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TITLE:

MODELLING THE COSTS OF NATURAL DISASTERS (EARTHQUAKES, FLOODS AND WILDFIRES)

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DEDICATIONS

To My Beloved Mother and Sister:

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ACRONYMS AND ABBREVIATIONS

AAL- Annual Average Losses
ABD- Asian Development Bank
ADPC- Asian Disaster Preparedness Centre
ADRC- Asian Disaster Reduction Centre
AFDB- African Development Bank
AIC- Alkaline Information Criterion
ARTs- Alternative Risk Transfer Techniques
BNPB- Badan Nasional Penanggulangan Bencanna
CAT BONDS- Catastrophe Bonds
CAT DDO- Catastrophe Deferred Drawdown Option
CDF- Cumulative Distribution Function
CDP- Center of Disaster Philanthropy
CGE- Computable General Equilibrium
CRED- Centre for Research on the Epidemiology of Disasters
CRS- Community Rating System
DFID- Department For International Development
DPL- Development Policy Loan
DRI- Disaster Risk Index
EAP- East Asia and Pacific
ECLAC- Economic Commission for Latin America and the Caribbean
EMDAT- Emergency Events Database
FEMA- Federal Emergency Management Agency
FONDEN- Fondo de Desastres Naturales (Natural Disaster Fund)
GDP- Gross Domestic Product
GDRI- Global Disaster Risk Index
GFDRR- Global Facility for Disaster Reduction and Recovery
GIS- Geographic Information System
GRAVITY- Global Risk and Vulnerability Index Trend per Year Programme
HDI- Human Development Index
ICRC- International Committee of the Red Cross
IDR- Indonesian rupiah
IFRC- International Federation of Red Cross and Red Crescent Societies
IIM- Inoperability Input-Output Model
ILO- International Labour Organisation
ILS- Insurance Linked Securities
IO- Input Output
JICA- Japan International Cooperation Agency
KM- Kilometres
NDRF- National Disaster Reserve Fund
NFIP- National Flood Insurance Program (US)
NIFC- National Interagency Fire Centre (United States of America)
NOAA- National Oceanic and Atmospheric Administration

OFDA- Office of U.S Foreign Disaster Assistance
PNPM- Probabilistic Network Performance Models.
SHASH- Sinh-arcsinh
TCIP- Turkish Catastrophe Insurance Pool
UN- United Nations
UNDP- United Nations Development Programme
UNISDR- United Nations Office for Disaster Risk Reduction
UNOCHA- United Nation Office for the Coordination of Humanitarian Affairs
UNU-EHS – United Nations University Institute for Environment and Human Security
USA- United States of America
USD- United States Dollar
USGS- United States Geological Survey
WMO- World Meteorological Organisation

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Earthquakes, floods, cyclones, storms, wildfires, volcanic eruptions, and landslides are natural processes that have sculptured the landscape of the earth for millenniums. These natural processes can cause natural disasters on interaction with human-made features such as settlements, agriculture and infrastructure. Theories of origin of disasters have evolved over time, showing advancements in human understanding of the physical natural phenomena and their interaction with the social systems and infrastructure built by man. An understanding of these theories is necessary for natural disaster planning, preparedness, and mitigation. Three theories of disaster are briefly reviewed in the following;

Earliest usage, with continued acceptance in some communities, suggests that disasters are acts of God, which happen as “a divine retribution for human misdeeds and failings” (White & Kate, 2001). A recent study found that the concept of disasters as act of God is still prevalent worldwide and such a belief is strengthened after occurrence of a major natural disaster. This fatalistic viewpoint encourages accepting the negative consequences of such event(s) as part of one’s fate and proposes that mitigation of a disaster’s impact is beyond human capacity. Such fatalistic attitude could be one of the reasons for lack of disaster preparedness and adoption of better land-use planning and disaster mitigation measures in many parts of the world (Yari, Zarezadeh, & Ostadtaghizadeh, 2019). However, it is to be noted that the disaster risk management community has moved away from this theory of disasters since the 18th century.

Progress in scientific thinking and knowledge after the Renaissance started to alter the perception of disasters from the supernatural paradigm to the natural physical realities. The Lisbon earthquake of 1755 was probably the first natural disaster that shaped the viewpoint of natural and geophysical phenomena as the agents responsible for a natural disaster. According to Dynes (Dynes, 1993): “Prior to that, earthquakes traditionally had been interpreted as a dramatic means of communication between gods and humans. In particular, such events previously had been explained as indicating some disturbance between earthly and heavenly spheres. The Lisbon earthquake can be identified as a turning point in human history of which consideration of such physical events as supernatural signals toward a more neutral or even a secular, proto-scientific causation. This theory of disasters became widely accepted by the early 20th century. However, the fatalism associated with disasters remained to some extent, especially for the geophysical hazards of earthquakes and volcanic activity. The only difference was the change in the causative agent, from God to Mother Nature. This theory was instrumental in the adoption of engineering measures to ‘tame’ the natural forces that cause disasters in human settlements. The earliest examples of such attempts can be found in the building of river dams in the Middle East about 4000 years ago and earthquake-resistant dwellings in China about 2000 years ago. Great strides were made in understanding the origin, physical causative mechanism, and future prediction of natural hazards (e.g., floods, earthquakes, storms, volcanic activity, etc.) after the advent of the industrial age in the late 18th century. Continuous discovery and innovation in this field continue today. This scientific knowledge was then utilized for engineering solutions that can either ‘tame’ the forces of nature (as is the case with flood control dykes, dams, embankments, and related irrigation works) or withstand the impact of brutal forces unleashed by natural phenomena such as earthquakes, windstorms, or volcanic activity by building strong, ductile, and integrated structures. However, despite the adoptions of these engineered solutions, continuously increasing human life and economic losses stemming from natural disasters in the early half of the 20th century led to the realization that natural phenomena alone are not the only cause of disasters and the problem cannot be adequately solved by adopting hard scientific and engineering methods alone.

Carr (Carr, 1932) was the first to propose that disasters occur due to the interaction between a geophysical (natural) system and a human-use system. Absence of either one will not result in a disaster. For example, a powerful earthquake happening in a remote uninhibited area is a natural hazard but will not result in a disaster. After observing the limits of flood protection works to reduce economic losses in the USA, White (White G. , 1936) introduced his theory that disasters have a societal dimension, in addition to the presence of a geophysical hazard agent and the human-use system. He noted with dismay that reliance placed on the engineered solutions of flood protection works encouraged the social behaviour of development of flood-prone lands for short-term economic gains. However, such actions resulted in greater economic loss after failure of the flood protection system. He advocated the 'human ecology' concept of Barrows (Barrows, 1923), which calls for judicious land use planning and interconnectivity between the natural and the human systems for betterment of the society as well as the natural environment. This concept was applied to more complex interactions in subsequent studies by various authors (Burby, 1998). A similar viewpoint of ecological design was championed by McHarg (McHarg I. , 1969) for urban planning, which called for modification in the natural face of the earth for human use with due consideration to the ecology of the landscape. He argued that such planning will reduce the impact of natural hazards on human settlements. Recent studies applied principles advocated by McHarg to the 2011 Fukushima Nuclear Power Plant disaster in Japan and to the settlements in Staten Islands subjected to Hurricane Sandy in 2012, respectively, and concluded that the economic impact of these disasters could have been considerably reduced by implementing the ecological design principles proposed by McHarg.

The purpose of this study is to understand, prepare and mitigate the impact of natural disasters by employing sophisticated modelling techniques to estimate the economic consequences including property damage and infrastructure losses. This information is invaluable for governments, insurance companies and disaster response organizations in developing effective risk management strategies such as resource allocation for preparedness and response efforts, devising policies to enhance community resilience. Furthermore, also to aid in the assessment of the long-term economic repercussions guiding decision-makers in prioritizing investments in resilient infrastructure and fostering a proactive approach to disaster risk reduction to contribute significantly in building a more resilient and prepared society in the face of unpredictable environmental challenges.

According to a 2020 report by the United Nations (Nations, 2020), since 1994, more than 5 billion people have been affected by disasters, which claimed nearly 2 million lives and cost US$2.5 trillion in economic losses. Low and lower-middle-income countries are disproportionately affected by natural disasters. In the same period, 33 percent of countries that experienced disasters were low- to lower-middle income, but 81 percent of people who died in disasters lived in these countries. Women and children in developing countries are often the most vulnerable demographic groups after natural disasters. Natural disasters affect the number of people living below the poverty line, increasing their numbers by more than 50 percent in some cases and the problem is getting worse with estimation of up to 325 million extremely poor people are expected to live in the 49 most hazard-prone countries by 2030. While developed countries are better prepared to handle the impact of disasters as well as the aftermath, in developing nations natural disasters trap people in a cycle of poverty because they do not have the resources to rebuild their homes and meet other basic needs making them less able to recover in the long run. Certain factors in developing countries will turn a natural hazard into a disaster hence such as poorly constructed buildings, poor sanitation, rapid population growth/high density population, limited resources for disaster response and rebuilding, lack of economic safety nets and most importantly lack of technological advancement to detect natural hazards such as earthquakes for better preparedness.

Most researchers rely on input output models to estimate the effect of disasters on economies. On the basis of a theoretical discussion, it is argued by Yasuhide Okuyama and Adam Rose (Yasuhide Okuyama.; Adam Rose, 2019) that the traditional demand-driven IO model and the IIM models may be suitable for modelling man-made disasters which will mainly result in spatial and product shifts in final demand (i.e., effect on tourism and consumer demand). For the modelling of natural disasters such as earthquakes or floods, which primarily affect the supply-side of economy, they argued that the IO models are unsuitable, as they suffer from shortcomings in representing supply-side shocks. Therefore, in this thesis I decided to use probabilistic methods and risk assessment techniques to help predict the potential damage natural hazards might to hurt the economy hence leading to a pivotal/central question guiding this whole research which is:

How can we estimate and predict the costs of floods, wildfires and earthquakes on a country?

In addition to the central question, a secondary question arises which is;

What are some of the mitigation and adaptation strategies that can be used to reduce the costs of natural disasters on a country?

Research hypotheses;
H1: Insurance and Risk transfer strategies have a positive impact on the economic recovery and reduce on the general costs of natural disasters.
H2: Economic growth tends to have a positive relationship with the increase of costs of natural disasters

I analysed Indonesia's historical data from 1970 to 2022 to project the potential financial impact of earthquakes, floods, and wildfires. This was achieved through probabilistic distribution methods and Monte Carlo simulations, which are statistical techniques used to understand uncertainty and make informed predictions.

While existing studies have largely relied on Input-Output (IO) models and Computable General Equilibrium (CGE) models to assess the economic effects of natural disasters, these models often require extensive and detailed data that isn't always available. Moreover, they tend to overlook the likelihood of extreme, yet infrequent, catastrophic events, leading to potential inaccuracies.

The rationale behind my choice of modelling techniques is rooted in the practices of insurance companies. Probalistic and Monte Carlo simulations are some of the methods used by insurance companies to create their risk assessments. These models are particularly effective when backed by a comprehensive historical database, as they emulate the past patterns of losses incurred from specific disasters in certain areas

I relied on the existing written documents about modelling the costs of natural disasters from mainly articles, books, theses, academic databases such as JSTOR, Google Scholar, PubMed, Research Gate

The structure of study includes 3 chapters where chapter 1 I delve into the fundamental concepts related to natural disasters. I explored different terminologies and shaded light on historical trends and significant past disasters. Additionally, I conducted a literature review on the macroeconomic impacts of disasters, based on various findings of different authors.

In Chapter 2 focuses on cost management related to natural disasters. I discussed various mitigation strategies aimed at reducing the economic burden on countries. Additionally, I explored risk financing strategies and provided detailed examples to illustrate their importance.

In Chapter 3, I presented a detailed methodology for analysing natural disasters in Indonesia. Following this, I share and discuss the empirical results obtained from the analysis.

CHAPTER 1: THE THEORETICAL FOUNDATION OF NATURAL DISASTERS

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INTRODUCTION

Natural disasters have long been a formidable force that shapes the fate of nations, impacting both developed and developing countries with varying degrees of intensity. The indiscriminate nature of these catastrophic events transcends geographical, socioeconomic, and political boundaries, exposing vulnerabilities[1] and testing the resilience of nations. This chapter aims to provide a comprehensive overview of the impacts of natural disasters on both developed and developing countries, shedding light on the distinct challenges each category faces. By delving into existing literature, we seek to analyse the diverse consequences of natural disasters and the coping mechanisms employed by nations to mitigate the aftermath. Through this exploration, we aim to contribute to a deeper understanding of the intricate dynamics between natural disasters and societal development, paving the way for informed policy decisions and proactive measures in the face of an increasingly unpredictable environment.

1. SECTION 1 : OVERVIEW OF NATURAL DISASTER

This section delves into the world of natural disasters exploring the extreme events triggered by environmental forces. First, we look at common terminologies used and then uncover the different types of natural disasters and how they're formed.

1.1 COMMON TERMINOLOGIES OF NATURAL DISASTERS

1.1.1 DISASTER

Disasters may be classified as natural disasters, technological disasters, or complex emergencies. The last includes civil wars and conflicts. The classification refers to the immediate trigger: a natural phenomenon or hazard (biological, geological, or climatic), a technological accident, or a conflict. The term *natural*, if used to qualify disasters, is not meant to deny any human or societal responsibility in the consequences of the truly natural hazard (seismic or cyclonic activity, for instance). In reality, all disasters stem from the interaction of external phenomena (hazard) and a vulnerability of society that has resulted because of risk ignorance, poverty, or misconstrued development among people. Therefore, a disaster is an actual event having unfavourable consequences, in natural disaster management, a disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses or impacts which exceed the ability of the affected community or society to cope using its own resources. On the other hand, according to the Center for Research on the Epidemiology of Disasters (CRED), a disaster is a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance, an unforeseen and often sudden event that causes great damage, destruction and human suffering. Disasters affect a community and have social consequences that disrupt societal functioning and cause human and/or material loss.

[1] Sometimes vulnerability is referred to as susceptibility or as the inverse of resilience, or just set equal to risk as e.g. done in the climate change research community

1.1.2 **HAZARD**

According to Cutter (Cutter, 2001), "A hazard, in the broadest term, is a threat to people and the things they value. Hazards have a potentiality to them (they could happen), but they also include the actual impact of an event on people or places. Hazards arise from the interaction between social, technological, and natural systems". This definition of hazard implies that the interaction between the natural and the social systems is the key element, which transforms a natural process to a hazard. It is also to be understood that 'hazard' by itself is harmless, as it is only a 'threat' that has the potential to cause harm. Therefore, Federal Emergency Management Agency (FEMA, Multi Hazard Identification and Assessment, 1997) portrays hazards as "events or physical conditions that have potential to fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss". In the same vein, the United Nations International Strategy for Disaster Reduction (UNISDR, UNISDR Terminology on Disaster Risk Reduction, 2009) defines a natural hazard as "any natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage".

1.1.3 **VULNERABILITY**

According to Jean-François Heimburger (Heimburger, 2018), Vulnerability refers to the level of predictable consequences of a phenomenon on society. Therefore, in relation to natural disaster management vulnerability refers to the susceptibility to loss of human life, physical injury, or economic loss of livelihoods and assets when exposed to hazard events (Cardona, et al., 2012). The extent of vulnerability depends on the construction, predisposition, fragilities, inherent capacity, or weakness of the exposed elements.

1.1.4 **EXPOSURE**

According to the Cambridge Dictionary, exposure is "the fact of experiencing something or being affected by it because of being in a particular situation or place". Therefore, in the context of natural disaster management, exposure refers to the inventory of elements (i.e., people, property, systems, or functions) in an area in which hazard events may occur. Hence, if human or capital resources are not located in an area that is exposed to natural hazard(s), then there is no risk of a natural disaster. Exposure to a hazard is a necessary but not a sufficient requirement for a disaster situation to develop. For example, an asset could be exposed to a hazard but may possess sufficient capacity to withstand the hazard without damage and thus avoiding a disaster.

1.1.5 **RISK**

The Oxford English Dictionary defines risk as "(Exposure to) the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility". In risk management terms, a risk can be stated as a combination between hazard and vulnerability. Ansell and Wharton (Ansell & Wharton, 1992) argue: "Risk is the likelihood of an event's occurrence multiplied by the consequences of that event, if it occurs" and can be stated as the following mnemonic[2]:

Risk (R) = Hazard (H) × Vulnerability (V) (1)

Risk depends on the combination of hazard, vulnerability, and exposure. Risk is the estimated impact that a hazard would have on people, services, infrastructure, and physical assets in a community. It refers to the likelihood of a hazard event becoming a disaster. Wisner (Wisner, Blaikie, Cannon, & Davis, 2004) modified the relationship presented in (1) by including personal protection capacity (C) and larger scale risk mitigation measures at the societal level (M) and proposed the following mnemonic relationship between these variables:

R = H × [(V/C) - M] (2)

1.2 DIFFERENT TYPES OF NATURAL HAZARDS

There are so many types of natural hazards which can't be all presented in this thesis; therefore, the main focus was attributed to three main natural hazards including earthquakes, Floods and Forest fires (McDonald, 2003).

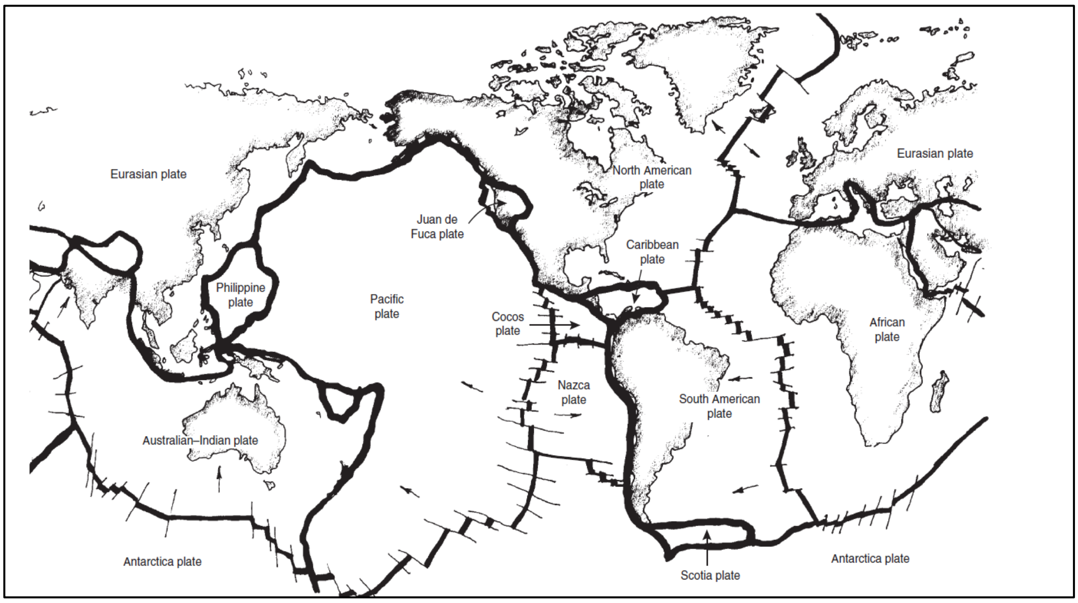
1.2.1 EARTHQUAKES

An earthquake is a wave-like vibration, which travels through the earth's crust. The Earth is a living planet and forces under the surface layer (the *lithosphere*[3]) are in constant turmoil affecting its surface. Observation of a number of phenomena, such as the drift of continents, grouping of volcanic eruptions, or ridges on the ocean floors, has led to the development in mid-twentieth century of the theory of plate tectonics, based on the premise that the Earth's surface is made out of gigantic rigid plates of rock, 80km thick, floating in slow motion on top of the earth's hot and malleable core. Tectonic earthquakes occur when accumulated strain is suddenly released. Rocks break and brittle failure takes place.

[2] expressions given by the mnemonics above are not exact mathematical relationships but are merely attempts to correlate various factors in the complex phenomenon.

[3] The lithosphere is the rigid, outermost shell of the Earth. It includes the Earth's crust and a portion of the upper mantle. The lithosphere is divided into several large and small tectonic plates that float on the semi-fluid asthenosphere beneath them. These tectonic plates are in constant motion, driven by processes like mantle convection

Figure 1: Earth's Tectonic Plates



Source: Roxanna McDonald; Introduction to Natural and Man-made Disasters and their Effects on Buildings

- Tectonic plates

  There are seven major plates, sub-divided into smaller ones, and they change size and position moving relative to one another at speeds between 1 and 10cm/year. As they move, intense geologic activity, such as earthquakes, formation of mountain ranges, or volcanic eruptions occurs.

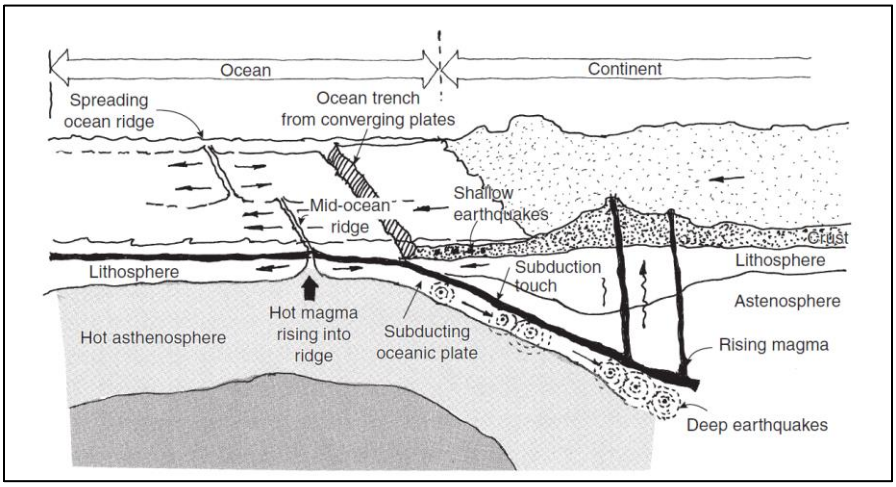
  Different types of seismic zones can be observed relative to the plate movement: When plates move apart at divergent boundaries, such as at the mid-Atlantic Ridge, hot magma flows up and, as it cools down, fills the gap forming new ridges, adding new material to the edges of oceanic plates. This process is known as *sea-floor spreading*[4]. This seismicity is associated with volcanic activity along the axis of the ridges.

  Plates can move towards each other at convergent boundaries, and in doing so, they can either overlap (one side submerging the other), or push upwards against each other, forming major mountain systems such as the Himalayas. When the plates collide, and one plate becomes submerged by the collision, the hot temperatures it encounters deep in the earth's interior, melts the rocks creating new magma, which rises to the surface and erupts forming chains of volcanoes around the edges of the plates like in the case of *the Ring of Fire*[5]. Where earthquakes and volcanic eruptions are frequent. These narrow plates boundary areas, known as 'subduction zones', are associated with the creation of deep ocean trenches and big earthquakes.

[4] Sea-floor spreading is a technical geographical term signifying the addition of magma from the earth's mantle supporting the ever expanding earth theory

[5] The ring of fire refers to a horse shoe shaped area in the Pacific Ocean basin known for high seismic and volcanic activity hence characterised by frequent earthquakes and numerous active volcanoes making it a geographically dynamic region.

