local councils are preparing more details bushfire planning regulations to minimize new urban development being constructed in high fire risk areas.

Mallacoota and the 2019/20 extreme wildfires

Traditionally a fishing village surrounded by forest, lakes and a stunning coastline, it is now a favoured tourist destination surrounded by protected lands, Croajingolong national park comprising 88,355 hectares and following 100 kilometers of coastline. Mallacoota is representative of many coastal townships that significantly expand their populations during the summer month; in this case from just over 1000 people to over 5000 people, bringing additional challenges during the high fire season.

During 2019/20 bushfires of Australia, Mallacoota became emblematic of the serious wildfire risks to Australia from climate change. On New Year's Eve 2019, Mallacoota was struck by an extreme wildfire that had travelled from the west along the coastline. The impact was intense, destroying many homes and killing wildlife and biodiversity. The intense fire event left white ash in many parts, destroying coastal ecosystems below the ground as well as above (see photo by author soon after the event).

Nevertheless, in a short time, the community has worked together and developed its own recovery and resilience plan with practical projects short and longer term and secured funding to start implementing the actions. The community quickly established an elected local community to work through a process of immediate action and then through a significant community engagement process, vote for priority community projects. A key project chosen by the community is ‘‘review and update Mallacoota and District Planning overlays to incorporate bushfire lessons learned’.

An important message of the case study of Mallacoota is that ‘community-based led recovery’ is emerging as leading practice for building long term resilience. For more details see MADRA (2022).

Figure 1. Mallacoota, Victoria, Australia February 2020, taken by Barbara Norman

The other major natural disaster risk in Australia is coastal inundation and increasingly intense storms projected by climate change. Australia is a highly urban nation with most people living in cities and most of the cities being on the coast. Again, recent experience with coastal storms and erosion has increased community awareness of the need to better plan for coasts and climate change.

The Peron Naturaliste Partnership

A successful case study on better management of coastal risks is in the southwest of Australia where there is an innovative collaborative partnership between nine local councils – the Peron Naturaliste Partnership – an example of collaboration at the local and regional level of government (https://www.peronnaturaliste.org.au/). This voluntary partnership emerged as a result of increasing coastal erosion and flooding impacting the built environment and coastal ecosystems. The result of over 10 years of collaboration is a sharing of knowledge and experience to improve land use planning in the south west region of Australia. With the support of the national and state governments, there has been detailed mapping and improved monitoring of risk and the embedding of these coastal climate risks into land use decision making.

Working together has made a significant difference to better planning for mitigating disaster in the future. The Peron Naturaliste Partnership (PNP) has endured through a shared commitment to managing risks and investing in forward planning. The PNP is working with local communities to develop land use plans for managing coastal hazards and risks- identifying coastal erosion, future areas coastal inundation and developing appropriate adaptation responses (see Peron Naturaliste Partnership, 2021).

The above two examples dealing with wildfire and coastal inundation provide an insight into managing disaster through better land use planning. The lessons highlighted are:

- The need for better mapping and monitoring of risk to identify high risk areas unsuitable for development.
- The importance of community led recovery with the support of higher levels of government.
- The need to support regional cooperation and collaboration to enable sharing of leading practices in land use planning and development.
- The importance of embedding up to date climate projections to mitigate risk and disaster in the future e.g. investing in urban and regional planning.
- The importance of embedding climate risks into everyday land use decision-making so that forward planning can play its part in reducing future disasters and better protecting local communities (see Routledge, 2022).

2.2 Building Disaster Resilience in Hong Kong

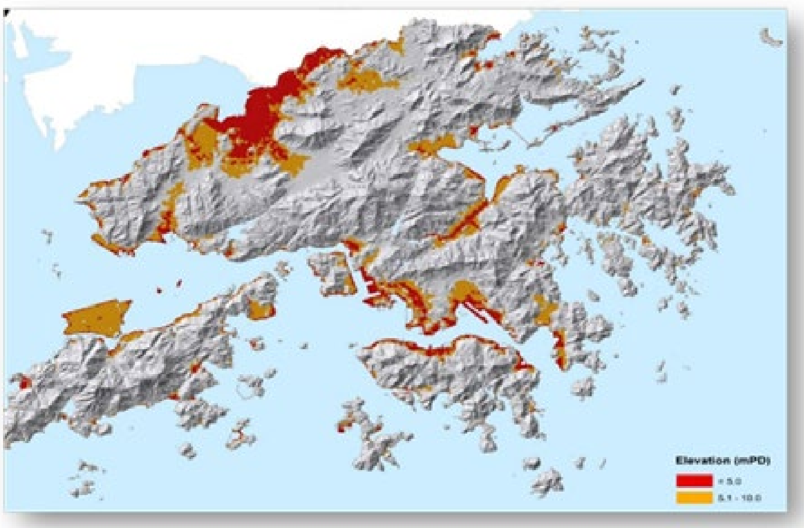
Sustainable Development of Cities

To achieve sustainable development of a city, it is paramount to adopt a holistic strategy integrating engineering inputs to its meticulous land use planning process. In particular, effective disaster management plans have to be implemented to effect the resilience of the planned infrastructure.

Challenges of City Developments

Cities are densely populated urban areas with continuous growth in economic and social activities. Land is frequently a scarce resource resulting in developments advancing into areas facing hazard events like earthquakes, tsunamis, landslides, hurricanes, droughts and climate change related challenges. Old urban developments are exposed to increasing risks due to climate change and adverse impacts caused by densification and new urban developments in the vicinity.

Hong Kong is one of the highest density cities in the World. About one-quarter of the urban development areas are sitting on low-lying area (as below in red) which are mostly reclamation areas less than 3m above the mean sea water level, susceptible to flooding during storm surges and rainstorms and as the sea level rises. The city has been ranked with the highest natural disaster risk in Asia by the Sustainable Cities Index. (NL News, 2015)



Notwithstanding its natural constraints, Hong Kong still managed to score high for its infrastructure resilience with reference to the United Nations Office for Disaster Risk Reduction. This proved that cities can still own a resilient infrastructure, utilities and services despite their high exposure to hazard events.

Figure 2. Hong Kong elevation map showing low-lying areas.

Engineering Inputs to the Land Use Planning Process

Engineering inputs to the town planning process is certainly one of the critical factors in achieving resilient city infrastructure. Technical studies and preliminary design of essential infrastructure works should be carried out during the land use planning stage to ascertain

- The engineering feasibility;
- Coastal and climate-related risk assessment and mitigation;
- Geotechnical risk and slope stability assessment and mitigation;
- Infrastructure and utilities provisions;
- Environmental impacts and mitigation;
- Landscape and visual impacts,
- Hydraulics assessment and mitigation;
- Land and marine traffic impact, and
- Economics and social aspects.

Incorporating these findings into the land use planning and statutory control plans, would to a large extent, build disaster resilience into the formulation of the land use proposals.

Emergency Response Management System

To complement resilient infrastructure, an emergency response management system which establishes policies and principles for crises arising from natural disasters and terrorist attacks is equally important. (Sim & Wang, 2017)

As outcomes from this case, it is recommended that engineering inputs and hazard risk assessment be incorporated into the land use planning process, and that governments dedicate sufficient financial resources for building emergency response management systems to support a resilient and sustainable city.

2.3 The Great East Earthquake and Tsunami 2011, Japan

The disaster

On March 11 2011, at 2.46 pm, a magnitude 9.0 earthquake hit the north Pacific coastal area of Japan. The Japanese government immediately issued major tsunami warnings. The recorded heights of the tsunami were, 9.3 m+ (Soma, Fukushima), 8.5 m+ (Miyako, Iwate), and 8.6 m + (Ishinomaki, Miyagi). Around 20,000 people lost their lives and more than 2,500 people were still missing as of 9th March, 2021 (Reconstruction Agency of Japan, 2021a). More than 122,000 houses were completely destroyed. In the next few days, 470,000 people took refuge in shelters. As of September 2021, there are still 40,000 people who are yet to return to their homes.

Figure 3. Devastated community and debris, Yuriage, Miyagi (taken by author in September 2011)

Relocation of residents and land readjustment

Relocation of residents to safer inland areas or higher ground was discussed from the early stage of recovery. Consultation with residents started in 2012 and consensus building was completed by March 2013, which was a relatively quick process for Japan. Land readjustment projects, land levelling and the development of public housing (30,000 units, for people who had lost houses) started immediately. These projects were completed by March 2021, 10 years after the disaster (Reconstruction Agency of Japan. 2021b). Although they understood the reasoning, relocation was not easy for some residents. For example, in Kesennuma, Miyagi prefecture, residents in fishing villages had a strong desire to remain in their pre-disaster settlements as they thought they should continue their fishing businesses which most of them had inherited from their family. However, the prefecture government insisted that if they wished to live close to the ocean, they needed infrastructure to protect them (i.e. seawall below) as well as migrating to higher ground.

New infrastructure: seawall

This was not the first tsunami that had taken many lives and severely damaged infrastructure in northeast Japan. Historically, this area has always suffered from the risk of tsunamis. In consequence, dykes and flood gates were constantly updated. The number of households which moved to higher ground was around 18,000. Based on the National Government's guideline (Cabinet Office, 2011) in consultation with the Committee established by the Ministry of Agriculture, Forestry and Fisheries of Japan and the Ministry of Land, Infrastructure, Transport and Tourism, seawall projects were proposed by prefecture governments (in this paper, the author is using the example of Miyagi prefecture). The levelling of land in the coastal area and the re-location of some high-risk housing to higher ground was also detailed within the 'seawall' plan. In Miyagi prefecture, a 'seawall' of 5.0m to 14.7m in height was proposed to be built along the coastline of Kesennuma, which is more than 100km in length. The seawall is a gigantic concrete construction. The wall requires a base to support it, and this is also enormous: the 9.8 m high wall has a base 45m wide to support it. The most controversial aspect of the plan for many residents was the height of the seawall. The prefecture's planned seawall was regarded as 'too high' and residents felt that 'this is a city that has developed beside the sea but we will no longer be able to see the sea if the seawall is built' (comments from residents at Kesennuma city seawall study group meeting, 2012). There was also concern that the big 'seawall' would obstruct the view of the ocean, which could lead to a failure to evacuate when the next tsunami happened, as residents would be unable to see the tell-tale tsunami warning sign of a retreating ocean. Another concern of the community was the impact of the seawall on the marine environment and biodiversity. In the case of the 'Naiwan' area of the city, the city council established a town planning committee and the proposed height of the seawall (originally 6.2m) was reviewed and a tsunami simulation was conducted. The new seawall plan was 1m lower but residents did not accept this. The discussion of seawall design continued and, finally a consensus was reached whereby a 3.8m - 4.1m of concrete which could be extended by a flap gate in case of emergency (Abe, 2017). It took the city more than 3 years to reach an agreed plan. On the other hand, in Ogatsu, in the same prefecture, a seawall of 9.7m was built and residents were relocated to higher ground close to their pre-disaster location (Nakanishi et al., 2013), but with the view of the 'seawall'. Residents discussed an alternative plan as they thought 9.7m was too high but they eventually accepted the prefecture's idea. In consequence, the town's population has decreased significantly, from 4,300 to around 1,120 (as of September, 2021, City of Ishinomaki, 2021).

Figure 4. Seawall under construction, Ogatsu town, Miyagi (taken by author in July 2019)

Figure 5. View of seawall and Ogatsu bay, Miyagi (taken by author in July 2019)

Lessons learned from this case are that ten years after the disaster, most of the affected population resided in their repaired homes, their rebuilt homes or a new home. Relocating to new neighbourhoods on higher ground was accepted in the early stage of recovery because of the scale of the devastation. However, this presented difficulties for some residents, particularly those who lived in fishing villages, or who were reluctant to leave their ancestors' land. It is critical that infrastructure be built to reduce future risks. However, that alone will not save people's lives. A strategy needs to be put in place, which includes the cost of maintaining the infrastructure and the impact on sustainability. The impact of the seawall in Ogatsu town will become more apparent as time goes by, but still the most important way to reduce risk is to ensure that the evacuation measures and drills are shared and well understood by the residents, no matter what infrastructure is in place. 'Tsunami ten den ko' is an oral tradition that has been inherited in the area. It means 'everyone needs to evacuate by themselves when a tsunami comes'. Town planning and infrastructure are important in reducing risk but they are still complementary measures when preparing communities for natural hazards.

3. Key messages

1. Engineering inputs should be incorporated into the land use planning at an early stage, making the identification of risks and mitigation measures integral components of the whole process. Given the economic effect of disasters, Government should understand the need to invest in resilience for a sustainable city.

2. The case studies confirm the critical importance of community engagement in the continuing process of disaster and risk management for extreme events. Community input at an early stage of land use planning to minimise future risks is vital for community supported solutions that are appropriate for the cultural context and the environment.

3. In the recovery phase, processes leading to reconstruction and resettlement may take long time, up to 10 years. The new land use plans require: a) the assurance of terrain arrangement and landscaping, b) building of protective infrastructure, and c) agreement of the population as a function of their future life expectancy, traditional or innovative activities, etc.

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CHAPTER II
RESILIENT INFRASTRUCTURE SYSTEMS

Dave Brunsdon[a], Stefan Schauer[b], Carlien Bou-Chedid[c]

[a] New Zealand Lifelines Council, New Zealand, db@kestrel.co.nz
[b] Austrian Institute of Technology, Austria, Stefan.Schauer@ait.ac.at
[c] Ghana Institution of Engineers, Ghana, carlienbc@gmail.com

1. Introduction

Infrastructure systems are typically complex systems that are interwoven with a high degree of mutual interdependency. While both the control systems for the day-to-day operation of these networks and the modelling for future use are highly sophisticated, the maintenance and future investment planning depends on key human inputs.

