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Study on the Importance of Investment in DRR and Advanced DRR Technology in ASEAN Countries

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Abstract: *Rapid population growth and economic development have become apparent in ASEAN countries in recent years. Moreover, each year witnesses reported damage from major natural hazards, with a notable frequency of floods and storms. To mitigate the enormous damage caused by these natural hazards, the ASEAN countries are taking proactive measures through 'investment in disaster risk reduction (DRR).' These measures are varied and include early warning, disaster information sharing, and the utilisation of disaster prevention technologies. In addition, most of the practices reviewed in this study were found to be in line with the AADMER Work Programme 2021–2025 and the Sendai Framework, which are official documents in the field of disaster reduction. To further promote and effectively implement 'investment in DRR' activities in the future, collaboration between countries, including Japan, and related organisations will be important.*

Keywords: Investment in Disaster Risk Reduction, Technology for Disaster Risk Reduction, ASEAN countries and Japan, AADMER Work Programme 2021–2025

JEL Classification: B40; F01; F60; Q54; Q55

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1. Background and Purpose

The number of natural hazards and the damage they cause have been on the rise worldwide in recent years. For example, the June 2023 earthquakes in Turkey and Syria are still fresh in our minds, with the combined death toll between the two countries reported to be over 55,000. Also, the tsunami that resulted from the Great East Japan Earthquake that occurred in Japan in March 2011 caused extensive damage spread across a wide area. In addition, the occurrence of heavy rainfall, which is thought to be caused by climate change, and the resulting damage such as flooding and landslides, are being reported in Association of Southeast Asian Nations (ASEAN) countries in large numbers every year. According to a report by ASEAN Secretariat, more than 50% of the total global disaster fatalities, or 354,000 of the 700,000 deaths in disasters during the period of 2004 to 2014, were in ASEAN countries. Furthermore, due to Japan and the ASEAN countries being in the Pacific Rim orogenic belt, they have many active volcanoes that pose a risk of eruption.

On the other hand, in the Asian region, which includes the ASEAN countries with remarkable economic development, there are concerns about the further increase of damage from natural hazards that are feared to occur in the future. One concern is related to rapid population growth. Table 1 shows the population of ASEAN countries and Japan in 2002 and 2022, and the growth rate during this period. All the ASEAN countries are experiencing population growth, especially in Malaysia, the Philippines, and Singapore, where the population has increased by more than 40%. Although population growth is counted upon as a trigger for economic development, a lack of accurate disaster prevention knowledge (e.g. information sharing, routine stockpiling, evacuation behavior) and measures for structures that are vulnerable to natural hazards may lead to direct damage from natural hazards.

Table 1: Population of ASEAN + 3 Countries

	2002 (thousand)	2022 (thousand)	Population growth rate (%)
Brunei	347	449	129.4
Cambodia	12,562	16,768	133.5
Indonesia	220,115	275,501	125.2
Lao PDR	5,606	7,529	134.3
Malaysia	24,142	33,938	140.6
Myanmar	46,480	54,179	116.6
Philippines	81,286	115,559	142.2
Singapore	4,177	5,976	143.1
Thailand	64,223	71,697	111.6
Viet Nam	80,642	98,187	121.8
China	1,280,400	1,412,175	110.3
Japan	127,302	123,952	97.4
Rep. of Korea	47,645	51,628	108.4

ASEAN = Association of Southeast Asian Nations.
Source: Global Note: https://www.globalnote.jp/

As mentioned above, the ASEAN countries have experienced rapid population growth in recent years. Table 2 shows the real gross domestic product (GDP) of the ASEAN countries and China, Japan, and the Republic of Korea in 2015 and 2020, and the rates of growth. Positive growth has been observed in all the ASEAN countries. The rate of growth in Laos and Viet Nam has exceeded 30%. Japan, on the other hand, ranked third in the world in terms of real GDP in 2020, but it has experienced negative growth.

Table 2: Real GDP of ASEAN + 3 Countries

	GDP (2015)	GDP (2020)	Economic growth rate (%), (2010-2015)
Brunei	12,930	13,429	103.9
Cambodia	18,050	22,999	127.4
Indonesia	860,854	1,027,662	119.4
Lao PDR	14,390	19,050	132.4
Malaysia	301,355	344,099	114.2
Myanmar	63,835	74,454	116.6
Philippines	306,446	358,511	117.0
Singapore	307,999	335,357	108.9
Thailand	401,296	431,857	107.6
Viet Nam	193,241	258,509	133.8
China	3,275,123	14,616,670	446.3
Japan	4,444,931	4,363,131	98.2
Rep. of Korea	902,246	1,626,231	180.2

GDP = gross domestic product; ASEAN = Association of Southeast Asian Nations.
Source: Global Note: https://www.globalnote.jp/

Thus, we can see that the economy in each of the ASEAN countries has developed remarkably in recent years. However, poverty is still a major problem in rural areas, and a lot of infrastructure, houses, and other structures are vulnerable to hazards. In areas vulnerable to hazards, the reconstruction process after a disaster has occurred often results in the reconstruction of the same vulnerable houses and buildings that existed before the disaster. This makes it very difficult to expect mitigation that reduces the damage caused by recurring hazards.

Figure 1: The Scene in Tacloban, Philippines after Typhoon Haiyan
(photo taken in 2013)

Source: Authors.

Regarding this, the approach proposed in the field of disaster prevention is 'Investment in Disaster Risk Reduction' (DRR). Investment in DRR means investing funds in the field of disaster prevention in advance, to mitigate the damage caused by natural hazards, the occurrence of which cannot themselves be controlled. Investment in DRR includes, for example, 'hard' measures such as making structures earthquake resistant and 'soft' non-structural measures such as the formulation of disaster prevention plans and the implementation of disaster prevention drills. By promoting such initiatives, lives and property can be protected, and the total cost of disaster response, recovery, and reconstruction can be reduced. It will also lead to the strengthening of disaster resilience as defined at the Third UN World Conference on Disaster Risk Reduction. The importance of investment in DRR is also described in Priority 3 of The Sendai Framework for Disaster Risk Reduction 2015–2030 and in Priority Programme 2: Prevention and Mitigation of the AADMER Work Programme 2021–2025.

This study focuses on the trends of natural hazards in the world and ASEAN countries, as well as investment in DRR, and explores the various disaster prevention measures currently being implemented in ASEAN countries. The objective is to consider and make recommendations on effective means to limit the damage caused by natural hazards, with reference to examples from Japan.

In Section 2, we will review the trends in occurrence and types of natural hazards in the world and ASEAN countries over the past 30 years. We will also review the status of investment in DRR in ASEAN countries compared to the rest of the world, for example, the status of development of disaster reduction plans and investment in the field of disaster reduction technology.

In Section 3, we will introduce disaster prevention measures implemented in recent years in the ASEAN countries of Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, which have been selected as good examples of investment in DRR. In addition, we will discuss representative examples from Japan and consider the potential for their expansion to ASEAN countries.

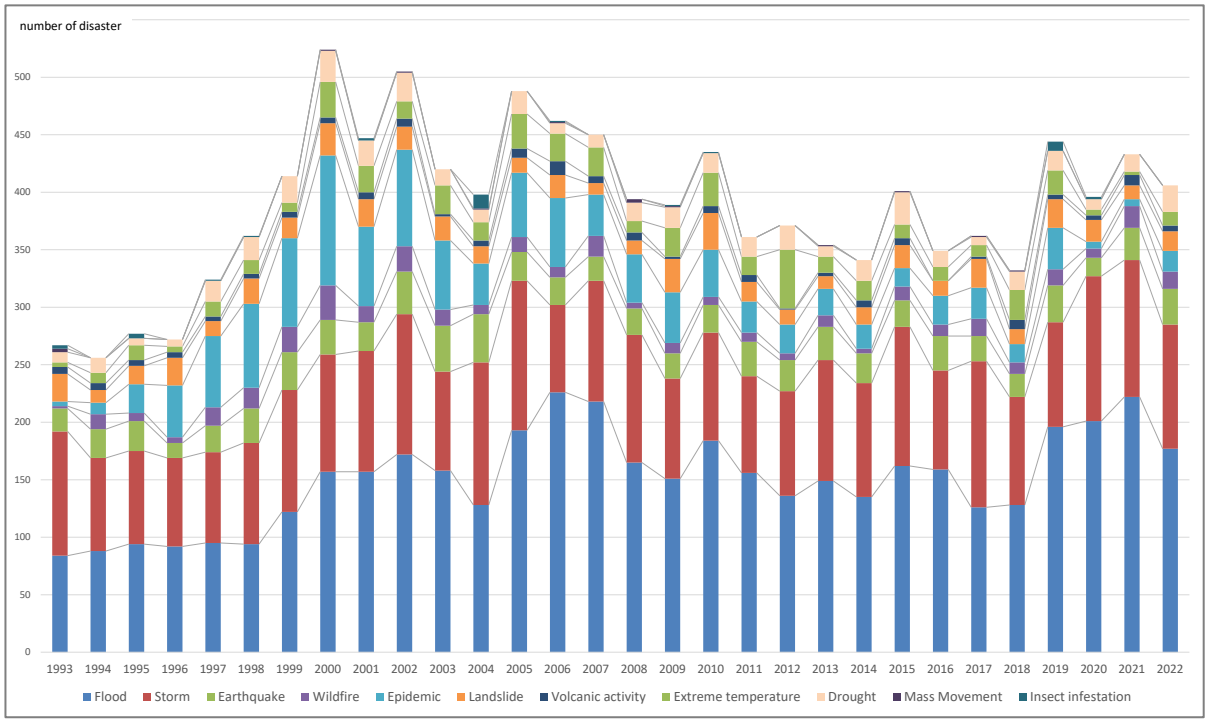
In Section 4, based on the information summarised in Sections 2 and 3, we will conduct a cross-sectional analysis of examples of disaster reduction measures that have been implemented and provide recommendations for ASEAN countries. Finally, Section 5 is a conclusion.

2. Status of Investment in DRR in ASEAN Countries Compared to the World

Natural hazards are not limited to the Asian region, but occur frequently and cause extensive damage worldwide. Figure 2 shows the number of all-natural hazards that occurred worldwide during the 30-year period from 1993 to 2022. The trend shows that the number of natural hazards peaked at 524 in 2000, followed by a gradual downward trend until 2018. Thereafter, the number of hazards has exceeded 400 each year since 2019.

Looking at the hazards by type, floods accounted for the largest percentage, followed by storms. Focusing on the 2022 data, there were 177 floods and 108 storms, accounting for 70% of the total of 407 occurrences of hazards. The same trend can be observed when the data is restricted to ASEAN countries, with floods and storms that occurred in ASEAN countries during the 30-year period from 1993 to 2022 accounting for about 71.7% of the total.

Figure 2: Number of Worldwide Occurrences of Natural Hazards, 1993–2022



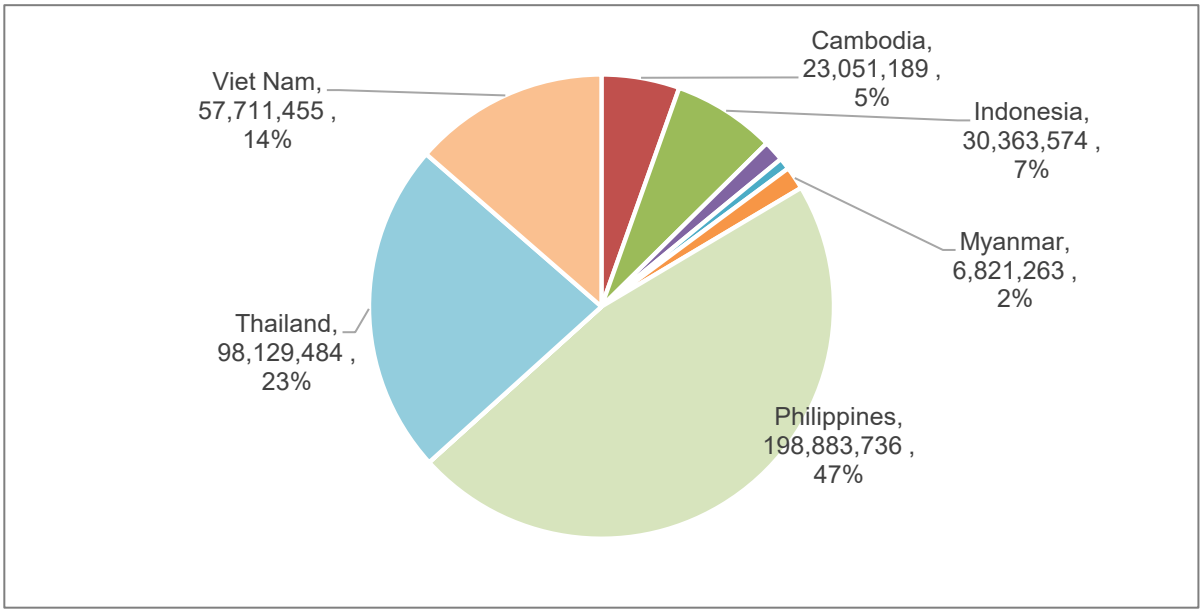
Source: EM-DAT: The Emergency Events Database – Université catholique de Louvain (UCL) – CRED, D. Guha-Sapir – www.emdat.be, Brussels, Belgium.