Figure 2: Process of formation of earth quakes



Source: Roxanna McDonald; Introduction to Natural and Man-made Disasters and their Effects on Buildings

1.2.2 **FLOODS**

Flooding refers to the overflow of water onto land that is usually dry. It is a natural disaster that can result from various factors, including heavy rainfall, storm surges, rapid melting of snow or ice, dam or levee breaches, and tsunamis. When the volume of water exceeds the capacity of the natural or artificial drainage systems, it can lead to the inundation of low-lying areas.

- How do floods occur?

  If the total amount of water on Earth has remained fairly constant for millions of years, this is not, the case for its distribution. Although a small amount of water is lost every day high in the atmosphere, by the breaking of water molecules by ultraviolet rays, an equal amount of new water is emitted from the inner parts of the earth through volcanic activity.

  Water takes a number of forms; liquid in seas, rivers, etc.; solid in glaciers of North and South Poles; gaseous as vapours in the air. And it changes from one form to another as it is moved around the planet by winds. When the sun heats certain zones more than others, a heat discrepancy is created and cycles of air movement are initiated by the hot air rising and cool air sinking. These cycles determine consequential water cycles: The heat causes water to evaporate, the heated air rises and when meeting colder layers condense into droplets, which form clouds. As the clouds become saturated with droplets, they begin to fall through the air forming precipitation: rain, snow, sleet, hail, etc. The water so created forms rivers and streams and some accumulates underground. At certain times, these cycles are affected by an unusual interaction of certain factors, like the development of a hurricane, resulting in an uncharacteristically large amount of water being produced. When this sudden, greater than normal, volume of water appears it causes the normal waterways to overflow and water engulfs the surrounding land. Flood is an unusually large accumulation of water in an area of land.

- What causes flooding?
  The most common cause of flooding is the succession of storms bringing massive amounts of water through rain. This often tends to be seasonal due to the different amounts of time the sea and land take to heat up or cool. In winter, the air above the sea is warmer than that above the land and the wind flows away from the sea but in summer the process is reversed and more water is carried hence wind currents creating a monsoon effect, melting snow, unusual tidal activity such as tsunamis (giant waves triggered by earthquakes), dam breaks. This can happen either as a result of a dramatic ground shift due to earthquakes or landslides, or due to design parameters not anticipating the extent of the amounts of water occurring. Flooding and its severity are subject to a number of factors including the amount of water which accumulates as explained above, the absorbency of the land which is saturated with water and cannot absorb any more will cause the surplus to overflow as runoff (Farm areas will be less absorbent than rock and concrete, asphalt and man-made cover even less as they reduce the Earth's natural absorbency), flood relief systems which conduct rainwater through culverted flood relief channels into other areas, Levees (raised embankments along rivers built to keep them from overflowing and which whilst protecting the local area from being flooded, may cause worse problems further down the line hence they can also break in which case like dams can cause even more dangerous flooding), excessive water along coastlines.

1.2.3 **FOREST FIRES**

Forest fires, also known as wildfires or bushfires, are natural disasters characterized by the uncontrolled and rapid spread of fire through forested or wooded areas. These fires can be caused by both natural and human factors. Natural causes include lightning strikes, while human causes involve activities such as campfires left unattended, discarded cigarettes, equipment sparks, or intentional arson. This fire can travel at high level through the forest canopy, before affecting the forest floor. The difference of air pressure created causes hot updraughts and firestorms. According to the US National Interagency Fire Centre in 2002 (NIFC, 2002), between January and May, 24421 fires burned 442575 acres of wild land and a severe drought has devastated much of the Great Planes, which has left the area susceptible to forest fires. In 2001, 84079 separate fires destroyed 3570911 acres of land and 731 structures. It cost US$ 542 million to fight these fires. In 2000, nearly 123000 separate fires burned 8.5 million acres of forest and it took 30000 people and US$ 1.3 billion to fight the fires. It is estimated that two thirds of forest fires are started accidentally by people of which almost a quarter is intentionally set and about 10% caused by lightning. Causes of forest fires include arson, campfires, discarded lit cigarettes, burning debris, fireworks, prescribed fires, lightning.

2. SECTION 2: IMPACTS OF NATURAL DISASTERS

Natural disasters leave a mark far beyond the immediate zone of destruction. This section explores the widespread consequences of these events, from the human cost to the economic toll and the environmental repercussions felt across the globe. Additionally, we look at already established research on the topic of disasters through a literature review.

2.1 **STATISTICS ON DISASTERS**

2.1.1 **SOME OF THE SIGNIFICANT DISASTER EVENTS**

2.1.1.1 **Turkey-Syria earthquake (2023)**

On 2nd February 2023, a magnitude 7.8 earthquake struck south-central Turkey near the town of Gaziantep. It was the strongest quake to hit Turkey since 1939, and the damage was devastating. More than 50,000 people died in Turkey and Syria, according to ICRC. More than 1.9 million people were displaced in the month after the quake, which was followed by a series of strong aftershocks. According to ICRC, more than 173,000 buildings collapsed or were damaged in Turkey alone (ICRC, 2023). According to the U.S. Geological Survey (USGS), the quake and its aftershocks occurred on a long strike-slip fault at a shallow depth. Shallow quakes produce more intense shaking. Many buildings in the region were made of cement, which easily crumbles during earthquakes.

2.1.1.2 **Australia wildfire (2019 and 2020)**

Between 2019 and 2020, Australia experienced some of the deadliest wildfires in recent history. The official death toll for the wildfires was 33, according to the Parliament of Australia. A further 445 people died from conditions related to smoke inhalation from the wildfires, and 4,000 people were admitted to hospital, according to the ICRC. Between September 2019 and March 2020, 46 million acres (19 million hectares) of forests in southeast Australia were burnt, according to the Center of Disaster Philanthropy (CDP, 2020). Generally, the majority of wildfires are believed to have been ignited by lightning, according to the Parliament of Australia; however, according to research conducted by the University of Oxford, the risk of intense fire weather during the bushfire season in southeastern Australia has increased by 30% since 1900 as a result of climate change.

2.1.1.3 **China floods (1931)**

Between June and August 1931, rivers in Central China began to swell, fed by an unusually rainy season. Along the Yangzi, Huai and Yellow rivers, as well as the artificial Grand Canal linking the Yangzi and Yellow, flooding began to inundate riverside cities and villages. At one point, an area larger than England was underwater. Over 100,000 people are thought to have drowned. Estimates of the final death toll vary widely, especially because tens of thousands died in the months after the flooding, when cholera swept through camps of refugees. Malaria, smallpox and typhus also killed many people, according to the League of Nations Report (Legue of Nations Report, 1932)[6]. Up to 4 million people may have died in total, Chris Courtney, an environmental and social historian, wrote in "The Nature of Disaster in China (Chris Courtney, 2018)

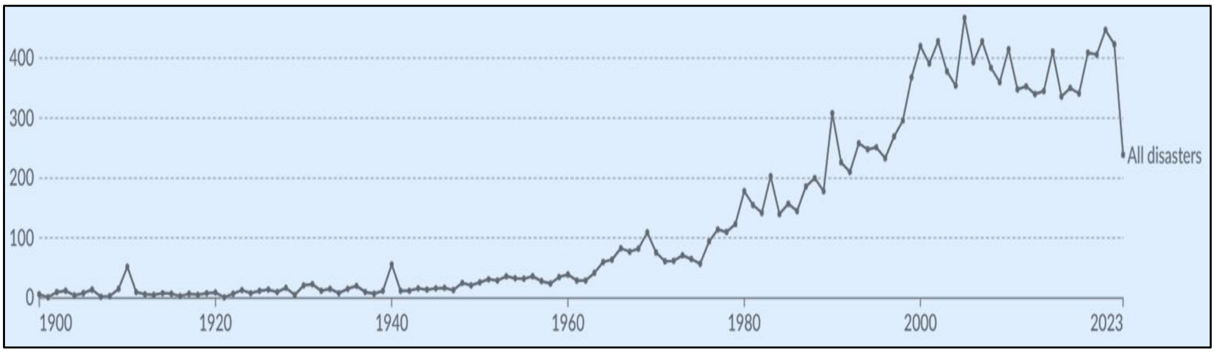
[6] This report can be obtained from the JSTOR website; https://www.jstor.org/

2.1.1.4 **Japan earthquake (2011)**

The Japan earthquake and tsunami of 2011, also known as the 2011 Tohoku earthquake and tsunami or the Great Tohoku earthquake, was a natural disaster that shook northeastern Japan on 11th March 2011. The disaster began when a magnitude 9 earthquake shook the region in the early afternoon, unleashing a savage tsunami. The effects of the great earthquake, which was the strongest in Japan's recorded history, were felt around the world, from Norway's fjords to Antarctica's ice sheet. Tsunami debris has continued to wash up on North American beaches years later. In Japan, residents are still recovering from the disaster. As of 2024, there were still about 39,000 evacuees who lost their homes; 1,000 of them were still living in temporary housing, according to Japan's Reconstruction Agency. More than 120,000 buildings were destroyed, 278,000 were half-destroyed and 726,000 were partially destroyed, according to the agency. The direct financial damage from the disaster is estimated to be about $199 billion dollars (about 16.9 trillion yen), according to the Japanese government. The total economic cost could reach up to $235 billion, the World Bank estimated, making it the expensive natural disaster in damage costs in world history (NOAA, 2011) (Legue of Nations Report, 1932).

2.1.2 GLOBAL STATISTICS ON NATURAL DISASTERS

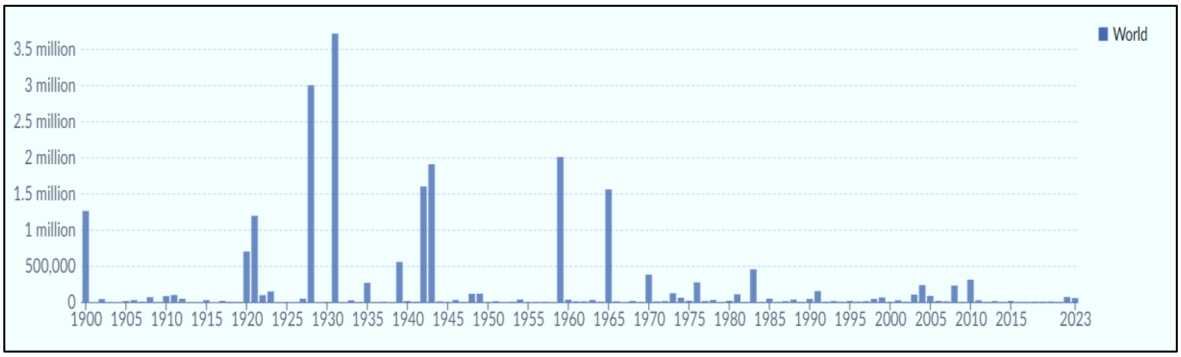
Figure 3: Number of recorded natural disaster events (1900-2023)



source: *EM-DAT, CRED / UCLouvain (2023)*

While there were about 10 disaster events per year in the beginning of the century, now about 300 hundred events are registered on average each year. It has to be noted, however, that the population exposed and overall welfare increased as well over this period which increased the risk widely. The number of natural disasters that have been recorded gradually increased the past century. Hence the number of natural disasters was low in the 20th century compared to the 21st century.

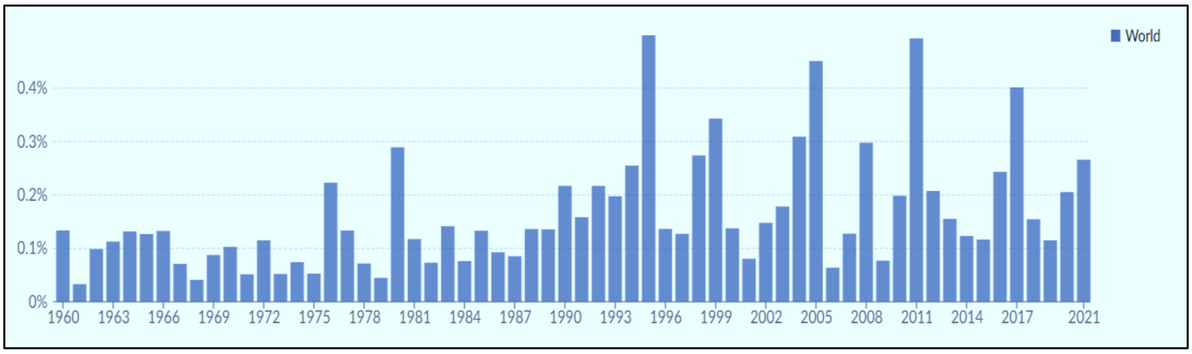
Figure 4: Number of fatalities as a result of natural disaster events overtime (1900-2023)



source: *EM-DAT, CRED / UCLouvain (2023)*

Despite having lesser disaster events in the 20th century than the 21st century, the number of fatalities recorded however are much greater than those in the 21st century. This can be explained by technological advancement in the 21st century, more extensive research about disasters and so much more factors. The general outlook is looking good for the future generations.

Figure 5: Total economic damages from disasters as a share of GDP (1960-2021)



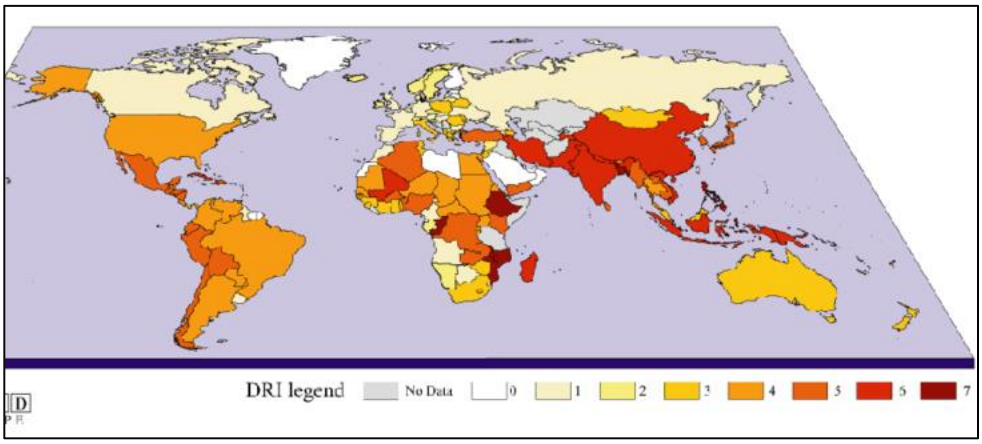
source: *EM-DAT, CRED / UCLouvain (2023)*

Natural disasters not only have devastating impacts in terms of the loss of human life but can also cause severe destruction with economic costs. When we look at global economic costs over time in absolute terms we tend to see rising costs. But importantly, the world and most countries have also gotten richer. Global gross domestic product has increased more than four times since 1970. We might therefore expect that for any given disaster, the absolute economic costs could be higher than in the past. A more appropriate metric to compare economic costs over time is to look at them in relation to GDP. This is the indicator adopted by all countries as part of the UN Sustainable Development Goals to monitor progress on resilience to disaster costs.

2.1.3 GLOBAL DISTRIBUTION OF NATURAL DISASTERS (WORLD'S HOTSPOTS)

Disaster occurrence and impact on a world scale is presented by the Disaster Risk Index (DRI) of the United Nations based on the "Global Risk and Vulnerability Index Trend per Year Programme". The disaster risk assessment presented here (Figure 6) covers the risk of mortality exclusively. The assessment clearly revealed that the Asian and Eastern African countries are especially at the highest risk of mortality from natural disasters worldwide.

Figure 6: Spatial distribution of risk mortality classes assessed by the Disaster Risk Index (DRI) of the UNDP-GRAVITY Programme



Source: UN Global Risk and Vulnerability Index Trend per Year Programme (2002)

UNDP has initiated the GRAVITY-Programme to assess worldwide vulnerability as a compulsory step to identify the countries' different risk exposure levels. The purposes of the GRAVITY research were to identify whether global datasets could be used for identifying populations living in risk-exposed areas. The program moreover was targeted to identify the links between socioeconomic parameters and vulnerability. With the GRAVITY-Programme UNDP was able to highlight the root causes leading to human vulnerability and provided substantial information identifying the populations at risk. The research was focused on the four natural hazards: earthquakes, volcanoes, cyclones, and floods based on data provided by the CRED-EMDAT database.

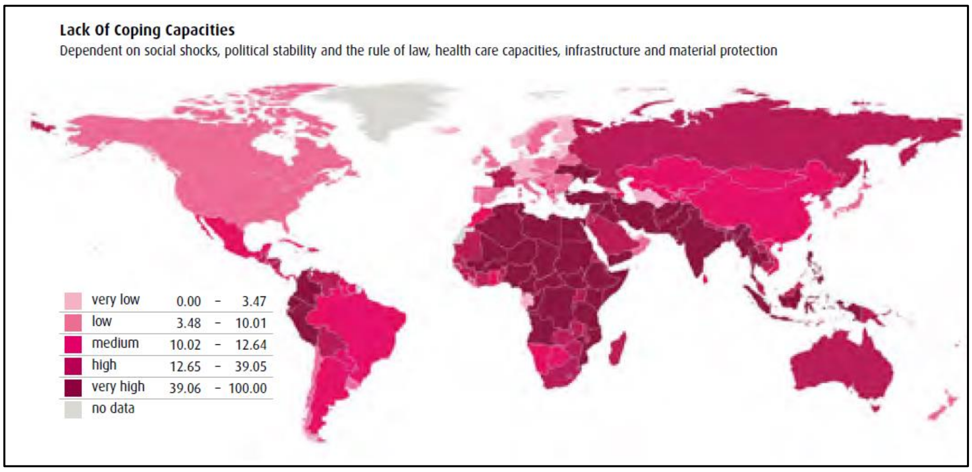
The maps on vulnerability/exposure and on risk clearly indicate where on the globe the people are exposed to a higher risk. But maps at global scale like the Disaster Risk Index (DRI) and its accompanying statistical findings should not be used as risk predictors. Local disaster risk reduction should always be based on detailed local assessments. By using GIS for spatial analysis, a significant relationship between the number of casualties, physical exposure, and socioeconomic parameters was found. By statistical evidence it was possible to show the role of the development in the resilience capacity, a relationship that thus far was more intuitively understood. The analysis revealed that there is a clear relation, that a low development may lead to high casualties, while a high hazard exposure may also result in a low economic development. The statistical analysis demonstrated that physical exposure constitutes the major factor leading to casualties, but other socioeconomic parameters are also substantial variables that lead to high human vulnerability. The level of correlation achieved delineates that both physical exposure and socioeconomic variables are of significant importance and can be easily adopted from international statistics. All in all, the method used in this statistical analysis proved to be appropriate and allows the identification of the parameters leading to a higher risk and vulnerability.

The Global Risk Index was able to highlight the areas of high natural hazard occurrences by combining the number of people living in an exposed area with their respective socioeconomic variables, mainly the HDI, GDP, urban growth, percentage of arable land, and local population density. The main limitation of mixing geophysical and socioeconomic parameters lies in the difference of time scale. Earthquakes or volcanoes may have a returning period measured in several centuries, whereas socioeconomic features can change extensively during a single decade. Other difficulties are inherent to global scale, such as how to compare the situation of earthquakes in South America with the problem of drought in Africa. Not only is the number of people affected very different, but also the percentage of occurrence varies largely for each continent. Hazard impacts differ in scale, in regional extension, and frequency or magnitude as well as in duration.

Such a model, however, should not be used as a predictive model: first because of the level of data quality and second, because significant discrepancy of losses between two (similar) disaster events in the same country was found. This shows the high variability is often due to a temporal context. For earthquakes the number of those killed is highly dependent on where and at what time the disaster happened (during the night or during the day); it moreover depends on the type of habitat, type of soils, direction of fault lines, depth of epicentre, and so on. To bring such variables into a worldwide context is hardly possible.

Another approach for a generalized world disaster risk distribution assessment, called the World Risk Index 2012, was given by the United Nations University, Bonn (UNU-EHS, 2012) . The assessment was also mainly based on the CRED EMDAT database. But other than the assessments of UNDP and World Bank, the UNU-World Risk Index (WRI) is not only restricted to risk exposure as indicated by the "frequency" of disaster occurrence and social vulnerability, but furthermore included the factor of "coping capacity." In this regard UNU-EHS further distinguishes between the coping capacity, defining the capability of a society to cope with adverse effects from natural disasters, and the adaptation capacity. Adaptation capacity in this sense sets in when "a society has already changed structurally before a disaster strikes in a sense that this makes much mitigation no longer necessary". From the many World Risk Index Maps published by UNU-EHS (United Nations University institute for Environment and Human security), the one on "Coping Capacity" is presented here (Figure 7). Although the map might at a first glance not be informative regarding the disaster risk distribution of the world, the factor "coping capacity" describes a substantial input society may be provided in order to reduce disaster impact and is thus contributing to a better understanding of risk exposure of the world.

Figure 7: World Risk Index Map showing the Deficit in Risk Coping Capacity



Source: World Risk Index Maps published by UNU-EHS

Like the other world maps on disaster distribution, the distribution of deficits in the coping capacity also revealed that the Asian countries are at high exposure to risk from disasters. Nevertheless, the coping capacity shows certain differentiations: the highest deficits are identified in Central Africa but also for parts of Central America. When the assessment of World "Coping Capacity Deficit" is combined with "Hazard Distribution" and the DRI-Index maps (here on "Risk of Mortality") a realistic impression of the world risk from disasters can be derived. For example, Australia and Chile both are in the same high-risk exposure class, although their technical standards to cope with a disaster differ a great deal. The opposite holds true for Mongolia. There, the overall risk exposure is low, but the country has a very high deficit in disaster structural and socioeconomic capability, especially against risk from climate change, a situation Mongolia shares with Bolivia and Paraguay. Africa (with the exception of South Africa) is the region of the world that is at the highest risk in all categories, the same as Afghanistan and Pakistan, whereas the other Asian countries down to Papua New Guinea have already made quite significant advances in their local capacity to withstand a disaster (e.g., Thailand and Malaysia).

The most comprehensive and therefore most adopted index-based risk assessment of the world has been worked out by the International Bank for Reconstruction and Development or The World Bank. The Bank has over many years successfully tried to establish a generalized risk index: the Global Disaster Risk Index (GDRI) that intends to provide an overall assessment on the risk of mortality from natural disasters for the world in total. Due to the varying quality and quantity of the databases available, the approach aggregated all data accessible to the World Bank into one set of data, and consequently could only provide a very generalized impression. The DRI therefore should not be taken as a source of information on a regional differentiation of the disaster type and its severity and frequency. The GDRI assessed the distribution of risks worldwide based on two disaster-related outcomes: mortality and economic losses. Both parameters are assessed by combining the regional exposure to earthquakes, volcanoes, landslides, floods, drought, and cyclones with vulnerability data on population distribution and the national gross domestic product. The study presented the first successful approach for an index of the global risk to natural hazards. The calculation was based on grid cells, as such an approach gave a more detailed insight to the subnational and local distribution of the risks than an assessment based on a national scale. The GDRI of the World Bank gives two more sets of information of the global risk distribution: on the total economic losses and the economic loss as a portion of the GDP.