These systems are also highly vulnerable to damage and disruption from a range of geophysical and meteorological hazard causes and events. While any given hazard event has a low probability of occurring, the community impacts are usually severe and can extend over a considerable period of time. In major events, the failure of infrastructure adds another layer of distress to a community that may have suffered loss of life and damage to homes and other facilities.

Climate change presents different challenges, with the incremental nature of its effects making present day adaptation design decisions difficult. The increasing frequency and severity of weather events, however, presents a real urgency to this task.

It is therefore essential that infrastructure systems receive the highest standards of disaster risk management to enable operational risks to be identified and mitigated as much as is practical. While new infrastructure elements are typically designed to standards which encompass resilience, the progressive treatment of the vulnerabilities of older existing infrastructure provides a greater challenge.

This chapter outlines the characteristics of key infrastructure networks, and the associated resilience concepts. The hazard context and DRM concepts outlined in the introduction to this booklet are used as the basis for this section.

2. Scope and Characteristics of Infrastructure

The term 'Infrastructure' can encompass a wide range of services to the community, including health and education services. This chapter focuses on ***physical infrastructure systems*** – those networks that enable the other elements of societal infrastructure to function. Physical infrastructure systems are also those which have the greatest degree of reliance upon engineering inputs.

For the purposes of this chapter, the scope of infrastructure systems is taken as follows:

- Water networks (potable, wastewater and stormwater, including dams and pipelines)
- Energy networks (electricity and gas, including transmission and distribution lines)
- Telecommunication networks (landline and mobile telephone networks, data networks)
- Transportation networks (highways and rail, including bridges and tunnels, ports, waterways and airports)

In many jurisdictions, these systems are referred to as ***critical infrastructure***. Although the legal definitions vary from nation to nation, all those definitions have in common that critical infrastructures are responsible for the maintenance of essential economic and societal functions and whose disruption or failure would have a significant impact on the economic and social wellbeing of the population.

Over the last decade, critical infrastructures have become more and more interconnected with each other. Due to the ongoing digitalization in the industrial sector, much of the existing infrastructure depends on the resources from other infrastructures and also exchange a vast amount of information and data or use each other's services. Hence, critical infrastructure has developed into a highly complex and sensitive network with a variety of interdependencies as illustrated in Figure 1.

As a result, incidents involving one critical infrastructure asset can no longer be treated as an isolated event. Rather, due to the complex interdependencies among infrastructure systems, incidents can have far-reaching consequences, affecting multiple other infrastructure assets as well as society as a whole. Several incidents in the past, such as the hacking of the Ukrainian power grid in 2015 which left about 250,000 people without power (E-ISAC, 2016), the (Not-)Petya ransomware attack in 2017 (US-CERT, 2017) which infected millions of systems in the health and transportation sectors and the major blackout in South America in 2019 (Nordrum, 2019), have highlighted how the impacts of one major event can propagate through multiple sectors. Therefore, future disaster risk management approaches need to take those ***cascading effects*** into account when estimating the consequences of a major event and identifying mitigation actions to improve the resilience of the overall critical infrastructure network.

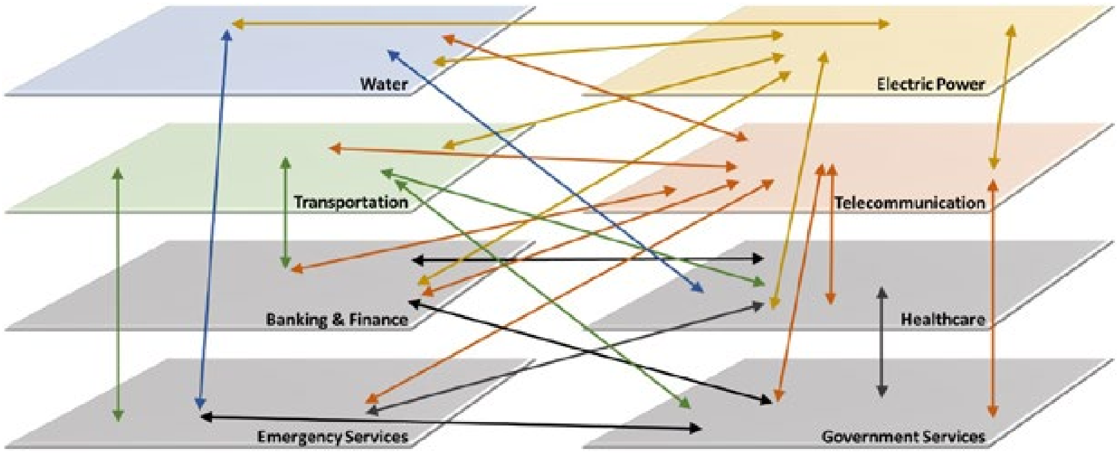

Figure 1. Schematic illustration of the interdependencies among critical infrastructure sectors

3. The Components of Resilience

The term 'Resilience' also has different meanings depending on the context in which it is applied, and an associated range of definitions. In the introduction, resilience at the societal level was defined as:

> *The capacity of a society to cope, as a system, with stressors related to its development by withstanding, adapting, and recovering with regard to their impacts*

The resilience of infrastructure systems is typically thought of in terms of the physical aspects – the vulnerability of key facilities (sometimes referred to as 'nodes' of the network) and the routes by which the service is delivered (e.g. transport routes or reticulation systems). Technical resilience is inherent in many networks through redundancy (multiple paths of supply) and robustness (design codes for strength). However, there can be geographical and other constraints in providing alternative supply routes, and 100% security of supply is neither feasible nor affordable.

There are however other considerations that can also have a significant impact on the resilience of an infrastructure network. A key factor is the degree of organisational resilience of infrastructure providers. This brings many other aspects into consideration, such as financial resilience, leadership and the ability to adapt. Organizational resilience is broadly defined as:

> *The ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper*

This encompasses what can be termed 'resilience culture'– the extent to which the infrastructure provider firstly understands the vulnerabilities of its network to the full range of hazard events, and secondly its attitude towards actively addressing them and having comprehensive plans to respond to extreme events.

A further consideration is the resilience of the 'receiver' of infrastructure services. These 'end users' also have a role in the ultimate resilience of an infrastructure network or service through their self-reliance in the face of adverse events. It is particularly important for critical facilities such as hospitals to have adequate levels of standby power and emergency water, in the same way that any consumer of these services needs to be prepared for system outages.

Taking these other components of resilience into account, the four key attributes of infrastructure resilience can be articulated as follows (New Zealand Lifelines Council, 2021):

1. Robust assets and networks (attributes such as structural integrity, network redundancy, adaptability, etc.).
2. Appropriate resource commitment by infrastructure organization (to enhance preparedness and speed restoration).
3. Effective collaboration with all members and stakeholder parties (both pre-event and in emergency responses).
4. Realistic community expectations (informed by understanding of network vulnerabilities, leading to end-users with appropriate back-up arrangements).

4. Application of the DRM Principles

The principles and wider context for DRM were outlined in the introductory section of this document. Emphasis was given to the need for decisions on *technical* systems to be taken with full regard to the associated *economic* and *social* systems within which they operate (refer to Figure 2 of the introductory chapter).

Disaster Risk Management is explained by the United Nations Office for Disaster Risk Reduction as (UNDRR, 2015):

> *Disaster risk management includes actions designed to avoid the creation of new risks, such as better land-use planning and disaster-resistant water supply systems (prospective disaster risk management), actions designed to address pre-existing risks, such as the reduction of health and social vulnerability, retrofitting of critical infrastructure (corrective disaster risk management) and actions taken to address residual risk and reducing impacts on communities and societies, such as preparedness, insurance and social safety nets (compensatory disaster risk management).*

This commentary provides an important linkage with the core risk management steps that managers of technical systems usually follow, as reproduced in Figure 2 below from the international risk management standard, ISO31000.

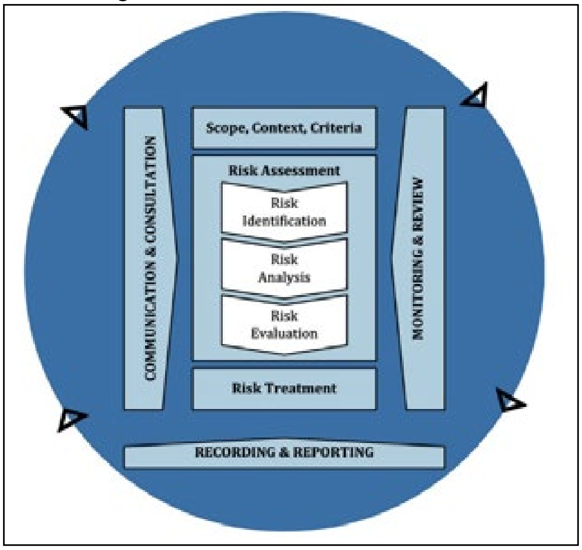

Figure 2. ISO 31000:2018 risk management process

It can be seen from this figure that *Context* is a key aspect of the first step of any risk management process. It is where the wider social and economic considerations are taken into account in framing how the identified risks are *evaluated*, and in turn, *treated*.

Conventionally, risk is taken as a combination of *likelihood* and *consequence*. However, disasters are by their very definition *high impact, low probability* events. Risk analysis and evaluation processes should therefore focus on the consequences to the system (and hence the community) of a disaster event occurring, rather than the likelihood of the hazard. This means that the key part of the risk analysis process is assessing the likelihood of damage to the various system elements should the hazard event occur.

The key risk management steps for existing infrastructure therefore involve:

1. Understanding the vulnerability of the key elements of infrastructure systems and networks.
    - both the physical vulnerability and the likelihood of damage occurring in foreseeable hazard scenarios.
2. Evaluating the consequence of failure of key infrastructure components (including cascading effects).
    - Firstly, the operational consequences for the network – this requires evaluation of the ability to continue to deliver the service.
    - Secondly, the consequences for the community of the loss of service - this requires evaluation the importance of the service).
3. Identifying cost-effective ways of mitigating the vulnerabilities identified to prevent and reduce the risk of failure.
    - Pre-event – preparing mitigation plans to be implemented over a period of time.
    - Post-event-preparing specific plans to respond to the occurrence of the vulnerabilities identified in order to limit the damage and be prepared to respond.

New infrastructure elements should be located and designed with resilience to foreseeable hazard events being uppermost, utilizing the latest knowledge of those hazards and current design standards. This includes making due allowance for climate change effects. The principal challenge for the location and design of new infrastructure is that it often involves the extension of existing infrastructure facilities. In many cases, key infrastructure facilities have been situated in areas of high hazard exposure. Prime examples are port facilities and wastewater treatment plants in areas of poor ground conditions that are susceptible to liquefaction following earthquakes; electricity sub-stations close to active earthquake faults; and bridges over flood-prone rivers.

This highlights the importance of carefully considering extending existing infrastructure facilities during the initial planning stages before the detailed design commences.

5. The Role of Codes and Standards

Codes and Standards have over the years served as a means to ensure minimum levels of safety and health for communities in the design of infrastructure, and they also provide a means to build resilience in infrastructure. There are, however, a number of issues that must be taken into consideration.

The development of codes and standards has often been dependent on significant levels of human and financial resources. Writers of codes and standards have required an understanding of potential hazards and have relied on research, past experience and technical knowledge. Many countries therefore rely on the codes and standards developed by a few better resourced countries and may adopt and sometimes adapt them to suit their environments. (Examples of Building Codes, American Codes, Eurocodes, and others. See a review of the former in Nienhuys, 2015).

Codes and standards are generally specific to different elements of infrastructure, such as buildings, bridges and roads. In most countries, the importance of building safety is paramount and building codes have been developed or adopted for use. Unfortunately, the use of these codes has not always been made mandatory, and many buildings are constructed that are not code-compliant. Furthermore, it is often very difficult to enforce retrofitting requirements for buildings that are in existence before the introduction of codes, due to the costs involved. This is especially difficult where retrofitting is required for low incidence-high impact events like earthquakes. And yet, seismic design codes for buildings have been highly successful in reducing loss of life from building collapse in areas that have enforced their use (examples, Chile and Japan).

Buildings are, however, the 'nerve centre' of infrastructure networks, and require consideration of continued functionality in addition to life safety as a minimum requirement.

Many countries are yet to adopt codes and standards for other forms of infrastructure as they have for buildings. The main code developing countries have specific requirements for non-building structures, but this is often not the case with less developed countries. Lifeline utilities also operate under a variety of business and regulatory models and there are no internationally consistent standards for resilience-these are defined by each lifeline utility and in some cases the individual sector regulator. All countries must be encouraged to adopt specific standards for all types of infrastructure. While performance requirements to achieve resilience of infrastructure are likely to differ from country to country, a framework approach may be used to guide the development of internationally consistent standards for resilience.

Incorporating resilience requirements in Infrastructure Codes and Standards would require a performance-based approach. In general, codes and standards have tended to address the safety and performance requirements of individual components of infrastructure. Incorporating resilience requirements would include examining the performance of infrastructure systems. The interdependence of different infrastructure systems would have to be recognized. (e.g. water systems may rely on electricity to operate and electricity systems may require functioning communication systems and vice versa). There is a need to further prioritize performance requirements to ensure adequate capacity for essential dependent systems, acknowledging that aspects of these may vary from country to country.