Figure 3 shows the number of people affected by natural hazards that occurred in ASEAN countries during the 30-year period from 1993 to 2022, and the percentage of the total number. The total number of people affected by natural hazards over the 30-year period is approximately 42,457,800. Of these, those affected in the Philippines accounted for the largest share, approximately 47% of the total. This is followed by Thailand with about 23%, Viet Nam with about 14%, Indonesia with about 7%, and Cambodia with about 5%.

In other words, an effective way to reduce the damage caused by hazards in ASEAN countries is to focus on floods and storms caused by climate change and to promote disaster prevention activities by making appropriate investments in DRR.

The following will discuss the current status of investment in DRR in ASEAN countries and around the world.

Figure 3: Number of People Affected by Natural Hazards in ASEAN Countries and Percentage of Total, 1993–2022



Source: EM-DAT: The Emergency Events Database – Université catholique de Louvain (UCL) – CRED, D. Guha-Sapir – www.emdat.be, Brussels, Belgium.

2.1. The Growing Importance of Disaster Financing and Investment in ASEAN

Disaster financing and investment are crucial components of disaster risk management in the ASEAN region. As natural disasters become more frequent and severe due to climate change, the economic and social costs associated with these events are expected to rise. Adequate disaster financing mechanisms can help countries better prepare for, respond to, and recover from these disasters, ultimately reducing their impacts and improving resilience. In this section, we will discuss disaster financing and investment in ASEAN, focusing on key trends, statistics, and examples from the region.

The Association of Southeast Asian Nations (ASEAN) is a region known for its rich cultural diversity, burgeoning economy, and strategic geopolitical importance. However, it is also a region that is particularly vulnerable to natural disasters, including typhoons, floods, earthquakes, and volcanic eruptions. Over the past two decades, the frequency and intensity of these disasters have increased significantly, severely affecting the lives and livelihoods of millions of people. In fact, according to a report by the United Nations Office for Disaster Risk Reduction, between 1998 and 2017, the direct economic losses caused by disasters in the ASEAN region amounted to over $151 billion, with the number of people affected exceeding 400 million.

This alarming trend of increasing disaster risks and impacts can be attributed to various factors, such as rapid urbanisation, environmental degradation, and climate change. As a result, the region faces significant challenges in safeguarding its people, assets, and infrastructure from the adverse effects of natural disasters. To mitigate these impacts and foster sustainable development, it is imperative that ASEAN countries invest in comprehensive disaster financing and investment solutions. These solutions must be designed to help nations prepare for, respond to, and recover from the devastating impacts of natural disasters, while also enhancing their overall resilience.

2.2. Disaster Financing and Investment Trends

Disaster financing and investment in ASEAN are not only critical for protecting lives and property but also for ensuring the region's continued economic growth and stability. Given that the ASEAN economy is one of the fastest-growing in the world, with a combined GDP of over $3 trillion in 2021, any disruptions caused by natural disasters can have far-reaching consequences, both regionally and globally. Additionally, as the region becomes increasingly interconnected through trade and investment, the need for coordinated disaster risk management efforts across ASEAN countries has become more pronounced.

2.3. ASEAN Insurance and Risk Transfer Mechanisms

One of the key trends in disaster financing in ASEAN is the growing use of insurance and risk transfer mechanisms to manage disaster risks. Insurance penetration, which is the ratio of insurance premiums to gross domestic product (GDP), is a useful indicator of the level of insurance coverage in a region. Between 2004 and 2018, the penetration of non-life insurance in the ASEAN region increased from 1.1% to 1.7% of GDP (Swiss Re Institute, 2019). This growth reflects a greater awareness of the importance of insurance to manage disaster risks and transfer the financial burden in the event of a natural disaster.

However, this level of insurance penetration remains relatively low compared to other regions, indicating that there is still significant potential for growth in disaster insurance markets in ASEAN. To illustrate this point, we can compare the non-life insurance penetration rates in ASEAN with those in other regions, as shown in the table below.

Table 3: Non-life Insurance Penetration Rates by Region (2018)

Region	Non-life insurance penetration rate (% of GDP)
ASEAN (2018)	1.7%
North America (2018)	3.4%
Europe (2018)	2.8%
Latin America and the Caribbean (2018)	1.6%
Africa (2018)	0.9%
Asia–Pacific (excluding Japan) (2018)	1.5%

Source: Swiss Re Institute, 2019.

As the table illustrates, the non-life insurance penetration rate in ASEAN is lower than that in North America and Europe but is slightly higher than the average for the Asia–Pacific region (excluding Japan) and significantly higher than the average for Africa. This comparison highlights the potential for further growth and development of insurance markets in ASEAN, particularly in disaster risk management.

Several factors may contribute to the relatively low insurance penetration in the ASEAN region, including low public awareness of the benefits of insurance, limited availability of affordable insurance products, and regulatory barriers that restrict the growth of insurance markets (Swiss Re Institute, 2019). To address these challenges, ASEAN countries can implement various strategies, such as promoting insurance literacy, developing innovative and accessible insurance products, and fostering a supportive regulatory environment.

By enhancing insurance penetration and promoting the use of risk transfer mechanisms, ASEAN countries can improve their financial resilience to disasters and reduce the economic and social impacts of these events on affected populations. The development of robust and inclusive insurance markets in the region can also contribute to long-term sustainable growth and improved overall resilience to natural disasters.

2.4. Regional Risk Pooling Mechanisms Trends

Regional risk pooling mechanisms are an innovative approach to disaster financing that allow countries to collectively manage and transfer risks associated with natural disasters. By pooling resources and sharing risks, countries can access more affordable and efficient insurance coverage, which can help to reduce the financial burden of disaster response and recovery efforts. In this section, we will discuss regional risk pooling mechanisms in the ASEAN context and compare them with similar mechanisms in other regions. In ASEAN, one prominent example of a regional risk pooling mechanism is the Southeast Asia Disaster Risk

Insurance Facility (SEADRIF). Established in 2018, SEADRIF provides parametric insurance coverage to participating ASEAN countries, enabling them to access affordable and quick-disbursing financial protection against climate and disaster risks (SEADRIF, n.d.). As of 2021, SEADRIF has extended coverage to Cambodia, Laos, and Myanmar, providing insurance protection worth up to $10 million per year for each country (World Bank, 2021).

To further contextualise the role of regional risk pooling mechanisms in disaster financing, we can compare SEADRIF with similar mechanisms in other regions, as shown in the table below.

Table 4: Regional Risk Pooling Mechanisms for Disaster Risk Reduction

Region	Risk Pooling Mechanism	Established	Example of Coverage
ASEAN	Southeast Asia Disaster Risk Insurance Facility (SEADRIF)	2018	Up to $10 million per year for Cambodia, Laos, and Myanmar (World Bank, 2021)
Caribbean	Caribbean Catastrophe Risk Insurance Facility (CCRIF)	2007	$100 million payout to 19 Caribbean countries following Hurricane Irma (CCRIF, 2017)
Pacific Islands	Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)	2007	$3.5 million payout to Tonga following Cyclone Gita (PCRAFI, 2018)
Africa	African Risk Capacity (ARC)	2012	$25 million payout to Senegal, Mauritania, and Mali following drought (ARC, 2014)

Source: SEADRIF, n.d.; CCRIF, 2017; PCRAFI, 2018; ARC, 2014.

As the table illustrates, regional risk pooling mechanisms have been established in various parts of the world, including the Caribbean, the Pacific Islands, and Africa. These mechanisms have provided significant financial protection to participating countries, helping them to manage the economic impacts of natural disasters more effectively. While regional risk pooling mechanisms such as SEADRIF play an essential role in disaster financing in ASEAN, there is potential for further expansion and development of these mechanisms in the region. This may involve increasing the number of participating countries, enhancing the scope of coverage, and exploring new risk transfer solutions, such as catastrophe bonds and contingent lines of credit.

Regional risk pooling mechanisms like SEADRIF offer a promising approach to disaster financing in ASEAN, allowing countries to collectively manage and transfer disaster risks. By learning from the experiences of other regions and further developing regional risk pooling

mechanisms, ASEAN countries can improve their financial resilience to disasters and reduce the economic and social impacts of these events on affected populations.

2.5. ASEAN Governmental Investment on Disaster Resilience

Governments in the ASEAN region have increasingly recognised the importance of investing in disaster resilience as a means of mitigating the social, economic, and environmental impacts of natural disasters. Disaster resilience refers to the ability of a community, system, or society to resist, absorb, accommodate, adapt, and recover from the effects of disasters in a timely and efficient manner, preserving or restoring its essential basic structures and functions (UNISDR, 2009). In this section, we will discuss various initiatives and investments made by ASEAN governments in enhancing disaster resilience, with a focus on trends and comparative analysis.

One trend observed in the ASEAN region is the development and implementation of comprehensive national disaster risk reduction and management (DRRM) plans, which serve as strategic frameworks for guiding investments in disaster resilience. The table below provides an overview of selected national DRRM plans in ASEAN countries by focusing on the investments and initiatives taken by five ASEAN countries: the Philippines, Indonesia, Malaysia, Thailand, and Viet Nam. These nations were chosen as they have all developed comprehensive national DRRM plans, which provide a strategic framework to guide investments in disaster resilience. Each plan emphasises key objectives and strategies, such as prevention and mitigation, preparedness, response, and recovery and rehabilitation. By analysing these plans, we can identify regional trends and compare the approaches taken by these ASEAN countries to enhance their disaster resilience capabilities.

Table 5: National Disaster Risk Reduction and Management Plans in Selected Asian Countries

Country	National DRRM Plan	Key Objectives and Strategies
Philippines	National Disaster Risk Reduction and Management Plan (NDRRMP) 2011–2028	Prevention and mitigation, preparedness, response, and recovery and rehabilitation
Indonesia	National Action Plan for Disaster Risk Reduction (NAP-DRR) 2006–2009	Strengthen DRRM capacity, reduce disaster risks, and promote a culture of safety and resilience
Malaysia	National Disaster Management Plan (NDMP)	Disaster prevention, preparedness, response, and recovery
Thailand	National Disaster Prevention and Mitigation Plan (NDPMP) 2021–2027	Enhance disaster management capacity, promote risk reduction and prevention, and foster preparedness
Viet Nam	National Strategy for Natural Disaster Prevention, Response, and Mitigation	Disaster risk reduction, capacity building, resource mobilisation, and international cooperation

Source: Government of the Philippines, 2011; Government of Indonesia, 2006; NADMA, n.d.; Government of Thailand, 2015; Government of Viet Nam, 2007.

Figure 4: (Left) National Disaster Risk Reduction and Management Plan (NDRRMP) of the Philippines, (Middle) National Disaster Prevention and Mitigation Plan (NDPMP) 2021–2027 of Thailand, (Right) National Strategy for Natural Disaster Prevention, Response, and Mitigation of Viet Nam.

Source: Government of the Philippines, 2011; Government of Thailand, 2015; Government of Viet Nam, 2007.

As the table illustrates, national DRRM plans in ASEAN countries often encompass a range of objectives and strategies, spanning from prevention and mitigation to response and

recovery efforts. These plans typically involve a combination of structural and non-structural measures, such as infrastructure investments, land-use planning, early warning systems, risk assessments, public education, and capacity building initiatives.

Another trend in ASEAN government investments in disaster resilience is the establishment of dedicated funding mechanisms and financing instruments to support DRRM activities. These funding mechanisms can take various forms, such as national disaster risk reduction and management funds, disaster relief trust funds, and contingency budget allocations. For example, the Philippines has allocated at least 1% of estimated government revenues to the National Disaster Risk Reduction and Management Fund (NDRRMF) (Republic Act No. 10121, 2010), while Malaysia has established the National Disaster Relief Trust Fund to finance disaster risk reduction activities (NADMA, n.d.).

ASEAN governments have also been investing in regional cooperation efforts aimed at enhancing disaster resilience, such as the establishment of the ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre) and the Southeast Asia Disaster Risk Insurance Facility (SEADRIF). These regional initiatives not only facilitate collaboration and knowledge sharing amongst ASEAN countries, but also help to leverage additional resources and expertise from international partners, such as the World Bank, the Asian Development Bank, and the United Nations.