The Natural Disaster Hotspots study identified that East and South Asia, Central America, and large areas of the Mediterranean and the Middle East are at the greatest risk of loss from multiple hazards and indicated that about 3.4 billion people, more than half the world's population, lives in areas where at least one hazard could significantly affect them. Other key findings of the report were:

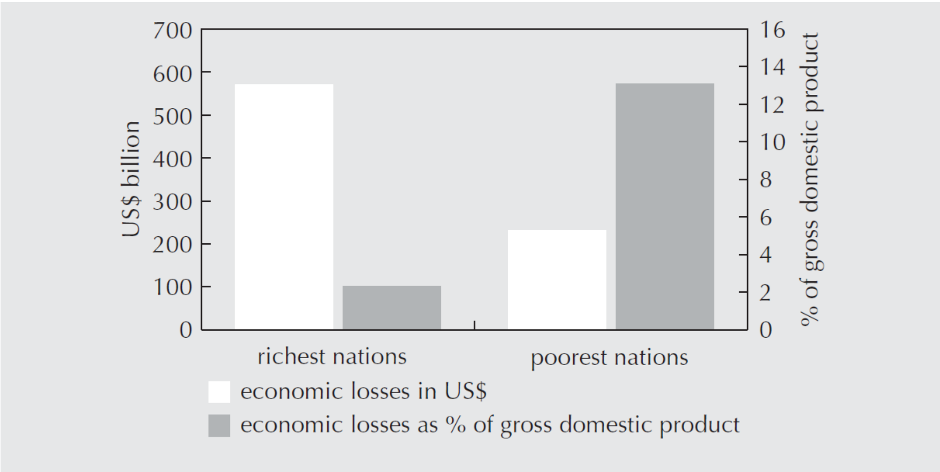
- About 20 % of the Earth's land surface is exposed to at least one natural hazard.
- 160 countries have more than one quarter of their population in areas of high mortality risk from at least one hazard; more than 90 have more than 10 % of their population in areas of high mortality risk from two or more hazards.
- In 35 countries, more than 1 in 20 residents' lives at a relatively high mortality risk from three or more hazards.
- Taiwan may be the place on Earth most vulnerable to natural hazards, with 73 % of its land and population exposed to three or more hazards.
- More than 90 % of the populations of Bangladesh, Nepal, the Dominican Republic, Burundi, Haiti, Taiwan, Malawi, El Salvador, and Honduras live in areas at high relative risk of death from two or more hazards.

Although the World Bank approach provided an impressive comparison of the disaster hotspots of the world, it is nevertheless obvious that even such an impressive data collection cannot cover all parameters that define "risk." For example, the risk distribution from volcanic eruptions has not been incorporated in the study, as the World Bank argues that volcanoes on a world scale are only represented by very tiny spots. The study moreover deliberately left out those areas with low population density or without agricultural importance, a systematic approach that is contradicted by many researchers such as Birkmann (2007) who claimed that many of these areas show a high relative mortality to floods. The World Bank although confessed that the findings should not be overinterpreted as the database is still sparse concerning availability and quality of natural hazards and occurrences as well as on historical economic losses. Therefore, the World Bank sees its global hotspot analysis as an instrument for identifying the relative levels of risk rather than an indicator on the absolute risk levels. The fundamental drawback of the study results from the lack of availability of reliable and reproducible indicators of vulnerability. Vulnerability, in the understanding of the concept, cannot simply be determined by past losses of life and economic values. From the many world maps of risk distributions only those from earthquakes, landslides, floods, cyclones, and drought were therefore taken up.

2.2 DIFFERENTIAL IMPACTS OF DISASTERS ON WEALTHY AND POOR COUNTRIES

The myth that disasters are the greatest equalizer striking everyone in the same manner has long been dispelled. There is a strong relationship between vulnerability to natural disaster and poverty. On the human health level, “while only 11 percent of the people exposed to natural hazards live in countries classified as low human development, they account for more than 53 percent of total recorded deaths” (UNDP 2004, 10). On the economic level, the burden of disaster is proportionally much higher in the poorest countries (World Bank 2006; UNISDR 2004). Although the absolute economic loss is greater in wealthier countries, the losses as a share of gross national income affect most profoundly the poorest countries. The loss of US$125 billion in the United States because of Hurricane Katrina represented only 0.1 percent of the gross domestic product to the country, while losses to disasters in developing countries in recent decades have been between 134 and 378 percent of gross domestic product

Figure 8: Disaster losses in the richest and poorest nations (1985-99)



Source: UNISDR 2004, adapted from Munich Re 1999.

What is observed at the national level holds true at the household level. The poorest individuals are more vulnerable to disasters, and the impact of disasters is making them poorer. This is well summarized by paraphrasing the International Federation of Red Cross and Red Crescent Societies: disasters seek out the poor and ensure that they stay poor (Von Oelreich, 2002). Whereas the contribution of disaster risk reduction in the fight against poverty is beyond debate, the impact on long-term poverty arising from the generous international humanitarian response and early recovery effort once a disaster has occurred calls for more investigation.

2.2.1 A deeper dive into the disparities between wealthy and poor nations

Table 1: Classification of country's wealth according to world and the country's exposure and disaster risk index calculated by the World risk index

Country	Status	Population[7]	Natural Hazard Exposure index	Disaster Risk index
Japan	High income country	125.1 million	43.67	20.86
Ecuador	Upper income country	18 million	14.57	23.58
Pakistan	Lower income country	235.8 million	13.11	26.45
Somalia	Low income country	17.5 million	8.55	25.09

Source: World bank 2022; World risk report2023

As the table shows above, Japan has a lower risk of a disaster even though it's the most exposed to natural hazards. Japan being high income country has greatly impacted this result hence the availability of economic safety net following a disaster, technological advancement (disaster resistant infrastructure, early warning systems). Somalia is a country which has a very low exposure index but a high disaster risk index. This is due to the vulnerability of Somalia to natural hazards, lacking of coping capacities and so many more. This is not possible for this country because it lacks funds most importantly to cover up the damage caused. Hence this disparity between the exposure index and risk index is evident with fall of a country's income status

2.3 LITTERATURE REVIEW

A smaller, but growing amount of research has been conducted on the macroeconomic costs. The main bulk of this body of research focuses on the cost-effectiveness of various mitigation and adaptation strategies in reducing the macroeconomic impact of natural disasters, assessing the impacts post-event using statistics on actual, historical events. The main empirical studies on the macroeconomic effects are (Benson C. , The Economic Impact of Natural Disasters in Viet Nam., 1997b) (Benson C. , The Economic Impact of Natural Disasters in Fiji, 1997a) (Benson C. , The Economic Impact of Natural Disasters in the Philippines, 1997c), (Benson C. a., The Impact of Drought on Sub-Saharan African Economies, 1998), (Benson C. a., Developing Countries and the Economic Impacts of Catastrophes, 2000) (Benson C. a., Dominica: Natural Disasters and Economic Development in a Small Island State, 2001),

[7] The population variable has been added to show the variability of exposure to disasters among different countries hence countries with higher population are more susceptible to natural disasters than low populated countries

ECLAC [several studies e.g. (ECLAC, Nicaragua: Las inundaciones de mayo de 1982 y sus repercusiones sobre el desarrollo economico y social del pais, 1982), (ECLAC, Damage caused by the Mexican Earthquake and its repercussions upon the country's economy. Santiago de Chile, 1985), (ECLAC, Damage caused by Hurricane Joan in Nicaragua. , 1988), (ECLAC, Manual for estimating the socio-economic effects of natural disasters, 1999), (ECLAC, A matter of development: how to reduce vulnerability in the face of natural disasters, 2000), (ECLAC, Handbook for estimating socio-economic and environment effects of disasters, 2002); Otero and Marti (Otero, 1995)], (Albala-Bertrand, 1993), (Murlidharan, 2001), (Crowards, 2000), (Charveriat, 2000). The empirical research literature generally finds significant short- to medium-term macroeconomic effects and considers natural disasters a barrier for longer-term development. The only dissenting view is (Albala-Bertrand, 1993).

Dacy and Kunreuther (Dacy, 1969) mainly examined industrialized countries and found that tax revenue decreased while demand and prices did not change considerably. The authors claimed that the main objective of was "to formulate a clear-cut case for the development of a comprehensive system of disaster insurance as an alternative to the current paternalistic Federal policy" (page *ix*). The book consists of four major parts: first, the framework of analysis was set up using various economic theories, based on the general trends of natural disasters and the damages in the United States; the following two parts are the analysis of the empirical evidence for the short-period recuperation and the long-term recovery; and the final part discussed the role of the Federal government in natural disasters, mainly focusing on the need for comprehensive disaster insurance. Empirical evidence parts (Parts II and III) are quite extensive using the historical data then from various disasters in order to support the framework constructed in Part I. The concluding part (Part IV) proposes and analyses disaster insurance programs, and this particular part on disaster insurance has been extended to a series of papers/books by the authors to this date (for example, Kunreuther et al., 1978; Kunreuther, 1996; and Kunreuther and Roth,1998)

Benson (1997 a, b, c) and Clay (1998, 2000, 2001) produced a number of case studies on Fiji, Vietnam, the Philippines, and Dominica. The timeframe of this analysis was mainly short-term, i.e. the period up to one year after a disaster. They detected severe negative economic impacts, with agriculture being hit most strongly, an exacerbation of inequalities, and reinforcement of poverty. However, they also found it difficult to isolate disaster impacts on economic variables from other impacts.

ECLAC has been conducting numerous case studies on disaster impacts in Latin American countries since 1972. Based on this experience they have developed a manual for the quick identification and assessment of the direct, indirect, and macroeconomic impacts to be carried out shortly after the occurrence of an event to identify necessary rehabilitation and reconstruction measures and needed international aid. Otero and Marti (1995) summarized results and generally found serious shorter term impacts as national income decreases, an increase in the fiscal deficit as tax revenue falls, and an increase in the trade deficit as exports fall and imports increase. Substantial longer term impacts on development prospects, perpetual external and fiscal imbalances due to increased debt service payments post-disaster and spending requirements, and negative effects on income distribution were also found (ECLAC and IDB 2000: 16; Otero and Marti 1995: 28ff.). To give an example, more than twenty years after the Managua earthquake, part of destroyed urban structures have still not been rebuilt (Otero and Marti 1995: 28). Reasons for this are discussed in the following quote:

"Predominance of cumulative negative effects as a result of disasters is explained by the fact that the countries affected in the region [i.e. the Latin America and Caribbean region] never manage to obtain all the resources needed to completely replace the assets lost, much less to rebuild them with significant improvements where risk reduction is concerned. If this is true for the region as a whole, it is more so for the smaller, less diversified economies which as a result are more vulnerable, because in these cases reconstruction processes take long periods in which the reduction of activities and production (indirect and secondary consequences) is not compensated for with the increase in replacement activity (ECLAC and IDB 2000: 13)."

However, they also assert that it is difficult to measure impacts of disasters in the long term because there is a complex interaction between the impacts due to a particular disaster event and prevailing economic conditions as well as the relations to the international community. They hold that the significance of the impact depends on the size of the disasters, the size of the economy and the prevailing economic conditions (Otero and Marti 1995: 32).

Murlidharan and Shah (2001) by means of a regression analysis analysed a large data set of 52 catastrophes in 32 developed and developing countries with the same time horizon approach as Albala-Bertrand: in the short-term (year before event compared to year of event). They found catastrophes for all country income groups to affect short-term growth very significantly. In the medium-term (average of two preceding years compared to average of event and two following years), the effect on growth was still significant. As time passes, they found the impact on economic growth to 28 subside. They also found associations between disasters and the growth of external debt, the budget deficit and inflation (2001: 18-19).

Crowards (1999) examined the impacts of 22 hurricane events in borrowing member countries of the Caribbean Development Bank and found that GDP growth slowed by 3% on average post-event, but rebounded due to the increase in investment the following year. He also found large variations around averages.

Charveriat (2000) for most cases in her disaster sample found a typical pattern of GDP with a decrease in the year of an event and a recuperation in the following two years due to high investment into fixed capital. She detected the scale of short-term impacts to depend on the loss-to-GDP-ratio and whether the event was localized or country-wide. For high-loss-to-GDP ratios and country-wide events she found larger impacts. She identified as another crucial variable economic vulnerability, as defined by the size of the economy, the degree of diversification and the size of the informal and agricultural sectors. For example, there were severe impacts of disasters for the smaller undiversified Caribbean Island economies. Also, she lists the case of the earthquake of 1987 in Ecuador that damaged the most important oil pipeline of the country which caused a large loss of earnings from oil exports. She discusses the following crucial variables affecting the scale of aggregate effects: structure of the economy and general conditions prevailing, the size of economy, the degree of diversification and the speed of assistance of the international community.

In contrast to the above studies, Albala-Bertrand (1993) comes to different conclusions and finds himself partially in opposition to accepted views when analysing impacts mainly on developing countries. He first statistically analysed part of the ECLAC data set and found that natural disasters do not negatively affect GDP, public deficit and inflation in the short to medium term. His findings on the trade deficits are in accordance with ECLAC and another research. These findings he explains with a sharp increase in capital inflows and transfers (private and public donations). He holds that natural disasters do not lower GDP growth rates and "if anything, they might improve them" (1993: 207). However, this statement is not fully tenable when analysing his statistics more closely. He compared 28 disasters in 26 countries, mainly developing countries between 1960 to 1979, with a short– and medium-term focus (1-3 years). In 7 out of the 28 cases the GDP growth rate slowed in the year of the event compared to the year before and in only one case it became negative. However, 16 of the 28 events in his sample happened in the second half of the year. Accordingly, when comparing the year of the event and the year following it, GDP in the year after the event declined in 15 cases. Also, when comparing the average of the year of the event and the two years succeeding it with the average of the two years before the event, the effect is ambiguous as average GDP went up 15 times and down 12 times. Albala-Bertrand also examined longer-term effects for a number of developed and developing countries and found no significant long-term effects in developed countries; he came to the conclusion that in developing countries aggregate effects fade away after two years, but that some negative effects on income distribution and equality persist. In total Albala-Bertrand occupies a dissenting position and considers disasters "a problem of development, but essentially not a problem for development." (Albala-Bertrand 1993: 202). According to his analysis, while the number of deaths and people affected, and the extent of economic losses are determined by the current state of a country's development, disasters do not normally hinder long-term development, with the sole exception being widespread droughts. However, ECLAC finds three assumptions used by Albala-Bertrand in his argumentation on the inexistence of long-term development impacts of disasters particularly problematic (ECLAC 2002: 373-374). Concerning the assumption about GDP and inflation not being impacted adversely, ECLAC has shown contradicting examples as discussed. Albala-Bertrand also posits that direct disaster damages are frequently overstated for political and technical reasons; ECLAC maintains that there are many examples where damages were underestimated due to electoral reasons, when vulnerable social sectors were affected or when strict fiscal discipline had to be maintained. ECLAC also disagrees with Albala-Bertrand’s assertion that disaster events are scarce and occur only occasionally, and rather posits that they happen more often, an observation which can clearly be corroborated for Latin America (see also fig. 45 in chapter 10). In conclusion, contrary to Albala-Bertrand, ECLAC considers disasters to be a problem for development, the existing gaps between expected and actual economic growth may become larger, and of development, disaster impacts are determined by vulnerability, which is affected by the state of socioeconomic development.

CONCLUSION

In conclusion, the examination of the impacts of natural disasters on both developed and developing countries, coupled with a comprehensive literature review, has illuminated the multifaceted nature of this global challenge. As discussed, the consequences of natural disasters are far-reaching, affecting economies, infrastructure, healthcare and the overall well-being of communities. While developed countries may possess greater financial resources and advanced infrastructure but they are not immune to the profound and often enduring effects of such events. Developing nations with their limited resources and vulnerabilities face additional hurdles in the aftermath of disasters, amplifying the complexity of their recovery processes.

The literature review has underscored the importance of proactive measures, preparedness and adaptive strategies in mitigating the impact of natural disasters. Successful models from various regions have demonstrated the effectiveness of community engagement, early warning systems and sustainable development practices in reducing vulnerabilities. Furthermore, the evolving nature of climate change introduces an additional layer of complexity necessitating a dynamic and collaborative approach on a global scale.

As we move forward, it is imperative for policymakers, researchers and communities to foster a collective commitment to building resilience against natural disasters. Integrating lessons from the literature and recognizing the unique challenges faced by both developed and developing countries will enable the formulation of more effective strategies. By doing so, we can aspire to create a world better equipped to navigate the unpredictable forces of nature fostering sustainable development and safeguarding the well-being of present and future generations.

CHAPTER 2: FROM CATASTROPHE TO RECOVERY: A COMPREHESIVE APPROACH TO DISASTER COST MANAGEMENT

CHAPTER 2: FROM CATASTROPHE TO RECOVERY: A COMPREHESIVE APPROACH TO DISASTER COST MANAGEMENT

INTRODUCTION

This chapter explores the multifaceted field of natural disaster management exploring the strategies, principles and practices employed to mitigate risks to enhance preparedness and facilitate effective response and recovery efforts by understanding the complexities of natural disasters and the dynamics of disaster management. Hence, this chapter includes an overview of institutional risk-based planning of natural disasters and its financing.

1. SECTION 1: INSTITUTIONAL MANAGEMENT OF NATURAL DISASTERS

This section looks at risk-based planning and mitigation strategies of natural disasters to be taken to manage natural hazards in-order to reduce the impact of the disasters.

1.1 **FRAMEWORK FOR RISK-BASED PLANNING OF DISASTERS**

Risk transfer mechanisms enable the distribution of the risks associated with natural hazard events such as floods and earthquakes to reduce financial and economic impacts. This might not fully eliminate the country's financial risk exposure but it allows risk to be shared with other parties. The common risk transfer tool is catastrophic insurance, which allows countries to recover some of their disaster losses and thus managing the financial impacts of disasters. Other financial instruments include catastrophic bonds (cat-bonds) and weather risk management products. The issuance of catastrophe risk linked bonds by insurance or reinsurance companies enables them to obtain coverage for particular risk exposures in case of predefined catastrophic events (e.g. earthquakes). These catastrophe bonds allow the insurance companies transfer risk and obtain complementary coverage in the capital market and increase their capacity to take on more catastrophe risk coverage risk transfer mechanisms enable the distribution of the risks associated with natural hazard events such as floods and earthquakes to reduce financial and economic impacts. This might not fully eliminate the country's financial risk exposure but it allows risk to be shared with other parties. The common risk transfer tool is catastrophic insurance, which allows countries to recover some of their disaster losses and thus managing the financial impacts of disasters. Other financial instruments include catastrophic bonds (cat-bonds) and weather risk management products. (Ulrich Ranke, Integrated Disaster Risk Management., 2016)

According to the international consensus, disasters whether natural or man-made have to be reduced in order to increase the living conditions of societies. This understanding is the rationale for social and economic development planning and was first formulated by the Brundtland Commission in 1987. The commission introduced the term "sustainable living" in regard to resources, ownership, access to basic needs, and livelihood security. The intention of the vision is that people's capacities to generate and maintain their means of living in order to enhance their well-being and that of future generations should be strengthened wherever possible and wherever necessary. The discussions following the recognition of climate change have specially made such a reorientation necessary. According to DFID (Twigg, 2002), sustained individual and societal livelihood comprise a pentagon of human, technical, financial, natural, physical, and social assets that enable them to cope with the adverse impacts of disasters. Thus, livelihood resilience describes the capacity of a population to adapt and adjust to actual or potential impacts from natural disasters as well as from the changing climate. After the Second World War this approach has widely been used under the term “civil defence” but in the last decades efforts to cope with threats to local communities are called “emergency management” or “disaster planning” (Quarantelli, 1995).

A sustainable disaster resilience will not be achieved without a national strategy that describes short-term responses to periodic stress, as well as long-term perspectives in response to anticipated future challenges. As a result of these outcomes, the Hyogo Framework of Action initiated a multitude of documents and research papers on the current status of disaster risk management and called for an integration of disaster risk management into national strategies for sustainable development. Meanwhile that initiative has been adopted in nearly all countries of the world and disaster risk reduction has been taken up by governmental bureaucracies. All over the world the countries have meanwhile integrated natural/ man-made disaster risk reduction in their vision of civil defence. Especially after the 9/11 terror attack when the United States reorganized their civil defence sector and established the Department of Homeland Security, all countries have put a “generic or all-hazard or risk reduction” in their focus. In general, there is no great strategic and conceptual difference between risk reductions from external attacks than that from natural disasters.

As an outcome of the UN Decade on Disaster Risk Reduction (IDNDR 1990–1999) the importance of policy and its resulting implementation has now become generally accepted. By law, the envisaged disaster risk reduction is defined at first concerning the national “level of protection” and secondly under which legal framework the objectives should be achieved. The definition of the level of protection is a matter that requires a nationwide consensus of all stakeholders (national governmental authorities, local governments, nongovernmental organizations, research institutions, business, and the representatives of the social groups at risk) in an embracing dialogue. To find such a consensus is not a matter of weeks or months but should be implemented as a permanent review process. Next to the law, risk reduction requires a set of regulations defining the operational environment that enables the authorities to bring risk reduction into being. Guidelines are to follow that explicitly describe who is doing what, where, and who is benefiting, but also who may not be benefiting from the countermeasures. Thus, the policy sets the frame by defining regulations, authorizations, prohibition, provisions, sanctions, declarations, or restrictions but does not outline activities actually to be carried out.

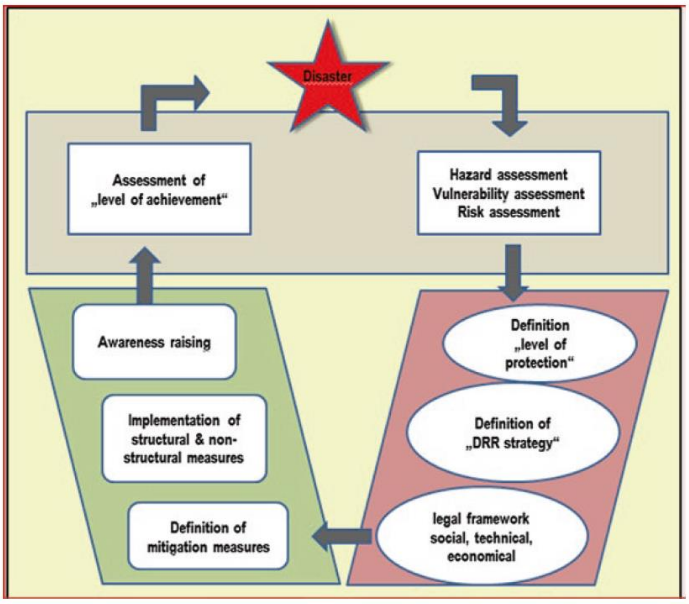
1.1.1 **Mitigation Strategies**

Mitigation is the step where policies and strategies are institutionalized before a disaster strikes. Thus, mitigation has a very close causal relationship with the step of “preparedness and prevention” where the mitigation policies are actually implemented. Although there is no generally accepted definition of mitigation, most disaster risk managers nevertheless stick to this definition rather than to define it as an overall term describing all the measures from disaster assessment to real implementation of risk reduction countermeasures. Focusing on mitigation as a central part of national development strategies has been driven by several factors. First, due to the ever-increasing economic costs of disasters and disaster relief, societies are increasingly expecting and demanding that their governments protect them from disasters before a disaster strikes rather than just reacting to its impact. Second, the increasing understanding of the cause–effect relationship between hazard exposure and poverty calls for state intervention long before a crisis. In developing countries moreover risk reduction is traditionally seen as the state's task. Altogether the arguments raised give a distinct rationale to link disaster planning to development planning, a linkage often reiterated by the World Bank and other international donor agencies (Kreimer, 1991).

