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Resilient Infrastructure in Indonesia: A Way Forward*

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Executive Summary

Indonesia is in the middle of its long-term development challenge to escape the 'middle-income trap'. As often as developing countries face the same challenge, one common strategy to be implemented by the Government of Indonesia (GoI) is to develop a massive infrastructure plan across the country. Despite the ambitious development and planning of infrastructure in Indonesia, Indonesia's current state of infrastructure is under threat due to natural disasters. Natural disasters cause damage to infrastructure, which affects the infrastructure's ability to provide benefits for the society and economy. The geographical position of Indonesia and climate-related factors have raised the exposure of environmental risks and climate change to Indonesia's infrastructure. In general, the current infrastructure conditions in Indonesia are simply not resilient enough to endure future disaster and climate change risks.

Therefore, to mitigate and adapt to these risks, Indonesia should build resilient infrastructures, which are able to withstand damage or disruptions, but if affected, can be readily and cost-effectively restored (Scalingi, 2007). Indonesia has created several national-level development plans for resilient infrastructure development, such as the 2014 RAN-API, 2012 RAN-MAPI, and the 2020–2024 RPJMN that complement each other, emphasize resilient infrastructure to reduce losses due to disasters. Regionally, several districts have their own climate change adaption disaster risk reduction plan, such as Makassar City and Kupang City, that accommodate local disaster and climate risks. However, not all districts have designed their climate change adaptation disaster risk reduction plan as it is not mandatory. Moreover, the GoI has created several regulations regarding resilient infrastructure, such as Green Buildings, infrastructure in tsunami-prone areas, and building technical requirements. These plans and regulations have also been supported by several actors, both from the public and private sector.

The challenges faced to improve resiliency of infrastructure in Indonesia into three broad categories; regulatory and policy challenge, institutional challenge, and sectoral challenge:

1) Regulatory and policy's main challenge is in the enforcement of resilient infrastructure standard. Standards related to infrastructure resilience, such as the construction quality of buildings that manifests in the SNI, are already in place. However, the adoption of standards for the existing infrastructure still faces challenges due to the relative absence, to some degree, of policy incentives to enforce such standards. Furthermore, challenges in the mainstreaming of resilient infrastructure regulations or policies to regional planning also exist.
2) The institutional challenge in developing resilient infrastructure include technical and financial capacity. For technical capacity, the first issue is the limited supply of qualified human resources to support the development of resilient infrastructures. A limited supply of professionals to assist in the conduct of spatial planning, implement resiliency standards, and carry out constructions can result in an environment that is unsuitable for the development of resilient infrastructures. For the financial capacity challenge, the main issue is the high financing need required for resilient infrastructure and limited fiscal space of GoI. Thus, resilient infrastructure cannot be fully funded by the state, while at the same time, alternative financing is fairly limited.
3) Sectoral specific issues may provide challenges due to the variety of issues. The sectoral challenges include, but not limited to, transportation, energy, water management, coast, health, and industry. Sectors such as coast and energy infrastructures have issues regarding the disaster-proneness of the locations. Transportation suffers from low maintenance, causing deterioration of the infrastructures. Health-related infrastructures, in general, have not achieved resilient level standards. Whereas industrial infrastructures contribute to climate change and, at the same time, are prone to climate change-related disasters.

In general, Indonesia may learn certain lessons regarding resilient infrastructure development. The lessons include a continuous learning process in the event of disasters and research and development to improve infrastructure standards, a comprehensive approach of infrastructure development, optimizing local government coordination and contribution in resilient infrastructure development, strengthening financial tools and instruments for resilient infrastructure financing, and improving the resiliency of critical infrastructure.