In terms of comparative analysis, it is worth noting that government investments in disaster resilience in ASEAN countries vary significantly, reflecting differences in the scale and scope of disaster risks, as well as the availability of financial resources and institutional capacities. Nevertheless, there are some commonalities and shared priorities across the region, such as the focus on comprehensive DRRM planning, the establishment of dedicated funding mechanisms, and the promotion of regional cooperation.

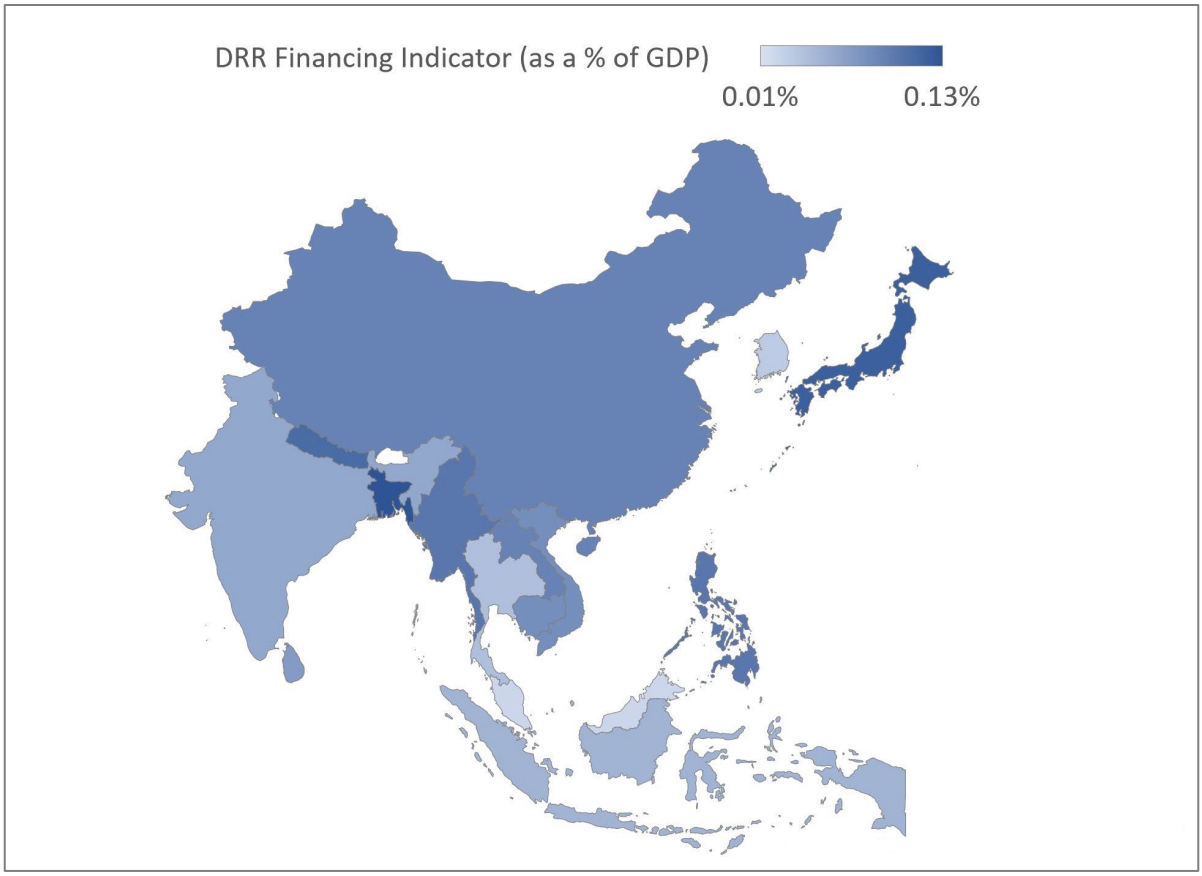
To further illustrate the trends in disaster resilience investments in the ASEAN region, we can examine some key indicators of disaster risk reduction (DRR) financing. The table below presents a comparison of selected DRR financing indicators for ASEAN countries.

Table 6: Disaster Risk Reduction Financing Indicator as a Share of GDP for Selected Asian Countries

Country	DRR Financing Indicator (as a % of GDP)	Disaster-related Official Development Assistance (ODA) per capita (US$)	Insurance Penetration (as a % of GDP)
Malaysia	0.02%	0.07	1.57%
Thailand	0.04%	0.16	2.17%
Indonesia	0.05%	1.46	1.34%
Viet Nam	0.08%	1.28	1.21%
Philippines	0.10%	2.3	1.72%

DDR = disaster risk reduction; GDP = gross domestic product.
Source: Global Assessment Report on Disaster Risk Reduction, 2019.

Figure 5: Disaster Risk Reduction Financing Indicator as a Share of GDP for Selected Asian Countries Compared with Other Countries in Asia



Source: ADB, 2020.

The table highlights some notable variations in DRR financing indicators amongst ASEAN countries. For instance, the Philippines and Viet Nam allocate a relatively higher share of their GDP to DRR financing compared to other countries in the region, while disaster-related ODA per capita is also higher in these countries. On the other hand, insurance penetration rates remain relatively low across the region, suggesting that there is still significant potential for growth in disaster insurance markets in ASEAN.

ASEAN governments have made substantial investments in enhancing disaster resilience, both at the national and regional levels. The main trends in disaster resilience investments in the region include the development of comprehensive national DRRM plans, the establishment of dedicated funding mechanisms, and the promotion of regional cooperation initiatives. By further strengthening these investments and addressing existing gaps and challenges, ASEAN countries can improve their capacity to manage the impacts of natural disasters and enhance the overall resilience of their communities and economies.

2.6. Trends in ASEAN Investment in Disaster Innovation and Technology

In recent years, ASEAN countries have increasingly recognised the potential of innovation and technology in enhancing disaster resilience and reducing the impacts of natural disasters. The adoption of advanced technologies and innovative approaches can significantly improve the effectiveness of DRRM efforts in the region. This section will discuss the main trends in ASEAN investments in disaster innovation and technology, with a focus on comparative analysis.

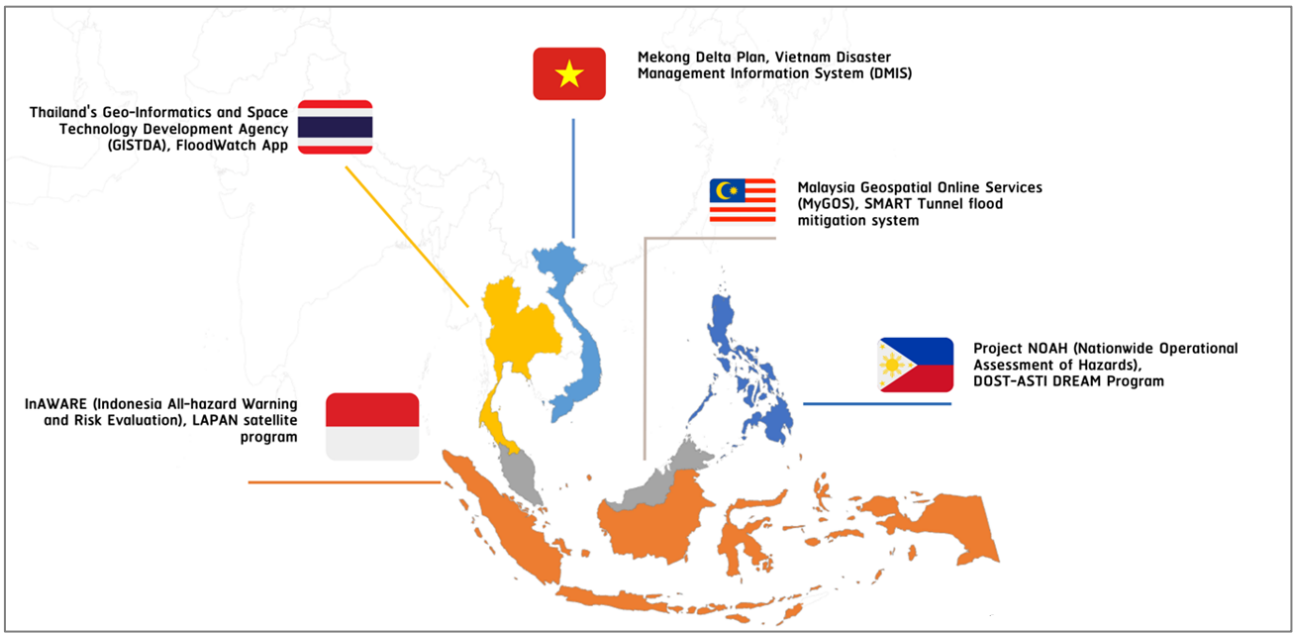
One key trend in ASEAN investments in disaster innovation and technology is the growing use of remote sensing and geographic information systems (GIS) for disaster risk assessment, monitoring, and early warning. Satellite-based remote sensing and GIS technologies enable governments and other stakeholders to collect, analyse, and visualise spatial data on hazard exposure, vulnerability, and potential impacts, which can inform DRRM planning, decision-making, and resource allocation (Pham et al., 2019). ASEAN countries have invested in the development of national spatial data infrastructures and the integration of remote sensing and GIS technologies into their DRRM systems, albeit to varying degrees.

Another trend in ASEAN disaster innovation and technology investments is the increasing emphasis on digital communication and social media platforms for disaster preparedness, response, and recovery. Digital communication tools and social media

platforms, such as Facebook, Twitter, and WhatsApp, can facilitate real-time information sharing, coordination, and collaboration amongst various stakeholders, including government agencies, emergency responders, affected communities, and volunteers (Huang et al., 2020). ASEAN countries have started to leverage these digital technologies to enhance their public awareness campaigns, early warning dissemination, and disaster response operations.

In addition, ASEAN countries have been investing in the development and deployment of innovative technological solutions for disaster resilience, such as Internet of Things (IoT) devices, drones, and artificial intelligence (AI) algorithms. IoT devices, for example, can be used to monitor environmental parameters, such as temperature, humidity, and water levels, and transmit real-time data to disaster management agencies for analysis and decision-making (Islam et al., 2018). Drones can provide aerial imagery and mapping for damage assessments, search and rescue operations, and post-disaster recovery planning (Chittilappilly et al., 2021). AI algorithms can be employed to process large amounts of data from various sources, such as remote sensing imagery, IoT sensors, and social media feeds, and generate actionable insights for DRRM practitioners (Meier, 2015). The figure below presents a comparative overview of selected disaster innovation and technology investments in ASEAN countries:

Figure 6: Disaster Innovation and Technology Investments by Country



Source: Authors' compilation based on various sources.

As the figure illustrates, disaster innovation and technology investments in ASEAN countries cover a wide range of initiatives, from remote sensing and GIS programs to digital communication platforms and innovative technological solutions. These investments not only enhance the capacity of ASEAN countries to manage the impacts of natural disasters but also contribute to the development of local expertise, infrastructure, and industries in the field of disaster innovation and technology.

ASEAN investments in disaster innovation and technology have been characterised by several key trends, including the adoption of remote sensing and GIS technologies, the utilisation of digital communication and social media platforms, and the development of innovative technological solutions such as IoT devices, drones, and AI algorithms. The economic impact of these investments can be significant, as they contribute to reducing the direct and indirect costs associated with natural disasters, strengthening the resilience of communities and economies, and promoting sustainable development in the region.

While it is difficult to quantify the exact amount of investment in disaster innovation and technology across all ASEAN countries, some case studies can provide insights into the scale and scope of these investments. For example, the Philippines' Project NOAH (Nationwide Operational Assessment of Hazards) had an initial budget allocation of PHP 1.6 billion (approximately US$31.3 million) for its implementation between 2012 and 2015 (DOST, 2012). Similarly, the Indonesian government invested US$16.9 million in the development of the LAPAN-A2/LAPAN-ORARI satellite, which was launched in 2015 and has since been used for various disaster management applications, such as forest fire monitoring and maritime surveillance (LAPAN, 2015).

In terms of economic impact, investments in disaster innovation and technology can lead to substantial cost savings by reducing disaster losses and damage, as well as enhancing the efficiency and effectiveness of DRRM efforts. For instance, the SMART Tunnel flood mitigation system in Malaysia, which was completed in 2007 at a cost of RM1.9 billion (approximately US$459 million), has reportedly prevented an estimated RM1.4 billion (approximately US$338 million) worth of flood damage in Kuala Lumpur between 2008 and 2012 (Ismail et al., 2015).

Moreover, these investments can generate broader economic benefits by fostering innovation, entrepreneurship, and job creation in the disaster innovation and technology sector. For example, the establishment of Thailand’s Geo-Informatics and Space Technology

Development Agency (GISTDA) has not only enhanced the country's capacity for disaster risk assessment and monitoring but also contributed to the growth of the domestic geospatial industry, which is projected to reach a market value of THB 20 billion (approximately US$605 million) by 2025 (GISTDA, 2019).