6. Case studies

6.1 Recent major earthquakes affecting New Zealand infrastructure

New Zealand is formed on the collision zone between the Pacific and Australian plates, creating a high earthquake, volcanic and tsunami risk. Climate challenges across the country range from ex-tropical cyclones to droughts, flooding and snow events.

There is a legislative requirement in New Zealand for 'lifeline utilities' (infrastructure providers) to "function to the fullest possible extent" following an emergency (the NZ Civil Defence Emergency Management Act 2002). This enabling legislation is supported by an environment where infrastructure providers collaborate at regional and national levels to firstly, understand their vulnerabilities (with an emphasis on the interdependency between lifeline utilities) and secondly, integrate their plans to address these vulnerabilities in areas where their networks physically interface (for example, at bridges) and have collective risks. This requires a considerable degree of impact modelling, and has led to the strong involvement of the research sector.

By working together, this builds relationships -both organizational and individual- that can also be drawn upon in the response and rebuild phases following a disaster.

Both the Canterbury Earthquake Sequence (commencing with the Mw7.1 Darfield earthquake in September 2010) and the Mw7.8 Kaikoura earthquake in November 2016 had a significant impact on both local and national infrastructure networks. A sample of the key learnings are summarized below, under the headings of Technical and *Organisational/ Contractual*:

Technical learnings

- Highway and rail networks–repairing and replacing bridges to current standards is Build Back Better in practice, and additionally has achieved effective asset renewal. Also, some bridges were either not rebuilt or rebuilt in better locations to avoid geohazards. This acknowledges the need to consider Building Back ***Differently.***
- Residential wastewater networks - the use of holding tanks at individual properties, that pump into street mains as a means of overcoming inadequate hydraulic grades due to local or global earthquake settlement.
- Telecommunication networks–Telco providers have since increased the size of fuel storage tanks for the standby power generators of their exchanges. This was a response to the cordoning of streets due to damaged multistorey buildings preventing access for re-fueling.

Organizational/ Contractual learnings

- Recognition of the need for a contractual approach during the recovery that is less controlling than customary contracts led to the solution of an incentivized alliance involving funders (government), network owners and contractors. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) following the Canterbury Earthquakes and the North Canterbury Transport Infrastructure Recovery Alliance (NCTIR) following the Kaikoura Earthquake were formed to facilitate the rebuilding of water and transportation networks
- This has emphasized the importance of relationships and collaboration to take common mitigation opportunities in ‘everyday’ infrastructure resilience planning.

6.2 Comparison of power grid problems in Europe and South America

In the morning of June 16th 2019, a major blackout affected Argentina, Uruguay and Paraguay when a short circuit disconnected one of three 500-kV transmission lines running from Colonia Elía to Belgrano near Buenos Aires (Nordrum, 2019). With one transmission line already down and undergoing maintenance and the second one tripping, the third one also could not hold the high-power levels being transferred at that time and was disconnected by the Automatic Generation Shutdown system (in Spanish: DAG). Although the DAG is a fall-back system designed to automatically disconnect generators if a problem is detected, it was operating on false data since the maintenance of the third line and the resulting change in the network grid was not reflected in the DAG’s system at that time.

The blackout had a major impact on the water, health and transportation sector. People in Argentina were recommended to reduce their water usage, medical patients who were dependent on home equipment had to go to hospitals where backup generators were in place and people were queuing in front of gas stations. Furthermore, local elections in some regions of Argentina had been interrupted by the power outage and people had to fill out the ballots in the dark. By mid-morning, power was restored in Buenos Aires and around noon at across 75% of Uruguay; until the evening almost all parts of Argentina and Uruguay were again connected to the power grid.

In the afternoon of January 8th 2021, the Continental Europe power grid was separated into two parts as a 400 kV busbar coupler in Ernestinovo (Croatia) tripped because of overcurrent protection (ENTSO-E, 2021). This led to a decoupling of the two busbars in Ernestinovo substation, causing a shift of electric power flows to neighbouring lines and subsequently the overload and further tripping of that lines, which eventually caused the system separation in two parts. The North-West area suffered a deficit of power and a frequency decrease; accordingly, there was a surplus of power and an increase in the South-East area.

As a consequence, a couple of services in France and Italy were shut down to reduce the power deficit. Those services are contracted by the transmission system operators to be disconnected if frequency drops under a certain threshold. Similarly, power production of a large generator in Turkey was reduced and the frequency could be held stable in both areas. Due to the automatic response and the coordinated actions taken by the TSOs in Continental Europe, a power outage was avoided and the situation was quickly restored to close to normal operation.

Although the incidents happened in separate parts of the world with different impacts, similar mitigation actions were in place with distinct effectiveness. Key learnings from both incidents are described below, under the headings of *Technical* and *Organisational/ Contractual:*

Technical learnings:

- Automatic protective systems are in place in many large power grids all over the world but the incident in South America showed that the correct configuration is a big issue. If protective systems are not working properly, they can be the cause for problems
- Black start capabilities are an essential feature to recover quickly from a power outage. Due to the large amount of hydro-electric power plants in Argentina, the grid could be brought back online in a brief time. With a more diverse landscape of power plants in Europe (nuclear, coal, wind, etc.), a recovery might take more time.

Organizational / Contractual learnings:

- In both cases, detailed emergency response plans represent the most valuable tool for successfully preventing or recovering from such an incident. Pre-contracted shutdown plans for large consumers can help to quickly react in case of an emergency.
- As power grids nowadays span over an entire continent, cross-border co-operation is also a core aspect in preventing large power outages. The coordinated reaction of the TSOs in Europe supported by digital systems and classical phone communication shows the importance of aligned processes in this area.

7. Key Messages

This chapter has highlighted the many considerations involved in achieving greater resilience of infrastructure networks. Key themes and messages that reflect the opportunities to achieve greater infrastructure resilience are summarized below:

Understanding the different components of infrastructure resilience

Infrastructure resilience involves several different components and attributes, as follows:

1. Robust assets and networks
2. Appropriate resource commitment by infrastructure organization
3. Effective collaboration with all members and stakeholder parties
4. Realistic community expectations and preparedness

This highlights the need to look beyond physical resilience (the typical domain of engineers) and consider organizational resilience aspects as well as the community as end-users.

The influence of ownership and regulatory systems

There are different funding constraints and regulatory regimes both between and within the public and private sectors. Infrastructure organizations operate under a variety of business and regulatory models. Organizations in private ownership require a commercial return on resilience investment projects, and the economic justification of resilience investments can therefore have different characteristics which influence the level of investment in resilience improvements. Local authorities and organizations who own networks and facilities directly on behalf of the community are inherently more conscious of community considerations and the need to invest in resilience.

Taking account of interdependencies

Taking account of network interdependencies and the potential for cascade effects is an essential element in risk reduction. This indicates that while risk reduction can be incrementally achieved by individual utilities, the most effective mitigation measures require planning and implementation across key infrastructure providers as integrated programmes.

Reducing risk at the time of new infrastructure development

Any future infrastructure development needs to be carefully thought through –both for general natural hazard risk and climate change considerations. There is a need to be bold in questioning the appropriateness of the location of key existing infrastructure facilities. An overarching question is how adaptive and resilient is our long-life infrastructure? A key aspect of infrastructure resilience is to not automatically further develop existing infrastructure that is already at risk– but this is often a difficult call given the 'sunk costs' associated with existing facilities.

Engineers clearly have a critical role in promoting and achieving enhanced resilience of urban and rural infrastructure networks. Disaster Risk Management requires the full consideration of the context of the community, and so technical knowledge must be applied with an understanding of all the dimensions of resilience, and with a community focus.

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CHAPTER III
DATA AND INFORMATION MANAGEMENT

Fang Chen[a], Marcial Rivera Rodríguez[b], Zeeshan Shirazi[a], Lei Wang[a]

[a] International Research Center of Big Data for Sustainable Development Goals, China, chenfang@radi.ac.cn, zeeshan@radi.ac.cn; wanglei@radi.ac.cn
[b] Federated Association of Engineers and Architects of Costa Rica, San José, Costa Rica, mrivera@cfia.cr

1. General concepts

Improvement in data and information has always been a priority for Engineering over the years, however, rapid development and growth of data sciences as a separate and specialized field, has created new possibilities for their use, while the diversity of information available from modern digital infrastructure calls for rapid improvements in our capacity to obtain, save, cluster, and share the data, to convert it to actionable information to enable science-informed decision-making processes across the world.

Engineering structured data, consisting of a row heading to contextualize data ordered in rows (normally numbers or names), enable calculations and analysis of information. Examples of structured data can be the temperature measured per hour from a sensor, the amount of water passing through a dam, the quantity of precipitated water over a period, and which was collected from a specific (and normally expensive) device. However, in recent times, the growth of IoT (Internet of Things) have enabled development of a networks of sensors resulting in large volume of structured data. Beyond growing volumes of structured data, there is also an exponential growth in the amount of accessible unstructured data that is diversifying and introducing new forms of data and changing the way that governments, scientists, and communities get information. The unstructured data all the information lacking row headings that allowed to order it in chart or any pre-defined manner, such as video, imaging, or a conversation.

An important amount of the information captured in disasters is structured. The magnitude, depth, and location of an earthquake can be tabulated on charts. But in recent times, the information obtained from satellite images, or the information from social media concerning the impact of a disaster on a population, requires a process to transform it into data.

2. Major worldwide and regional databases on disasters (and their accessibility)

Data on disasters are collected for a variety of users including Governments, regional and global organizations, NGOs and financial institutions and are used for a diverse range of applications, from guiding disaster response and prevention activity, developing insurance products, city design and planning, to scientific research and disaster case studies (Wirtz et al., 2014). This data is essential to characterize and analyze previous events and to study, understand and identify the underlying causes to predict and if possible, prevent recurrence, loss, or reduce the risks and associated consequences, of these disruptive events. Through scientific and technological progress, over time our capacity to generate and collect data on different aspects of disasters is improving in quantity, quality and efficiency, improving our capacity to learn from even minor events through improved measurements and better analysis (Editorial Nature Geoscience, 2017). This level of data and information is highly desirable and possible for individual types and classes of disasters; however, it is extremely challenging on a large scale due to varying capacity and resources within different countries.

Data collection activity, its scope and the resulting amount of historical disaster data that is archived is non-uniform across different administrative levels and is not spatially consistent across the globe. Some emerging countries simply lack the ability, resources and institutional capacity to adequately collect this data and therefore also lack historical data within their jurisdictions (Moriyama, Sasaki and Ono, 2018). Consequently, basic data on disaster mortality, disaster affected populations, economic losses, and damage that provide means to link disaster with development and identify causes, casual factors and vulnerable populations, are not sufficiently accessible for analysis. Without this data, proper reference benchmarks cannot be established to evaluate the impact of disasters and monitor the progress and effectiveness of the disaster risk reduction efforts in place or to identify what measures are required. These limitations have also restricted the pace and progress of actions to support global frameworks such as the Sendai Framework for Disaster Risk Reduction and the 2030 Agenda for Sustainable Development. UNDRR has reported a lack of comprehensive data to evaluate meaningful trends at local, regional and global scale. This has highlighted the need to improve data quality and the need for well-managed and maintained disaster loss databases (UNDRR, 2020).

Disaster risk drivers are essentially trans-boundary such as, climate change, air pollution and other risk factors that are common in many parts of the world such as poverty, uncontrolled urbanization and population growth (UNISDR, 2020). Risk management requires open access to disaster-related data that provides potential for a more comprehensive understanding of risk and opportunities for collaborative and sustained solutions, by enabling improved modeling, assessment, mapping and early warning capabilities. To improve data coverage and reporting, data standards and comprehensive approaches to data collections are being implemented throughout the UN member states (UNDRR, 2020). International programs such as UNDP, UNDRR and CRED are facilitating development of regional and country level databases since the early 2000s (UNDP, 2013). UNDRR has successfully sponsored the adoption of a common disaster database format in several countries provided through the DesInventar software (UNDP, 2013). It is now updated as DesInventar-Sendai, an advanced disaster information management system that provides “a conceptual and methodological tool for the generation of National Disaster Inventories and the construction of databases of damage, losses and in general the causes and impacts of disasters” (DesInventar, 2019). These disaster loss and damage databases aim to capture homogeneous multi-scale data at multiple locations and times, openly accessible for research and analysis to understand disaster trends and patterns and emerging risks. With open accessibility, DesInventar hosts data for 90 mostly developing countries, and can be considered as a benchmark framework for data collection and reporting within the Sendai Framework. It obtains extensive information from official government records, national and local print media and public health records on disasters due itsflexible definition of a disaster event as being a cause of a single death or a cause of damage worth a single US dollar. Furthermore, there is also an element of spatial detail in DesInventar as it assigns each disaster entry with a country, province/state, district/town label (Panwar and Sen, 2020).

The other major global disaster database freely accessible and most widely used and cited is the EM-DAT. EM-DAT only assigns disaster events entries country labels but has the advantage of more extensive global coverage with data from over 200 countries globally. The criteria for defining an event as a disaster are also stricter and more extensive and include reported deaths (>= 10), people affected (>= 100), declarations of emergency by the affected country and request for international assistance. It collects data from international agencies such as the UN, inter-governmental organizations and US government agencies as sources for disaster data (Panwar and Sen, 2020). There are several other databases for disaster loss data; however, they are either not open or not widely used, such as the NatCat and Sigma, that are not openly accessible, while CatDat is limited to earthquakes only.