JEL Classification: H54; O21; Q54; Q58; R58

Keywords

climate change — development planning — Indonesia — natural disasters — resilient infrastructure

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1. Climate and Disaster Risk and its Relevance to Infrastructure Development in Indonesia

Indonesia is in the middle of its long-term development challenge to escape the 'middle-income trap'. As often the case of developing countries facing the same challenge, one common strategy to be implemented by the Government of Indonesia (GoI) is to develop a massive infrastructure plan across the country. In the first regime of the Jokowi administration (2015–2019), GoI sets a progressive plan for infrastructure development to improve interregional connectivity, boost economic growth, and enhance national competitiveness. The government spending on infrastructure rose significantly from IDR154.6 trillion (USD13 billion) in 2014 to IDR394.1 trillion (USD27.2 billion) in 2019 or approximately multiplied by 254.9%. The budget size straightforwardly represents Indonesia's high ambition

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for infrastructure expansion which includes, among others: 3,432 km national roads, 1,852 km highways, 65 dams, 41.1 km bridges, 38,431 hectares of urban slum revitalization, 559,660 units of public housing equipped with a drinking water system, 27 seaports, and ten international airports (*CNBC Indonesia.com*, 2020).

Despite the ambitious development and planning of infrastructure in Indonesia, Indonesia's current state of infrastructure is under threat due to natural disasters. Natural disasters cause damage to infrastructure, which affects the infrastructure's ability to provide benefits for the society and economy. The geographical position of Indonesia and climate-related factors have raised the exposure of environmental risks and climate change to Indonesia's infrastructure. In the last decade, the number of disasters has increased significantly and has severely impacted Indonesia, costing USD16.8 billion in damage and affecting nearly 8 million lives (Carter et al., 2016). In general, the current infrastructure conditions in Indonesia are simply not resilient enough to endure future disaster and climate change risks.

Therefore, to mitigate and adapt to these risks, Indonesia should incorporate resiliency in its infrastructure development. Resilient infrastructure is defined as "a component, system or facility that is able to withstand damage or disruptions, but if affected, can be readily and cost-effectively restored" (Scalingi, 2007). OECD (2018) further elaborates that resilient infrastructure should anticipate, prepare to, and adapt to changing climate conditions so that this idea is integrated into every stage of infrastructure development (i.e., planning, designing, constructing, operation). OECD also points out that a climate-resilient infrastructure must be capable of withstanding or recovering rapidly if it gets affected by any forms of distractions. Asian Development Bank (2019) provided additional points to the OECD's definition that include the importance of the infrastructure to maintain essential features over a longer-term – even after natural hazards strike the infrastructure. Moreover, UNDP Green, Low-Emission, Climate-Resilient Development (Green LECRD) points out the need for an incorporated effort in an infrastructure development strategy that considers various risks from climate change. The approach adapts infrastructure decision-making into three dimensions: spatial, sectoral, and cross-cutting dimensions while encompassing several critical sectors consisting of the coasts, water, energy, transportation, agriculture and food security, and the health sector. UNDP (2011) delivers the idea of a Rubik's Cube[1] that illustrates the intersections of those three dimensions, including the sectoral dimension, and how these can influence the development of infrastructure. The approach emphasizes a holistic view that can accommodate how infrastructure's impacts and adaptation matters can fit a country's broader development model.

Building infrastructure (and other corresponding non-physical aspects, such as social and institutional) resilience in the face of increasing shocks and stresses from climate change and natural disasters should not be a secondary agenda anymore. According to Lu (2019) and World Bank (2019), building resilient infrastructure provides benefits, especially for Indonesia as one of the most disaster-prone countries in the world, which are extensive. Incorporating climate and disaster risks in building and maintaining infrastructure increases the infrastructure's lifespan and ensures more prolonged utilization, lower maintenance costs, and minimize the damage of livelihoods and welfare of citizens impacted by natural disasters. Moreover, resilient infrastructure can ensure business continuity due to minimum business disturbances in the events of disasters. The minimum disturbance caused by disaster events leads to the protection and enhancement of Indonesia and its cities' prosperity, inclusiveness, and liveability that will improve the well-being of the citizens. When people, in general, are already benefited economically, it will be easier for them to also build resilience amongst themselves to be more prepared to deal with future risks exposed by natural disasters and climate change.