Besides these positive economic impacts, it is essential for ASEAN governments and other stakeholders to continue investing in disaster innovation and technology, as the region remains highly exposed to various natural hazards, such as earthquakes, typhoons, floods, and droughts. By leveraging the potential of innovation and technology, ASEAN countries can further enhance their disaster resilience and reduce the social, economic, and environmental costs associated with natural disasters.

2.7. Building a Resilient Future for ASEAN through Strengthened Financing, Investment, and Innovation

ASEAN countries have made substantial progress in disaster financing and investment, recognising the importance of enhancing their disaster resilience in the face of increasing natural hazards. This section has provided an overview of the key trends in disaster financing and institutional arrangements, investments in disaster resilience, and the growing focus on innovation and technology in the region.

The ASEAN region has seen the development of comprehensive national DRRM plans, the establishment of dedicated funding mechanisms, and the promotion of regional cooperation initiatives. While insurance penetration remains relatively low compared to other regions, there is significant potential for growth in disaster insurance markets in ASEAN.

Investments in disaster innovation and technology have also become increasingly important, with ASEAN countries adopting remote sensing and GIS technologies, leveraging digital communication and social media platforms, and developing innovative technological solutions such as IoT devices, drones, and AI algorithms. These investments have contributed to reducing the direct and indirect costs associated with natural disasters, strengthening the resilience of communities and economies, and promoting sustainable development in the region. Meanwhile, the economic impact of these investments is also significant, leading to substantial cost savings by reducing disaster losses and damages, as well as enhancing the efficiency and effectiveness of DRRM efforts. Moreover, these investments can generate broader economic benefits by fostering innovation, entrepreneurship, and job creation in the disaster innovation and technology sector.

Despite the progress made in recent years, it is crucial for ASEAN governments and other stakeholders to continue investing in disaster financing, resilience, and innovation, as the region remains highly exposed to various natural hazards. By strengthening these investments and addressing existing gaps and challenges, ASEAN countries can further enhance their capacity to manage the impacts of natural disasters and ensure the overall resilience of their communities and economies.

As the world continues to face the increasing frequency and intensity of natural disasters, it is vital that ASEAN countries continue to prioritise disaster financing and investment. By learning from one another and cooperating regionally, these countries can collectively build a more resilient future for the people of Southeast Asia.

3. Good Practices: Consideration of Appropriate Investment Involving the Utilisation of DRR Technologies in ASEAN Countries and Japan

The outbreak of the COVID-19 pandemic has intensified the already significant disaster risk in the ASEAN region, which ranks highly in global terms. From 2020 to 2022, the region grappled with the public health crisis while also facing a record number of natural disasters. This section appraises recent disaster risk reduction strategies within the ASEAN region and explores the influence of modern technologies on disaster risk, management, and emergency response. It encompasses both structural and non-structural measures adopted by local and national governments.

Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam are the ASEAN Member States (AMS) most vulnerable to natural disasters. Heightened vulnerability and reduced coping abilities primarily contributed to the increased disaster risk. The COVID-19 pandemic exacerbated the disaster risk in the region by an average of 33%, marking a substantial detrimental impact. This required National Disaster Management Organizations (NDMOs) to adapt and incorporate innovative technologies in their individual disaster response operations (The AHA Centre, 2022).

Modern innovations and technological advancements have created possibilities for enhancing resilience to disasters and reducing vulnerability. Ground-breaking developments in fields such as artificial intelligence (AI), the Internet of Things (IoT), and big data, alongside advancements in robotics and drone technology, are impacting a broad spectrum of industries, including those focused on disaster risk reduction and management. Technological

progress in wireless broadband networks, mobile phones, and cloud computing has facilitated the integration of innovative strategies for disaster risk management. (ITU, 2019).

The AMS, especially Thailand, the Philippines, and Indonesia, have showcased dedication and initiative by drawing lessons from the application of innovation and modern technology to enhance disaster management and mitigate various disaster risks. This is particularly relevant in urban areas prone to natural disasters due to factors such as complex demographic characteristics, economic significance, and social inequality. Innovation is employed in diverse forms, encompassing both structural measures that reduce risks with high precision and non-structural measures where technology enables broader access to risk information and personalised risk reduction strategies for individuals. Notably, there has been consistent and significant progress in risk assessment, knowledge development, and early warning systems for floods. This section will delve into these practices in detail, highlighting the commitment of AMS to advancing the ASEAN Agreement on Disaster Management and Emergency Response (AADMER).

As mentioned, the ASEAN community has made strides toward initiating early warning systems, which involves enhancing knowledge and risk information through the utilisation of advancements in state-of-the-art technology. This includes the key guidelines, policies and international operating frameworks as described below.

As stipulated in Article 7 of the legally binding AADMER, AMS are required to ‘establish, maintain, and regularly review national disaster early warning procedures’ (ASEAN, 2020). The AADMER mandates encompass (1) regular risk assessments, (2) early warning information systems, (3) a communication network for timely information dissemination, and (4) public awareness and preparedness. The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030 was adopted to minimise disaster risk and losses globally. SFDRR's Target G aims to improve the availability and accessibility of multi-hazard Early Warning Systems (EWS), and bolstering the EWS approach is a practical means to achieve this goal (UNDRR, 2015). The Paris Agreement, a landmark accord from 2015, highlights climate change adaptation as one of its priorities, with disaster risk reduction as an indirect consequence of the increased urgency due to the anticipated changes in hazards caused by climate change. Article 7 of the Paris Agreement emphasises the need to enhance climate science, including EWS, in a manner that informs climate services and strengthens policymaking (UNFCCC, 2016). The Paris Agreement encourages cooperation and

facilitation to raise awareness, responsiveness, and support for EWS (Article 8). Apart from addressing climate change, the 17 Sustainable Development Goals (SDGs) outlined in the 2030 Agenda for Sustainable Development aim to eradicate poverty and other forms of inequality worldwide by 2030 (UNFCCC, 2016). The SDGs promote adaptation to climate change and disaster risk reduction measures, as disasters can prolong or even exacerbate poverty and inequality.

The 2022 ASEAN Risk Monitor and Disaster Management Review's regional disaster risk assessment underscores the trend in the ASEAN region, where flood impacts persist as the natural hazard with the greatest risk in terms of frequency of occurrence, as well as economic and social consequences (AHA Centre, 2022). Floods pose the highest economic exposure to the region, totaling US$7.6 trillion. Moreover, flooding is the most prevalent natural disaster in the area. During the COVID-19 pandemic, floods accounted for 66% of all recorded disasters in all AMS, excluding Brunei Darussalam and Singapore (ADINet, 2022).

As a result, it is reasonable to expect that Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam are developing and enhancing their flood risk reduction measures, concentrating on leveraging the most advanced technologies available within the region to minimise physical exposure and economic impact as much as possible.

The next section will introduce the latest disaster management investment initiatives in Thailand, Indonesia, the Philippines, Malaysia, and Viet Nam, as well as good practices from Japan's most recent disaster management activities aimed at sharing disaster information.

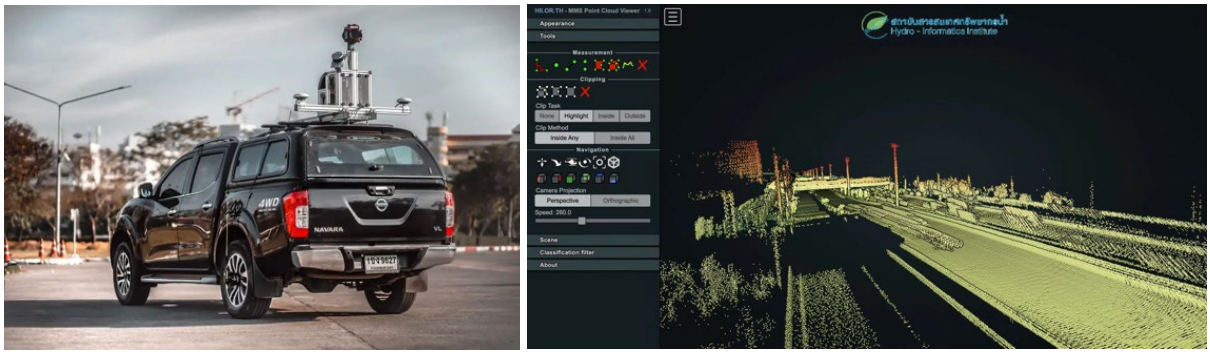
3.1. Thailand: Public 3D Map Database for Urban Development with Highly Accurate Flood Resilience Designs

Following the 2011 flood in Thailand, it was discovered that spatial data for analysis and planning were unavailable. There was also insufficient attention and modernity towards disaster risk management. Thailand’s Hydro-Informatics Institute (Public Organization) develops mobile topographic survey technology and produces precise maps (MMS: Mobile Mapping System) to increase the accuracy and validity of topographic information that is appropriate for use in all applications. Utilising advanced technologies, it includes the following components: 1. Mobile Mapping System (MMS); 2. Seafloor Echoboat Unmanned Surface Vessel (USV); 3. Unmanned Aerial Vehicle (UAV). The information acquired from the three parts of the survey is used to create high-resolution maps and 3D topographic models

of high-risk flood-prone areas that support decision-making. These maps and models enable local governments to make decisions based on highly accurate evidence. The specific details are as follows.

First, the topographic elevation survey vehicle (Mobile Mapping System: MMS) is a surveying device that generates 3D virtual terrain models and produces extremely accurate maps quickly to support routine and emergency operations. Additionally, model data can precisely determine distance, height, and capacity coordinates, and can be used to effectively plan water management. It consists of a high-resolution omni-directional camera and 3D topographic survey point data with a placement precision of 3 cm. The vehicle is frequently used in many regions of Thailand to gather physical data after a natural disaster for impact analysis and improved reconstruction planning.

Figure 7: (Left) Topographic Elevation Survey Vehicle Operated by the Hydro-Informatics Institute, (Right) Example of a 360-degree, High-resolution Photograph of the Area taken with Ladybug Camera



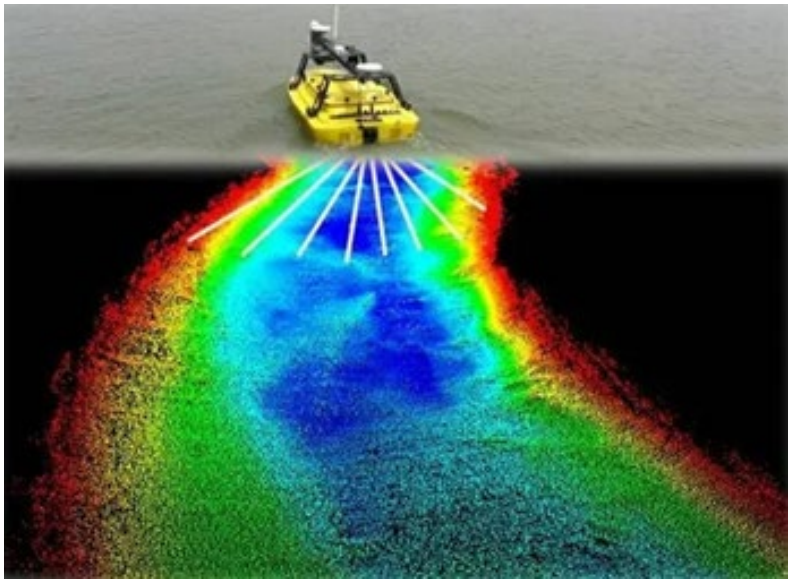
Source: Hydro-Informatics Institute, 2019.

Second, the Seafloor Echoboat Unmanned Surface Vessel (USV) is designed for portable topographic surveying and the generation of maps for precise area planning processes. The Chao Phraya River Basin in the centre of the country is a low-lying area with a high risk of flooding. The USV, which is compact, portable, and provides reliable survey findings without the need for human control, has begun to be utilised there.

Figure 8: Components of the Automated Survey Vessel

Source: Hydro-Informatics Institute, 2019.

Figure 9: Example of a Survey on the Chao Phraya River



Source: Hydro-Informatics Institute, 2019.

Third, the Unmanned Aerial Vehicle utilizes these remote sensing systems, including in densely populated metropolitan areas, with an emphasis on aiding missions to explore difficult-to-reach regions with limited preparation space, by generating photographic and three-dimensional map data. This technology has been utilised in several missions, including

the restoration planning mission of the building and the Urban Search and Rescue (USAR) operation in Bangkok, the capital of Thailand.

The 3D imaging metadata from these three technologies is also being made publicly available. Based on this data, the Bangkok Metropolitan Administration has developed a comprehensive city risk map for five hazards, which will be utilised to make investment decisions for resilience infrastructure based on reliable insights and highly accurate evidence. According to interviews with senior executives, efficient, data-driven decisions can save cities hundreds of millions of dollars through proper investments based on local risks. As these databases are 'open data' that are accessible to everyone, not just government authorities, they are also increasing public awareness.