Natural hazard mitigation comprises every step taken to contain or reduce the effects of an anticipated or already occurred disastrous event, regardless of whether these steps are taken by an individual, a social group, the public, or states' official emergency management agencies. The aim of hazard mitigation is sustainably to reduce or better eliminate the long-term risk to life and property from hazards. Mitigation is taking action (in general) before a disaster strikes to reduce human and financial consequences later. But often actions that are taken right after a disaster occurred are called mitigation. Nevertheless, mitigation is used exclusively here in context with prevention and preparedness as has already been described above. Mitigation when successful increases the resilience of formerly vulnerable societies. Effective mitigation requires that all stakeholders understand local risks, and address the root causes as well as the consequences and define the political will to invest in long-term community well-being. This definition distinguishes actions that have a long-term impact from those that are more closely associated with immediate preparedness, response, and recovery activities. Hazard mitigation is the only phase of emergency management specifically dedicated to breaking the cycle of damage, reconstruction, and repeated damage. The primary purpose of mitigation is to identify community policies, actions, and tools for implementation that will result in a communitywide reduction in risk of future losses.

Figure 9 gives a generalized overview on how risk mitigation is addressed today. In the past emergency management agencies very often started disaster management as a relief and recovery scheme. Experiences from the last decades, however, revealed that the long-term effects of severe disasters require a shift in paradigm: to assist hazard-prone communities in a holistic way before, during and after a disaster. Moreover, there was a strong drive in the management focus towards cost-effectiveness. The long-time prevailing evidence-based disaster response and crisis reaction thus got a strong movement towards a culture of prevention. All these demanded a new disaster risk management strategy framing the legal and operational base. The new approach is that today the factor of prevention became an indispensable part of any strategy.

Figure 9: Disaster risk mitigation planning structure



Source: (Ulrich Ranke, Integrated Disaster Risk Management., 2016)

The strategy shows disaster risk management as a cycle. As with every cycle it has neither a beginning nor an end. Nevertheless, let’s start with the onset of a disaster, the impact of which, root causes, people at risk, and their affected livelihoods have to be assessed in a scientifically sound, careful, and neutral manner. In these tasks, geoscientists, technicians, sociologists, and development planners are called upon to combine their expertise to come up with a reliable assessment. A legal frame for a systematic and rigorous disaster risk assessment on the national level must be established, that must furthermore comprise a stipulation on data collection systems and research and analysis by scientific institutions to ensure a knowledge-based disaster risk assessment. Only such a multisector knowledge-based assessment reveals the best opportunity for an in-depth assessment of the disaster that occurred and thus lays the basis for sustained disaster mitigation. But such an assessment alone will not give a realistic assessment of future events. Therefore, based on the deterministically assessed single event, it is necessary to draw scenarios for probable future events. For such probabilistic risk assessments, well-educated and experienced scientists are necessary. Their findings are handed over to the national authorities to serve as the basis for defining the national level of protection. This definition should not be declared by government order. It has to be the outcome of a dialogue process that incorporates all stakeholders. Based on the level of protection, a national strategy of disaster risk reduction can be formulated: in general, by a law that defines the legal framework of the national disaster risk management. The legal frame together with adjoining regulations benchmark the operational setup required, stipulate the different mandates, and define (in general) the task necessary to reach the envisaged level of resilience. Based on the law and the regulations topic-oriented guidelines should be formulated that describe the different tasks at the implementation level. Here again geoscientists’ expertise is indispensable to develop and implement mitigation measures at the local level. But not only technical matters are to be addressed. Sustainable risk reduction needs to get the people involved in mitigation. Therefore, mitigation programs have to start right from the beginning initiatives with the focus on community awareness raising, risk-reduction education, and on strengthening the self-help capacities of the populations at risk. Another effective means for increasing resilience is by disaster preventive land-use planning. Next, every mitigation measure has to be subject to a critical review of its achievements. Only when lessons learned are been drawn regarding the strength and the weaknesses, can the next measures be designed more efficiently.

To institutionalize implementation at the local level the provision of financial and technical support for cost-effective natural disaster mitigation measures as well as an effective expenditure monitoring is required. Without sufficient adequate financial support and the "binding forces of law" any attempt to increase resilience by planning and organization will be not successful. Therefore, the state and its local authorities must endorse cost-sharing principles that nevertheless include a focus on the responsibilities of individuals, businesses, and insurers. Only when all decision-making levels are collaborating and are coordinated according to national strategy, can the government take up its original responsibility in guiding natural disaster risk management but not being actively involved in local mitigation.

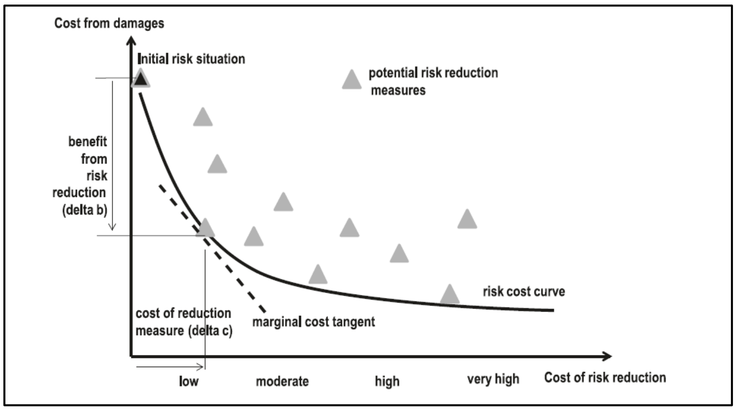
1.1.2 **Risk Based Planning**

The preceding statements clearly point out that risk-based planning is a prerequisite to shift the paradigm from a culture of reaction to a culture of prevention. Such a shift allows planning for future risk reduction based on a coherent risk assessment, defining safety levels that are applicable to the respective risk level, and moreover, facilitating the setting of priorities and defining the level of public and private interactions. Risk-based planning is the main step in achieving this. In order to develop a long-term strategy to protect people from the adverse impact of future natural disasters, risk-based planning creates the general framework on the national as well as on the local level. Therefore, mitigation planning has to involve the science sectors, the legally mandated authorities, and the implementation sectors, as well as the populations at risk. The envisaged benefits are that exposed people understand the nature of risk, the problems are addressed properly, and that reduction measures lead to an increase in societal resilience. The most important aspect of risk-based planning is that understanding risk is deeper and more broadly anchored in the society.

Risk-based spatial planning lay the base for a long-term management of a disaster risk reduction strategy. The planning comprises elements from hazard identification to the definition of risk reduction measures and their respective implementation. Furthermore, it allows the monitoring of the effectiveness of the countermeasures long after the actual measures have been completed. Spatial risk reduction planning should also entail conceptual means to identify alternative or additional uses for the area at risk under the assumption that these newly introduced land-use patterns will not lead to further endanger the area. To achieve completeness in planning, all possible alternative reduction measures have to be considered and have to be checked against their technical realization as well as against the envisaged economic benefits. These many requirements define the integral nature of any risk planning concept. As already mentioned, risk planning is in general based on a snapshot of the actual risk exposure situation, but it has to be considered in the planning that the implementation measures may be in effect for some time. A time span of up to several years may have to be considered, for instance, for stabilizing a slope against avalanche debris falls or even decades in the case of reforestation measures.

The risk-planning strategy has to comprise a methodological approach for time-differentiated quantitative risk assessment, based on the technical implement ability and the benefit–cost relation as given in Figure 10.

Figure 10: Benefit–cost relationship of risk reduction measures



Source: (Ulrich Ranke, Integrated Disaster Risk Management., 2016)

Generally, the envisaged level of resilience should be oriented at the state of technology. Such a demand holds true especially for strong economies, whereas in many developing countries such a claim is often not achievable. In these countries the implementation in fact is mainly based on the low cost principle, although the measures should at least serve a minimum level of resilience and should be locally adoptable and socially accepted. In this context, the issue of translocation has to be mentioned. This describes the strategy to locate risk-affected people in other no risk areas, an instrument that is often practiced in developing countries. Translocation is often seen by the authorities as the sole measure as it is easily implemented, based on hierarchical decision-making structures, and is generally taken by technocrats. But such decisions mostly disregard the emotional "soft" aspects of regional planning. It turned out that as long as such measures are not rooted in the society at risk, the effectiveness proved to be very questionable. The operationalization of the risk reduction measures should be laid down in the planning documents defining the main steps of the implementation process:

- Define the local prevention level (individual, public).
- Carry out risk assessment of the area under investigation.
- Outline the risk reduction measures.
- Define the cost regime with respect to the envisaged level of resilience (benefit).
- Enhance acceptance of the reduction measures by early involvement of the people at risk.
- Assess compliance of the risk reduction measures with other claims on the area, for example, industrial activities, agricultural production, environmental protection, social and cultural heritage, and ethical values.

2. SECTION 2: FINANCIAL MECHANISMS OF MANAGING ECONOMIC IMPACTS OF NATURAL DISASTERS

This section looks the proper financial mechanisms to be undertaken in-order to deal with natural disaster impacts

2.1 FINANCING OF RISKS ASSOCIATED WITH DISASTERS

Although in industrialized countries the great majority of damages are covered by insurance, most of the developing and many advanced countries still lack appropriate means to cover financial losses from natural disasters. In such countries the traditional way of covering losses by the individual is to wait for the government to cover the losses, often by providing money for reconstruction of the damaged buildings. But as many of these countries (e.g., a country like Bangladesh) do not have appropriate means at their disposal to cover at least the minimum losses, most of the burden rests with the victims. Many of the countries at risk, however, have generally only a very limited financial resource base from their tax income. Thus, many of these highly risk-exposed countries depend on foreign aid either in the form of donations, like Indonesia that received about US$8 billion for rehabilitation of the tsunami damage, or in the form of long-term loans from the World Bank or from one of the regional development banks. But such loans are made at market conditions and one day have to be paid back. The deep dependency on external resources makes these countries even more vulnerable and was in many cases the reason that hindered a sustainable recovery.

The low income levels make such poor or deprived countries non-target areas for the international insurance business, and if not, then it is restricted to the wealthier segment of the society or the highly productive industrial sector. The lack of many financial resources often hampers a fast recovery after a disaster as the necessary infrastructure rehabilitation measures are either not implemented or at best start with much delay and not to the necessary dimensions. To overcome this lack of money, risk-related financing schemes have to be implemented before a disaster strikes, especially in those societies at highest risk that have the lowest access to risk splitting or risk transferring mechanisms. This holds true for marginalized societies in industrialized countries (e.g., Hurricane Katrina) or entire societies such as Bangladesh. Both damages are, if covered, only to a limited extent. The most appropriate way for societies at risk not to depend on external help from international donor agencies such as the Holdback, the International Regional Development Banks, or from private donations, is that the national governments declare their willingness to institutionalize a state, parastate, or privately organized risk transfer mechanism. Such a willingness opens good chances to uncover not only effective means for financing disaster losses but also can include risk prevention elements. Most important is that state authorities:

- Base their assumptions on realistic pictures of the local risk exposure.
- Understand sharing of risk to be a social challenge.
- Acknowledge that prevention pays off (reduces the costs by two to five times).

- Know about what kind of social, scientific, and technical elements disaster risk management should include.
- Be open to a dialogue with the private sector for identifying options for risk transfer mechanisms.
- Institutionalize a conducive legal framework that fosters cooperation of the government authorities with the private sector.

Sharing risk means that there is a mechanism that transfers or splits the risk from the people who are affected by a disaster to those who are not affected. All partners in the mechanism contribute a “low” amount of money (premium) to cover a high loss of an individual. But such kind of risk sharing is significantly different in countries with high and low income. There are many societies that cannot afford even the lowest premium, and those are often at the highest risk. In industrialized countries private as well as industrial buildings are generally comprehensively insured against damages. There are even countries where parts of the risk premiums are taken over by the government or by tax exemption. In many developing countries, however, such risk- sharing mechanisms either do not exist or are only of a limited capacity and thus loss compensation is seen by the society as a national task, a situation that is well known also in many industrialized countries. In this Kunreuther (Kunreuther, 1966) emphasized that instead of covering the losses by the states, the insurance companies should be “convinced” to assess regularly the building standards of private homes as a prerequisite for insurance. Another point in defining the premium should be not to base its exclusively on the individual’s risk pattern but also take the livelihood conditions, the location, and the social environment as an equal determinant of vulnerability into account when defining the insurance premium.

Consequently, risk mitigation should always be accompanied by an insurance industry. Insurance is by definition a form of disaster preparedness. It represents an important, if not decisive, prerequisite for many economic activities (Berz, 1997). Without insurance coverage, for example, engineering projects in highly risk-exposed regions, such as power stations in earthquake zones, would expose such installations to uncontrollable risk of failure that is not acceptable to the investors as well as to regional development efforts. Insurance is a market-oriented instrument that allows for a more even distribution of the financial burden from disaster among the four parties concerned: the insured, the insurer, the reinsurer, and the government (MunichRe 2012). The insurer and the reinsurer bear most of the burden. But where the financial losses overstep the insurer’s liability, in general governments step into help out as the last-resort insurer or provide financial incentives to the victims either by direct loans or by tax relief. The insurer moreover can contribute to increasing self-responsibility in disaster risk reduction behaviour with the insured by introducing a rebate in the insurance policy: a substantial deductible as a clause in the insurance policy often initiates individual prevention measures. This cost-sharing principle is for both parties involved (insured and insurer) a vital means that rewards the insurer with a substantial premium rebate and on the other side reduces the risk of the insurer. The wealth of data makes the insurance able not only in calculating premiums and in classifying hazard areas known as rating zones but also in tracing relationships between event intensity and loss intensity and estimating loss potentials from realistic disaster scenarios (MunichRe ibid). By this information they contribute a broad experience to worldwide cooperation with governmental, non-governmental, and scientific institutions, industry, and the media. Also due to this information pool it was possible recently to reduce drastically the financial expenditure of the insurers, eligible for settling natural disaster losses by relatively modest deductibles as most of the natural disasters always entail a large, sometimes enormous, number of minor losses.

In general, people make choices on how much risk they are willing to bear and how much money they want to spend for the desired amount of prevention. But this choice is a matter of income. In this sense the people distinguish between a risk they are willing to tolerate and those they do not accept. It turned out that the individual often sees the sector for a personal involvement in the field of "tolerable" risks, and he attributes the intolerable risks generally as a state's responsibility. Reaching a higher level of resilience is thus not only a matter of personal experience but also of a substantial risk reduction commitment by society. In this regard risk mitigation is a prominent example for the "paradigm of social balance" that makes a society vital and sustainable.

Practically the populations at risk distinguish between self-insurance, when the person feels able to absorb a loss, and insurance coverage, which pays a specified sum when the event occurs. Prevention entails measures that have a cost, and insurance entails a financial premium, and a person chooses the level and combination that best moderates consumption fluctuations. The following tiers summarize effective measures of risk sharing at individual and household levels:

- Savings for loss prevention
- Personal hazard and risk assessment (individual disaster risk profiling)
- Investment to protect and maintain assets
- Insuring assets, property, and household goods
- Retrofitting stability of building structures
- Timely repairs
- Relocating to safer areas
- Awareness rising, training, evacuation drills
- Part of the early warning system
- Increasing participation in social networks

People who are insured for a risk often develop a different awareness of the risk to which they are still exposed. This makes them less sensitive to the hazards and makes them lose interest in taking their own loss prevention measures. Insurers thus see their role not only in just covering financial losses but also to counteract this mode of thought and behaviour through awareness-raising campaigns. This scenario is for them the rationale to inform their clients comprehensively on the relationship between hazard, vulnerability, and risk. All major insurance companies therefore have established scientific and technical expertise in risk assessment. In so doing, the companies often find themselves at the forefront of scientific and technological development. They regularly publish information in the form of leaflets, brochures, and in the media in order to alert the public to risks and draw attention to the precautions they could take.

Three terms are fundamental to understand risk sharing:

- Deductible; describes the amount or percentage of an insured loss that the policyholder must cover before any claims are paid by the insurer.
- Insurance pool; is the collective pool of risk from multiple insurance companies. Pooling facilitates the development of insurance markets by spreading risk across insurers that would otherwise lack financial capacity to participate in the market. It enables insurers to provide affordable coverage for high-risk events.
- Reinsurance; describes the mechanism to sell an insurance by an insuring company to another specialty insurance company (the reinsurer) for the purpose of spreading risk and reducing the insurer's own losses from large insurance claims.

2.2 **DIFFERENT TYPES OF RISK FINANCING**

2.2.1 **Insurance (self-insurance)**

Damages from natural disaster occur as we have seen worldwide, hitting industrialized nations as well as nations that are in a development status. But as in industrialized countries most of the values that are at risk are (normally) insured, so that losses did not extremely burden the economy of the individual as well the country in general, low-income households as we find in many developing countries are highly vulnerable to losses from natural disasters. An appropriate means to protect households from such kind of economic losses is through insurance. Insurance is an instrument to share the risk among a group of the society that is exposed to the same kind of risk. The principle of insuring losses from risks such as accidents, health, life term, equity price risk, or crop failure, as well as from natural disasters are based on assessing the possible financial losses of randomly occurring events based on statistically measurable and thus predictable distributions of disaster events. Such statistics allow the insurer to assess the risks and consequently to define the burden. "Ironically the widely accepted practice of insurances in the World's largest economies reflects a collective method of socializing losses" (World Bank, Attacking Poverty - The International Bank for Reconstruction and Development, 2001). As catastrophic events occur comparatively seldom, their potential loss is quite high, making the use of the traditional insurance practice of spreading risks over a large number of insured individuals difficult. The insurance risk management therefore developed a series of alternative risk financing concepts of which the most important are described below.

Turkey is one of the countries in the world that is most exposed to natural disasters, particularly earthquakes. Around 70 % of Turkey's population and 75 % of its industrial facilities are exposed to large-scale earthquakes. The 1999 Kocaeli-Izmit earthquake along the North Anatolian Fault Zone claimed a death toll over 17,000 and caused economic losses estimated at about US$5 billion; or around 2.5 % of gross domestic product. The nation's disaster hotspot is located at the city of Istanbul. There almost 15 million inhabitants making the city the fourth biggest megacity on Earth and a high industrial density, living on the highly active fault zone. According to recent assessments carried out by JICA (Ilkesik, 2002) the probability of a major earthquake affecting Istanbul in the next 30 years is higher than 60 %, resulting in a seismic risk exposure comparable to Los Angeles; but with damage potential that is much higher because of Istanbul's greater structural vulnerabilities. A seismic event of the same magnitude as that in 1999 would result in more than US$2.0 billion economic loss, up to 87,000 fatalities, 135,000 injuries, and heavy damage to 350,000 public and private buildings. Experts see this risk exposure as very dramatic, as it would burden the national economy to an extent that it would take Turkey years to recover again economically. But the Turkish exposure to natural disasters is not unique on Earth. There are many other places that also suffer economically from such disasters. Although the costliest disasters generally occur in developed countries, for instance, hurricanes since 2005 in the United States added up to losses of more than US$250 billion, fortunately mostly covered by risk insurance, in low- or median-income countries facing increasing economic losses only a few of them get insured. Thus, disasters often significantly affect the national economies, leading to expenditures that normally were earmarked for social development projects and that then have to fund emergency and recovery needs.

Covering losses from natural disasters can either be managed before a disaster strikes, ex-ante, which means financial means are invested to prevent losses from occurring, or ex-post, which means losses from disaster events have to be covered.

Ex-ante[8] disaster loss financing requires that the potential losses are known and have to be assessed prior to the event and a provision of money has to be made in the budgets for such an event. In fact, regarding loss assessment from many natural disasters of the 1990s (World Bank/GFDRR) it was possible to prevent economic losses of more than US$280 billion by investing US$40 billion in prevention, a ratio of 1:7. There are also other figures giving ratios of 1:5 or 1:8, but all of them bearing the same message: prevention pays. In this context another effect has to be considered, that in the case where prevention was successful, no loss occurred. Such a situation often brings the decision makers into a bias situation that can be described as the prevention dilemma, leaving the authority to explain why money has been invested, although nothing has happened.

Ex-post[9] disaster coverage has the advantage that the costs can be quantified quite exactly but on the other hand this puts a huge financial burden on the national budget. In many countries with limited economic resilience, the financial means to be allocated were in general financed by new debts. Such financing has often heavily affected the country's debt service in the past and consequently could only be adjusted by raising taxes that once again strongly affected and discouraged new private investments. In addition, the lack of financial means in the aftermath of a disaster often has led to hamper recovery and forced governments to conduct an emergency budget reallocation often at the burden of other social development programs. Therefore, many disaster-stricken low–middle income countries in the past had mostly to rely on foreign

[8] In the context of disaster events, ex ante instruments are arranged before the event

[9] based on actual facts hence after the disaster event happens rather than forecasts

assistance. But such assistance is often rendered only for a short time (weeks or months) and is generally scheduled to finance relief and rehabilitation measures rather than to change the risk exposure. Moreover, such donations do not cover the entire losses. An exemption on this was the overwhelming support by the international community on the 2004 tsunami in Indonesia, where more money was allocated by the international community than the actual loss of about US$5 billion. Furthermore, in the future it is most probable that due to the rising frequency and intensity of losses from climate- related disasters, the traditional model of post-disaster financing and reliance in low- and middle-income countries on the donor community is no longer guaranteed (UNISDR, Hyogo Framework for Action 2005-2015, 2005) (Cummins, 2008).

Despite the frequency and expenses of natural disasters in industrialized and developing countries, there is no internationally agreed-upon system in either the public or private sector for consistently compiling information about their economic impacts. Therefore, for a long time, organizations involved in economic loss assessment pledge to establish an informed risk management policy that integrates any data on the direct as well as on the indirect losses from natural disasters. The committee proposed to base such calculations not on the reconstruction costs but on the losses from the disaster impact. This approach covers a much broader range of cost categories, as the term “costs” conventionally is understood to cover the losses that are reimbursed by insurance companies and governments. A calculation method should be developed that not only incorporates the local direct reconstruction costs but also the indirect costs such as price increases in far remote areas, death toll from medical service functioning failure, restricted energy generation due to disruption of the traffic connections (transport of coal), and many more. The algorithm furthermore should address the benefits of mitigation measures on the basis of a life-cycle investment, or at least for a decade in the future and not calculate the costs just by comparing the invested money and the cost of a normal or worst-case scenario.