Despite these shortcomings, various regional and global disaster damage and loss databases are actively maintained and updated. A comprehensive list of these databases is presented in table 1.

Table 1 – List of disaster loss databases with details

	Dataset	Coverage	Access	Scope	Managed By	Types	Period of Record
1	EM DAT	Country	Open	Global	CRED	Natural	1900 - Present
2	DesInventar	Multi-scale	Open	Global	UNDRR	Geological & Weather Related	Varying Coverages for different countries
3	Sigma explorer	Event based	Open	Global	SWISSRE	Natural & Manmade	1980 - Present
4	NatCatService	Event Based	Closed	Global	MUNICHRE	Natural & Manmade	1980 - Present
5	Global Disaster Identifier Number	Event based	Open	Global	ADRC	Natural & Manmade	1930 - Present
6	SIAPAD - Andean Information System for Disaster Prevention and Relief	Andean countries	Open	Regional	CAPRADE	Natural	
7	CDEMA - Disaster events database	CDEMA Member Countries (Caribbean)	Open	National	CARIBBEAN DISASTER EMERGENCY MANAGEMENT AGENCY	Natural	1780 - Present
8	Disaster Management Information Center (DMIC)	Bangladesh	Open	National	MINISTRY OF DISASTER MANAGEMENT AND RELIEF	Natural	
9	Canadian Disaster Database	Canada	Open	National		Natural & Manmade	1900 - Present
10	SHELDUS - Spatial Hazard Events and Losses Database for the United States	United States	Open	National	University of South Carolina	Natural	1960 - Present
11	U.S Natural Hazards Statistics	United States	Open	National	NOAA, National Weather Services	Weather Related Hazards	
12	DANA - Damage and Needs Assessment system of Vietnam	Vietnam	Open	National	Central Committee for flood and storm control	Hydro-Meteorological	1989 - 2008
13	DIBI - Indonesian Disaster Information and Data	Indonesia	Open	National	National Agency for Disaster Management	Natural & Manmade	1815 - 2012
14	The Australian Emergency Management Knowledge Hub	Australia	Open	National	Emergency Management Australia	Natural & Manmade	1622
15	Web SIG -DISASTER	Portuguese	Open	National	Science and Technology Foundation	Floods/Landslides	1865

3. Innovations in Big Data processing for DRR

The rapid improvements to digital capacities across the social, economic and business spectrums of human society and growing digital capability globally has provided us with the opportunity to collect and utilize data and information from new and non-conventional sources and complement existing digitized data and information for a more comprehensive, in-depth understanding and analysis. Generally this large volume of multi-source data is called Big Data, and is characterized by 5 Vs: Volume, referring to the quantity of data; Variety, referring to the diverse sources of data; Velocity, referring to the speed of data generation, transmission and processing; Veracity, referring to data quality and accuracy; and Value, referring to its end benefits in terms of solutions, applications, development etc. (Yang et al., 2017). With increasing sources of raw data, the nature of the collective dataset becomes complex and requires more intensive and complicated processing due to the inherent diversity in formats, quality and nature (static vs. dynamic data updates) of data.

Big Data helps to understand both the nature of data and the relationship between data (Terziet al., 2016). Big Data processing generally involves four main processes including, data acquisition, data storage, data analysis and data exploitation (Casado and Younas, 2014). Due to the voluminous nature of Big Data, earlier generation of Big Data frameworks essentially implemented distributed file systems employing distributed data processing. Data processing systems have evolved over the past couple decades, shifting focus from batch processing to real-time processing to deal with the increasing influx of new form of streaming data, with low latency and high velocity requirements. Since 2014, innovations in hybrid computations are being pursued (Casado and Younas, 2014) to cater for both volume and velocity of incoming data from evolving and expanding modern digital infrastructure.

Data analyzers not only meet the challenge of collecting and handling the data, but also to define the software language to mine it. There are some main open-source programming languages that lead the investigation on data mining, R and Phyton. Each of these programming languages can be run on different software and cloud systems. It is highly recommended to a person who wants to develop on these fields, to get used to these languages and libraries of functions.

Major developments in Big Data processing have been concentrated in big technological firms, including more famous companies such as Google, Yahoo, Facebook, LinkedIn and Amazon among others. These developments were driven by the need to manage and process the growing amount of data being generated from user activity on their online digital platforms due to their attractive digital products and services, growing accessibility to internet and digitally connected devices. A major development, enabled by improved online connectivity and data connection speed, is the concept of Cloud Computing. Developments in cloud computing enabled remote access to large data centers developed by these large technological companies and other specialized data businesses providing computational resources for storage and processing of digital data. This incentivizes other business enterprises to focus their efforts and resources to develop their core products and services, and reduce their cost and resources on hardware and software management of digital data. These Big Data processing resources are now generally available as Infrastructure as Service (IaaS), Platform as Service (PaaS) and Software as Service (SaaS) models (Elshawi et al., 2018).

Cloud computing has also enabled innovative uses of Big Data from these data centers in different commercial, social and scientific research, including disaster risk management. However, the nature of Big Data for disaster risk management is more diverse and multi-disciplinary. Presently there are several sources of Big Data that are actively been used and can be broadly divided into: sensor generated data, which include remote sensing data from multiple platforms, such as satellite, LiDARs and UAVs, on ground sensors; user generated data, which include data from IoT and Web, and increasingly new applications of social media, crowd sourcing, mobile GPS and caller detail records; and simulation data from predictive models (Ragini, et al., 2018; Yu, Yang and Li, 2018).

The significance of the Big Data processing infrastructure and the cloud computing platforms, especially for disaster risk management is highlighted through potential application of data from social media extracted in real time or near-real time for situational awareness (Ofli et al., 2016; Zhang et al., 2019) and sentiment analysis (Ragini, et al., 2018) during the disaster or disaster response phases for communication and information purposes (Gray, Weal and Martin, 2016). Even though the social media platforms are increasingly being used to disseminate and exchange information, their utility as a source of information during crisis situation is still being studied. A growing body of literature is being developed that provides information on links and patterns between disaster events and the content, frequency and temporal patterns of social media activity. Meta-data information from shared images such as user tags, geo-location, temporal information provide valuable details for information on disasters (Said et al., 2019). New developments such as geo-tagging tweets, mobile tracking software, and media post and crowd sourcing is adding spatial dimension and enriching the quality of information that can be extracted from these social media platforms.

However, unlike these new forms of user generated data, remote sensing data from different platforms has been widely used for various applications in disaster for over several decades. Both the number of remote sensing platform, the resulting amount of data and the capability to process large volumes of image data has improved over the years. Similarly, open data policies, improved digital data management, accessibility and data processing software and accessibility to cloud computing resources has improved the adoption of these dataset especially for spatially relevant applications such as disaster risk management (Guo 2017a; Guo 2017b). A 2018 survey (Kumar and Mutanga, 2018) of literature on use and trend of the Google Earth Engine, a free dedicated cloud computing environment for remote sensing data and applications, found that about 6 out of the 300 research articles (2%), reviewed between 2011 and 2017, had used the platform for disaster related applications, A more recent literature survey (Amani et al., 2020) of 450 research articles published between 2010 to 2020 found about 40 papers related to natural disasters suggesting a trend towards adoption of these cloud platforms and Big Data techniques in earth observation data processing for disaster related applications. Unlike Google, Amazon, as a part of its public dataset program has initiated the “Earth on AWS” cloud platform providing data access to Landsat 8, Sentinel 1 & 2 data NOAA and China-Brazil Earth Resource Satellite Program remote sensing datasets pay-as-you-go service. Microsoft’s Azure and its AI for Earth initiative is a pay-as-you-go service with much limited data variety and regional coverage (Amani et al., 2020).

Another important concept in Big Data processing and application is the big earth data ecosystem concept that focuses on integration of multisource data within a geographic context ensuring open accessibility and democratization of data and information towards data driven solutions for global challenges. One example of such an ecosystem is the Chinese Academy of Science’s Big Earth Data infrastructure being developed through its Big Earth Data Science Engineering Program (CASEarth), which includes a big earth data cloud platform and a decision support system for science driven policy and decision support. CASEarth has prioritized the integration of multi-disciplinary and multi-source data for various applications (Guo et al., 2020). Similarly, Global Earth Observation System of Systems (GEOSS) being developed by Group on Earth Observation (GEO) which are linked earth observation and processing system providing strengthen monitoring for earth processes. Both these systems provide data analytical services for actionable information including on disaster risk management and broadly sustainable development. CASEarth has also recently published case studies which also include a few case studies on use of big earth data for disaster application in 2019 and 2020. Selected case studies form this report have also been presented as a part of official documents submitted to the UN during the 74th and 75th UN General Assembly in 2019 and 2020 respectively. From a broader perspective and within context of sustainable development, such systems also provide an opportunity for comprehensive analysis for example, connecting information on urbanization and land degradation with disaster risk management activities for a more effective analysis of risks and opportunities for improvement.

4. Applications of artificial intelligence and machine learning to different DRM processes

The potential for innovation within Big Data, a part from technological developments and data processing, also lies in data analytics. As highlighted in the previous section Big Data introduces challenges due to growing volume, sources and formats of data. While technological developments have enabled data centers to store increasing volume of data, improved access to them and facilitated processing of large volumes of raw data through cloud computing infrastructure, the process of translating this data to actionable and valuable information also requires a special class of analytical techniques collectively termed as Big Data analytics. Big Data analytics focus on innovations and advancements to improve the quality of information intrinsic within these complex datasets and the pace of the process of its extraction.

One of the key concepts within the Big Data analytics is that of Artificial intelligence (AI), which has been around for a long time, but with improved computing infrastructure and data volume has rapidly developed in the past couple decades. AI deals with the ability of computers to perform tasks independently with minimal or no human interaction. AI facilitates automation at scale and can generally be divided into two main groups applied and general AI. General AI strives to make machines perform a wide range of actions independent of human input, which is understandably complicated. It has been responsible for major innovations in this field. Applied AI is more widely used and deals with specific applications in a field where such applications include pattern recognition in its different forms, including but not limited to face recognition and speech recognition, classification problems of enormous diversity spanning fields such as micro and molecular biology, environment, and text classification. AI has wide implementation in both data processing and in data analytics. In both aspects, AI algorithms are designed to learn from data, supervised or unsupervised, and make use of patterns identified within the data to carry out assigned instructions. This widely used data driven process is termed as Machine Learning (ML) (GFDRR, 2018).

Retailing, aircraft companies, streaming (music and video) system, have been leaders in using Big Data to model consumption patterns, and through this, increase profits. Basket market, that analyses costumer purchasing, is an example of using ML on databases. Supermarkets know which product has to be placed near another that is consumed together. Aircraft companies can estimate the number of people who are going to travel, to select the type of aircraft and flight crew needed.

Disaster risk management can use models to calculate the impact of natural hazards on populations and infrastructure. Emergency response teams, damage to infrastructure for insurance, and the expected demand of the health system could be estimated.

In disaster-related studies, both ML and AI techniques have enormous potential in decision support systems at various stages of disaster risk management. Complete automation of warning, alert and response systems are likely, although not yet possible, due to various factors, including the associated lives at stake, data quality challenges and inter-agency disaster response and relief coordination. However, these techniques, through improved image recognition, natural language processing, object recognitions (Ogie, et al., 2019) and other improvements in data analysis have accelerated the decision-making process through rapid generation of useful information providing an advantage in response and recovery stages that helps to save valuable lives. During preparedness and planning phases AI and ML driven systems enable a more comprehensive situational awareness and understanding of ground realities (Sun, et al., 2020) and is one of the most extensive of its application areas (Tan et al., 2020). These techniques have also demonstrated strong success in disaster prediction and warning. The only limitations to the use of these systems are access to or availability of digital data for detailed analysis.

Several challenges still persist in using ML and AI for disaster-related applications. There are several studies on remote sensing data integration, however, multi-source data integration for AI and ML research still requires adequate data integration to ensure that smart sensor and data from social media can be effectively utilized for improved information and decision making. Moreover, the research into application of AI and ML to natural processes and social dynamics is not adequately integrated to provide a more comprehensive overview of human response to crises for effective relief operations and identification of disaster risk during planning stages (Tan et al., 2020). More importantly ML driven AI requires high quality and high-volume input data for reliable informational output (Guo, 2018). With restricted access to multisource data especially on-site and traditional data sources, the reliability and effectiveness of ML and AI application will remain limited (Guo, 2017). However, there is still potential for improved uses of these rich data and analytical resources for disaster risk management. For example, for more comprehensive analysis of different aspect of disaster risk, existing methods of information extraction from social media and other unconventional data sources should be used to develop new standard databases with the intent to diversify information and fill existing data gaps. These new databases can be integrated with existing sources of data for a more comprehensive analysis and management systems.

5. Opportunities and obstacles

There is extensive academic and research work exploring innovative applications of emerging technologies and information systems for disaster risk management in many parts of the world. There are also several successful implementations of Big Data and AI in disaster risk management system. However, these implementations, while validating the benefits of these methods, have not been widely put into practice. One of the main limiting factors towards adoption of the data intensive solutions is lack of data itself or data analysis capabilities.