3.2. The Philippines: Utilisation of Digital Innovation and Telecommunications Technologies to Strengthen Early Warning Capabilities

In the Philippines, the sharing of knowledge about preventive actions is increasingly reliant on digital innovation and telecommunications technologies. As an example, in 2019, PAGASA initiated a pilot programme to test out a Multi-Hazard Impact-Based Forecasting and Early Warning System (MH-IBF-EWS), which will remain in place until 2027. This project employs mobile technology to furnish national, provincial, and municipal government agencies with a knowledge and decision support system (KDSS). Impact-based forecasts and warnings can be visualised, and response protocols can be disseminated through a mobile app. Users are provided with standard operating procedures via the app so that they can take preventative measures before an emergency occurs. Using telecommunications technology, the Philippines has significantly increased its capacity to respond to the impact of climate change, natural disasters, and climate change adaptation since 2010. Accelerating the development of early warning technologies to reach diverse populations significantly reduces geographical limitations.

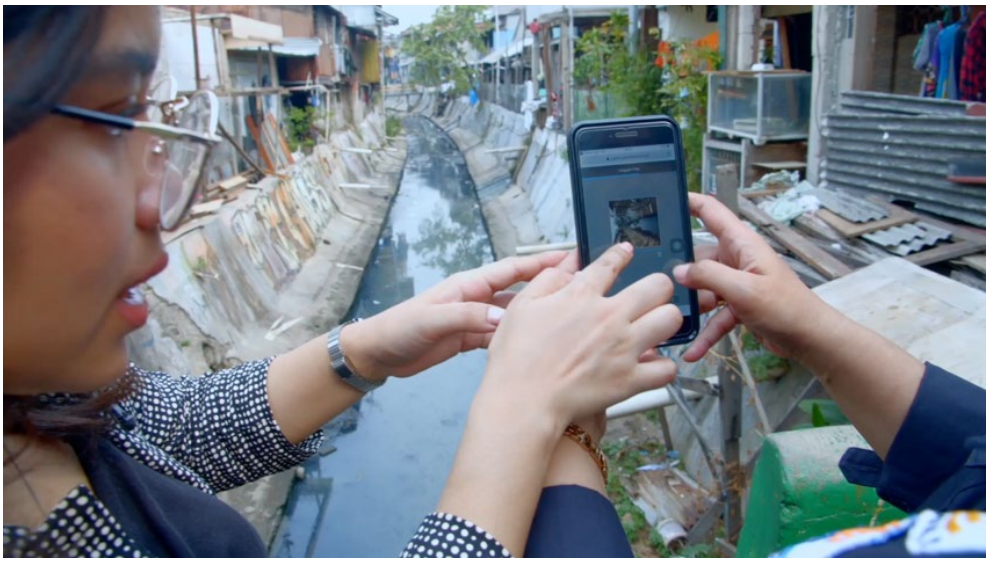
The 2010 Philippine DRRM Act established the National Disaster Risk Reduction and Management Council (NDRRMC) as the primary policymaking body at the national level, with similar structures at the regional, provincial, city/municipality, and barangay (the smallest administrative unit in the Philippines) levels. The Department of Science and Technology (DOST) is responsible for providing EWS through two organisations and has a duty to oversee disaster prevention and mitigation. Weather-related hazards are reported and warnings are issued by the Philippine Atmospheric, Geophysical, and Astronomical Services

Administration (PAGASA), while geotectonic events including landslides, volcanic eruptions, earthquakes, and tsunamis are reported and warnings are issued by the Philippine Institute of Volcanology and Seismology (PHIVOLCS). Moreover, evaluations and benchmarking by international organisations indicate the Philippines' progress in and commitment to the continued digitalisation of the EWS through new technologies. The Philippines' most advanced solutions include: (1) using crowdsourced data to improve detection, monitoring, and forecasting; and (2) using mobile and digital innovations to increase the reach of warnings and alerts though digital platforms for risk knowledge integration. The details are as follows.

Crowdsourcing, mobile technology, and social media are changing disaster response. Crowdsourcing employs public intelligence to gather information and do tasks that would otherwise be limited or outsourced. Philippines disaster response has had this technological strength, where crowdsourcing assists rescuers, authorities, and academics discover problematic areas, acquire crucial information, and complete time-sensitive tasks during humanitarian situations (Robbins, 2022). Crowdsourcing can also help the examination of neighbourhood impacts in real time.

MapaKalamidad.ph is a website that utilises social media and the crowdsourcing methodology to collect data from both official and unofficial sources and then arrange and broadcast it in real time during a flood. It was created by the Indonesian nonprofit 'Yayasan Peta Bencana' in collaboration with the MIT Urban Risk Lab (Fadmastuti, 2022). The website PetaBencana.id, which was developed to capitalise on the popularity of social media and instant messaging in Indonesia, has been adopted and deployed on a national scale by the National Agency for Disaster Management (BNPB). It takes in data from users in the field in real time and presents it in the form of a live map. To achieve this goal, it analyses how frequently specific terms are used during critical situations. Launched in Quezon City and Pampanga in 2020, MapaKalamidad.ph's goal is to serve as a hub for the public to access this data by capitalising on the widespread dissemination of real-time postings and reports. The data is subsequently uploaded on the website for public use. There are also chatbots on the platform, which are backed by AI. These bots automatically respond to social media posts about an emergency, referencing the event in question and asking individuals to submit a disaster report to verify the situation. To monitor and communicate real-time flood information and make time-sensitive choices to minimise risk, these reports are validated and shown on a web-based map that is data-light, mobile-centric, and available to all users.

Figure 10: Demonstration of the Use of the Mapakalamidad.ph System



Source: Petabencana, 2022.

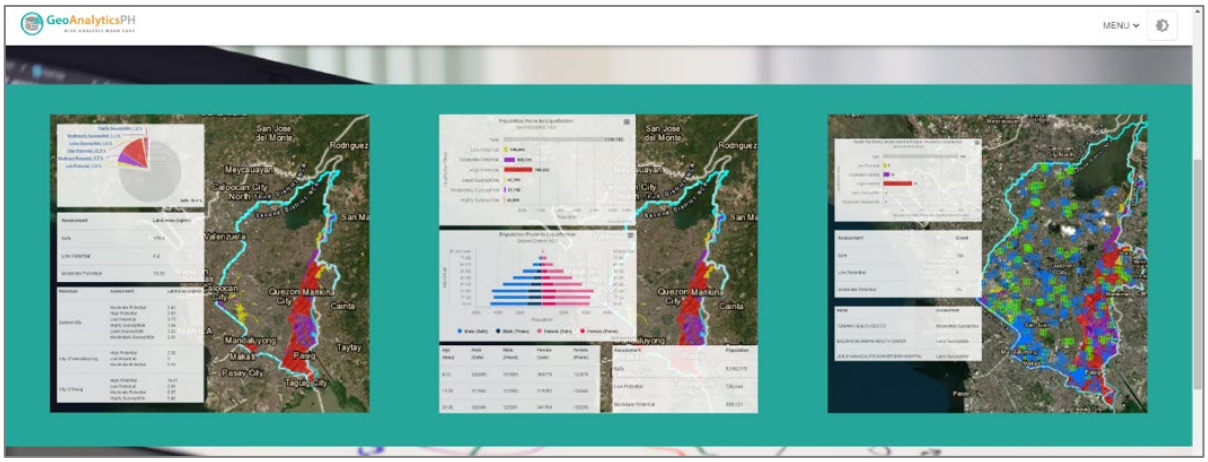
Second, to save lives, warnings must be communicated promptly and clearly through communications with relevant and tailored information. Media and communication channels are typically used to disseminate warnings and alerts to vulnerable populations, but end users and last-mile communities must find ways to receive such communications in remote locations, such as satellite and mobile cellular networks, social media, flags, sirens, bells, public address systems, radio, television, and door-to-door dispatch. Frequently, it is necessary to collaborate with the private sector to deploy and use their resources to spread warnings and assist communities' reaction measures (e.g. mobile cellular networks, satellite, television, radio broadcasting, amateur radio, social media).

Once a potential disaster event has been discovered by monitoring agencies, information is forwarded to the NDRRMC. Through the OCD, the NDRRMC operates a round-the-clock Emergency Operations Center that transmits alert and warning messages to mobile phones via MNOs such as Globe and Smart, as well as television. Additionally, the NDRRMC provides periodic updates through its situation reports. PAGASA has worked with Google to guarantee that its notifications are automatically shown in Google's public alerts. Moreover, the Philippines agencies incorporate risk data, forecasts, and alarms using mobile and digital technology. Since 2018, NAMRIA, OCD, MGB, and PHIVOLCS have deployed impact-based prediction and warning systems (IBFWS) nationwide (WMO, 2021). HazardHunterPH, GeoAnalyticsPH, and GeoMapperPH are all part of the Geospatial Information Management

and Analysis Project for Hazards and Risk Assessment in the Philippines (GeoRiskPH).

The platform is a part of GeoRisk Philippines, which enables national government agencies, local government entities, and non-government groups to access, utilise, and contribute data to the integrated GeoRiskPH database. It is intended to enable the collection and maintenance of risks, exposure, vulnerability, and coping capacity information to support decision-making before, during, and after disasters.

Figure 11: Disaster Innovation and Technology Investments by Country



Source: DOST-PHIVOLCS, 2022.

3.3. Malaysia: The Stormwater Management and Road Tunnel (SMART Tunnel), a Groundbreaking Solution for Flood Management and Urban Resilience

In recent years, urban flooding has become an increasingly significant challenge for cities around the world due to climate change, rapid urbanisation, and inadequate infrastructure. Malaysia, a rapidly developing Southeast Asian country, has faced its share of challenges with frequent flash floods, particularly in its capital city of Kuala Lumpur. In response to these challenges, the Malaysian government commissioned the Stormwater Management and Road Tunnel (SMART Tunnel) project in 2003. This groundbreaking solution, completed in 2007, was designed to mitigate flooding in the city centre while also alleviating traffic congestion. This article will explore the innovative design of the SMART Tunnel, its role in improving urban resilience, and its effectiveness in reducing flood risk.

The SMART Tunnel is a 9.7 km long dual-purpose tunnel, with a 4 km stormwater bypass and a 5.7 km motorway that stretches from Jalan Sungai Besi to Jalan Istana in Kuala Lumpur (Rahardjo et al., 2012). Designed by the Malaysian Public Works Department, the

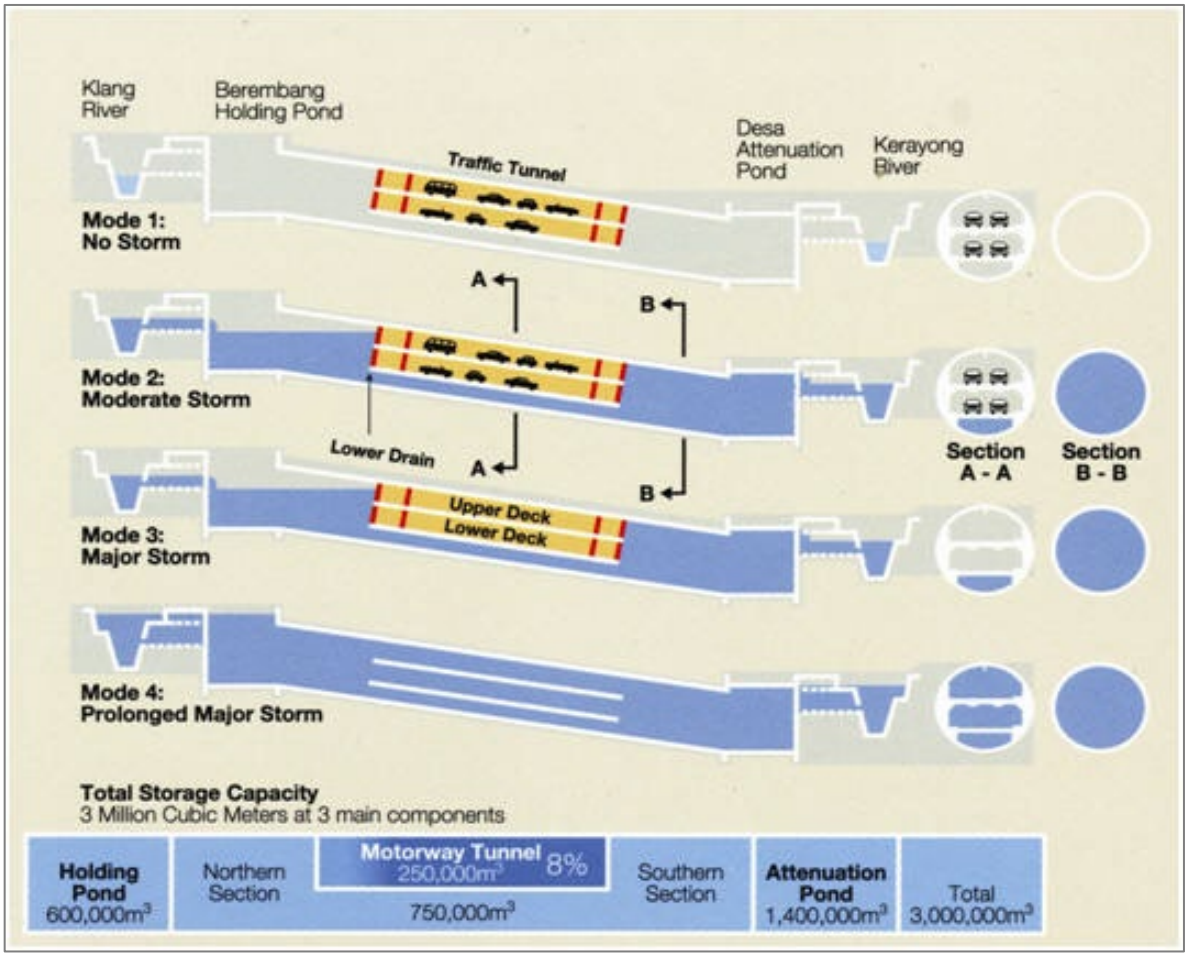
project was a collaborative effort between the Malaysian Highway Authority (MHA) and Gamuda Berhad and MMC Corporation Berhad, two prominent Malaysian engineering and construction firms. The SMART Tunnel project has garnered international recognition for its innovative engineering, winning the prestigious UN Habitat Scroll of Honour Award in 2011 and the 2018 Global Road Achievement Award from the International Road Federation (IRF) (SMART, 2011; IRF, 2018).