The experience from the many risk events brought the developing countries and the international donor community to review the situation and was the rationale for many political approaches to economically secure disaster risk financing. The long-used practice just to rely on the international donor community to cover the losses is anticipated in regard to the many costly hydrometeorological disasters to be increasingly unrealistic. In addition, more and more countries realized that it would be less costly to invest in disaster prevention measures than to cover post-disaster losses. Therefore, the UN Framework Convention on Climate Change and the subsequent Kyoto Protocol refer to the potential role of insurance in disaster mitigation and the Hyogo Framework for Action 2005–2015 (UNISDR 2005) identified the need to promote the development of financial risk-sharing mechanisms, particularly insurance and reinsurance against disasters, as a priority action for building the resilience of nations and communities to recover from disasters and recognized the need for innovative risk-financing mechanisms to be particularly relevant to the middle- and low-income countries.

Thus far funding for disaster mitigation and prevention in developing countries mostly was provided by industrialized country-financed international donor agencies such as the World

Bank, the United Nations, or the many regional development banks (ABD, AFDB, etc.). In more advanced economies, losses from natural disasters are typically funded through a combination of private risk-financing arrangements and an efficient public revenue system. In middle- and low-income countries, with fiscal pressures, funding of post-disaster reconstruction strongly was based on ex-post borrowing and assistance from international donors.

Well-established forms of financing losses from natural disasters or of preventing future losses include different economic approaches. Risk compensation can be financed either through risk retention or risk transfer to an outside party.

2.2.2 **Microfinancing**

A special type of insurance that offers protection against the risks in life, especially for low-income people in the developing countries is called micro-insurance. There have been in the past many successful attempts to provide financial means to such a group of people, who normally do not have access to the financial markets. The first to start such a credit scheme was Professor M. Yunus in Bangladesh, who invented the Grameen Bank model and was later honoured with the Nobel Peace Prize. Since then, the microfinancing market has strongly developed. Today many different credit schemes are offered by the international insurance business; all of them aim at risk financing for low-income groups and can be tailored according to the needs in developing countries. The world market for micro-insurance is estimated to comprise more than two billion people, representing an economic potential of US$40 billion, according to information from Allianz, Germany (Allianz Insurance Company, Pro Vention Consortium).

The basic principles for micro-insurance are that the losses must occur by chance, unexpected, and randomly. The losses must be pre-defined in terms of timing, region, type of risk, and severity. The rate of losses must be predictable, must embrace quite a large insured clientele, and should have quite a large areal distribution. The premium must be proportionate to the likelihood and costs of the risk involved but the mode of payment can be tailored according to the needs of the clientele. The insurance payments can be used to restore household and productive assets that were damaged during a disaster. The social and economic sectors that are subjects for micro-insurance comprise the entire sector of insurance, from term life insurance, accidents, home insurance, to livestock insurance, as well as protection against natural perils including floods, rain, hail, or others.

Micro-insurance can help split the risks especially of low-income households. Munich Re and ILO (International Labour Organisation) published in 2006 (Churchill, 2006) a brochure that explained how micro-insurance schemes can help to split risks from natural disasters. Traditionally such kind of informal risk splitting is known from many societies worldwide, but in fact such insurance schemes preferably covered agricultural losses, or economic burdens in the health sector or from accidental deaths. The outreach for such systems is limited and in reality, only small. The poor are that fraction of a society who are more vulnerable to a crisis than all other societal groups and are those who are the least able to cope with disasters. The traditional coping strategies are normally restricted in the effects and low in return, thus providing only insufficient protection. According to ILO (ILO, 2001) half of the world's population is excluded from any type of social security protection; in sub-Saharan Africa not even one in ten. Various experiences with micro-insurance proved it a valuable instrument of risk sharing. Traditional micro-insurance can mean that a peasant puts aside money from a good harvest for a time of emergency. Micro-insurance in the sense ILO is propagating even goes a step further. It is rather designed to cover risks through a regular payment of premiums that is proportionate to likelihood, saliency, and the losses from natural disaster. Thus, ILO pointed out micro-insurance does not differ much from normal insurance but has a clear focus on low-income people, people who are in their majority defined by not having a regular income and not having access to formal social protection neither by employers nor from the government. The basic concept of micro-insurance is "risk pooling" that means all insured participants pay the premium in a great pool from which a loss in a certain time period and of a defined nature will be covered. Thus, all contribute a small amount of money but only a few benefits strongly. ILO pointed out that micro-insurance schemes are best applicable when the risks are sudden, not predictable and of a significant severity. Ensuring such kind of risk is a means to give social protection for all those who are lacking respective government schemes.

Micro-insurance examples from Asia and Africa reveal that also the poor can increase their disaster resilience, thus making them interesting partners for the insurance business. The normal insurance business tries not to insure high-risk persons whereas the low-income oriented micro-insurance policy runs the opposite way. It seeks to get many people into the portfolio thus sharing the risks to all and thus reducing the risk of a particular household. A reasonable way to share the risk is to identify groups of persons that share the same type of risk: agricultural cooperatives, small-scale entrepreneurs and religious groups or women associations. Such associations exist in all developing countries, making them a preferable target group for micro-insurers.

Micro-insurance schemes have already in many cases proven their general capability to provide security against natural perils. But "in practice there are only few successful experiences and it has proved extremely challenging to structure and implement affordable and high value micro-insurance products specifically for disasters" (Linnerooth-Bayer, 2009). They recognized that to implement a micro-insurance system successfully, a couple of basic factors must be operational, including a powerful and diversified risk pool, low transaction costs and affordable premiums, together with a transparent and efficient mode of payouts. In addition, micro-insurance requires a highly specialized staff that operates under clearly defined procedures. Furthermore, experience clearly shows that micro-insurance deserves a backing by reinsurers, "as it is very difficult for most systems to provide insurance alone."

2.2.3 **Risk Retention**

Retaining a risk means that the individual, a company of (even) the government puts money aside from the annual budget in order to cover a loss when it occurs. This can be managed either according to plan or be done unplanned. If neither loss reserves nor disaster reconstruction funds have been established or designated, very often losses are just taken from available cash. From a risk-financing point of view, this technique is acceptable for losses that are small in nature and infrequent in occurrence. A more sustainable approach is to establish a loss reserve. Such an approach comprises a significant difference from the technique described above, as it recognizes a liability for loss and demands setting aside money or assets to fund that liability. Such a loss reserve is typically based on expected losses and is treated as a budget provision, requiring a pre-defined liability in the financial statements. The losses can be funded by cash, securities, or other liquid assets that are earmarked for the designated liabilities. Another element in risk financing is self-insurance which means that such an organization finances its losses through a planned strategy. The most typical forms of self-insurance are a self-insurance trust or a captive insurance company. A self-insurance trust is not insurance but a funding vehicle (e.g., a bank account with an independent third party/trustee) that is designated for the sole purpose of paying losses. The trustee administers the trust through a formalized agreement and a statement that outlines the type and limits of loss to be paid. The trusts were for long the most common vehicle for self-insurance, but they are gradually being replaced by captive insurance companies because these vehicles can more flexibly accommodate the various exposures and risk financing needs (Carroll, 2001). A captive insurance company is an organizational structure established for instance by a large company or a private entity to cover their respective losses from natural disasters. The insurance business is primarily controlled by its owners who are also the principal beneficiaries. As before (self-insurance), captives are also insurance vehicles but with a greater flexibility to accommodate the many and different types of risk. As captives are obliged to tax and income statements, there is a great importance that they act in line with the company's risk-management program, which consequently will elevate risk management a part of the organization management.

2.2.4 **Risk Transfer**

Risk transfer by definition transmits an individual, party, or organization, and so on, risk to an insurance company which itself spreads it among many insurance holders. The most common method of risk transfer is a commercial insurance first-party insurance also called direct damage coverage of losses, providing financial reimbursement as the result of damage that also comprises all types of natural disasters. Insurance is a contractual relationship that exists when the insurer agrees, for a premium, to pay the insured a loss caused by a pre-defined event (peril). The risk premium is the amount of money the insured pays regularly to the insurer and depends on the agreed-upon level of returns. The premium thus describes the willingness of the insurance taker to accept a certain risk. From a practical view, insurance will nearly always involve some form of risk retention on a planned or unplanned basis and is generally subject to a deductible. A deductible is the percentage of an insured loss that the policyholder must cover by himself, before a claim will be paid by the insurer. The insurance companies themselves also seek to split their respective risks by passing their risk to a reinsurer or a group of reinsurers. In many countries the insurance companies are legally bound not to issue policies exceeding a maximum solvency margin of normally 10 % of their company net worth, unless those policies are reinsured. This significantly improves the insurer's capability to take on higher risks because some of that risk is transferred to collective risk pools with reinsurers like the Munich Re, the Swiss Re, or the Hannover Re. Over the years the reinsurers have developed sophisticated and reliable models to assess risk from natural disasters. One of the most famous is the Munich Re-Insurance Company that for a long time has established a powerful natural disaster risk assessment division and that has established the Munich Re Foundation to develop in-depth assessment of methods and strategies for risk assessment.

Today, risk financing is as described above viewed as a complex system involving economic aspects, contracts between insured and insurer, and a legal framework. The goal of risk financing is ultimately to protect assets and personal lives including some of the following:

- Identification of types of exposures and losses faced
- Anticipation of risks of the groups
- Financial provision to cover losses
- Pooling resources
- Spreading/transferring risks
- Risk prevention and retention
- Legally binding contracts
- Identification of ways to finance loss without jeopardizing the financial integrity of the contract partners

Transferring risks to the capital market often uses so-called insurance-linked securities (ILS) to reach a higher level of security by subsequently trading risks onto the secondary insurance market. This holds true especially for risks from natural hazards or to hedge against pandemic risks. This concept gave ILS a "foothold as an alternative asset category for investors and as an alternative form of reinsurance for insurers" (MunichRe 2012, 2013). And it is expected that this form of insurance will continue to gain in significance, because developments in supervisory law such as Solvency II are likely to give a further boost to their popularity.

Risk transfer also can be accomplished through the use of an indemnification provision. In natural disaster risk financing such a method can be a rationale if someone's interference with nature (e.g., the construction of a building) amplified the impact of a natural disaster leading to a claim for indemnification to be restored or reimbursed to make whole again. Nevertheless, it should be noted that any insurance policy should never be viewed as a complete transfer of risk.

In developed countries private organizations and entities other than the government take over a large portion of the financial risk by insurance. Thus, insurance is the primary tool for risk transfer in such countries. Risk transfer by insurance has several major advantages: it spreads risks between parties thus reducing the risk to the individual and it "allows the segregation of risk" (Freeman, 2003). In the higher-income countries about 30 % of the loss from natural hazards is insured, whereas in low- to middle-income countries insurance covers just 1 % of the losses.

2.2.5 **Catastrophic Bonds (Cat Bonds, Cat Swaps, Risk Swaps)**

Not only traditional financial insurance is an option for transferring risk. In the aftermath of the big disasters in the United States, for example, the Northridge earthquake and Hurricane Andrew, the insurance industry realized that the financial losses from such mega disasters can reach magnitudes that the insurance industry assumed not to be able to absorb in the future (Damnjanovic, 2010). The insurers therefore initiated a number of studies to estimate financial exposure based on the natural disaster experience. The anticipated financial losses from such disasters have led economists and geoscientists to develop alternative risk financing strategies, also known as alternative risk transfer techniques (ARTs). Among them are the so-called catastrophe bonds (cat bonds). Both instruments, insurance and cat bonds, are risk-management strategies potentially to embrace the impact of financial risks. Generally speaking, the difference of cat bonds and insurance is that cat bonds are paid by the insurance company when the economic losses from a natural disaster overstep the pre-disaster-defined level risk. Cat bonds are other than normal investment bonds not depending on the solvency of the creditor rather than on pre-defined type, location, and severity of a natural disaster.

The concept of cat bonds emerged from the intention of insurance companies to share the high to very high risks they would face if a major catastrophe occurred, and that could not be covered by the premiums. An insurance company therefore issues such bonds which are then sold to investors. If until the end of the contracted period no catastrophe occurs, the insurance company pays back the invested capital plus the premium and the interest to the investors. On the contrary, if a catastrophe occurs as defined in the bond's contract, then the incurred losses are paid by the insurance company to the claimholders, a situation that happened lately with the US$300 million cat bond of the Japanese Muteki Ltd catastrophe bond issued in 2008 by Munich Re after the damages of the March 11th Tohoku (Fukushima, Japan) earthquake cum tsunami were declared a total loss.

The advantage for the insurance company lies in comparatively high interest rates (when the losses are rated low), and those who want their risks from earthquake, flood, or hailstorm events to get covered, do not need to make respective budgetary provisions and can thus hand over their risks to the capital market. But not only private insurance companies are issuing cat bonds, governments also make more and more use of that financing scheme. Today the value of the worldwide assets reached about US$100 trillion, making that market highly interesting to the insurance business.

In response to increasing demand from risk-exposed countries, international donor organizations developed catastrophe bond issuance platforms that allow governments to use a standard framework to buy insurance. One of the best-known tools was launched by the World Bank, called the MultiCatProgram (World Bank, MultiCat Program. - The International Bank for Reconstruction and Development, 2014). The objective of the program is to facilitate access to insurance coverage for governments on terms that are better than normal market conditions, to help with disaster preparedness and to ensure governments' access to immediate liquidity to finance emergency relief and reconstruction work after a natural disaster. The first country to make use of the MultiCatProgram was Mexico that in 2009 had already sold US$290 million in catastrophe bonds that will cover up to US$140 million of earthquake damage, US$100 million against Pacific hurricanes and US$50 million against Atlantic hurricanes. The bond sale was managed under the lead of the World Bank by Goldman Sachs Group Inc. and Swiss Reinsurance Co. The World Bank's function in the program is to reduce the cost of issuing the bonds and make it easier to sell the bonds on emerging markets: “The bank will be playing a real catalytic role in getting some of these countries that have no access or are afraid to get this access to the markets.”

2.2.6 National Risk Sharing

There are a multitude of examples on national insurance programs. One of the most popular programs worldwide are the US National Flood Insurance Program (NFIP) that was created in 1968 through the National Flood Insurance Act (FEMA, The National Flood Insurance Program (NFIP), 1968). Floods are the most destructive natural hazard in terms of economic loss to the United States of America. The program enables property owners to purchase insurance protection from the government against losses from flooding. The insurance is designed to provide a nonmarket-based insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings caused by the yearly occurring floods mostly along the Mississippi/Missouri river path and in Florida. Since its inception in 1969, the National Flood Insurance has covered losses of more than US$40 billion in claims, of which more than 40 % of that money has gone to residents of Louisiana. The program moreover reiterates retrofitting the building standards that today save an estimated US$1 billion annually. In 2010, the program insured about 5.5 million homes in nearly 20,000 communities. Within the program, flood-prone areas are identified, specifically tailored flood insurance offered, and flood-prone communities are encouraged to implement flood-plain management activities. Originally, NFIP was meant to be self-supporting and intended that its operating expenses should be paid from the premiums collected for flood insurance policies. But it was found that there is a repetitive loss of about US$200 million annually that has to be covered by US taxpayers. Actually, there is an initiative underway that aims at raising the premium in order to make the NIFP self - supporting.

Homeowners who want their property to be insured can participate in the NFIP if their local community has signed a legally binding agreement with the federal government that stipulates that if a community will adopt and enforce a “flood plain management ordinance” to reduce future flood risks, the federal government will make flood insurance available to the community. The agreement furthermore demands that flood risk maps be set up and regularly updated, for a sustained flood plain management and for the identifying local flood risk premium zones. The compensation of losses, the money spent on future flood reduction measures, as well as the implementation of the communal flood management plans is overseen by the FEMA. The compensation of losses provided by the program is oriented on the value of flood damage on houses and assets. The loss compensation is based on either the replacement cost value or the actual cash value. The replacement cost value is the cost to replace that part of a building that is damaged. To be eligible, certain conditions must be met: (1) the building must be a single-family dwelling; (2) it must be the principal residence, meaning the family lives there for at least 80 % of the year; and (3) the reconstruction costs are at least 80 % of the full replacement cost of the building. The actual cash value is the replacement cost value at the time of loss, less the value of its physical depreciation, and the replacement costs of personal property are always valued at actual cash value.

In order to encourage communities to do more and better in flood risk reduction a Community Rating System (CRS) was implemented in 1990 (FEMA, National Flood Insurance Program Community Rating System (CRS)., 1990) as a voluntary program for recognizing and encouraging community flood plain management activities that is in full compliance with or even exceeds the minimum NFIP flood plain management requirements, and may apply to join the CRS. CRS-eligible communities can get their flood insurance premium rates discounted to reward community actions if the activities meet three goals:

- Reduce flood damage to insurable property.
- Strengthen and support the insurance aspects of the NFIP.
- Encourage a comprehensive approach to floodplain management.

Meanwhile more than 1200 communities participate in CRS, reaching nearly 3.8 million policyholders. Although CRS communities represent only 5 % of the over 20,000 communities participating in the NFIP, almost 70 % of all flood insurance policies are negotiated in CRS communities. Eligible for CRS support are communities that qualify a class rating system that is very similar to the fire insurance rating system of the United States. CRS classes are rated from 1 to 10. Each CRS class improvement produces a 5 % greater discount on flood insurance premiums. A community that does not apply at all for the CRS or that does not comply with the minimum requirements is considered a “class 10,” and a “class 1” community thus receives the maximum 45 % premium reduction. But lowering the costs of flood damage is only one of the rewards a community receives from participating in the CRS.

Citizens and property owners have increased opportunities to learn about risk, evaluate their individual vulnerabilities, and take action to protect themselves, as well as their homes and businesses. Flood plain management activities provide enhanced public safety and reduced damage to property and public infrastructure to avoid risk of lives, economic disruption, and loss. Communities can better evaluate the effectiveness of their local flood programs against a nationally recognized benchmark. Provision for technical assistance in designing and implementing flood reduction activities. Communities have incentives to maintain and improve their flood programs over time.

Although the NFIP is widely accepted as significantly increasing flood loss reduction in the United States, the program itself is under great criticism. Most of the criticism refers to the financial situation of the program. The cash-based budgeting is seen to obscure the program’s actual costs and does not provide transparent information on emerging financial problems. A system that allows for an accrual-based budgeting is anticipated to better address the revenues and expenses situation. Moreover, it has been estimated that less than 50 % of eligible property owners in flood plains participate in the program. In addition, even when the purchase of insurance is mandatory, the extent of noncompliance with the mandatory purchase requirement is unknown and remains a concern. In the past organization introduced reduction of the subsidies often caused policyholders to cancel their policies or reduce their program participation, thus leaving them vulnerable to financial loss from floods. Furthermore, placement of the program within the Department of Homeland Security and no longer with

NFIP itself, bears the risk of decreasing the attention, visibility, and public support the program receives. Moreover, homeowners who have built their houses before the flood zone was defined are also eligible for reduced premiums of up to 40 % lower than the normal risk premium. The incorporation of properties with two or more losses in a 10-year period has also added to program losses. This group of persons represents 38 % of claims losses, but accounts only for 2 % of insured properties.

On October 1st, 2013, the *New York Times* reported that the National Flood Insurance Program had changed its insurance policy. The report is summarized here. From that day on, the insurance premium will start going up steadily by 25 % per year for regions that are severely or repeatedly flooded, until the rates balance the actual risk expenditure. That means property owners in flood-prone areas who might have once been paying around US$500 a year (rates that were well below what the market would charge) will go up by thousands of dollars over the next decade. This took many homeowners affected by Hurricane Sandy to the streets to call for a “Stop FEMA” rally. Congressional representatives from states such as Louisiana and Florida that were likely to be hit by the NFIP changes called on FEMA to delay the implementation of the new rule, although the law got overwhelming support from all political parties. FEMA said its hands were tied, as the Biggert-Waters Act obligates the program to adjust flood premium rates accordingly. By November 2012 the NFIP was more than US$20 billion in debt, a number that would take the NFIP 100 years to recoup its losses. The changes were aimed at those 1.1 million policyholders who were paying far less than what the market value for flood insurance would have been. Thus, quite a number of policy owners have essentially been subsidized with public money for years, even decades. Therefore, property owners were confronted with unexpected outcomes of the subsidized flood insurance policy, although the NFIP was once created to support these people. Before NFIP, the private insurance industry was unwilling to provide flood insurance simply as it wasn’t profitable for them. The premiums did not cover the payouts following the many big floods. Thus, the government stepped in, offering subsidized flood insurance to property owners, often at below market rates.

But shifting the burden from the private market to the government didn’t really lower the costs of major floods, especially as more and more Americans moved to coastal areas. From 1970 to 2010, the population of shoreline counties increased by almost 40 %, to 120 million and is projected to increase by an additional 10 million people by 2020. Some critics mention that just the subsidized flood insurance, by shifting the risk from the individual to the public, had perversely incentivized building in flood-prone areas. And it is anticipated that things will get even worse if the consequences of sea-level rise continue as in the last decades. A recent study found that if no actions are taken to reduce flooding risk, losses could approach US$1000 billion by mid-century, assuming a sea-level rise of just 40 cm. The sea level around New York City has risen by about a foot and a half over the past century, which added to the devastating flood damage during Sandy. Investing in mitigation such as raising homes and protecting coastal communities with sand dunes and seawalls is therefore seen as the only alternative.

2.2.7 Turkish Catastrophe Insurance Pool (TCIP)

Turkey is one of the most risk-exposed countries in the world to earthquakes. Around 70 % of Turkey's population and 75 % of its industrial facilities are exposed to large-scale earthquakes. Most of the earthquakes occur along the North Anatolian Fracture zone (bordering the Marmara Sea) and along the East Anatolian Fracture zone. Since 1984 more than 120 earthquakes occurred with a magnitude higher than M5 that resulted in direct property and infrastructure losses frequently exceeding US$5 billion per event. The last major earthquake in the Marmara region in 1999 resulted in the loss of 15,000 lives and placed a financial burden of about US$6 billion on the economy and the government, also due to the fact that only less than US$1 billion in losses were covered by risk insurance.

Earthquake insurance coverage was relatively low at the end of the 1990s in Turkey. Only around 3 % of residential buildings were insured, as households traditionally relied on the government to finance the reconstruction of private property after major natural disasters. In the aftermath of the Marmara earthquake, the government decided to develop a property catastrophe risk insurance mechanism to reduce its fiscal exposure to natural disasters arising from the traditional government-funded reconstruction of private property. In 2000, the Turkish government created by Law No. 587 an earthquake insurance system compulsory for all residential buildings on registered land in urban areas. The World Bank (Gurenko, 2006) provided financial and technical assistance by the Global Facility for Disaster Reduction and Recovery (GFDRR). The TCIP has become the first national catastrophe insurance pool in World Bank client countries that provides standalone earthquake insurance coverage to homeowners and small and medium enterprises. The catastrophe risk-financing strategy of the TCIP relies on both covering the losses by their own financial resources and by transferring the risk to the reinsurance market. About US$80 million of losses will be covered through TCIP reserves; this part of the expenditures is initially complemented by a US$100 million World Bank contingent loan facility. The overage will be transferred to the international reinsurance markets. Moreover, the Turkish government covers losses that would exceed the overall claims, which is currently sufficient to withstand a 1-in-350-year earthquake. The main objectives of the TCIP are to:

- Ensure that all property dwellings have affordable earthquake insurance coverage.
- Create a culture of prevention and resilience.
- Reduce citizens' dependence on government to fund the reconstruction of private property.
- Reduce government's fiscal exposure to earthquake and fire damages.
- Transfer catastrophe risk to the international insurance markets.
- Encourage physical risk mitigation and safer construction practices.