Data analysis platforms enabled by cloud technology are quickly improving data analysis and allowing for rapid adoption of new and emerging techniques. With time, the accessibility to these cloud platforms is also improving due to the growing and expanding IoT infrastructure world over. Aided by modern communication technologies, such as the 5G networks, improving data speeds will enable analysis of even larger Big Data volumes. However, this rapid pace of development has resulted in an explosion of data analysis techniques which is expected to continue to increase in number. There is, therefore, a need to standardize methods for more consistent and reliable results, and wide acceptability and implementation.

The CDRM and other international organizations working on disaster risk reduction systems should work and introduce guidelines to establish systems to identify reliable data analysis methods and processes as global standards. This will also enable large cloud-based data analysis platforms to develop and launch the standard methods and their implementations, enabling wider adoptions and use of these new technologies and methods. Similar initiatives are also required to standardize digital data and data collection processes for their use in disaster risk management analysis.

One of the more challenging aspects of adopting new technologies and methods is the limited human resource capacity that require time and concerted effort to develop and deploy. With growing IoT infrastructure the potential for growing user base will depend on capacity development programs ensuring rapid adoption and utilization of these digital infrastructure and resources for local, national and regional disaster risk management practices.

The resulting development of institutional capacities will facilitate not only effective engagement between different organizations at local scales but also enable close and meaningful cooperation between different countries enabling a more comprehensive risk reduction effort towards cross-border disasters.

6. Key Messages

The sources of data and information have diversified following rapid digital transformation of our societies. New sources of data and information facilitate more comprehensive analysis of the disaster risk and therefore, enables new management techniques and innovation solutions to reduce or mitigate disaster risks. To ensure that human society as a whole benefit from these developments, accessibility to existing resources and capacities to efficiently utilize these diverse sources needs to be improved. Standardization of data and methods has a good potential to enable wider dissemination of common and reliable solutions and also enable wider adoption for collective sustainable development and reduced disaster risk.

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CHAPTER IV
CAPACITY BUILDING

Ashok K. Basa[a], Valentina Putrino[b], José Macharé[c], Arturo Muiña[d]

[a] The Institution of Engineers (India), akb.beb@gmail.com
[b] University College London, The United Kingdom, v.putrino@ucl.ac.uk
[c] National University of Engineering, Peru, jmachare@hotmail.com
[d] Instituto de la Ingeniería de España, Spain, amuinad@hotmail.com

1. Introduction

As stated in the introductory section, here we work with the concept agreed on by the UN that resilience is the capacity of a society to cope, as a system, with stressors related to its development by withstanding, adapting, and recovering with regard to their impacts.

In a world that is fast-paced and subjected to the increasingly more frequent impact of natural and man-made disasters, it is necessary for society to become more adaptable and more inclined towards a fast change of direction, both in terms of policy-making and in developing a self-contained capacity to cope with these new stressors.

Initially disaster management involved activities after the occurrence of the disaster such as Relief, Rehabilitation and Reconstruction (3R). However, radical changes in the concept of Disaster Management were brought in by the three World Conferences on Disaster Risk Reduction, held in Yokohama in May, 1994, in Hyogo (Kobe) in January, 2005 and in Sendai in March, 2015. After these World Conferences, the approach towards disaster management has shifted from Post-Disaster reactive approach to a Pre-Disaster proactive approach, from response to preparedness with prevention and long-term mitigation measures, involving Planning, Preparedness and Prevention (3P).

Disaster, particularly natural disasters, cannot be prevented but its effects can be reduced. It is generally found that the effects of disaster are less in developed countries in comparison to developing or underdeveloped countries. Let us take the example of Earthquake. The so-called "developed countries" such as the US, Japan and New Zealand experience very high intensity earthquakes quite frequently. Yet the effects are minimized due to the efforts of engineers and technocrats of these countries and because of their updated engineering codes and strict adherence to these codes during design and construction. In the case of developing and underdeveloped nations, even a moderate earthquake causes huge human casualties.

For instance, in the Kobe earthquake in Japan in 1995 measuring 7.2 in Richter Scale, about 6425 people died whereas in the case of the 2010 Haiti earthquake measuring 7.0 on the Richter Scale, more than 316,000 people died. Besides, the overall economic loss is also prohibitively high in the underdeveloped countries which causes further misery to these nations. Hence, reduction of the effects of any disaster is crucial. Capacity building helps in reducing the effects of disaster.

Figure 1 clearly shows that the three levels of capacity are interrelated and not mutually exclusive. All the three levels need to be taken into account while determining "who" needs "what capacities" for "what purpose".

The main objective of this chapter on "Capacity Building" is to highlight how the self-contained capacity of the society can be strengthened and the strategies to adopt to make people feel more ready to manage risk and become more resilient. Three case studies, each dealing with one natural disaster are elaborated to emphasize on these aspects.

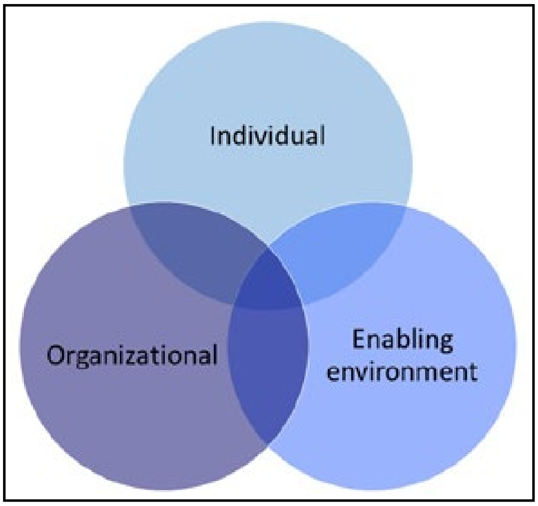

Figure 1: Source: Adapted from UNISDR (United Nation International Strategy for Disaster Reduction)

2. Case studies

2.1 Cyclonic Hazard, the case study of India

A cyclone is a natural disaster causing high economic loss besides large human casualties. 7 cases out of 9 recorded cases of loss of human lives of 40,000 or more, took place in Indian sub-continent within the past 300 years. Therefore, Indian sub-continent is the worst cyclone-affected region in the world. This region is affected by tropical cyclones in two seasons: Pre-Monsoon (April-May) and Post-Monsoon (October-December).

In India, Odisha, a state located in the eastern part adjacent to the Bay of Bengal, is the worst victim of cyclones. The latest report on "Vulnerability to cyclones" reveals that Odisha alone is 17% vulnerable to total cyclones faced by India. Apart from this, surge height in the Odisha coast is very high, in the order of 5-6 m. Cyclonic storms associated with storm surges inundate large tracts of Odisha. Thus, during a cyclone, Odisha faces heavy wind, intense rainfall and high surge waves.

In 1999, Odisha encountered a devastating super cyclone from 29th-31st October that crossed the port town of Paradip with a wind speed of more than 300 kph, killing over 10,000 people. About 18.9 million people were affected with crop losses of 1.84 million hectares of land and 75 % of the standing trees on coastal Odisha. The cyclone destroyed almost 90% of the coastal vegetation, besides affecting mangroves and casuarina forest. Power failure remained for more than 4 weeks (Kalsi, 2006).

Lots of lessons were learnt from the 1999 Odisha Super Cyclone.

(i) Creation of a specific organization to coordinate all activities before, during and after the cyclone. That is how Odisha State Disaster Management Authority (OSDMA) was set up in December, 1999.

(ii) Creation of the first state-wide community-based Disaster Risk Governance System.

(iii) Construction of cyclone proof shelter buildings along the coast.

(iv) Forecasting and developing Early Warning System.

(v) People from an early age have to be made aware of the disaster.

Priority was given to Capacity Development. Training was provided to more than 23,000 of the most vulnerable villages under the Disaster-Risk Management Programme. This was taken up by emphasizing training at an individual level and at the organisational level, apart from formation of the State Disaster Management Authority, Disaster Management Planning was initiated from village/ Panchayat/Sub-Division/District level. While at the state level, it was headed by the Chief Secretary; at the District level, it was headed by the District Magistrate. Thus, adequate emphasis was given at the organisational level to create an enabling environment. Dedicated Odisha Disaster Rapid Action Force (ODRAF) was created in 2001 to deal with the task of search and rescue. Presently, 20 units of ODRAF and 335 units of fire service people are there. Emergency Communication in the form of satellite phones is provided. 879 cyclone shelters along with safe drinking water, lighting with power back-up etc. have been made.

The Indian Meteorological Department is now capable of tracking the cyclone since its formation and to know the speed and direction of winds along with the place of landfall. Because of this early information, there is time for the administration to get prepared for the cyclone, and evacuate people from the affected areas to save lives.

It is necessary that such information is disseminated to the remotest place. To achieve this, a project "Early Warning Dissemination System (EWDS) for last mile connectivity has been implemented, funded by the World Bank, through which 1,205 vulnerable coastal villages within 5 km from coastline have been covered. It is achieved by Satellite-Based Mobile Data Voice Terminals (SBMDVT) in State Emergency Operation Centre (SEOC) and District Emergency Operation Centre (DEOC), Digital Mobile Radios (DMR), Mass messaging system at SEOC, Alert Siren System at 122 locations near the coast (within 1.5 km approximately), Universal Communication Interface. Thanks to this, a person based on a remote corner in the coastal area could be warned about an impending disaster in a very short time. Simultaneous warnings can be disseminated from Block, District and State levels through different forms such as sirens, messages, voice etc. Any information from the State level can be communicated to the entire coast of Odisha at the push of a button.

All these together improved the Capacity Building. Needless to say, in all these, engineers did play a vital role.

Table 1. Loss of human lives in different cyclones

Date of Cyclone	Name of Cyclone with wind speed	Loss of human lives
29-31 October, 1999	Odisha Super Cyclone (more than 300 kmph)	More than 10,000
12-14 October, 2013	PHAILIN (250 kmph)	44
3-May-19	FANI (205 kmph)	64
9 November, 2019	BULBUL (155 kmph)	41
16-May-20	AMPHAN (190 kmph)	118
26-May-21	YAAS (130 kmph)	0 (Zero)

The above table clearly indicates the drastic reduction of loss of human lives because of the emphasis given to Capacity Building.

It is to be noted further that during cyclone Phailin (2013), about one million people were evacuated, whereas during cyclone Fani (2019), 1.2 million people were evacuated creating a global record. The long-awaited target to achieve zero human loss, was accomplished in the recent cyclone YAAS (2021). The UN not only congratulated the Government for such exceptional handling of cyclone Phani (2013), but also announced that it would highlight the efforts of the Government as a model for disaster management globally. The Govt was commended by the UN for such great accomplishment. Similarly, the UN also acknowledged the accomplishments for managing cyclone Yaas successfully with zero loss of life.

Apart from cyclone, occurrence of other natural disasters, such as earthquakes, floods, tsunamis, storm surges, landslides, thunderstorms are common features in Indian subcontinent. In order to save life and property in different disasters, Disaster Management became a national priority of Government of India (GoI), resulting in the formation of the National Disaster Management Authority (NDMA).

NDMA, headed by the Prime Minister has been created in accordance with the enactment of

Disaster Management Act 2005, to spearhead and implement a holistic and integrated approach to Disaster Management in India. “It lays down institutional and coordination mechanisms for effective Disaster Management at national, state, district and local levels.” National Policy on Disaster Management was adopted in 2009 followed by the National Disaster Management Plan in 2016 (NMDP 2016). NMDP 2016 is the world’s first ever national plan explicitly aligned with Sendai framework of March 2015.

It is necessary for a disaster management plan to be dynamic, which it has to be updated periodically, based on the feedback/experience available from implementation. Accordingly, in November 2019, NDMP 2016 was revised. NDMP 2019 aims at “enhancing the understanding of stakeholders and further strengthening our capacity to recover in the wake of natural disasters.” NDMA helps in “adopting a Technology-Driven, Pro-active, Multi-Hazard, and Multi-Sectoral strategy for Building a Safer, Disaster Resilient and Dynamic India.”

While making any disaster management programme involving prevention, mitigation and preparedness; identification of vulnerable areas which are severely affected by natural disasters is of prime necessity. Publication of the Vulnerability Atlas of India in 1997 is another important step carried out by GoI as a part of its Disaster Management Strategy. Immediately, after the Yokohama World Conference for a safer world in May 1994, GoI formed an expert group in July 1994 to release a suitable document containing the vulnerability of different places related to various disasters. The expert group came out with a wonderful document entitled as “Vulnerability Atlas of India” in March 1997 within less than three years. This Atlas gives state-wise hazard maps and district-wise damage risk table for the country as a whole. This document was commended by the UN Centre for Human Settlement, Nairobi, Secretariat for International Decade for Natural Disaster Reduction (IDNDR). This document has also been adjudged as a Project with high demonstration value by IDNDR. This Atlas is interlinked with population and demographic data for every ten years available from the census. Thus, the Atlas of 1997 and 2007 are based on censuses of 1991 and 2001 respectively. The current volume of 2019 is based on the 2011 census which helps in evolving micro-level action plans for reducing the impact of natural disaster. This Atlas is greatly utilized by the State Government and other agencies as a valuable guide, while making engineering plans for developmental works.

After the Gujarat earthquake in 2001, many important changes were introduced to the seismic analysis of structures. Accordingly, the National Building Code (NBC) of India was revised in 2005. It was further updated in 2016 so that resilience is imbibed in the structure against earthquake, wind etc.

The above information has been collected from Odisha State Disaster Management Authority, National Disaster Management Authority and similar other government organisations.