The SMART Tunnel boasts a unique design that combines stormwater management and vehicular traffic solutions. Its primary purpose is to divert stormwater runoff from the heavily urbanised Klang River basin, thereby reducing the risk of flash floods in the city centre (Rahardjo et al., 2012). The tunnel is designed to handle a peak stormwater flow of 3 million liters per second, effectively mitigating the flood risk in Kuala Lumpur (SMART, 2011).

During dry periods, the tunnel serves as a motorway to alleviate traffic congestion in the city centre. The motorway, located above the stormwater bypass, is capable of handling up to 30,000 vehicles per day. This dual-purpose design not only serves the primary goal of flood mitigation but also addresses the city's growing traffic problems.

In addition to its innovative design, the SMART Tunnel incorporates cutting-edge technologies to monitor and control its operation. The tunnel is equipped with a sophisticated flood detection system that monitors rainfall and water levels in real-time, allowing for rapid response to potential flooding events (Rahardjo et al., 2012). Furthermore, the tunnel features advanced ventilation systems and safety measures, such as emergency evacuation routes, to ensure the well-being of motorists and tunnel personnel.

Figure 12: Stormwater Management and Road Tunnel (SMART Tunnel) in Malaysia



Source: Department of Irrigation and Drainage, 2017.

Since its completion in 2007, the SMART Tunnel has proven to be an effective solution for flood management in Kuala Lumpur. According to the Malaysian Department of Irrigation and Drainage (2017), the tunnel has successfully prevented several major flooding events in the city, safeguarding billions of dollars in economic assets and averting potential loss of life.

Moreover, the tunnel has contributed to improving the city's overall resilience to flooding. The enhanced stormwater management capacity has allowed for increased urban development in the city centre, which, in turn, has contributed to the city's economic growth (Khalid et al., 2014). The Malaysian government has also been able to leverage the SMART Tunnel's success in attracting foreign investment, further bolstering the city's development.

In addition to flood management, the SMART Tunnel has played a significant role in reducing traffic congestion in Kuala Lumpur. According to a study by the Malaysian Institute of Road Safety Research (MIROS, 2018), the tunnel has effectively reduced motorists' travel

time by up to 30 minutes during peak hours, contributing to improved traffic flow and reduced carbon emissions.

The success of the SMART Tunnel highlights the importance of innovative and integrated solutions for addressing complex urban challenges. By combining flood management and traffic congestion alleviation, the project has demonstrated the potential for dual-purpose infrastructure to contribute to urban resilience and sustainable development. The SMART Tunnel serves as a model for other cities facing similar challenges, both in Malaysia and internationally. Several cities in flood-prone regions, such as Bangkok in Thailand, and Jakarta in Indonesia, have expressed interest in adopting the SMART Tunnel concept to address their own flood management and traffic congestion issues (Rahardjo et al., 2012). The project also emphasises the importance of collaboration between government, private sector, and international stakeholders in developing and implementing innovative solutions. The involvement of Gamuda Berhad and MMC Corporation Berhad, as well as international partners such as Mott MacDonald and the Asian Development Bank, played a crucial role in the successful completion of the SMART Tunnel project.

Moving forward, it is essential for cities and countries to continue investing in innovative infrastructure projects that address multiple urban challenges. As climate change and urbanisation continue to exacerbate the risks of flooding and other disasters, projects like the SMART Tunnel serve as a testament to the potential of innovative solutions to build more resilient and sustainable urban environments. The SMART Tunnel in Malaysia stands as a groundbreaking solution to the challenges of urban flooding and traffic congestion. With its unique design and cutting-edge technology, the tunnel has effectively mitigated flood risks and improved traffic flow in Kuala Lumpur, contributing to the city's overall resilience and sustainable development. As urbanisation and climate change continue to pose significant challenges for cities worldwide, the SMART Tunnel serves as a model for innovative, integrated, and sustainable solutions that can address complex urban problems and improve the quality of life for millions of people.

3.4. Indonesia: Nature-Based Solutions for Building Resilient Communities in Indonesia's Informal Settlements

In the last two decades, the frequency and severity of large-scale disasters and their effects on cities have increased dramatically, and have indicated that gender, ethnicity, poverty,

and geography have considerable bearings on urban vulnerability (Davis, 2006).

Low-income communities are being pushed into disaster-prone areas, and four out of ten non-permanent settlements in the developing world are now located in places at risk from natural hazards (UN-Habitat, 2009). In the previous 50 years, floods were by far the most common natural disaster in Indonesia. They were the second worst significant hazard after earthquakes and tsunamis (CRED, 2022). A climate change risk assessment of the city of Makassar, which included findings of informal settlements, showed that although precipitation amounts will stay constant in the next decades, precipitation would be concentrated over a shorter time. This indicates a longer dry season and more heavy precipitation, leading to floods (UN-Habitat, 2014). Improving our understanding of the effects of floods on the millions of urban poor Indonesians is, ultimately, critical.

In recent years, Indonesia has been committed to upgrading and strengthening critical infrastructure to serve a greater number of urban poor (Government of Indonesia, 2020), promoting safe access and water services to reduce vulnerability to health matters, and reducing the impact of sea level rise trends on natural water supplies, both surface and underground (Rahmawati, 2013).

Expanding and enhancing the capacity of communities, particularly low-income populations residing in informal settlements, is insufficient to combat the effects of climate change trends (Quesada-Román, 2022). The synthesis of modern approaches, e.g. integrating natural principles with risk reduction in communities, known as natural based solutions (NbS), is prevalent in several cities throughout the world and a well-established practice in Indonesia as follows.

Case of Makassar city, the fifth-largest urban centre in Indonesia, demonstrates the achievement of promoting community resilience through the implementation of nature-based solutions in informal settlements. Each monsoon season, locals in a tiny village in the district of Batua in Makassar gather together to construct bamboo rafts and pathways to protect their homes from the days-long flooding. These coping methods are essential for assisting families in informal settlements to manage their daily requirements despite the numerous challenges and obstacles they face.

The critical point is that neighbourhood-scale nature-based solutions such as built wetlands and biofilters, in combination with more traditional ‘gray’ infrastructure, provide a comprehensive, water-sensitive approach to enhancing services in urban informal settlements.

The city tries to limit feces in the environment and, consequently, human exposure to diseases. The initiative comprises actions at many scales to address issues with water supply, drainage, sanitation, flood management, and accessibility (Asian coalition for housing rights, 2022). Co-designing infrastructure solutions with each community ensures that the solutions are fit for their intended purpose. In addition, it appears that Yogyakarta, a nearby city in Java, is utilising community mechanisms to establish local financial instruments available to low-income people in informal settlements to subsidise essential infrastructure upgrades, such as houses and community public spaces, by focusing on utilising nature-based solutions.

Figure 13: Landscape of Makassar City's Riverside Informal Settlement

Source: NetworkNature, 2023.

Case of Yogyakarta city, Informal riverside settlements have been renovated using revolving city-level loans and an Asian Coalition for Community Action (ACCA) grant to provide micro loans to households for basic infrastructure improvements and housing restorations. This represented an alternate strategy for developing these riverside communities in a manner that prevents river encroachment and reinforces their resilience through improved housing and infrastructure. The process also addressed the issue of tenure insecurity, as the community negotiated the right to remain on the government land they had previously occupied, in accordance with the objectives of the local government to address the problems of riverfront kampungs throughout the entire city of Yogyakarta. Such a community-driven approach is essential from a resilience perspective, as it encourages a local understanding of climate risk, promotes inclusive decision-making, ensures the longer-term sustainability of assets through community ownership and maintenance, and facilitates the development of a

longer-term relationship between communities and local government, which is essential for addressing difficult issues pertaining to land, tenure, and encroachment.

Figure 14: Landscape of Yogyakarta City's Riverside Informal Settlement

Source: Kampung Kali Chode, Yogyakarta, 2023.

3.5. Viet Nam: Disaster Management and Flood Control System

One of the core organisations for disaster management in the Viet Nam Government is the National Steering Committee for Natural Disaster and Prevention Control (NSCNDPC). The Vice Prime Minister is the Chairperson of this committee, and the Head of the unit is organised by related ministries and agencies. As a standing office of NSCNDPC, the Viet Nam Disaster Management Authority (VNDMA) is established under the Ministry of Agriculture and Rural Development (MARD) and it has functions covering the management of natural disasters, including response and recovery from natural disasters under the coordination of related ministries and agencies in the central government and provinces. MARD is also responsible for structural measures for disaster prevention, such as construction, repair, and enhancement of dykes, dams, reservoirs, flood control works, erosion control works, ports of refuge, etc., and the construction and management of dykes, which are ranked from grade Special to grade V, are carried out. In terms of river management, the Prime Minister's Decision 1879 QD-TTg was adopted, and MONRE has developed integrated operating rules for dams in 11 river basins, and these dams are operated under the operating rules during floods.

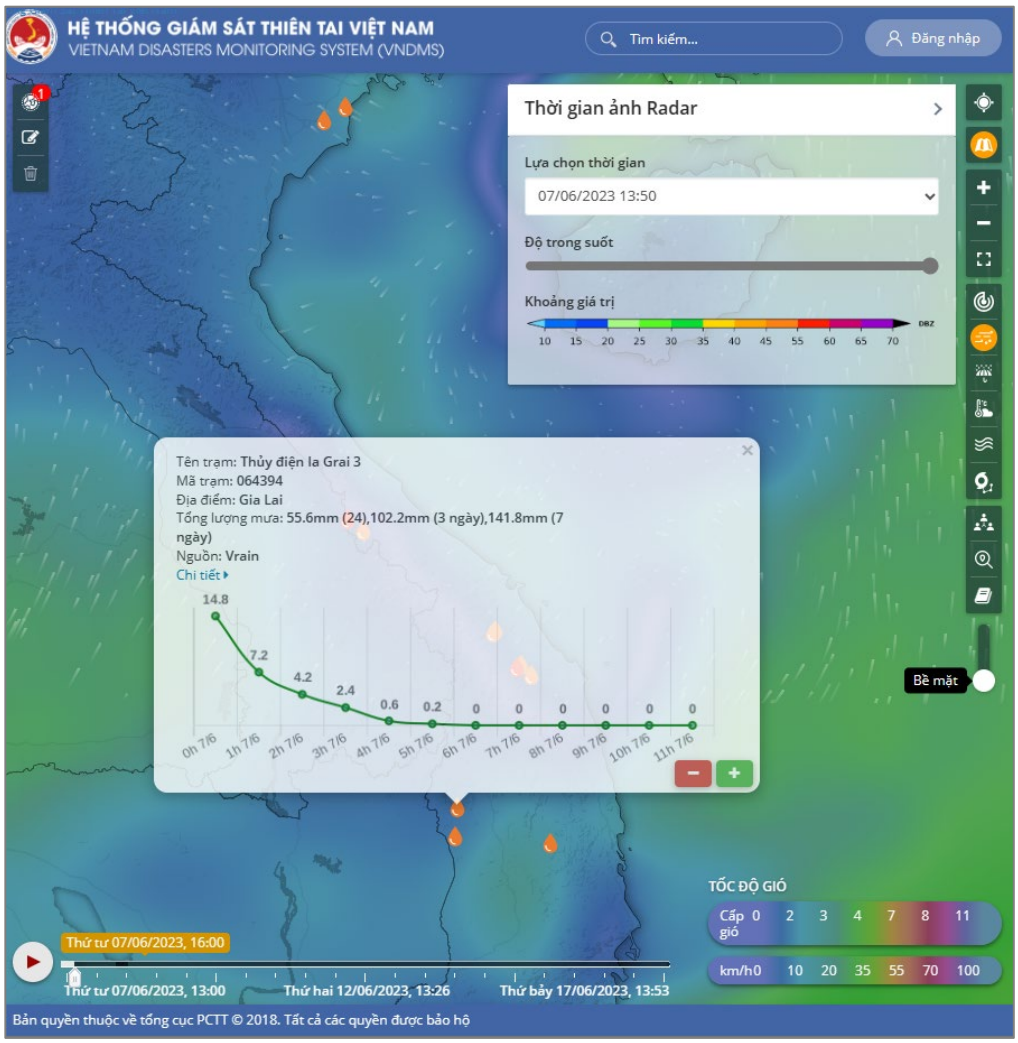
VNDMA has also established the Viet Nam Disaster Monitoring System (VNDMS) and the inter-reservoir management software for the Red River basin was developed for sharing current information.