In August 2000 the TCIP became a legal public entity targeted to lower government expenditure for catastrophes. Moreover, the government intends with the TCIP to improve the risk prevention culture and insurance consciousness in the public by incorporating the three stakeholder groups into a public–private partnership: the risk-exposed individual, the national mandated authorities, and the insurance cum reinsurance market for a socially affordable risk sharing. The program is not subsidized and the premium rates are oriented at levels for people with an average income with a deductible of 2 % with a contract duration of 30 years (Around US$62 per homeowner; the maximum coverage lies at approximately US$92,000 per policy). This financial scheme will lay the base for long-term fund accumulation and aims at sharing the financial burden between the individual and the international insurance market. The program offers a variety of insurance possibilities according to building type and property location. The risk coverage includes earthquakes and fire damage to residential structures but no household contents. Since the year 2000 the TCIP public–private partnership has stimulated the growth of the catastrophe insurance market in Turkey significantly. The number of earthquake policies sold increased sixfold from 600,000 in 1999 to more than 3.5 million in the year 2010. Nevertheless, the TCIP still needs more time to achieve deeper market penetration. Today, the insurance coverage is at about 23 % of dwellings countrywide and about 40 % in particularly disaster-prone areas. Still the expectation prevails with homeowners that the government will pay for damages regardless of the insurance program. It became obvious that a program such as TCIP relies on a strong communication strategy (Gurenko et al. ibid) to ensure that residents are aware of earthquake risk, mandatory insurance laws, and the program's excellent claim-paying record. The World Bank has drawn furthermore the assumption from the TCIP, that catastrophe insurance requires high state-of-the-art catastrophe risk modelling techniques to price premiums that accurately reflect the underlying risk.

CONCLUSION

In conclusion, effective management of natural disasters is imperative for safeguarding lives, protecting infrastructure and preserving the environment by following a systematic approach that encompasses risk identification, assessment, mitigation, preparedness, response, recovery, monitoring and community engagement. In many developing countries, however, institutional and regulatory framework is still missing or is in its infancy. The lack of such structures hinders an insurance market from developing. And the traditional way the banking system is organized in many developing countries makes necessary institutional reforms that allow risk insurance to operate properly very difficult, although the strategies, structures, and operational setup for implementing insurance markets are already well understood. In addition to the regulatory framework, there are concerns related to the fundamental structure of the market for insurance, for example, many countries are ranked too small for a national insurance market to survive hence hindering the natural disaster management initiative at a greater extent. To initiate a risk insurance market is to make insurance mandatory by law and to demonstrate the benefits of insurance at the government level, for example, by insuring government-owned buildings and infrastructure construction.

CHAPTER 3: PREDICTING AND MITIGATING DISASTER COSTS IN INDONESIA: A MONTE CARLO SIMULATION APPROACH

CHAPTER 3: PREDICTING AND MITIGATING DISASTER COSTS IN INDONESIA: A MONTE CARLO SIMULATION APPROACH

INTRODUCTION

Indonesia ranks 12th among the most vulnerable countries to high mortality risk from multiple hazards. The country is situated in one of the most active disaster hot spots, where several types of disasters such as earthquakes, tsunamis, volcanic eruptions, floods, landslides, droughts and forest fires frequently occur. According to a global risk analysis by the World Bank, Indonesia is among the top 35 countries that have high mortality risks from multiple hazards. Approximately 40 percent of the population at risk, that is, more than 90 million lives. The increase in population and assets exposed to natural disasters, combined with the rise in the number and intensity of hydro-meteorological events resulting from climate change, may further increase the economic and human impact of natural disasters in Indonesia.

1. SECTION 1: OVERVIEW OF NATURAL HAZARD RISKS IN INDONESIA

This section briefly analyses at the main natural risk hazards in Indonesia

1.1 HAZARDS IN INDONESIA

The various types of disasters such as flooding, earthquake, mass movement-wet, and volcanic eruption occurred in Indonesia. Earthquake and flood disrupted 88% of the total number of affected people. On the other hand, earthquake caused the highest number of death and significant economic losses. This is mainly due to the Sumatra Earthquake in 2004 and Java Earthquake in 2006. Flooding and earthquake will be the two major disasters that have great impact in Indonesia

1.1.1 Analysing Hazard-Specific Risk in Indonesia

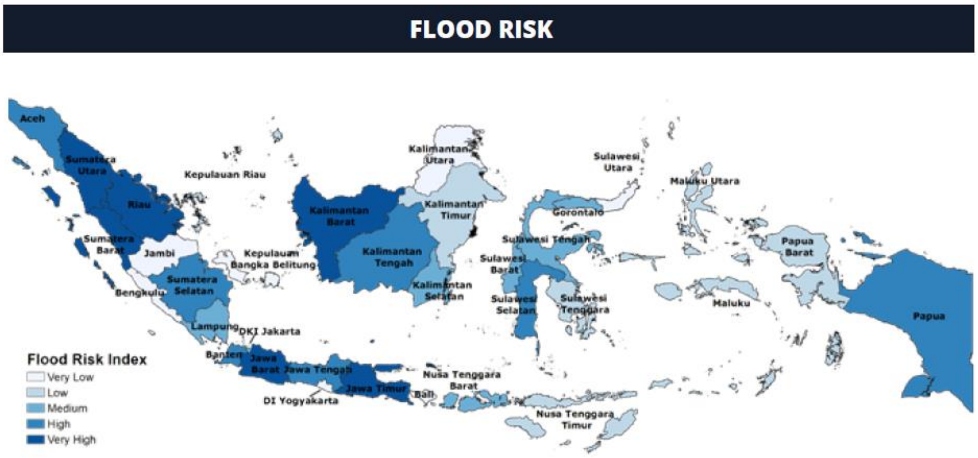
Hazard-Specific Risk examines individual hazard exposure in combination with provincial resilience to provide a clear understanding of risk drivers for each hazard type. Specific hazards assessed include flood, earthquake and wildfire. Hazard-Specific Risk provides a tool for disaster managers to anticipate, plan for, and mitigate outcomes of specific hazard events across Indonesia.

1.1.1.1 Floods

Indonesia, a nation comprising thousands of islands, is no stranger to the perils of flooding. With its vast archipelago, the country faces a significant flood risk due to a combination of factors including heavy rainfall, deforestation, and rapid urbanization. The Indonesian National Agency for Disaster Management (BNPB) reports that floods are the most frequent natural disaster in the country, occurring 464 times annually. This is exacerbated by the loss of tree cover, which is crucial for maintaining the hydrological balance of watersheds. The removal of vegetation reduces the soil's ability to absorb water, leading to increased surface runoff and heightened flood risks. Extreme weather events, often driven by climate phenomena such as the Madden-Julian Oscillation, contribute to the high intensity of rainfall, sometimes exceeding

100 mm per day which can lead to severe flooding. The topography of the region also plays a role such as steep slopes and poor watershed management can further increase the likelihood of floods. Urban areas in particular are vulnerable due to dense populations and inadequate infrastructure. The World Bank notes that over the past two decades that floods have displaced more Indonesians than any other disaster type, with the poor and vulnerable being disproportionately affected. Efforts to mitigate these risks include reforestation, improving urban planning, and investing in flood resilience. However, the challenge remains significant, with a large portion of the population living in high-risk flood zones. The figure below shows the flood risk distribution by province in Indonesia. As Indonesia continues to develop, addressing flood risk is crucial for safeguarding its people and ensuring sustainable growth.

Figure 11: Flood Risk Index in Indonesia



Source: Pacific Disaster Center report Indonesia 2020

1.1.1.2 **Earthquakes**

Indonesia’s geographical position on the Pacific Ring of Fire makes it one of the most seismically active regions in the world. The convergence of the Eurasian, Indo-Australian and Pacific tectonic plates create a complex and dynamic geological environment, resulting in thousands of earthquakes annually, many of which carry the potential for significant destruction. The country’s Earthquake Zonation Maps, which outline probabilistic seismic hazard zones with varying degrees of ground shaking probabilities, are a testament to the ever-present risk of earthquakes. The Indonesian archipelago with its 17,000 islands is not only prone to frequent seismic activity but also to the secondary hazards that earthquakes can trigger, such as tsunamis, landslides, and soil liquefaction. These events can have devastating effects on the densely populated areas, particularly in urban centres where infrastructure may not be designed to withstand such forces. The historical data reflects the gravity of the situation, with major earthquakes causing significant loss of life and property, disrupting communities, and impacting the nation’s development.

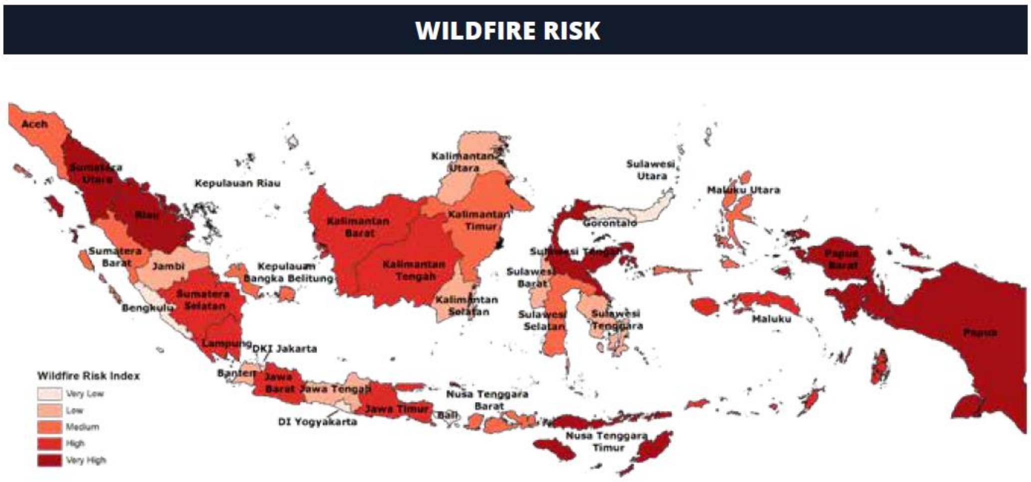
Figure 12: Earthquake Risk index in Indonesia

Source: Pacific Disaster Center report Indonesia 2020

1.1.1.3 **Wildfires**

Indonesia, with its rich biodiversity and extensive tropical forests, faces a significant risk of wildfires, particularly during dry seasons exacerbated by climate phenomena like El Niño. The country's vast peatland areas, especially on the islands of Sumatra and Borneo, are highly flammable and can sustain fires for months, leading to severe environmental and health impacts. The World Resources Institute highlights that the fires are not an isolated incident but part of a longstanding crisis, often related to human activities such as land clearing for agriculture and commodities like palm oil, pulp, and paper. The 2015 wildfire season was one of the worst in recent history with around 3 million hectares of forests and peatlands burnt affecting air quality and causing respiratory illnesses among the population. Despite extensive fire prevention efforts by the Indonesian government, the challenge persists due to factors such as prolonged droughts especially during the dry season, illegal burning for land conversion and the draining of carbon-rich peatlands. These do not only contribute to the immediate danger of fires but also have long-term effects on climate change due to the release of stored greenhouse gases.

Figure 13: Wildfire Risk Index in Indonesia



Source: Pacific Disaster Center report Indonesia 2020

2. SECTION 2: EMPIRICAL ANALYSIS OF NATURAL DISASTER LOSSES IN INDONESIA

This section looks at the methodology used to analyse the losses caused by natural disasters in Indonesia where the results are shared and interpreted. Additionally financial strategies to be undertaken for quick economic recovery are discussed

2.1 METHODOLOGY

A straight forward approach in estimating future disaster costs was used where l determined these costs by using probabilistic distribution methods and Monte Carlo simulations. The Monte Carlo is a powerful technique which involves random generation of statistical data that allows numerical solutions to problems that may be difficult to solve analytically. The method is named after the Monte Carlo Casino in Monaco where games of chance exhibit random behaviour similar to the random variables used in these methods. This methodology is adapted to model complex systems where there is significant uncertainty to understand potential outcomes and their likelihoods.

This thesis uses probabilistic models to forecast costs of disasters in the future. Simulating the extreme events with a mathematical model might provide a better understanding of the stochastic nature of these events. This thesis models each type of disaster separately and fits a probability distribution for the frequency and the cost for each type of disaster. The costs of disasters are unevenly spread for each type of disaster and split. I therefore simulated each type of disaster to generate an annual cost of these disasters in Indonesia. Just fitting probability distributions to all the losses/costs[10] of the disaster in the respective years they were record

[10] The terms costs and losses are used interchangeably throughout this thesis

(1970 to 2022) assumes that there is no economic growth and inflation. Since this is a very highly unlikely assumption, I therefore also incorporated real GDP (Gross Domestic Product) to account for the inflation and economic growth factor into a model and evaluate its effect on the costs of these disasters. It is important to note that this type of modelling assumes that the relationship between the costs of disasters and GDP remains constant over the time.

This thesis presents the simulated results to give a broader picture of the risk that Indonesia can face from natural disasters. A probabilistic forecast of disasters' costs provides better insights than a deterministic model into the risks. Policymakers can use these types of models to develop strategies and allocate resources to prepare for disasters in order to minimise damage costs

2.1.1 **Data Review**

A survey of literature on economic loss data due to disasters shows that disaster economic loss data for floods and earthquakes hazards are available from the late 1960s but insufficient for wildfires in the case of Indonesia. Thus, the report will present analyses and estimates of natural disasters based on the historical events that have affected the country over the last 53 years (1970 to 2022).

2.1.2 **Data sources**

Since 1970, significant efforts have been made by various academic and multilateral development agencies to compile historical disaster data and generate standardized data across the globe for disaster risk mitigation activities. As a result, numerous databases are available in print and on the Internet. This section describes the most relevant data sources that have been identified for this study;

1. The Centre for Research on the Epidemiology of Disasters (CRED) maintains the EM-DAT global emergency events database on disasters (natural and technological hazards), which is one of the most exhaustive sources of data available in the public domain. While EM-DAT data date back to the 1900s, data on economic losses caused by disasters in most countries have become generally available since the 1980s.

2. The Asian Disaster Reduction Centre (ADRC) has compiled data from various sources, including: UNOCHA, DesInventar, the Government of the United States, the Government of Japan, OFDA, IFRC, WMO and the reinsurance industry and private agencies.

3. Asia Disaster Preparedness Centre (ADPC) has compiled data from various sources. The data are available for Indonesia in the form of country and regional reports The World Bank's East Asia and Pacific (EAP) unit has prepared brief country disaster risk profiles for Indonesia

4. The World Bank

2.2 **APPLICATION OF THE METHODOLOGY**

I initially attempted to fit a probability distribution to this entire data set, but no distribution fits well to the observed data or provided good forecasts hence the better approach was fitting the models separately for each disaster type. Analysing each type of disaster also provided a better understanding of these disasters. Modelling each type of disaster separately made the model more robust to changes in the data. Using probabilistic models rather than deterministic models reflects the uncertainty that is inherent in forecasting future economic costs from natural disasters.

I modelled the distributions of each type of natural disaster separately: Earthquake, flood and Wildfires

First, i fitted a discrete distribution to the annual frequency of each type of disaster.
Then i fitted a continuous probability distribution to the cost of each type of disaster. I assumed that the cost for each type of disaster was identically and independently distributed. used the Akaike information criterion (AIC) and the log-likelihood as the criteria of best model selection and also used the goodness of fit test to validate that the selected distribution.

JMP Statistical Software was used to fit a continuous random variable for the costs of each type of disaster. I fitted the costs for each type of disaster to the following continuous distributions: Johnson with a lower bound, sinh-arcsinh (SHASH), lognormal, generalized log, gamma, normal mixtures (2 and 3), Weibull, extreme value, exponential, and normal. Two distinct models are created, and each model uses a different dataset to analyse the economic impact of these natural disasters.

I started by using all of the data to fit the discrete distribution to the annual frequency. This frequency was analysed and incorporated into a model to generate the number of disasters that occur in a year for each of the three types of disasters separately.

Then I used two different types of models for the costs associated with the natural disasters separately.

Model 1 – This model uses the actual costs recorded in their respective years without adjusting for economic growth or inflation. It uses all the historical data from 1970 to 2022 to model the costs of natural disasters where a probability distribution is fit to the cost of each type of disaster separately. Then the AIC and log-likelihood values are evaluated and the best fit of the probability distribution is selected for each type of disaster. Monte Carlo simulations are used to generate the estimated costs for all three disasters.

Model 2 – This model adopts the same methodology as model 1 but in this case, I incorporated the real GDP factor to adjust for economic growth and inflation over the years. In order to do this, I divided the natural disaster costs by the corresponding real GDP of every year since 1970 to 2022 in order to obtain the cost to real GDP ratio. I chose the real GDP of the year 2022 as reference (Base year) (because it was a relatively stable year without sudden economic booms and recessions) and then I multiplied each cost to real GDP ratio by the real GDP of the reference year (2022) where I obtained the costs of each year.

$$\textbf{GDP adjusted economic cost} = \frac{\textbf{Costs of disasters recorded for each year}}{\textbf{Real GDP of the corresponding year}} \times \textbf{Real GDP of 2022}$$

The new disaster costs were used in a Monte Carlo simulation and to generate a probabilistic estimate of the cost of natural disasters of each simulated year.

Then trials in the Monte Carlo simulations began to randomly generate the number of disasters that occur every year for each of the three disasters as well as their costs from the probability distribution that best fits each type of disaster. I excluded the white noise from the analysis because it makes the estimates highly volatile and give un realistic probabilities and significant inaccurate estimates. The Indonesian GDP in 2022 was $1,32 trillion. As mentioned previously for Model 2, to convert the ratio of data to the GDP to the costs of disasters, i multiplied the costs generated by the model for each type of disaster and the GDP in 2022. The total annual disaster costs in a single trial are obtained by summing the costs of individual disasters. This process is repeated 100,000 times to generate a simulated probability distribution of the annual costs of these disasters. The annual costs for each of the three types of disasters and the total annual costs from all the disasters are analysed and presented.

2.3 **RESULTS**

2.3.1 **Natural disaster Frequency Analysis**

The annual frequency of these disaster was analysed and found out wild fires tend to be more frequent followed by floods and earthquakes respectively. Table below depicts the distribution for the annual frequency for each disaster. The Poisson distribution is used to model the number of events for Wildfires, earthquakes and flood. The parameter λ (average number of annual events) for the Poisson distribution is given in Table 2 for these disasters. The average annual number of floods, earthquakes and wildfires was 5,54, 2.81 and 27.5 respectively from 1970 to 2022. The annual frequency of all the disasters increases.

Table 2: Distribution of annual frequency of Earthquakes, Floods and Wildfires in Indonesia

DISASTERS	DISTRIBUTION TYPE	MODEL PARAMETER
EARTHQUAKES	POISSON	λ=2.81
FLOODS	POISSON	λ=5.54
WILDFIRES	POISOON	λ=27.5

Source; Table made by author (See appendix 03)

2.3.2 **Validation of the selected distributions**

Sensitivity tests were carried out to make sure the selected distributions vividly fit the data well hence all the three distributions were validated using a goodness fit test where the probability of the calculated Pearson Chi-Square was largely inferior to the 5 % threshold rendering the distributions significantly viable. The predicted frequency was also compared to the actual observed frequency to further validate the model. Further illustrations are provided in the appendices (see appendix 04)

2.3.3 **Application of the monte Carlo simulation to the distribution**

A 100 thousand monte Carlo simulation was applied on the distributions where the summary statistics such as the mean and standard deviation are closely similar to those observed in the actual data. I analysed the frequency risk of these disasters in different return periods from a 10 to 100 year return periods and the number of wildfires is expected to be as high as 2850 in a 100 year return period followed by floods and earthquakes respectively. The table below shows the total number of disasters expected in different returns periods categorically

Table 3: Annual frequency of Earthquakes, Floods and Wildfires expected in different return periods

RETURN PERIODS	EARTHQUAKES	FLOODS	WILDFIRES
10 YEARS	32	54	277
20 YEARS	58	102	605
50 YEARS	135	291	1543
100 YEARS	257	574	2850
AA FREQUENCY	2.83	5.74	28.5

Source; Table made by author (see appendix 06)

The CDF plots at a 100 year return period of the three disasters were analysed where the annual frequency of earthquakes is expected to range between 0 to 6, floods is expected to range between 0 to 8 and wildfires is expected to range between 0 and 40 at a 90% confidence level (See appendix 07)

2.3.4 **Natural Disaster Cost/Loss Analysis**

The costs/losses were also analysed using the two models described in the methodology. The statistical summary was analysed for each of the disasters and therefore fitted a continuous distribution to each of the disasters to determine the best distribution for each of the disasters based on the AIC and loglikelihoods statistics. All cases lognormal distribution was found to be the most suitable distribution for all the three disasters

Table 4: Distribution types of costs/losses of Earthquakes, Floods and wildfires in Indonesia

NATURAL DISASTERS	MODEL 1	MODEL 2
EARTHQUAKES	Lognormal distribution	Lognormal distribution
FLOODS	Lognormal distribution	Lognormal distribution
WILDFIRES	Lognormal distribution	Lognormal distribution

Source; Table made by author (see appendix 02)

2.3.5 **Validation of the selected distributions in Model 1 and 2**

Sensitivity tests were carried out to see how well the selected distributions fit the observed data hence the goodness fit test was applied to all distributions and the probability of the calculated Anderson-Darling coefficient was found to be significantly inferior to a 5% threshold and PP plot was also applied to provide a visual context where most of the points followed the reference line which suggested that the fitted distribution was a reasonable representation of the data. Hence it indicated that the empirical cumulative distribution function (CDF) of the data was identical or similar to Fitted CDF of the historical data observed. Therefore, the model was deemed to be good and validated for all the three natural disasters (i.e. categorical illustrations are provided in the appendix 04)

2.3.6 **Application of the monte Carlo simulation to the distributions**

100 thousand Monte Carlo Simulations were carried out using the selected distributions

MODEL 1

- **Earthquakes**
  The Average Annual Losses of Earthquakes calculated was approximately 757.9 million US Dollars with a standard deviation of about 761,5 million US Dollars. The results also suggested that annual losses can be extreme and reach a maximum of approximately 114,5 billion US Dollars and minimum of around 3167.1 US Dollars.
- **Floods**
  The annual average losses of floods are expected to be approximately 506.33 million US Dollars with a standard deviation of about 253 million US Dollars. In a 100 thousand year return period Indonesia is expected to incur flood costs between 20 thousand US dollars and 25 billion US dollars annually.
- **Wildfires**
  The average annual losses in a 100,000 year return period are expected to be approximately to 125.9 million US Dollars with a standard deviation of approximately a billion US Dollars. And the costs/losses are expected to range between 2937 US Dollars to 124.8 billion USD dollars annually.

MODEL 2

- **Earthquakes**
  The Average Annual Losses of Earthquakes is expected to be approximately 396.7 million US Dollars with a standard deviation of about 2.54 billion US Dollars according the Monte Carlo Simulation of 100 thousand year return period. The results also suggest that annual

losses can be extreme and reach a maximum of approximately 241 billion US Dollars and minimum of around 78088.4 US Dollars in the same return period.