However, Indonesia internally still lacks the support system for resilient infrastructure development. First, Indonesia currently lacks specific regulations and guidelines for resilient infrastructure development. Although climate change adaptation and mitigation have been incorporated in terms of national planning, the infrastructure in each sector still lacks well-defined specifications and standards. Until now, only several regulations have been created on this matter, such as green buildings (Ministry of Public Works and Public Housing (MoPH) Regulation no. 2/2015) and sustainable construction (President Regulation no. 5/2015) and more far-reaching clarification on technical specifications and climate adjustments for infrastructure development). Second, mainstreaming the concept of climate-resiliency infrastructure from national to sub-national level is still an issue in Indonesia. Due to sub-optimal political will and institutional capacity in local government, the implementation of infrastructure resiliency is sometimes not achieved. Third, limited fiscal capacity at the national and sub-national level also poses an obstacle in financing the development of infrastructure in a climate-resilient manner adequately. Lastly, the fourth issue is the enforcement of resilient infrastructure. There have been limited official documents explicitly explaining the methods and outcomes utilized for the enforcement (such as monitoring or evaluation) of the National Action Plan for Climate Change Adaption (*Rencana Aksi Nasional Adaptasi Perubahan Iklim*, RAN-API) or National Action Plan for Climate Change Mitigation and Adaptation (*Rencana Aksi Nasional Mitigasi dan Adaptasi Perubahan Iklim*, RAN-MAPI).

This paper aims to address the issue of climate and disaster risk faced by Indonesia through the development of resilient infrastructures. We begin by assessing Indonesia's disaster risk and existing implementation of resilient infrastructure in terms of planning, regulations, and key actors. We then analyze the critical issues faced by Indonesia in the provision of resilient infrastructure. By identifying these issues and bench-marking other countries, we identify the potential gaps for future policy recommendations so that infrastructures in Indonesia can be more well-prepared in facing the changing conditions related to the occurrence of disasters.

[1] Known as the Adaptation Cube, see Appendix 1 for the illustration.

2. Landscaping Indonesia's Vulnerability and Infrastructure Resilience Regulatory Framework

2.1 Indonesia's Vulnerability to Disaster and Climate Impact

The incidence of natural disasters in Indonesia has increased in the past five years, peaking in 2019 (see Figure 2.1). On average, natural disasters have led to the death of 954 people, the destruction of 120,918 houses and 4,745 public facilities every year. Indonesia is prone to natural disasters for several factors. Firstly, Indonesia is prone to geophysical disasters as it is positioned in the ring of fire, where almost 90% of worldwide earthquake events occur (Kramer, 1996). Being as much as ten times that of the US', the level of earthquakes in Indonesia is among the highest in the world (Arnold, 1986). Among the biggest of earthquake events in Indonesia happened in Bengkulu in 2000 (Mw 7.8), Aceh-Andaman in 2004 (Mw 9.2), Simeulue in 2005 (Mw 8.7), Bengkulu in 2007 (Mw 8.4 and 7.9) and Padang in September 2009 (Mw 7.6). Indonesia's position in the ring of fire also implies the risk of damage from volcanic activities. In 2018, Indonesia had 127 active volcanoes, five of which on average take turns in showing significant volcanic activities (MEMR, 2018).

Additionally, both earthquakes and volcanic activities lead to the risk of tsunami in Indonesia. Between 1600 to 2018, there have been 172 big tsunami occurrences in the country, of which 90% were due to earthquakes, 9% were due to volcanic eruptions, and 1% were due to undersea landslides (Hamzah et al., 2000). On 26 December 2004, the Aceh-Andaman earthquake generated an enormous tsunami that quickly reached Indonesia, Malaysia, Thailand, Sri Lanka, Maldives, India, Kenya, Somalia, and Tanzania, causing a total of 283.100 human fatalities (Imamura et al., 1997). Meanwhile, an example of a big volcanic tsunami event in Indonesia occurred on 27 August 1983 with the eruption of Krakatoa, which resulted in at least 36.000 fatalities (Walter et al., 2019).