To further improve capacity building in DRR at all levels (central, provincial, district, commune, community, and individuals), VNDMA has built an initial database with the intention of gradually being able to have a large database utilising big data that will be shared from state management agencies to the community (VNDMS) to serve the direction and administration of DRR.

The system also assists with applying new technology and digital transformation in DRM and connects to other integrated real-time and near-real-time nationwide monitoring databases.

These systems are connected to related databases and systems such as: information on operation of hydroelectric reservoirs and irrigation reservoirs; information on supervision of fishing vessels; information from enterprises, monitoring information from 2,700km of dikes managed by the central government; real-time operation status of 6,995 reservoirs (including 176 hydroelectric reservoirs managed by the Ministry of Industry and Trade, 69 hydroelectric reservoirs managed by EVN Group and 6,750 irrigation reservoirs); location information of nearly 26,000 boats and 67 storm shelters; and the current status of 1,417 erosion points.

Figure 15: VNDMS Disaster Monitoring System



Source: Hui Lian Lee, 2022.

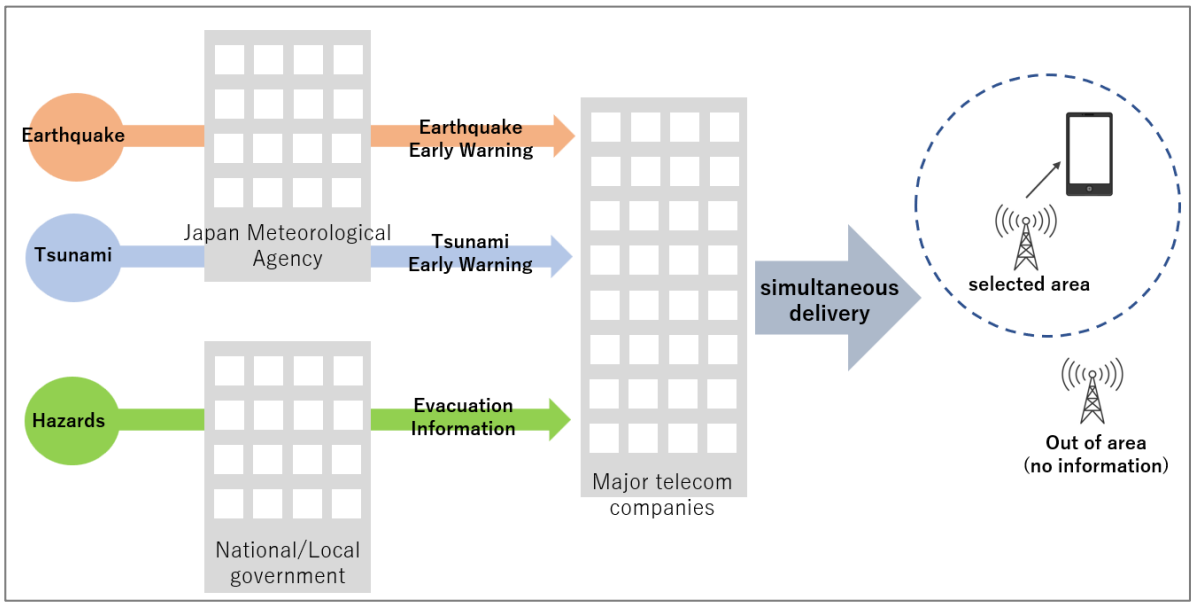
3.6. Japan: Initiatives Using the Emergency Alert System and Quasi-Zenith Satellite System for DRR

For people to protect themselves when a hazard occurs, it is important to obtain information about the hazard as soon as possible and take appropriate evacuation actions. Today, most people have smartphones, which serve as a useful device for sharing hazard information.

Therefore, in Japan, the ‘Emergency Alert System’ service is provided mainly by the Japan Meteorological Agency (JMA), national and local governments, and private telecommunications companies. As shown in Figure 13, this ‘Emergency Alert System’ service simultaneously distributes Earthquake Early Warnings and Tsunami Warnings issued by the JMA, and hazard and evacuation information issued by the national and local

governments to smartphones in a specific area. This service does not require prior registration of an email address and can automatically deliver emergency alert messages to smartphones that are within the area that is considered necessary.

Figure 16: Emergency Alert System in Japan



Source: Author.

There are four main types of hazard information provided. (1) Earthquake Early Warning (a service that enables cell phones to receive 'Earthquake Early Warnings for the general public' issued by the JMA, which are sent to phones in municipalities within the area* designated as the warning area by the JMA); (2) Tsunami Warnings (a service that enables cell phones to receive 'Major Tsunami Warnings' and 'Tsunami Warnings'* that are sent to phones in municipalities along a coastline that are designated by the JMA as being subject to a warning; the JMA aims to issue such warnings within three minutes after an earthquake occurs); (3) Emergency Warnings (the JMA issues Emergency Warnings regarding heavy rain, strong winds, storm surge, high waves, snow storms, and heavy snow if once-in-several-decades heavy rain or heavy snow is expected, or when strong winds from a once-in-several-decades typhoon is expected); and (4) Hazard / Evacuation Information (a service that enables cell phones to receive life-saving messages such as evacuation advisories, instructions and other warnings issued independently by the national or local governments; recipients are those within the municipality that issued the message).

Thus, the ‘Emergency Alert System’ is a service provided in cooperation with various organisations, and has become an indispensable tool for protecting people from hazards.

Figure 17: From Left to Right: Examples of an Earthquake Early Warning, Tsunami Warning, and Evacuation Information

Source: https://www.docomo.ne.jp/service/areamail/

Provision of Hazard Information Using the Quasi-Zenith Satellite and Collaboration with ASEAN Countries

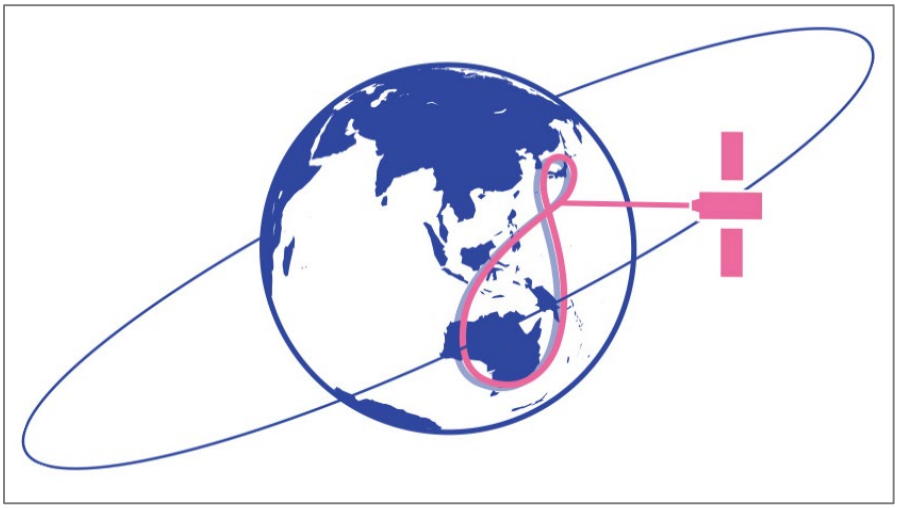
When a hazard occurs, if there are neighbouring countries, the damage will often extend beyond national borders. In the ASEAN countries, which have many neighbouring countries, it is important to provide common and appropriate hazard information promptly to protect lives and property. Therefore, a hazard information provision system using Michibiki (a Quasi-Zenith Satellite System) is currently being constructed in Japan and tested in the Asian region. Michibiki is a Japanese satellite positioning system consisting mainly of satellites in quasi-zenith orbit, and is also called the Quasi-Zenith Satellite System (QZSS). Currently, four quasi-zenith Satellites are in operation, with three additional satellites scheduled for launch from 2025.

The QZSS is a distribution service that enables high-precision positioning in cities by supplementing and augmenting positioning signals such as GPS. In terms of disaster

prevention, information on hazard risks and evacuation will be provided via personal smartphones and other devices, including messages on disaster and crisis management.

This QZSS currently has three satellites on a quasi-zenith orbit and one on a geostationary orbit, covering not only Japan but also the ASEAN countries in Southeast Asia and the Oceania region, and orbiting in a Figure 18 configuration.

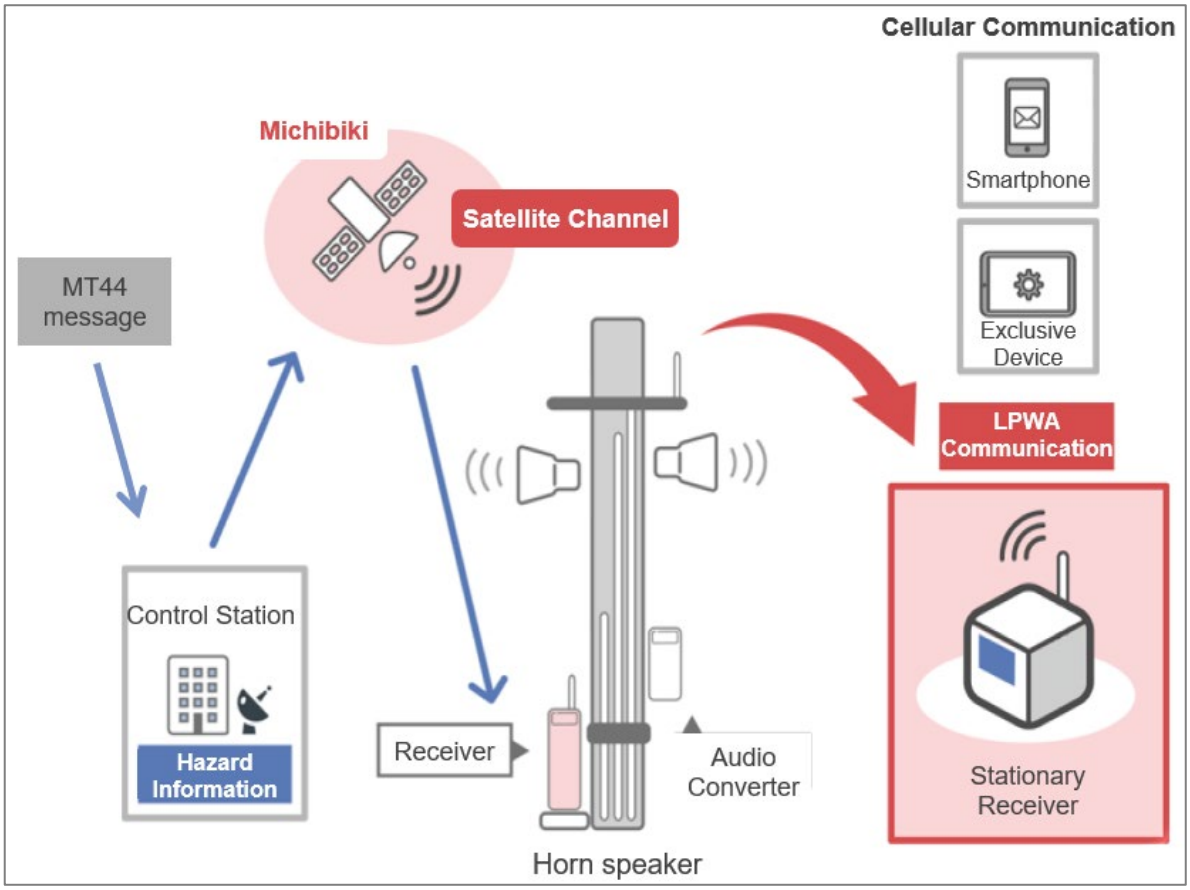
Figure 18: Michibiki's orbit covering Southeast Asia and Oceania



Source: https://qzss.go.jp/en/

Currently, the Japanese Cabinet Office, as well as universities and private companies, are conducting demonstration experiments using the QZSS in ASEAN countries and Pacific island countries. Amongst the ASEAN countries, the programme will be implemented in countries including Thailand, the Philippines, Malaysia, Indonesia, and Cambodia. By introducing this system, it is expected that hazard information will be sent to a wide range of people in the future on an equal basis, since hazard information can be acquired in the relevant countries simply by purchasing inexpensive receivers as shown in Figure 19.