- **Floods**

  The average annual costs of floods are expected to be approximately 159.2 million US Dollars with a standard deviation of about 517.1 million US Dollars. In a 100,000 year scenario, the costs of floods are expected to range between 362.7 thousand US Dollars and 37.54 billion US Dollars annually.

- **Wildfires**

  The average annual losses in a 100,000 year return period are expected to be approximately to 527.25 million US Dollars with a standard deviation of 6.82 billion US Dollars. The costs of wildfires are expected to range between 12907 US Dollars to 1.178 trillion USD dollars annually

2.3.7 MODEL COMPARISONS

Table 5 : Summary of Model comparisons between Model 1 and Model 2

	MODEL 1	**MODEL 2**
EARTHQUAKES	• Model 1 estimates the Average Annual Losses (AAL) at approximately $757.9 million with a standard deviation (SD) of about $761.5 million. The potential annual losses range from a minimum of $3,167.1 to a maximum of $114.5 billion.	• Model 2 estimates the AAL at approximately $396.7 million with a higher SD of about $2.54 billion. The annual losses can range from $78,088.4 to an extreme maximum of $241 billion.
FLOODS	• Model 1 predicts AAL of floods at about $506.33 million with an SD of $253 million. The costs can vary between $20 thousand and $25 billion annually.	• Model 2 has a lower AAL prediction at $159.2 million but with a higher SD of $517.1 million. The annual flood costs are expected to be between $362.7 thousand and $37.54 billion.
WILDFIRES	• Model 1 estimates the AAL to be around $125.9 million with an SD of $1 billion. The annual costs may range from $2,937 to $124.8 billion.	• Model 2 predicts a significantly higher AAL at $527.25 million with a much larger SD of $6.82 billion. The costs can vary from $12,907 to a staggering $1.178 trillion annually.

Source; Table made by author (see appendix 06)

Model 1 generally predicts higher average annual losses for earthquakes and floods but lower for wildfires compared to Model 2. However, Model 2 shows a greater variability in the potential losses across all three disaster types as indicated by the higher standard deviations. This suggests that while Model 1 might estimate a higher average loss, Model 2 predicts a wider range of potential outcomes including extreme events, which are crucial for risk assessment and management strategies. The choice between models would depend on whether the focus is on average expected losses or the full range of potential outcomes.

2.3.8 **Different return periods are analysed between the two models**

Table 6: Annual losses/ costs estimated by Model 1 and Model 2 in different return periods

RETURN PERIODS	**EARTHQUAKES**		**FLOODS**		**WILDFIRES**	
	MODEL 1 (IN MILLIONS)	MODEL 2 (IN MILLIONS)	MODEL 1 (IN MILLIONS)	MODEL 2 (IN MILLIONS)	MODEL 1 (IN MILLIONS)	MODEL 2 (IN MILLIONS)
10 YEARS	$1.960	$22.127	$456.182	$23,250.014	$2,611.108	$288,003.932
20 YEARS	$8.469	$33.210	$1,862.763	$33,691.754	$7,997.499	$295,536.056
50 YEARS	$23.307	$438.004	$14,481.904	$103,230.000	$33,784.278	$341,133.671
100 YEARS	$46.986	$558.196	$30,387.953	$185,997.459	$114,733.059	$491,146.959

Source: Table made by author (these results were obtained by manual calculations using the Monte Carlo output of the first 100 years[11])

The comparative analysis presented in the table clearly demonstrates that Model 2 forecasts a more pronounced financial impact from natural disasters across various return periods in comparison to Model 1.

In specific context, Model 2 projects a substantial financial burden in the short run which is significant but decreases as time advances while Model 1 on the other hand projects the same behaviour as Model 2 in the case of floods and wildfire but with a significantly lower financial constrain compared to Model 1. Earthquakes in Model 1 however show a very low financial burden in the short run but significantly increase in the long run.

[11] results of the first 100 year return period each model of the were cumulated in order to find the losses incurred in the different return periods

2.3.9 **The Cumulative Distribution Function analysis (CDF)**

Furthermore, CDF plot graphs of a 100 year return period for all the three disasters were analysed and the range of annual losses were determined at a 90% confidence interval both in Model 1 and Model 2

Table 7: Summary of expected annual range of losses/ costs caused by Earthquakes, Floods and Wildfires in a 100 year return period in Indonesia

NATURAL DISASTERS	MODEL 1(IN MILLIONS)	MODEL 2(IN MILLIONS)
EARTHQUAKES	1.8 – 150	2.5 – 500
FLOODS	0.9 – 100	15.3 – 400
WILDFIRES	0.9 - 150	0.2 – 1000

Source; Table made by author (see appendix 06)

3. SECTION 3: FINACIAL STRATEGIES TO COPE WITH THE NATURAL DISASTER LOSSES

This section discusses the risk financing options/ strategies to be adopted by the state of Indonesia in-order to deal with the financial burden caused by natural disasters

3.1 **DISCUSSIONS**

A national disaster risk financing strategy should be designed to improve the capacity of the Government of Indonesia to access immediate financial resources in case of natural disaster while maintaining its fiscal balance**.** Building on the country disaster risk financing framework promoted by the World Bank, six options for a comprehensive disaster risk financing in Indonesia are discussed below.

1. **Crafting Tools for Financial Disaster Risk Evaluation**

   Initiating a national strategy for disaster risk finance hinges on a comprehensive risk evaluation. Techniques in catastrophe risk modelling can enhance actuarial studies of historical loss data providing insights into the economic and budgetary risks posed by natural calamities.

   It’s essential to create hazard modules for significant threats. PT Maipark has pioneered an earthquake hazard module drawing from an exclusive historical earthquake catalog. Similarly, a flood hazard module tailored for major metropolitan regions such as Greater Jakarta is also viable.

   Constructing a national geo-referenced exposure database is imperative. This repository would encompass details of both public and private structures and infrastructure vulnerable to natural disasters including educational institutions, medical facilities, government buildings, thoroughfares and viaducts. Additionally, it could catalog private holdings like residential properties. When integrated with the catastrophe risk model, this database would facilitate among other functions, the evaluation of the economic and budgetary repercussions of natural disasters. Moreover, this data is crucial for the insurance sector to provide property catastrophe insurance solutions that are both viable and economically accessible.

The Ministry of Finance should adopt a financial catastrophe risk model. The existing earthquake risk model could serve as a foundation for a financial catastrophe risk model employed by the Ministry. This model would amalgamate an actuarial/financial framework that capitalizes on the projected losses from the catastrophe risk model and historical loss records. This instrument would be instrumental for the Ministry in formulating a national disaster risk finance strategy which includes determining the annual budgetary allocation for the Rehabilitation and Reconstruction Fund and any strategies for disaster risk transfer like insurance. The Ministry of Finance in Mexico is currently utilizing a similar financial model.

2. **Formulating a Strategic Framework for National Disaster Risk Finance**

A national disaster risk finance strategy should be anchored in a risk layering methodology. This strategy provides a balanced combination of risk retention mechanisms such as reserves or contingency budgets and contingent credit alongside risk transfer mechanisms like insurance.

Adopting a “bottom-up” approach to disaster risk finance is advisable. Initially, the Indonesian Government should ensure financial provisions for frequent lower-magnitude events (the bottom risk layer) through risk retention strategies. Subsequently, it can enhance its financial robustness by incorporating disaster risk transfer tools.

Presently, the national budget does not forbid insurance procurement yet there is no designated budget line item for insurance premium payments. As per the prevailing budget legislation, the BNPB is barred from utilizing its annual budget for insurance acquisition. The budget law should permit the allocation of a portion of its funds for insurance procurement. For instance, in Mexico, the budget legislation empowers FONDEN’s Trust Fund to allocate a part of its yearly budget for acquiring financial risk transfer instruments, such as insurance and catastrophe bonds, facilitated by the public reinsurance entity Agroasemex.

To bolster financial capacity, the Indonesian Government could integrate parametric insurance with its reserves or contingent credit. Parametric insurance policies disburse funds based on the severity of an event like wind velocity or earthquake magnitude rather than actual damages incurred. These policies employ a pre-established formula for loss estimation relying on external variables that correlate strongly with individual losses yet are independent of the policyholder and insurer. This enables swift claim settlements typically within two to four weeks and reduces susceptibility to moral hazard and adverse selection. Nonetheless, parametric insurance is subject to basis risk that payouts may not align precisely with individual damages. Therefore, meticulous calibration of index insurance parameters is crucial to mitigate basis risk.

The Government of Indonesia can also bolster its financial disaster risk transfer approach by issuing catastrophe bonds. These index-linked securities tap into capital markets providing funds in the event of predefined natural disasters. Typically, catastrophe bonds cover the most severe risks and are tailored to specific perils with an annual occurrence probability of 2 percent or less (equivalent to a return period of 50 years or more). Notably, Mexico issued catastrophe bonds in 2006 and 2009.

To fortify resilience, Indonesia could allocate 0.5 percent of its annual government budget expenditures (approximately US$500 million) for disaster recovery costs related to recurrent events within a return period of up to 4 years. Already, Indonesia increased its annual budget allocation to approximately IDR 4 trillion (around US$450 million) in 2011.

Additionally, securing a contingent credit line of US$500 million would enhance Indonesia's retention capacity. This credit line, akin to the World Bank's DPL with Cat DDO, would activate approximately every 4 years when the annual budget allocation is depleted. While Indonesia could raise the annual budget allocation to US$1 billion, opting for a contingent credit line may be politically more sustainable. It allows pre-funding of losses expected every 4 years, while larger losses (anticipated every 4 to 20 years) can be post-funded by repaying any drawn-down debt. The contingent credit serves as a bridging facility offering flexibility for post-disaster rapid recovery especially during budget revision cycles and repayment once the new fiscal year begins.

3. **Creating an Agile National Disaster Reserve Fund (NDRF)**

The current post-disaster budget allocation process faces delays leading to liquidity constraints. The Rehabilitation and Reconstruction Fund with an annual allocation of IDR 4 trillion in 2011 serves as a primary source for post-disaster recovery and early reconstruction. However, disbursements from this fund require parliamentary approval resulting in operational delays. To address this, the national disaster risk financing strategy should establish a National Disaster Reserve Fund (NDRF)**.** This financial trust akin to Mexico's successful FONDEN, would swiftly disburse funds after disasters, enabling rapid recovery operations.

Key features of the NDRF would be:

i. To ensure transparent allocation and efficient use of post-disaster funds. Immediate disbursement would be available for BNPB and implementing agencies bypassing parliamentary bottlenecks.

ii. To integrate existing disaster funding mechanisms, including the On-Call budget. Restrictions on disaster contingency funds should be lifted to maximize its effectiveness.

iii. To build up reserves over time from unspent portions of its annual budget allocations. This gradual accumulation would enhance its retention capacity.

iv. To purchase disaster risk transfer instruments to bolster its financial capacity during disasters. Government regulation would permit the NDRF to pay insurance premiums from its annual budget allocation.

v. To design and implement a comprehensive risk financing strategy. This could include contingent debt agreements, indemnity and parametric insurance, and the issuance of catastrophe bonds or alternative risk transfer mechanisms.

vi. To finance emergency assistance and post-disaster recovery prioritized by BNPB and local agencies. It would cover critical infrastructure damages (e.g., roads, bridges) and public buildings (e.g., schools, hospitals).

4. **Initiating a Public Asset Disaster Risk Insurance Initiative**

In Indonesia, vital public assets and infrastructure like schools, hospitals, roads and bridges are susceptible to natural disasters and lack insurance coverage. While developed nations often self-insure such assets due to their ready access to capital markets, Indonesia's public assets typically remain unprotected despite a few regions recently opting to insure select properties.

In nations with constrained fiscal resources and limited capital market access, legal mandates sometimes require property insurance for public assets to safeguard against natural calamities. This practice is observed in Latin American countries, including Costa Rica, Mexico, and Colombia. Yet, the reality is that many public assets are either uninsured or under-insured, as public administrators are hesitant to allocate scarce budgetary funds for insurance premiums and often lack the necessary information to choose cost-effective insurance options.

To enhance the protection of public assets against disasters, Indonesia could launch a Disaster Risk Insurance Program for Public Assets. This initiative would work in tandem with the private insurance sector to provide technical support to public entities in crafting their disaster insurance plans. The program would aim to establish uniform policy terms and conditions in partnership with private insurers, aiding public managers in assessing their risk profiles and insurance requirements. Furthermore, the program could organize a collective insurance portfolio for public assets, which would then be offered to the private (re)insurance market. Adopting a national stance on insuring public assets could yield scale economies and diversification advantages, potentially reducing reinsurance costs.

5. **Promoting Catastrophe Insurance for Private Dwellings in Indonesia**

Despite efforts by specialized reinsurer PT Maipark, the penetration of catastrophe property insurance in Indonesia remains low. Currently, less than 5 percent of properties are insured against natural disasters primarily commercial and industrial properties. This limited adoption is a consequence of the underdeveloped non-life insurance market in the country. Therefore, to mitigate Indonesia's implicit contingent exposure to major disasters, the government should encourage property catastrophe insurance for private residential dwellings. Establishing a robust domestic property catastrophe insurance market would be crucial. Here are some strategies:

i. Technical Support and Models: The government could finance and provide exposure and loss models to private insurers. These tools would assist insurers in assessing risk exposure and designing effective insurance coverage.
ii. Awareness Campaigns: Information and awareness campaigns can educate homeowners about the benefits of catastrophe insurance. Turkey's example provides insights.
iii. Turkish Catastrophe Insurance Pool (TCIP)**:** Turkey's TCIP established in 2000, addressed market failure related to earthquake coverage. The World Bank supported its design including earthquake exposure modelling and affordable compulsory earthquake-only policies for registered urban houses.
iv. Microinsurance for Livelihood Protection: Indonesia could develop microinsurance products to safeguard households affected by recurrent natural disasters. These products linked to savings or credit mechanisms would offer comprehensive coverage. Leveraging existing community empowerment programs such as PNPM, could enhance distribution.
v. Enhanced Insurance Supervision: Strengthening insurance supervision is essential. A risk-based assessment of insurers' retention capacity and reinsurance strategies informed by catastrophe risk modelling and actuarial tools would improve oversight. Developing an actuarial model to refine commercial earthquake premium rates and assess disaster impact on insurers' portfolios is crucial. Additionally, a scoring tool for evaluating insurers' reinsurance strategies could enhance quality and adequacy.

6. **Forming a Collective Disaster Reserve Fund for Indonesian Localities**

Over the past decade, it has become evident that local Indonesian authorities, such as municipalities and provinces, often face financial shortfalls when responding to natural disasters. Their limited economic scale often precludes them from amassing the necessary reserves to cover disaster-related losses not addressed by the Central Government.

A proposed Collective Disaster Reserve Fund would significantly enhance the disaster response capabilities of these local governments at minimal cost. Local authorities bear a substantial portion of disaster-related expenses and frequently struggle to gather the financial means for emergency response and recovery efforts. This Fund would serve as a communal reserve, ready to be deployed in the event of a disaster granting immediate access to substantial resources without the individual burden of reserve accumulation. Moreover, by consolidating their risks, local governments could more efficiently engage with the reinsurance market thereby reducing the costs associated with securing additional coverage.

The Fund would operate as a communal reserve for local governments with contributions tailored to each locality's risk profile and coverage needs. These contributions would maintain a reserve level adequate to cover annual disbursements to localities impacted by natural events. To address the variability of financial demands, the Fund would procure additional capacity from international reinsurance and capital markets.

The Fund would enable local governments in Indonesia to swiftly access unrestricted resources following a disaster. For transparency and expedience, disbursements would be based on parametric triggers which unlike traditional indemnity insurance do not require on-site loss verification. This immediate liquidity would alleviate reliance on Central Government allocations for post-disaster emergency and recovery operations.

By participating in the Fund, local governments gain access to catastrophe risk insurance at the most economical cost. A preliminary analysis indicates that a joint reserve Fund would consolidate the natural disaster risks of local governments into a diversified portfolio substantially lowering reserve costs. The expense of financial protection correlates with risk variability since local government disaster risks are not perfectly synchronized, a pooled portfolio's coverage cost is less than the cumulative individual coverage costs.

Conclusion

In this chapter, the probabilistic methodology was looked at and its application to the selected natural disaster costs in Indonesia.

The results suggested that, wildfires were estimated to be by far the most frequent natural disasters followed by floods and earthquakes respectively.

The Model 1 and 2 portrayed distinct characterises when applied to the costs of natural disasters;

Model 1 appeared to offer a historical perspective, presenting a more stable and predictable pattern of losses over time. It provided lower short-term estimates but projected an increase in potential losses as the time horizon extended. This model is particularly useful for understanding the long-term trends and preparing for the gradual escalation of financial impacts due to natural disasters such as floods and earthquakes. The lower standard deviation across all disaster types suggested a narrower range of potential outcomes, which may be beneficial for long-term financial planning and budgeting.

On the other hand, Model 2 delivered a dynamic and economically sensitive analysis, with significantly higher short-term loss estimates that underscored the immediate financial risks posed by natural disasters. This model is crucial for short-term risk assessment, especially given the high standard deviation indicating a wide range of possible outcomes. Such variability was particularly pronounced in the case of wildfires, where the potential for extreme events were captured by the model's predictions. This makes Model 2 invaluable for crafting emergency response strategies and allocating resources for potential disaster scenarios.

When considering the choice between these two models, it is essential to align the selection with the specific objectives at hand. For instance, if the goal is to develop immediate response mechanisms and allocate emergency funds, Model 2 would be the preferred choice due to its focus on the short-term impact and its accounting for extreme events. Conversely, if the aim is to engage in long-term urban planning or to structure insurance premiums over an extended period, Model 1 would be more appropriate due to its emphasis on historical trends and its predictability.

For a holistic approach to disaster risk management and economic analysis, it is advisable to employ both models in tandem. By doing so, stakeholders can benefit from a comprehensive understanding of the cost dynamics associated with natural disasters. This dual-model approach allows for the integration of both historical data and potential future scenarios, thereby facilitating a robust strategy that addresses both immediate and long-term financial implications of natural calamities. In summary, the complementary use of Model 1 and Model 2 can provide a multi-faceted perspective that is essential for informed decision-making in disaster risk management and economic resilience planning.

After obtaining the results, I also discussed disaster risk financing framework options promoted by the World Bank for a comprehensive disaster risk financing in Indonesia.

GENERAL CONCLUSION

GENERAL CONCLUSION

Natural disasters exert significant economic pressure on countries worldwide. As we grapple with the repercussions of climate change, understanding the various mitigation and adaptation strategies becomes paramount. My research focused on estimating and predicting the economic costs of natural disasters as well as exploring strategies to mitigate these costs.

For this study, I chose Indonesia as a case study due to its substantial exposure to the selected natural disasters (earthquakes, floods, and wildfires). Leveraging probability distributions and Monte Carlo simulations, I quantified the losses incurred by these calamities. Notably, the size of a country's economy emerged as a critical factor influencing disaster costs. This relationship was evident in the cost estimates, particularly as Indonesia's GDP increased in the second model.

Furthermore, my findings underscored the importance of insurance and risk transfer options in managing the extreme costs associated with natural disasters. Drawing from recovery strategies advocated by the World Bank, these mechanisms provide essential funds for both short-term and long-term for post-disaster recovery. Detailed discussions on these options can be found in section 3 of chapter 3(specifically in the context of Indonesia)

Recommendations

Carrying out careful planning and preparedness which includes expansion of early warning systems that provide timely alerts for impending disasters. It is important to also conduct a thorough risk assessment and create hazard maps to identify vulnerable areas and prioritize interventions.

Promoting investment in resilient Infrastructure that is designed to withstand natural hazards (such as, earthquake-resistant buildings, flood-resistant bridges).

Encouraging community engagement by raising awareness among communities about disaster risks, evacuation routes and emergency procedures. Also, integration of disaster risk reduction education into school curricula and community programs helps to raise awareness

Improving land-use practices and building codes such as enforcing more strict building codes and land-use regulations to ensure safer construction practices. This also includes properly zoning areas to prevent construction in high-risk zones (e.g., floodplains, earthquake and wildfire prone areas).

The government should carry out reforms in order to reduce the bureaucratic tendencies and provide the much needed funds for economic recovery. The government should be able to swiftly respond and implement disaster mitigation strategies which are instrumental in the cost reduction of natural disasters

In summary, my research underscores the critical role of cost-effective adaptation measures in mitigating the economic impact of natural disasters. As policymakers and practitioners navigate these challenges, a holistic approach that considers both economic and non-economic dimensions is essential for building resilience and safeguarding communities.

Challenges and limitations

In my research, I encountered several challenges. First, selecting the most suitable methodology was crucial. While IO (Input-Output) and CGE (Computable General Equilibrium) models are commonly used, their data requirements often exceed what is readily available. Second, data shortages especially for pre-2000s wildfire records which limited the accuracy of my models. Finally, choosing a relevant geographical area posed difficulties, as many countries were not significantly affected by all three natural disasters. Despite these obstacles, my research contributes valuable insights to disaster risk assessment and mitigation.