2.2 Volcanic Hazard, the case study of Peru

The Andean chain has three segments of active volcanoes. The Central Volcanic Zone (CVZ) extends from 15° to 28°S, in southern Peru and northern Chile, and has produced large and destructive eruptions throughout history. Populations of this mountainous region, that in few cases are larger than 10,000 inhabitants, occupy valley bottoms often at the foot of volcanoes because of the richness of soils derived from these structures.

In Peru, the knowledge on the character, intensity, frequency, and products of these eruptions has gradually improved in the las 30 years thanks to a) strengthening of the monitoring capacity, with the joint efforts of two volcanic observatories administered by the National Geophysical Institute (IGP) and the Peru Geological Survey (INGEMMET), and b) multiple scientific studies by Peruvian and mixed teams with French, Irish, and US volcanologists (Macedo et al., 2018). However, local managers of the Civil Defence Agency understood that this wealth of knowledge was not enough to prevent damage and loss of life in case of an eruptive event.

Within the framework of the Multinational Andean Project – Geoscience for Andean Communities (MAP-GAC), driven by the geological surveys of seven countries of the region and the one of Canada, the program Communicating with Communities (ComCom) was set up. ComCom is indeed a methodology aimed at strengthening local capacities that enable communities to properly manage their risks. In 2006, under the motto Transforming knowledge into action, INGEMMET launched the program that started with a focus on one large city Arequipa (about 1 million people) and on several small populations around the Ubinas volcano, the most active of the country. The program continues until today.

Activities of the program were developed with authorities at two different government levels: province/state (gobierno regional), and city/district municipalities (gobiernos locales), as well as with schools. The regional office of the Civil Defense Agency (INDECI) gave strong support.

Capacity building was conceived with a large scope and pointed out to two main objectives: a) Make the population aware of the risk, and b) Increase the knowledge and skills of local DRM technical officers (Macedo et al., 2010).

To achieve these objectives, the main activities include:

- The annual scientific and technical meeting “Volcanic Hazards Forum”, where outstanding international speakers shared knowledge with young Peruvian volcanologists receiving training, and issues on volcanic hazards were discussed with authorities and civil society officers of the Red Cross, fire and rescue brigades, engineers, and first aid teams.
- Implementation of a Center for Awareness on Volcanic Risks in Arequipa, in cooperation with the National San Agustin University and the Local Office of the National Institute of Civil Defence (INDECI). Native visitors learned that Misti, the huge dormant volcano at whose feet Arequipa is located, is not only their city guardian and the main tourist attraction, but is also a major natural hazard.
- A drawing competition among 10 to 14-year-old students, concerning true volcanic hazards was held. The twelve best figures were included in a printed calendar. Private companies supported its edition for several years.
- Promotion of land use plans and other norms based upon volcanic hazard maps.One example of results: Alto Selva Alegre district of Arequipa issued a Municipal Ordinance (201-2007 / MDASA, October 2007) establishing the limits of urban expansion towards the Mist volcano.
- Technical field workshops, where small populations, mostly around Ubinas volcano, were guided to organize themselves into task-oriented teams to execute processes of risk prevention and reduction, as well as basic preparedness and response in case of imminent eruption. A practical evacuation exercise was included.

The effectiveness of this program was demonstrated during two eruptive crises of the Ubinas volcano, in 2013 and 2019. Early warning and first response were managed by local authorities, while state support was being prepared and sent to the site.

Figure 2: Walls were built along the limit for urban expansion to warn about the risk. Neighbors are voluntarily entrusted with preventing invasions by squatters. Alto Selva Alegre district, Arequipa (Photo by Henry Pareja).

2.3 Seismic Hazard, the case study of The Philippines

The Philippines is one of the most hazard-prone countries in the world. It is regularly subjected to various hazards because of its geologic and geographic conditions. The Philippines is an earthquake prone country where at least five earthquakes occur per day. The 1990 Luzon earthquake which affected Baguio and Dagupan was one of the most destructive earthquakes that hit the country so far. A more recent earthquake in 2013 was the 7.2-magnitude Bohol Earthquake which destroyed cultural heritage structures in Bohol and Cebu. The high seismicity of the Philippines is due to the plate interactions, displacements along the Philippine Fault Zone which decouples the northwestward motion of the Pacific with the south eastward motion of the Eurasian, and movements along other active faults such as the Lubang, Casiguran and Mindanao faults (PHILVOLCS et al., 2020).

Among others, the Philippines has 22 active volcanoes including Pinatubo, is subjected to tropical depressions, tropical cyclones and typhoons with wind speeds from 120 kph. They move generally in a west-northwest direction at 15 kph on the average, intensifying as they approach the Philippine Sea. Winds of 200 kph or more can be observed in typhoons approaching the shores. On the average, 20 typhoons occur in the Philippines within the period from July to November each year [1,2] (De la Cruz, 2021).

Efforts in Disaster Risk Reduction in the Philippines are centred in the National Disaster Risk Reduction and Management Council (NDRRMC). The NDRRMC was created to consolidate various government efforts in mitigating disasters. The council was enacted by Republic Act 10121, otherwise known as the “Philippine Disaster Risk Reduction and Management Act of 2010.”

Under the council, the Department of Science and Technology (DOST) continuously develops important information about different hazards affecting the country. Through its attached agencies, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the Philippine Institute of Volcanology and Seismology (PHIVOLCS), DOST launched Project

NOAH (Nationwide Operational Assessment of Hazards). Project NOAH provides the public live advisory about flood warnings, rainfall advisory, landslide information, storm surge, tsunamis and the like. Another project under DOST is project DREAM (Disaster Risk and Exposure Assessment for Mitigation). Project DREAM is implemented by the University of the Philippines.

PAGASA is the foremost government agency handling climatologically related events, whereas PHIVOLCS handles geologically related events. Independently, PHIVOLCS develops hazard maps for seismic-triggered events. These include - but are not limited to - landslide susceptibility, ground shaking, soil liquefaction potential, fault maps and tsunami.

Another agency known as the National Mapping and Resource Information Authority (NAMRIA) provides geographic maps of the country. These maps are crucial in determining flood plain areas and low-lying areas prone to landslides. A recent project of the agency was able to develop a digital surface model and digital terrain model of the country through the use of Light Detection and Ranging (LIDAR). NAMRIA is an attached agency of the Department of Environment and Natural Resources.

This information can be obtained from various government agencies and non-government organizations. Some information is accessible on the websites of these agencies. The hazard information is usually in the form of hazard maps.

Single and multi-hazard assessment procedures are an on-going developing and collective effort, both at national and global level in the Philippines.

The legislative framework of cultural heritage conservation in the Philippines is composed of enacted laws and governing bodies mandated to implement the legislation. This framework may be simplistically drawn and discussed but the dynamics of the agencies and their coverage represent a complicated landscape of the heritage sector.

The Philippine Republic Act 10066 of 2009, or the Act providing for the protection and Conservation of the National Cultural Heritage, Strengthening the National Commission for Culture and the Arts (NCCA) and its Affiliated Cultural Agencies and for other purposes, establishes the national policy of the country. The main provisions cover the policies and principles, definition of terms, cultural property, heritage zones, registration and conservation of cultural property, regulating the export, transit, import and repatriation of cultural property, powers of the commission and cultural agencies, role of cultural agencies, cultural property incentive program, cultural education, cultural workers incentive program, Sentro Rizal, penal provisions, endowment and final provisions.

In the provision for powers and roles of commission and cultural agencies, few main agencies coordinate closely in the protection of built heritage structures that have national significance both historical and cultural. Among them, are:

1) The National Commission for Culture and the Arts (NCCA), the highest policy making body of the country, established in 1992. It has a Sub commission for Cultural Heritage composed of national committees on monuments and sites, museums and galleries, libraries, archives, and historical research.

2) The National Historical Commission of the Philippines (NHCP), formerly the National Historical Institute, was reconstituted by changing the nomenclature of the National Historical Institute into the National Historical Commission of the Philippines, Strengthening its Powers and Functions, and for Other Purposes. It is responsible for significant movable and immovable cultural property that pertains to Philippine history, heroes and the conservation of historical artefacts.

3) The National Museum (NM) of the Philippines was reorganized with the aim of providing for Its Permanent Home and for Other Purposes. It shall be responsible for significant movable and immovable cultural and natural property pertaining to collections of fine arts, archaeology,

anthropology, botany, zoology and astronomy including the conservation aspects.

4) The Intramuros Administration (IA) was established during the Marcos Administration. The mandate was primarily for the restoration and administration of the development of Intramuros, the inner city of Manila. Organizationally, this agency is under the supervision of the Department of Tourism. For the Multihazard Vulnerability Project, the Administration facilitated the documentation of significant fortifications like the Fort Santiago and Baluarte de San Diego.

The organizations and their jurisdictions provided the legislative framework for the heritage conservation framework of the country.

1) The Department of Tourism (DOT) and its attached agencies are primarily responsible to encourage, promote, and develop tourism in the country. The DoT is responsible for the protection of cultural property supplemental to the jurisdiction of the cultural agencies.

2) The Tourism Infrastructure and Enterprise Zone Authority (TIEZA), is a government corporation created to replace the Philippine Tourism Authority (PTA). TIEZA acts as Department of Tourism's and is mandated to designate, regulate and supervise the Tourism Enterprise Zones (TEZs) nationwide, particularly of cultural, economic and environmentally sustainable developments of TEZs to encourage investments.

The Filipino community is very much involved in taking active part in DRM efforts as well as providing help on a voluntary basis. After the 2013 earthquake and typhoon events, the local community actively engaged in helping with debris removal, and preparing the field for experts to conduct field investigation and work on multi-hazard vulnerability assessment frameworks which could help the community become more resilient.

Examples of such keen engagement have been reported in recent publications following the 2013 earthquake which struck Bohol Island in Central Visayas and the super Typhoon Yolanda, which severely affected 14 provinces in the Visayas.

Several centuries-old cultural heritage structures were seriously damaged, with some even totally destroyed. The Department of Tourism (DoT) expressed the urgent need to improve the resilience of these types of structures to natural disasters to ensure that their cultural, historical and economic value is sustained and continues to contribute to the overall development of the areas where they are located.

In the case of the Philippines, capacity building started with the events in 2015 and the collaboration began in 2016. Such collaboration and mutual enriching exchange of support is still ongoing. The local community has learnt the methods and mastered the tools for managing multi-hazard vulnerability, has proven willing to continue learning and is still keen to investigate and keep up-to-date with ongoing research happening in the rest of the world. However, they have also provided invaluable help to external experts to get to know more in detail their building portfolios, their peculiarities and their unreported building types. That has represented an incredible step towards knowledge exchange which is at the core of capacity building and resilient societies.

3. Key messages

For proper disaster risk management including improving Capacity Building of all stakeholders, the following actions ought to be taken up by each country:

1. Creating a nodal organisation to coordinate all activities before, during and after the disaster.
2. Making a Vulnerability Atlas of the entire country identifying the vulnerable areas affected by different natural disasters.
3. Updating the engineering codes of practice to design and build disaster-resilient structures.
4. Imparting training to the people about "Dos and Don'ts "during the disaster.
5. a Risk-awareness and involvement in its management should start from childhood.

Afterwards, the active participation in DRM activities is perceived to be normal to everyone. Thus, the continuous capacity maintenance comes from inside.

6. Fulfilling the everyone´s role is best performed when the local DRM system is built by all the community stakeholders instead of when it is prepared by third parties and handed over as a turnkey system.

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CHAPTER V
INSTITUTIONAL FRAMEWORK AND PUBLIC POLICIES

José Macharé[a], Myles Lind[b], Lizett López[c]

[a] National University of Engineering, Peru, jmachare@hotmail.com
[b] Institute of Public Works Engineering Australasia, New Zealand, myles.Lind@at.govt.nz
[c] National University of Engineering, Peru, llopezs@uni.edu.pe

1. Introduction

Institutionality is defined simply as the quality of being institutional – (i.e. being intended to regulate behaviors within an organization or entire societies). Applied to communities, it is referred to as the stage of social evolution marked by the conversion of customary relations into true institutions (*The Century Dictionary*). As customary relations are numerous and complex, conversion is gradual, and therefore it exists in different degrees. The degree of Institutionality reflects the extent to which a society supports its processes and relies on its institutions. This also reflects the performance of processes that are evaluated based on their outcomes. Thus, a suitable institutional structure provides an adequate framework for the set-up of public policies, governance and actions.

Disaster Risk Management (DRM), as a social process, operates through a system formed by four interlinked components: a *hardware* (infrastructure, equipment and instruments), a *software* (policy documents, norms, and manuals), *financial support* and *human capital* (planners, decision-makers, managers, and operators) (figure 1).