Figure 19: Configuration of an Early Warning System Using the Quasi-Zenith Satellite System



Source: Authors.

4. Comparison of Good Practices in ASEAN Countries and Japan, and Suggestions

As mentioned above, the importance of 'Investment in Disaster Risk Reduction (DRR)' has been proposed in the field of disaster reduction in recent years. Investment in DRR is intended to reduce damage in the event of a hazard by investing the budget in projects related to DRR in advance, including 'hard' measures such as earthquake-proofing of structures and 'soft' non-structural measures such as the formulation of disaster prevention plans and the implementation of disaster prevention training.

In The Sendai Framework for Disaster Risk Reduction 2015–2030, an international DRR guideline adopted as an official document at the Third UN World Conference on Disaster Risk Reduction in 2015, the necessity of investment in DRR is described in Priority 3 (Investing in disaster risk reduction for resilience). In addition, paragraph 29 under Priority 3 states that, 'Public and private investment in disaster risk prevention and reduction through

structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and reduce losses and ensure effective recovery and rehabilitation.

Furthermore, the importance of investment in DRR is also described in the AADMER Work Programme 2021–2025, an official document on DRR for ASEAN countries adopted at the 8th ASEAN Ministerial Meeting on Disaster Management (AMMDM) held in 2020. Priority Programme 2 (Prevention and Mitigation) of this document states that 'Investments in prevention and mitigation before emergencies have proven to substantially reduce the impacts of disasters. Moreover, prevention and mitigation strategies are also expected to reduce disaster vulnerability and protect development gains thereby reducing the socio-economic costs to ASEAN communities as well as negative impacts to the natural and built environment. To effectively implement such strategies in ASEAN, it necessitates the adoption of a multi-pronged strategic approach to strengthen disaster resilience in the community and targeted sectors in order to reduce the risk of roll-back of development gains invested into ASEAN across all ASEAN Community Pillars,' and that investment in DRR will reduce the socio-economic costs to the ASEAN community and the negative impacts on the natural and built environment. In addition, item 2 (Sustained Risk Financing and Insurance in the ASEAN) of the challenges and needs under Priority Programme 2 (Prevention and Mitigation) also describes the usefulness of risk financing and the further expansion of disaster insurance.

In this study, we compared the current status of investment in DRR between ASEAN countries and other regions such as Europe and the United States, and reviewed advanced disaster reduction initiatives in the ASEAN 5 (Malaysia, the Philippines, Thailand, Viet Nam, and Indonesia). We found that these initiatives are activities that are in compliance with the 'investment in DRR' described in the abovementioned Sendai Framework and AADMER Work Programme 2021–2025. Further scrutiny of each of the initiatives revealed that the details of the advanced disaster reduction initiatives comply with the other items defined in the abovementioned official documents.

First, in the practices from the Philippines and Viet Nam, the key words are 'early warning,' that uses ICT technology and spatial geographic information, 'information sharing with residents,' and 'cooperation with international organizations.' Regarding this, the

importance of each keyword is specified in Priority Program 1 (Risk Assessment and Monitoring), Sub-Priority 1.2 of the AADMER Work Programme 2021–2025, and it can be said that these keywords are consistent with strengthening existing disaster monitoring and early warning systems in order to protect lives and property in the event of a hazard. Paragraph 34(c) of Priority 4 of the Sendai Framework also describes the necessity of expanding 'early warning' in order 'to promote the further development of and investment in effective, nationally compatible, regional multi-hazard early warning mechanisms, where relevant, in line with the Global Framework for Climate Services, and facilitate the sharing and exchange of information across all countries.'

Next, in the practices from Thailand and Malaysia, we can see that the key words in their initiatives to counter large-scale flooding are 'hazard-resilient urban development,' 'utilization of disaster prevention technologies,' and 'public–private investment.' Sub-Priority 2.2. of Priority Programme 2 (Prevention and Mitigation) of the AADMER Work Programme 2021–2025 is precisely about 'hazard-resilient urban development' that utilises the latest disaster prevention technologies, and it can be said that these practices are consistent with this sub-priority in terms of strengthening disaster resilience based on appropriate urban planning. In addition, regarding hazard-resilient community building based on 'the utilization of disaster prevention technologies' through 'public–private investment,' Paragraph 29 of Priority 3 of the Sendai Framework states that 'Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and reduce losses and ensure effective recovery and rehabilitation.'

Finally, from Indonesia, we introduced the activities to support the housing of people vulnerable to hazards in the cities of Makassar in the southern part of South Sulawesi Province and Yogyakarta in the central part of Java. The key words in these activities are 'people vulnerable to hazards' and 'sanitation management.' Regarding these points, item 4 of the challenges and needs under Priority Programme 2 (Prevention and Mitigation) of the AADMER Work Programme 2021–2025 is entitled 'Empowering Vulnerable Groups through Community-based Disaster Risk Management (CBDRM) and Strengthened Social Protection Mechanism in Disaster,' and the purport of the activities in the Indonesian practices are in line

with this strengthening of societal structures aimed at people vulnerable to hazards. Also, Paragraph 27(d) of Priority 2 of the Sendai Framework describes the promotion of disaster reduction activities based on the effective utilisation of land and health and safety standards as being 'To encourage the establishment of necessary mechanisms and incentives to ensure high levels of compliance with the existing safety-enhancing provisions of sectoral laws and regulations, including those addressing land use and urban planning, building codes, environmental and resource management and health and safety standards, and update them, where needed, to ensure an adequate focus on disaster risk management.'

As described above, the advanced practices in the disaster reduction activities in the ASEAN 5 countries, centring on 'investment in DRR,' are in line with a wide range of items under the AADMER Work Programme 2021–2025 and the Sendai Framework, which are official international documents in the field of disaster reduction, and also show that many of the latest disaster prevention technologies are being used. When a large-scale hazard occurs, the damage may extend beyond national borders. In such cases, the prompt sharing of hazard information using the latest disaster prevention technologies can be expected to save many lives and property and limit the damage. Activities that utilise the Quasi-Zenith Satellite System (QZSS), which is the Japanese initiative introduced at the end of the section, can be expected to be deployed in ASEAN countries, as the satellites' orbits also encompass the ASEAN countries.

Table 7: Comparison of Good Practices in ASEAN Countries and Japan

	Project	Outline	Possibility of Expanding to Other ASEAN Countries
Indonesia	Nature-Based Solutions for Building Resilient Communities in Indonesia's Informal Settlements	Flood control in disaster vulnerable areas (communities). With the support of the government, the project will improve disaster preparedness in areas at high risk of disasters, as well as water supply, drainage, and sanitation during peacetime.	In Asian countries, there are still people living in areas of high disaster risk and in poor areas. The measures taken in Indonesia can serve as a model case.
Japan	Initiatives Using the Emergency Alert System and Quasi-Zenith Satellite System for DRR	A real-time disaster information provision system utilising the Quasi-Zenith Satellite (QZSS). Important information at the time of a disaster such as evacuation information is transmitted automatically and can received by users on their smartphones.	The QZSS orbit covers not only Japan but also all ASEAN countries. As each country only needs to install inexpensive receivers, there is very high potential for implementation.
Malaysia	The Stormwater Management and Road Tunnel (SMART Tunnel), a Groundbreaking Solution for Flood Management and Urban Resilience	Compatibility of stormwater management and road tunnels in Kuala Lumpur. The ability to utilise the system in normal times will help alleviate traffic congestion, which is an issue in metropolitan areas.	Flood control is a common issue amongst ASEAN countries, and rainwater management is important to maintain economic functions.
Philippines	Utilisation of Digital Innovation and Telecommunications Technologies to Strengthen Early Warning Capabilities	Facilitates sharing of early warning information using the latest communications technology. National, state, local governments, and all administrative units are able to check on appropriate precautionary measures in the event of a disaster.	There is the possibility that system know-how established at the national level could be deployed in other countries.
Thailand	Public 3D Map Database for Urban Development with Highly Accurate Flood Resilience Designs	Creation of 3D map data using vehicles and unmanned surface vessels. This information can be used to study reconstruction plans and accurate disaster prevention investments.	Effective in capital cities of ASEAN countries where urbanisation is progressing.
Viet Nam	Disaster Management and Flood Control System	A system for disaster prevention and flood control developed in cooperation with various ministries and agencies in Japan. Information is updated almost in real time and shared with related agencies and users.	Flood countermeasures are a common issue amongst ASEAN countries, and providing real-time information is effective for appropriate disaster management.

Source: Authors.

This paper reviewed initiatives related to advanced DRR technology and the state of DRR investments in the five ASEAN countries and Japan. It also found that these DRR activities are in line with the AADMER work plan.

On the other hand, there are still challenges to be overcome in order to sustain continuous investment for DRR. The first is that advanced DRR activities are still being implemented independently by each ASEAN country. To better facilitate the flow of information, cross-border information aggregation and sharing are desirable. For instance, support by an international organisation such as the AHA Centre can play an important role for this activity.

Another issue is the budget of DRR investments. In ASEAN countries, each country's approach to DRR activities differs to others in terms of budget size, disaster reduction systems, and other factors. Given that disasters can spread beyond national and regional boundaries, a common investment fund for DRR would be effective.

The last issue is recognising the importance of DRR investments. There are many personnel transfers between departments and ministries in charge of disaster management in ASEAN countries. Thus continuously ensuring an understanding of the importance of extensive DRR investments amongst staff in charge will be essential.

Japan has experienced many large-scale disasters in the past and implemented countless DRR measures. In what way are we able to contribute to the efforts being made in with ASEAN countries?

One way is to transfer DRR technologies. Utilising QZSS that was introduced in this paper is a very effective and inexpensive technology that can be implemented by countries on a budgetary basis. The next one is to run training programs for organisations involved in DRR in ASEAN countries. The aim is to ensure that they have a proper understanding of the importance of DRR investments and to strengthen measures in their respective countries. For this activity, involving other countries like Australia, China, India, Japan, the Republic of Korea, and New Zealand that have close relations with ASEAN countries would be effective.

5. Summary

In this study, we focused on 'investment in DRR,' which has been receiving attention in the field of disaster reduction in recent years, and against the backdrop of economic and population growth in ASEAN countries, we reviewed some good practices related to disaster reduction and examined their consistency with the AADMER Work Programme 2021–2025 and Sendai Framework, which are international guidelines for disaster reduction.

As a result, we found that most of the disaster reduction measures implemented in the ASEAN region, such as structural (hard) and non-structural (soft) measures, are in line with the AADMER Work Programme 2021–2025 and the Sendai Framework, thereby confirming the usefulness of 'investment in DRR'. Furthermore, many common keywords such as 'hazard information' and 'early warning' were identified in the good practices that were reviewed.

The results obtained in this study are summarised as follows.

- ✓ Population growth in the ASEAN countries has been remarkable in recent years, and the GDP of many of the countries has grown by more than 40% between 2010 to 2015.
- ✓ In terms of hazard occurrence trends in ASEAN countries, floods and storms associated with climate change account for about 71.7% of all hazards. The Philippines, Thailand, Viet Nam, and Indonesia are the countries with the most affected people.
- ✓ In recent years, the importance of disaster finance has become more prevalent in ASEAN countries, but the non-life insurance penetration rate of 1.7% is still low compared to other regions. The Southeast Asia Disaster Risk Insurance Facility (SEADRIF), which covers disaster insurance over a wide region spanning multiple countries, was established in 2018 and is being promoted as one solution to this issue.
- ✓ The advanced disaster reduction initiatives related to 'investment in DRR' in the ASEAN 5 countries that were reviewed are being effectively addressed in each country in cooperation with the relevant organisations. The activities were also found to be in line with the AADMER Work Programme 2021–2025 and the Sendai Framework, which are official international documents on disaster reduction.
- ✓ The advanced initiatives in each country were confirmed as featuring the sharing of hazard information with the keywords of 'early warning' and 'utilization of disaster prevention technologies,' as well as in hazard-resilient urban planning through 'public–private investment.'

- ✓ The rapid provision of hazard information using the Quasi-Zenith Satellite System (QZSS), which was introduced as an example of an initiative being led by Japan, is expected to help strengthen the disaster resilience of ASEAN countries.

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