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APPENDICES

NOTE: The statistical output presented below was generated by JMP software operated by the author

Appendix 01: Graphs showing frequency distribution of Floods, Earthquakes and Wildfires in Indonesia

Figure 14; Earthquakes frequency Graph

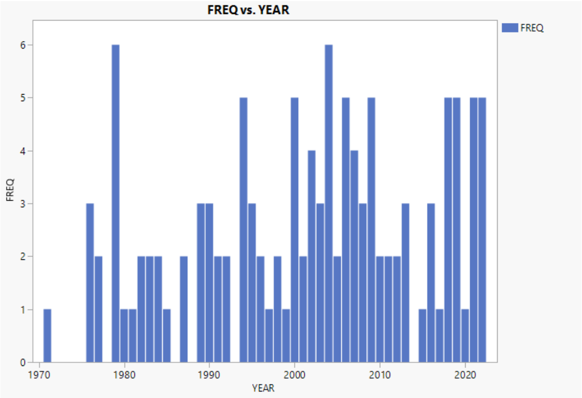


Figure 15; Floods frequency graph

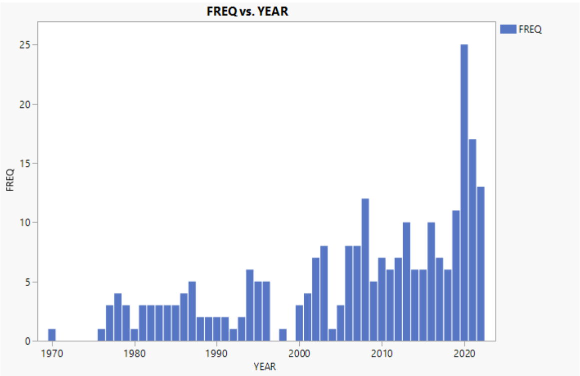
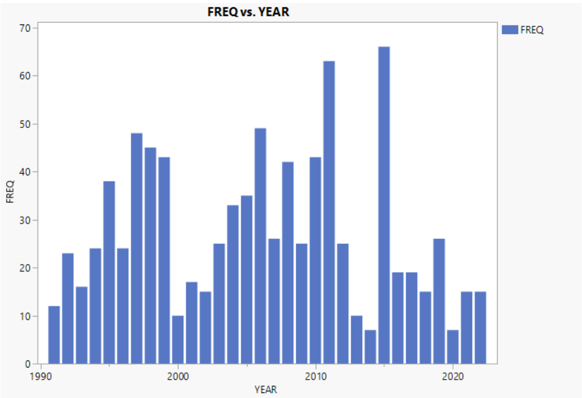


Figure 16;Wildfires frequency graph



Appendix 02: Comparison of the best fit distribution of Losses of Natural disasters

Table 8; Continuous fit of losses by Earthquakes (Model 1)

Compare Distributions

Show	Distribution	AICc	AICc Weight	BIC	-2*LogLikelihood
[x]	Lognormal	1097.5514	0.8346	1099.6431	1093.0514
[ ]	Johnson Sb	1101.4767	0.1173	1104.8419	1091.6585
[ ]	Weibull	1103.2617	0.048	1105.3534	1098.7617
[ ]	Gamma	1116.0162	0.0001	1118.1079	1111.5162
[ ]	Exponential	1150.06	0	1151.1958	1147.9
[ ]	Normal 3 Mixture	1160.6402	0	1163.0069	1136.6402
[ ]	Normal 2 Mixture	1204.6238	0	1208.2458	1191.7666
[ ]	Student's t	1219.9574	0	1222.8014	1212.9139
[ ]	SHASH	1220.6637	0	1224.0288	1210.8455
[ ]	Normal	1223.977	0	1226.0686	1219.477
[ ]	Cauchy	2351.986	0	2354.0777	2347.486

Table 9; Continuous fit of losses by earthquakes (Model 2)

Compare Distributions

Show	Distribution	AICc	AICc Weight	BIC	-2*LogLikelihood
[x]	Lognormal	1196.5341	0.8913	1198.6258	1192.0341
[ ]	Weibull	1202.0281	0.0572	1204.1198	1197.5281
[ ]	Johnson Sb	1202.2356	0.0515	1205.6008	1192.4174
[ ]	Exponential	1246.7494	0	1247.8852	1244.5894
[ ]	Normal 2 Mixture	1263.4772	0	1267.0993	1250.6201
[ ]	Gamma	1263.7119	0	1265.8036	1259.2119
[ ]	Student's t	1323.0199	0	1325.8639	1315.9764
[ ]	SHASH	1326.1359	0	1329.5011	1316.3177
[ ]	Normal	1331.6879	0	1333.7796	1327.1879
[ ]	Normal 3 Mixture	1337.5446	0	1340.9098	1327.7264
[ ]	Cauchy	2567.4078	0	2569.4995	2562.9078

Table 10; Continuous fit of losses by floods (Model 1)

Show	Distribution	AICc	AICc Weight	BIC	-2*Loglikelihood
[x]	Lognormal	1181.7993	0.7481	1184.0723	1177.3378
[ ]	Johnson Sb	1184.9166	0.1574	1188.7191	1175.2499
[ ]	Weibull	1186.0615	0.0888	1188.3346	1181.6
[ ]	Gamma	1191.5498	0.0057	1193.8228	1187.0882
[ ]	Exponential	1210.9112	0	1212.1304	1208.7631
[ ]	Normal 2 Mixture	1257.0538	0	1261.2816	1244.4451
[ ]	Normal 3 Mixture	1259.9922	0	1264.3777	1244.174
[ ]	Student's t	1273.5451	0	1276.6869	1266.5851
[ ]	SHASH	1275.1777	0	1278.9803	1265.5111
[ ]	Normal	1277.5734	0	1279.8465	1273.1119
[ ]	Cauchy	2452.4475	0	2454.7205	2447.9859

Table 11; Continuous fit of losses by floods (Model 2)

Show	Distribution	AICc	AICc Weight	BIC	-2*Loglikelihood
[x]	Lognormal	1266.8093	0.6266	1269.0824	1262.3478
[ ]	Weibull	1268.0862	0.3309	1270.3593	1263.6247
[ ]	Johnson Su	1273.3114	0.0243	1277.1139	1263.6447
[ ]	Exponential	1274.5523	0.013	1275.7715	1272.4042
[ ]	Normal 2 Mixture	1277.2614	0.0034	1281.4892	1264.6527
[ ]	Gamma	1278.4301	0.0019	1280.7032	1273.9686
[ ]	Normal 3 Mixture	1302.5501	0	1306.2884	1279.3501
[ ]	Normal	1321.2262	0	1323.4993	1316.7647
[ ]	SHASH	1321.6693	0	1325.4718	1312.0026
[ ]	Student's t	1322.9741	0	1326.116	1316.0141
[ ]	Cauchy	2539.7531	0	2542.0262	2535.2916

Table 12; Continuous fit of losses by wildfires (Model 1)

Show	Distribution	AICc	AICc Weight	BIC	-2*LogLikelihood
[x]	Lognormal	1328.486	0.9988	1331.0036	1324.0722
[ ]	Weibull	1342.2014	0.0011	1344.7191	1337.7876
[ ]	Johnson Su	1346.6976	0.0001	1351.079	1337.2161
[ ]	Gamma	1387.0544	0	1389.5721	1382.6406
[ ]	Exponential	1413.9258	0	1415.2582	1411.7925
[ ]	Normal 2 Mixture	1445.065	0	1450.086	1432.7573
[ ]	Normal 3 Mixture	1447.7704	0	1453.2048	1432.4104
[ ]	SHASH	1501.2757	0	1505.6571	1491.7942
[ ]	Student's t	1501.5198	0	1505.0599	1494.6627
[ ]	Normal	1507.2077	0	1509.7253	1502.7939
[ ]	Cauchy	2901.6082	0	2904.1259	2897.1944

Table 13; Continuous fit of losses by wildfires (Model 2)

Show	Distribution	AICc	AICc Weight	BIC	-2*LogLikelihood
[x]	Lognormal	1409.0254	1	1411.5431	1404.6116
[ ]	Weibull	1429.4533	3.7e-5	1431.9709	1425.0395
[ ]	Johnson Su	1455.6636	0	1460.0451	1446.1822
[ ]	Exponential	1529.1108	0	1530.4432	1526.9775
[ ]	Normal 2 Mixture	1548.1364	0	1553.1574	1535.8287
[ ]	Normal 3 Mixture	1551.697	0	1557.1314	1536.337
[ ]	Gamma	1582.4321	0	1584.9498	1578.0183
[ ]	Student's t	1624.6939	0	1628.234	1617.8368
[ ]	SHASH	1624.741	0	1629.1225	1615.2595
[ ]	Normal	1631.6735	0	1634.1912	1627.2597
[ ]	Cauchy	3150.5399	0	3153.0576	3146.1261

Appendix 03: Estimated distribution parameters of natural disasters in Indonesia

Table 14; Discrete fitted Poisson distribution of frequency of earthquakes

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Mean	λ	2.8139535	0.255814	2.3418933	3.3455502

Table 15; Discrete fitted Poisson of frequency of floods

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Mean	λ	5.5434783	0.3471461	4.8906317	6.2519888

Table 16; Discrete fitted Poisson of frequency of wildfires

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Mean	λ	27.5	0.9270248	25.722858	29.357169

Table 17; Continuous lognormal fit of losses by earthquakes (Model 1)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	18.036583	0.4224234	17.178307	18.894858
Shape	σ	2.1949766	0.2986985	1.7180725	2.9413354

Table 18; Continuous lognormal fit of losses by earthquakes (Model 2)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	19.911885	0.4049321	19.089148	20.734622
Shape	σ	2.1040887	0.2863302	1.6469318	2.8195428

Table 19; Continuous lognormal fit of losses by floods (Model 1)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	18.232206	0.3549191	17.512892	18.951519
Shape	σ	1.9112977	0.2509657	1.5079263	2.5325915

Table 20; Continuous lognormal fit of losses by floods (Model 2)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	19.860076	0.3017834	19.248452	20.471699
Shape	σ	1.6251536	0.2133931	1.2821716	2.1534322

Table 21; Continuous lognormal fit of losses by wildfires (Model 1)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	18.454406	0.3994826	17.647339	19.261474
Shape	σ	2.2598146	0.2824768	1.8017602	2.9506613

Table 22; Continuous lognormal fit of losses by wildfires (Model 2)

Parameter		Estimate	Std Error	Lower 95%	Upper 95%
Scale	μ	19.685766	0.4104439	18.856553	20.514979
Shape	σ	2.3218214	0.2902277	1.8511985	3.0316242

Appendix 04: Validation of the selected distributions

Table 23; Sensitivity test of frequency distribution of earthquakes

	X2	DF	Prob>X2
Pearson Chi-Square	8.5929257	3	0.0352*

Table 24; Sensitivity test of frequency distribution of floods

	X2	DF	Prob>X2
Pearson Chi-Square	31.426311	5	<.0001*

Table 25; Sensitivity test of frequency distribution of wildfires

	X2	DF	Prob>X2
Pearson Chi-Square	26.8344	2	<.0001*

Table 26; Sensitivity test of losses by earthquakes (Model 1)

	A^2	Simulated p-Value
Anderson-Darling	1.66436	0.0249*

Table 27; Sensitivity test of losses by earthquakes (Model 2)

	A^2	Simulated p-Value
Anderson-Darling	2.01336	0.0015*

Table 28; Sensitivity test of losses by floods (Model 1)

	A^2	Simulated p-Value
Anderson-Darling	0.72648	0.0435*

Table 29;; Sensitivity test of losses by floods (Model 2)

	A^2	Simulated p-Value
Anderson-Darling	1.77231	0.0386*

Table 30;; Sensitivity test of losses by wildfires (Model 1)

	A^2	Simulated p-Value
Anderson-Darling	0.864306	0.0236*

Table 31;; Sensitivity test of losses by wildfires (Model 2)

	A^2	Simulated p-Value
Anderson-Darling	1.2037197	0.0044*

Appendix 05: PP plots of natural disaster

Figure 17;PP plot of losses by Earthquakes (Model 1)

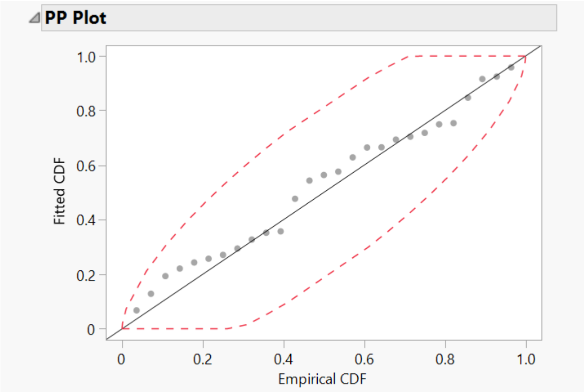


Figure 18; PP plot of losses by Earthquakes (Model 2)

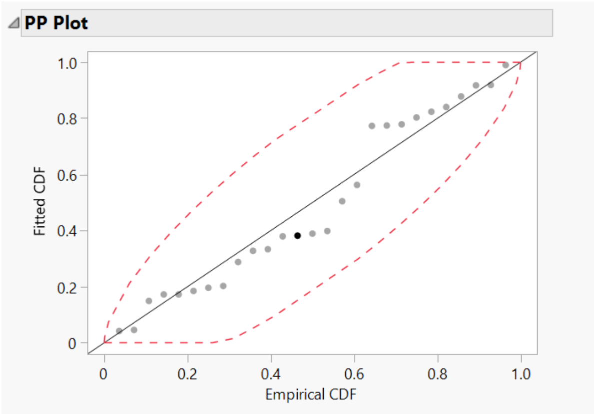


Figure 19; PP plot of losses by Floods (Model 1)

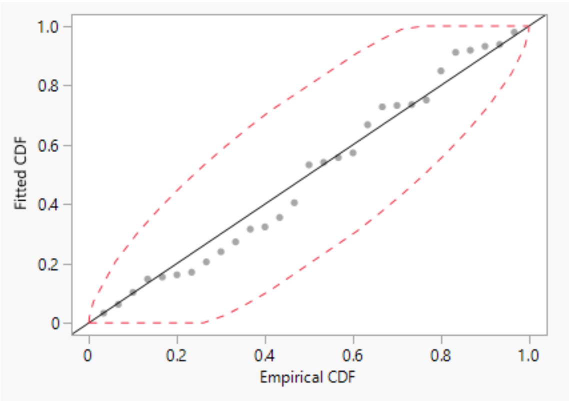


Figure 20; PP plot of losses by Floods (Model 2)

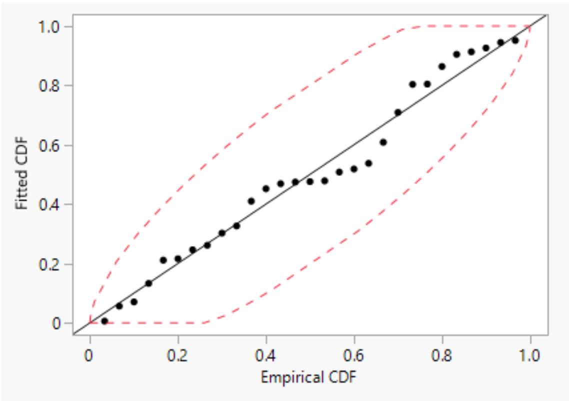


Figure 21; PP plot of losses by wildfires (Model 1)

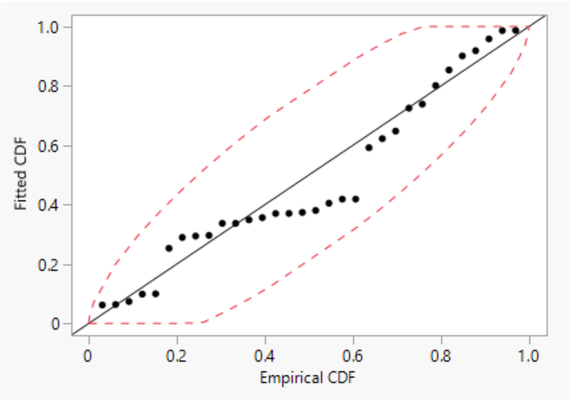
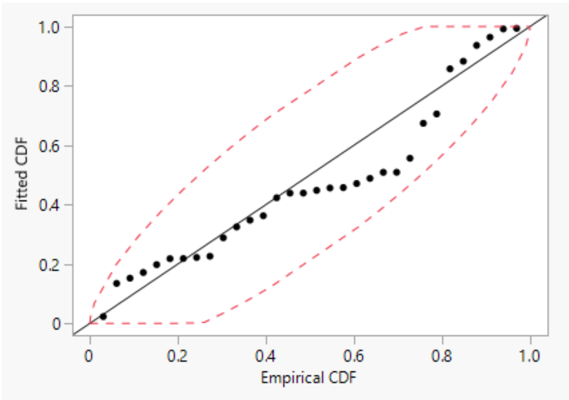


Figure 22;PP plot of losses by wildfires (Model 2)



Appendix 06: Statistics summary of the Monte Carlo simulations of the natural disasters

Mean	5.53245
Std Dev	2.3547192
Std Err Mean	0.0074463
Upper 95% Mean	5.5470446
Lower 95% Mean	5.5178554
N	100000
N Missing	0

Table 32; Frequency statistics of earthquakes

Mean	2.81456
Std Dev	1.6747955
Std Err Mean	0.0052962
Upper 95% Mean	2.8249404
Lower 95% Mean	2.8041796
N	100000
N Missing	0

Table 33; Frequency statistics of floods

Mean	27.48268
Std Dev	5.2441143
Std Err Mean	0.0165833
Upper 95% Mean	27.515183
Lower 95% Mean	27.450177
N	100000
N Missing	0

Table 34; Frequency statistics of wildfires

Mean	757919251
Std Dev	7.615e+9
Std Err Mean	24080741
Upper 95% Mean	805117207
Lower 95% Mean	710721296
N	100000
N Missing	0

Table 35; Statistics of earthquake losses (Model 1)

Mean	3.9673e+9
Std Dev	2.541e+10
Std Err Mean	80357316
Upper 95% Mean	4.1248e+9
Lower 95% Mean	3.8098e+9
N	100000
N Missing	0

Table 36; Statistics of earthquake losses (Model 2)

Mean	506334274
Std Dev	2.5309e+9
Std Err Mean	8003369.9
Upper 95% Mean	522020781
Lower 95% Mean	490647767
N	100000
N Missing	0

Table 37; Statistics of flood losses (Model 1)

Mean	1.5919e+9
Std Dev	5.1708e+9
Std Err Mean	16351566
Upper 95% Mean	1.624e+9
Lower 95% Mean	1.5599e+9
N	100000
N Missing	0

Table 38; Statistics of flood losses (Model 2)

Mean	1.2596e+9
Std Dev	1.009e+10
Std Err Mean	31918700
Upper 95% Mean	1.3222e+9
Lower 95% Mean	1.197e+9
N	100000
N Missing	0

Table 39; Statistics of wildfire losses (Model 1)

Mean	5.2725e+9
Std Dev	6.82e+10
Std Err Mean	215652321
Upper 95% Mean	5.6951e+9
Lower 95% Mean	4.8498e+9
N	100000
N Missing	0

Table 40; Statistics of wildfire losses (Model 2)

Appendix 07: CDF plots in a 100 year return period

Figure 23; Earthquakes frequency CDF

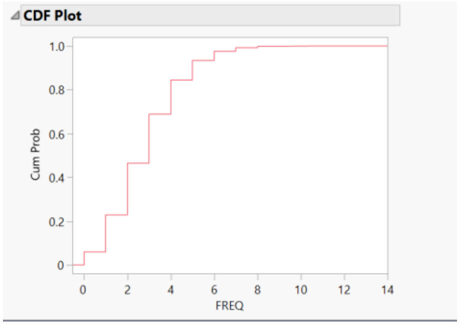


Figure 24; Floods frequency CDF

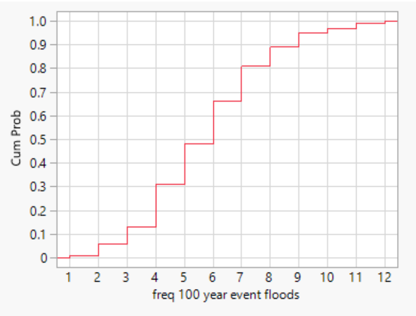


Figure 25; Wildfires frequency CDF

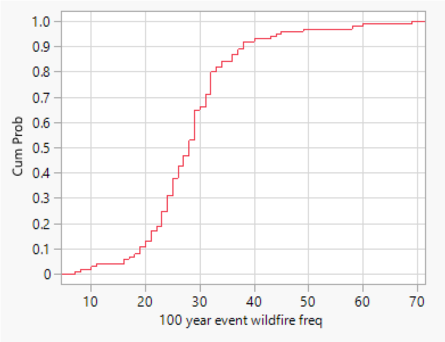


Figure 26; Earthquake losses CDF (Model 1)

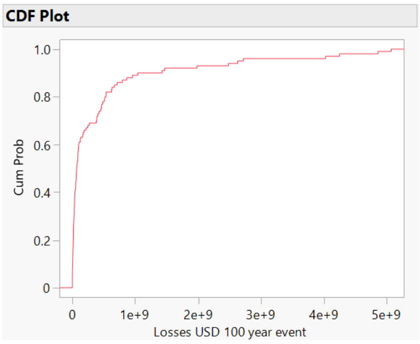


Figure 27; Earthquake losses CDF (Model 2)

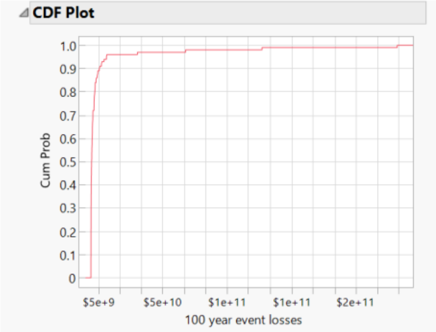


Figure 28; Flood losses CDF (Model 1)

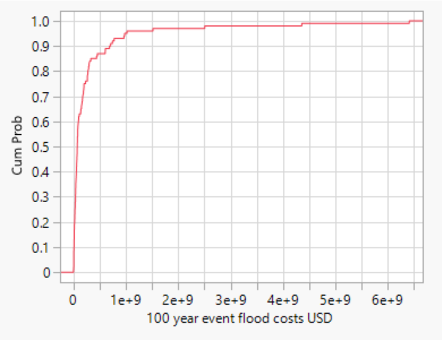


Figure 29; Flood losses CDF (Model 2)

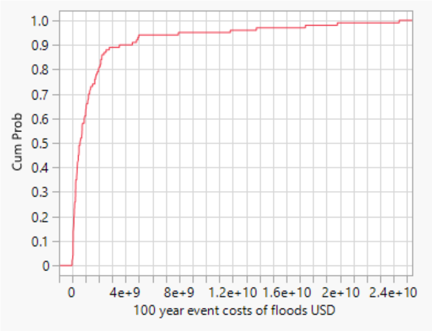


Figure 30; Wildfire losses CDF (Model 1)

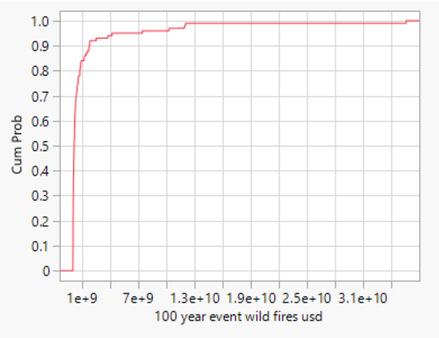
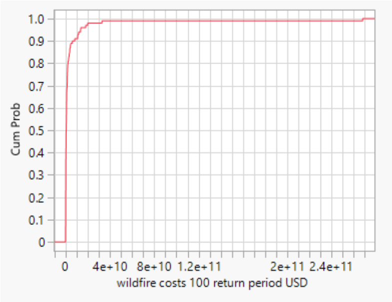


Figure 31; Wildfire losses CDF (Model 2)



ABSTRACT

This study investigated the cost-effectiveness of various mitigation and adaptation strategies for reducing the economic impact of natural disasters on a nation. Utilizing Indonesia as a case study, I employed probabilistic models and Monte Carlo simulations to predict future losses from earthquakes, floods and wildfires. This approach mirrored the risk assessment practices of insurance companies, leveraging historical disaster data to reproduce past loss patterns in specific regions. JMP statistical software facilitated the analysis generating estimates that empower policymakers to implement the most cost-effective measures for minimizing economic disruption. The discussions analyse these strategies to identify the most effective ones for reducing the financial burden.

Résumé

Cette étude a examiné la rentabilité de différentes stratégies d'atténuation et d'adaptation visant à réduire l'impact économique des catastrophes naturelles sur un pays. En utilisant l'Indonésie comme étude de cas, j'ai employé des modèles probabilistes et des simulations de Monte Carlo pour prédire les pertes futures dues aux tremblements de terre, aux inondations et aux incendies de forêt. Cette approche s'inspire des pratiques d'évaluation des risques des compagnies d'assurance, en exploitant les données historiques sur les catastrophes pour reproduire les schémas de pertes passées dans des régions spécifiques. Le logiciel statistique JMP a facilité l'analyse générant des estimations qui permettent aux décideurs de mettre en œuvre les mesures les plus rentables pour minimiser les perturbations économiques. L'analyse suivante porte sur ces stratégies afin d'identifier celles qui permettent de réduire le plus efficacement le fardeau financier.