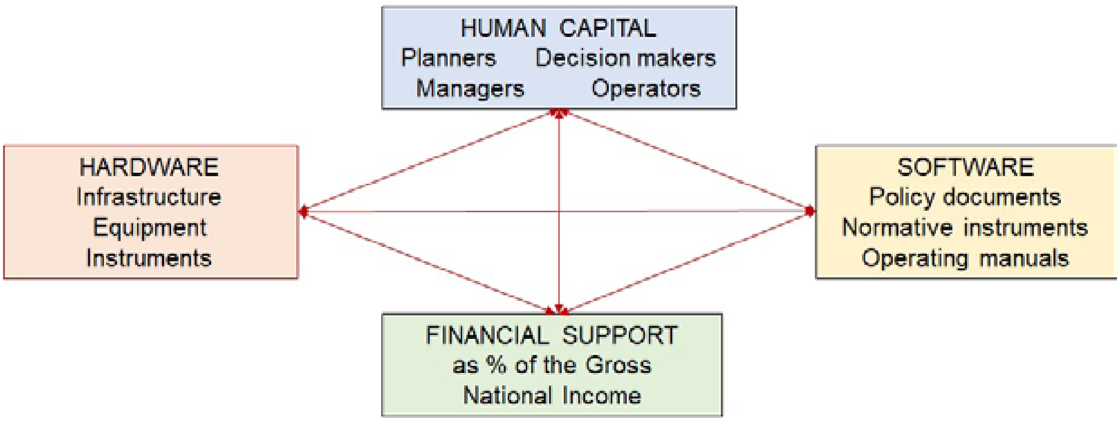

Figure 1. General components of a system, in this case applied to a Disaster Risk Management System at country level

This system becomes complex since similar structures are embedded in every organization composing the national system (e.g. government agencies, scientific and academic entities, non-governmental organizations and private companies). From national to local in scope, all these organizations are interlinked and have specific roles within the DRM macroprocess (figure 2). Each stage of the DRM cycle is linked to a set of policies and an institutional framework that, when executed through specific plans and programs, can provide a reduction in vulnerability.

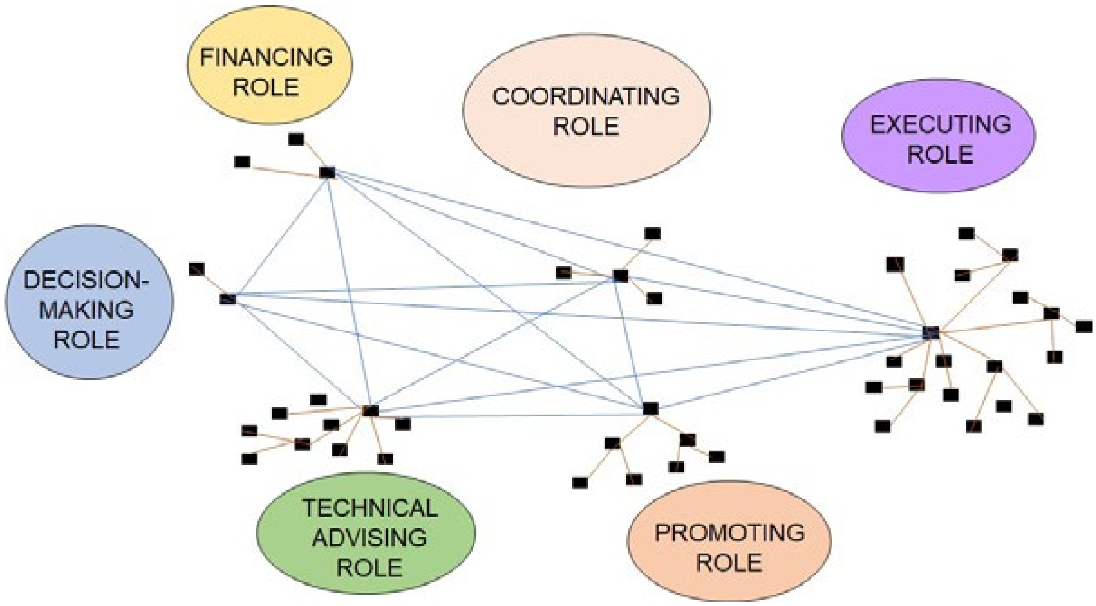

Figure 2. Schematic links among clustered institutions (squares) with given roles within the DRM system

The general objective of reducing vulnerability (i.e. losses and damage) can be achieved if the process is duly completed. This result is possible only with a fully functional and resilient system, with the inter-institutional links functioning correctly. The effectiveness of every relational link depends on each of the other interlinked components functioning in harmony and operating as a single inter-linked system.

Analyzing the possible sources of weakness in a DRM system draws the following observations:

1) The financial aspect is on the frontline. The lower the country's relative income, the higher the vulnerability and risk level. This d, generally post an event, with international aid.

2) The hardware is reliant on the existing technological assets available. This weakness can be addressed by purchasing or creating the required elements.

3) Policies and norms are usually developed by experts based on international experiences and frameworks and adapting the best practices to local conditions; thus, the risk of having ineffective policies is reduced.

4) The most challenging component is human capital. The formation of experts requires a long and sustained effort in the countries' educational policy. Poorly integrated societies suffer from a higher likelihood of corruption occurring within the different processes of the DRM macroprocess. Large events of natural or man-made hazards impact and disrupt these countries to the greatest extent.

At a country level, there are different schemes to manage risks, emergencies and disasters themselves, and everyone is based on a system interlinked with the DRM components. International agreements such as the Hyogo Framework for Action for building the resilience of nations and communities to disasters (2005-2015), the Sendai Framework for Disaster Risk Reduction (2015-2030) and the Sustainable Development Goals (2015-2030), for the signatory countries, creates a commitment to advance the development and implementation of the agreement outcomes. Thus, in order to improve the actions of the Governments in disaster management, they have designed and implemented public policies, as well as created and sought to strengthen institutions.

The benefit to a country in institutionalizing

DRM ultimately rests in the community, over the generations of people, being more readily able and consistently practiced at reducing risks and preparing for, responding to and recovering more quickly from natural hazard emergencies, independent of country or community leadership.

2. Disaster Risk Management in a Local Context

By their nature, natural hazard events that require a DRM response from the community, have occurrences that can be determined probabilistically. Said another way, these events are not a typical part of the communities 'normal' day-to-day functioning or activities. Due to the general infrequency of these natural hazard events on a single community, to improve its resilience and minimize the disruption of such events, a community needs to implement a risk-based approach to its technical systems (built environment), economic systems, and social systems to improve its resilience to stressor events.

Around the world we continue to see technical systems progressively improve to become more resilient to stressor events. The continued evolution and refinement of engineering design standards, building code regulations and construction standards are all good examples of applying a risk-based approach to keep the community safe and able to function pre, during and post an event.

Economic systems are increasing transitioning to on-line and digital platforms. The days of having to write a check or make payments with (physical) money have changed significantly. Much of society can complete transactions from almost anywhere in the world, at any time.

However, the evolution of the social system of the community is more challenging. Countries that have a higher recurrence probability of a natural hazard events are often better at embedding the disaster response practices into the community as part of everyday life. The members of these communities have a heightened awareness of the risks these events can cause, and through repeated exposure to the risk events, the community is practiced in knowing how to respond and manage the event and its response. However, the members of the community change with time, and if there is a longer period between natural hazard events, the communities learned responses can be forgotten or dulled.

In general, countries that have a higher recurrence probability of natural hazard events and that have applied a risk-based approach to DRM, often demonstrate two key common responses. In these countries, it is often seen that there is a consistent and long-standing recognition of the need to have an institutional framework that weaves DRM responses and training into people's everyday lives, supported by the need to have a trusted, community-wide understanding of communications and information sharing.

3. National policy frameworks on resilience in OECD countries

Collaboration with other levels of government is recognized as one of the key drivers to ensuring a coherent and integrated approach to resilience (OECD, 2021). Many national governments have plans for reinforcing their countries' resilience. In OECD countries that have national policy frameworks on resilience, nearly all refer to the role of cities or subnational governments for building national resilience in the respective national policy frameworks. These nations are aware of the importance of local actions for resilience through:

1) Emphasizing that local authorities are primarily responsible for building resilience (e.g. the "Fundamental Plan for National Resilience – Creating a Strong and Resilient Country" in Japan (2014); and

2) Promoting intense co-operation and sharing of best practices at all levels of government (e.g. Israel's "Sustainability Outlook 2030" (2012)).

It is also noted that some resilience frameworks include very specific roles and missions for cities.

4. Case studies

4.1 Strengthening the Chilean institutional framework for DRM

Due to its location in the "Pacific Ring of Fire", the Chilean territory faces various geophysical hazards, such as earthquakes, tsunamis, floods, and volcanic eruptions among others. In addition to these hazards, there is a significant increase in vulnerabilities, which are expressed in a greater concentration of people in sectors of the cities that are not safe enough to be inhabited (social construction of risk) (Martinez et al, 2017). The occurrence of disasters has caused high levels of fatalities, as well as considerable damage to property. On average, between 1980 and 2011, Chile recorded losses of close to 1.2% of its GDP per annum due to natural disasters (CREDEN, 2016).

Due to its history of natural disasters, Chile has created institutions, developed laws and practices over the years which seek to address earthquakes. Among these, the 1929 General Law of Urbanism and Construction, which prescribed the first seismic codes, including the definition of materials, construction procedures, among others, including the 1965 Law on Earthquakes and Disasters (Law No. 16.282). The institutional framework for dealing with disasters gained greater focus in 1974 with the creation of the National Emergency Office of the Ministry of Interior (Oficina Nacional de Emergencia del Ministerio del Interior, ONEMI), which holds the mandate to coordinate the national response to disasters and coordinate international disaster relief efforts. The activities of ONEMI were mostly focused on the emergency response rather than on prevention.

In 2002, the order to decentralize ONEMI's activities, the National Civil Protection System was implemented. This order sought to better enable DRM through public and private sector participation, including volunteer organizations throughout the community, and through planned actions with a focus on risk management. As well as disaster response, the 2002 National Civil Protection Plan also instituted prevention management activities in Chile.

The rapid recovery after the 2010 Maule earthquake was a key factor in Chile becoming the first Latin American country to be invited to join the Organization for Economic Cooperation and Development. In addition, this disaster event enabled improvements to ONEMI, modernizing its protocols and incorporating new technology, as well as legal regulations that allow for a rapid response to emergencies and reconstruction processes.

Following the recommendations in the implementation of the Hyogo Framework, the Charter of the National Platform for Disaster Risk Reduction in Chile was signed in 2012, creating an advisory body to ONEMI. This national platform's function is to achieve full incorporation of DRM into the policies, planning and development programs of Chile. Following up on this elaborated the National Policy for Disaster Risk Management 2014 was drawn up, and from this a National Strategic Plan for Disaster Risk Management (2015-2018) has been derived.

The National Policy for Disaster Risk Management (figure 3) was the first national instrument setting out a requirement for DRM reductions. This national policy is intended to become a guiding framework that aligns different sectoral and territorial initiatives in order to effectively reduce the country's exposure to disaster risk.

Chile is recognized worldwide for its ability to recover relatively quickly after the occurrence of a disaster, progress has been made to mitigate the major impact of natural disasters, improve the State's emergency response and reconstruction, and build the resilience of communities. For example, the use of early warnings and rapid response has been implemented, government assistance policies have also been created, and appropriate infrastructure design regulations have been incorporated, among others (CREDEN, 2016).

However, the country has been discussing the need to move towards a resilience and disaster risk reduction approach, as well as the modernization of the institutional framework for DRM. From different sectors, it was observed that the institutional framework does not effectively enable collaboration between territorial planning (i.e. land occupation) and

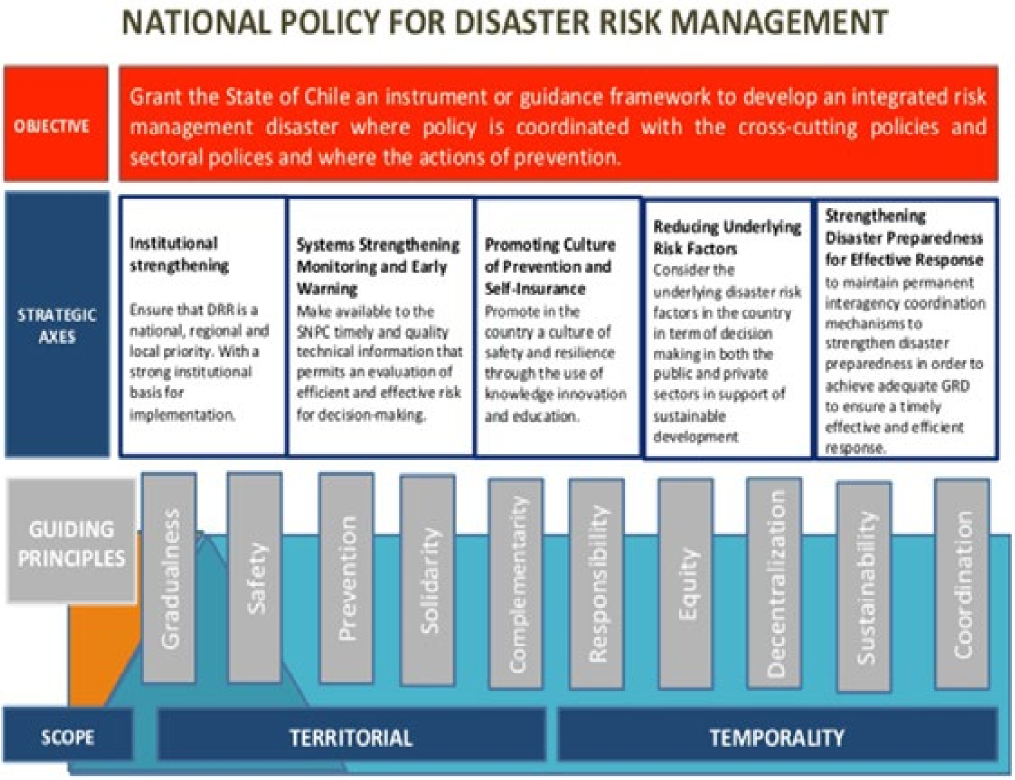

Figure 3. Chilean National Policy for Disaster Risk Management (CEDMHA, 2017)

risk management (i.e. prevention, emergency management, post-disaster reconstruction), which is considered a strong limitation to the creation of resilient cities.

As a follow-up, in July 2021, the Law that establishes the National System for Disaster Prevention and Response (SINAPRED) and the National Service for Disaster Prevention and Response (SENAPRED) was enacted to replace the National Civil Protection System and ONEMI. This new scheme seeks to update, strengthen, standardize and make these new institutions more binding to achieve standards of excellence in DRM focused on prevention and territoriality.

4.2 Observations on Institutionality in Aotearoa New Zealand Institutional Framework

Like other countries that have a higher recurrence probability of a natural hazard events, New Zealand (Aotearoa) has a federal government led institutional framework that embeds DRM responses into the community's everyday life. It is based on a similar system used in that recognizes the benefits of; common training standards, regular reviews and international compatibility.

Embedding the Framework

The government of New Zealand passed the Civil Defence Emergency Management (CDEM) Act in 2002. The CDEM Act creates a legislated, nation-wide framework within which New Zealand people can prepare for, deal with, and recover more quickly from local, regional and national emergencies.

The National Emergency Management Agency (NEMA) is the government headquarters for emergency management in New Zealand. NEMA is an operationally autonomous agency with its own chief executive within the Department of the Prime Minister and Cabinet and separate from the Department of Internal Affairs. NEMA's key functions to the Department of the Prime Minister and Cabinet, are steward, operator and assurer of the New Zealand emergency management system. Specifically, NEMA is required to provide leadership in reducing risk, being prepared for, responding to and recovering from emergencies. (NEMA, 2022).

New Zealand has a National Disaster Resilience Strategy (NDRS) which outlines the vision and long-term goals for civil defence emergency management in New Zealand. The NDRS sets out what the Government of New Zealand requires with respect to New Zealand being a resilient country, and what it expects to achieve and improve over the next 10 years.

The NDRS is supported by the National Civil Defence Emergency Management Plan (CDEMP). The CDEMP, which is also a Government document, sets out the roles and responsibilities of everyone involved in reducing risks and preparing for, responding to and recovering from emergencies. This includes central and local government, lifeline utilities, emergency services and non-government organizations.

First developed in 1998, the Coordinated Incident Management System (CIMS) represents New Zealand's official framework for operational delivery of incident management and coordination across responding agencies to an emergency or hazard event. CIMS describes in detail how New Zealand agencies and organizations (i.e. fire-fighters, police, hospitals, schools, border control, defense, local councils, etc.) coordinate, command, and control incident response of any scale, how the response can be structured, and the relationships between the respective CIMS functions and between the levels of response.

Importantly, throughout New Zealand, there are regular training and specific hazard event practice sessions for responding agencies, and the community is to continually develop and grow the available capability and capacity of the response system for when it will be needed in the future.

CIMS is an element of New Zealand emergency management doctrine that agencies use to manage incidents. Doctrine is the body of principles and practices that guide an agency's action. Doctrine informs the scope, material and types of training. Training is then designed and delivered to best support an operational response (figure 4). New Zealand experience suggests that doctrine is not applied during an operational response if the training programmes are inappropriate. An important feedback loop is ensuring that the lessons from the operational response are used to update and revise the doctrine.

Figure 4. The core interdependencies for institutionalizing DRM

The core foundation is that the institutionalization of DRM in New Zealand is based on the recognition that where you have people marginalized, you will often leave people behind and the community is adversely affected. In response the institutionalized approach in New Zealand seeks to support and protect the community through:

- Central Government leadership at the highest level, written into legislation, which has a strong community focus.
- An agile and flexible event response framework that can be used for small to large responses, and from local incident level through to national disaster level.
- Well trained, coordinated and supported response agencies and local community members through practiced scenario events.

- Highlighting the importance of the inclusion of indigenous peoples in response and recovery.

A key aspect of the New Zealand approach is its foundation of DRM mitigation policies and activities. These foundations are built around the core aspects: regulations, qualifications and simulations (figure 5).

- Regulations –building quality standards (Standards New Zealand, 2022), mandatory building system requirements (i.e. fire management systems), continuously improving seismic standards and government set timeframes to implement, regular Building Warrant of Fitness and safety/condition inspection requirements
- Qualifications – Washington Accord level engineering qualifications combined with national registers of engineers who are qualified and have the experience to undertake specialist engineering work i.e. structural/building foundation/geotechnical engineering, traffic safety and fire engineering.
- Simulations – regular use and refinement of computer models (nationally and regionally) to identify and map zones of vulnerable land, earthquake effects and flood hazard risks etc.

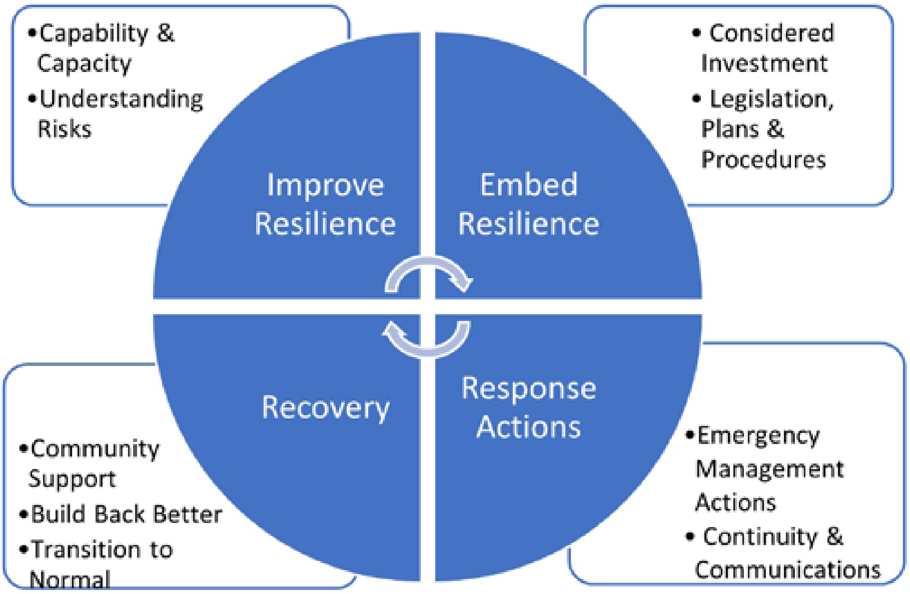

Figure 5. Improve resilience .. Embed resilience.

Ensuring Trusted Communication

It was reported by the UN that between 2000 – 2019 there were 7,348 major disasters events around the world (Nebehay, 2020), twice as many as in the previous 20 years. But disaster fatalities are diminishing. It has been recognized that communication throughout the community is a key factor in reducing the impacts of stressor events on the community. Where community leaders have not accepted the advice of the specialist technical experts (i.e. science, engineering and/or medical) community impact and fatality rates will generally be higher.

Key lessons from New Zealand on increasing the social system response and resilience to stressor events include:

- Community leadership needs to be based on a system of public trust in the communications of the leaders and it is difficult to have (or restore) community trust when DRM messages become political.

- The focus of communications with the community requires the placement of the health and wellbeing of the people at the top of the communications priority. More successful responses to a stressor events requires leaders to take the people with them – having public health and wellbeing as the key priority supports this outcome.
- If the communications are not risk-informed, they do not best serve the community. Employing the best non-political expert advice available (pre, during and post) – i.e. geotechnical, medical, flood, other risk / hazard mapping, earth quake modelling is essential.
- It is important that leaders and response agencies communicate clearly what they know and admit to what they don't know.
- When dealing with technical topics (i.e. storm surge), language that the community in general can understand is important, including how the public will be impacted.
- Accurate forecasts of events need to be communicated in terms that clearly set out the scale and extents of any public impact.
- The most critical element of risk event communications is trust. Asking people to "please stay home / leave your home" from government officials to the community requires trust. These communications are best made on the factual basis on which the government is putting the response measures in place.

5. Key messages

Disaster risk management systems are complex systems, operated by a number of institutions with an intricate web of links relating them to each other.

A robust and healthy institutional framework allows the optimal operation of DRM systems, and thus the achievement of goals concerning the reduction of loss and damage upon the occurrence of a hazardous event.

While the financial and technical components of the institutions can be managed through international cooperation, the human component appears as the most complicated. Strong anticorruption policies should be enforced to improve results.

The process to institutionalize DRM throughout a country requires consistent investment over many years, independent of the leadership of that country. There are efficiencies and other advantages in seeking to use systems and approaches that have been proven to work in other countries. Creating a level of international compatibility ensures that agencies, personnel and community members in general, can operate and respond effectively when overseas. In addition, response agencies can more easily analyze and incorporate learnings from overseas experiences.

During times of response to natural and other disaster events, ensuring and retaining public trust is essential. This is because during response events, communications are often focussed on preserving life, preventing an escalation of the emergency and providing essential services. There are times during a response when some members of the community may perceive that what is being requested of them in support of the response impacts their freedoms or human rights. Being able to maintain law and order and best responding to the needs of the many during these events is heavily reliant on public trust in the communications of government leaders. Communications during times of response benefit from being risk-informed, non-political and having community health and wellbeing at their core.

Incentives must be created to ensure that the rules of the game in DRM are well executed, by strengthening the institutional framework and improving regulations through the promoting of intense cooperation and sharing of best practices at all levels of government.

Generate an integrated, systematized and updated public database. This is of vital importance to stimulate research, provide information to citizens and facilitate the formulation of long-term public policies for mitigation, preparedness, prevention, response and recovery.

Although the general components of the DRM system need to be centralized, there are benefits to DRM activities being decentralized and emphasizing that local authorities are primarily responsible for building resilience through enabling public and private sector participation, including volunteer organizations throughout the community, through planned actions with focus on risk management.

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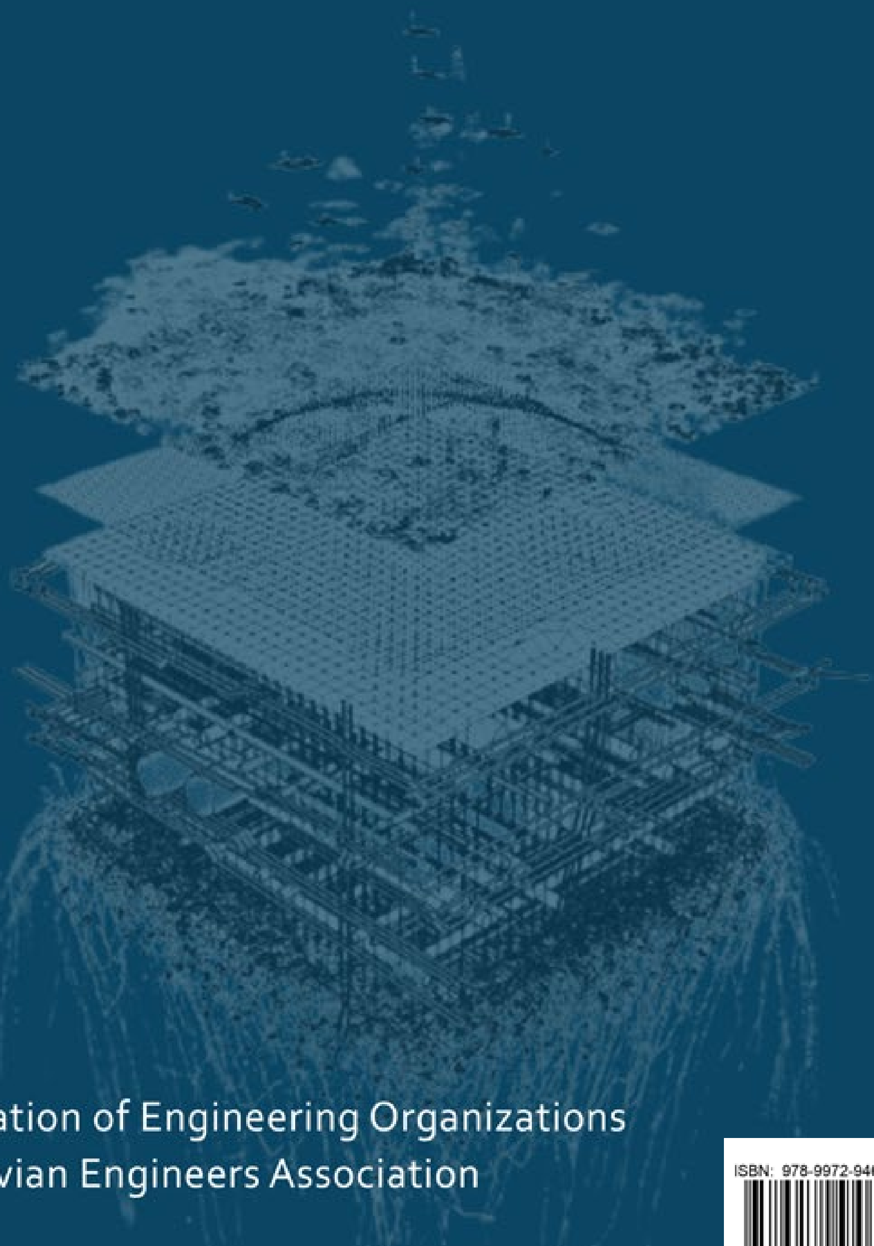

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