Secondly, Indonesia faces significant natural hazards caused by climate change. Global climate change increasingly exacerbates the nature of climate-related disasters in Indonesia as it affects temperatures and precipitation patterns. Increasing temperature is expected to continue at 0.2–0.3 degrees Celsius per decade and is estimated to increase to 0.9–2.2 degrees Celsius by 2060s and 1.1–3.2 degrees Celsius by 2100 (Ministry of Foreign Affairs of the Netherlands, 2018). Changes in rainfall occur differently between regions, with Borneo possibly receiving 10–30% more rainfall by the rainy season of 2080, the southern islands of Java, Bali, and Nusa Tenggara having a rainfall decrease by 5–15% by 2100, and Sumatera is projected to experience both rainfall decreases and increases (Oktaviani et al., 2011).

These effects of climate change may further influence climate-related disasters such as floods, fires, extreme waves, abrasion, and drought. According to the National Agency for Disaster Management (*Badan Nasional Penanggulangan Bencana*/BNPB), the number of disasters events in Indonesia increased significantly during 2000–2010, with around 70% of those are hydro-meteorological disasters. Floods are recorded as the natural disaster with the highest amount of occurrence (BNPB, 2021). Moreover, the erratic change in meteorological phenomenon poses the risk of unprecedented natural disasters, such as the Seroja Tropical Cyclone in East Nusa Tenggara in 2021. The extent of damage caused by natural disasters may vary among regions depending on the external and internal vulnerability of the region.

Indonesia's regional vulnerability varies between its islands (Ministry of Foreign Affairs of the Netherlands, 2018). Yusuf & Francisco (2008) identified a few climate change vulnerability hotspots, such as West Java and DKI Jakarta, while Kalimantan shows the lowest climate change vulnerability in Indonesia. This finding is supported based on the number of disasters occurring in the region, with most disasters are primarily concentrated in Java and Sumatra while most damage occurs in Java and Nusa Tenggara (see Figure 2.2). Locations of hotspots also differ according to disaster types (see Appendix 2). For floods, the incidence and damage are the highest in Java and Sumatra. For landslides, the incidence and damage are the highest in Java. For tornadoes, the incidence and damage are also the highest in Java. Earthquakes are most prevalent in West Java and Nusa Tenggara, while Kalimantan has a low incidence of earthquakes (only in East and North Kalimantan). The damages sustained from earthquakes are mainly in Java and Nusa Tenggara. In the case of Volcano eruptions, Java has the highest incidence and damage in Indonesia, whereas Kalimantan, Sulawesi, and Papua have low incidence. In comparison, Tsunamis are prevalent in Sumatra and Sulawesi, while Kalimantan, Java, and Maluku have low incidences. The damage of tsunamis is mostly sustained in Sulawesi. In general, Java is a natural disaster hotspot with floods, landslides, tornadoes, earthquakes, and volcano eruptions being prevalent in the region. While the number of disasters and damage are initial measures of natural disaster vulnerability, there are unexplained mismatches between natural disaster prevalence and damage as factors such as disaster severity and region capacity to handle disaster have not been included.

A comprehensive approach to calculate disaster vulnerability has been developed in Indonesia through the natural disaster risk index, namely the Indonesia Disaster Risk Index (*Indeks Risiko Bencana Indonesia*, IRBI), which calculates the vulnerability of regions based on potential damage caused by natural disasters. The index calculates three factors: (1) Hazard; (2) Vulnerability, and; (3) Capacity, thus considering the damage extent of disasters and regional capability in the face of disaster. The hazard represents the probability of spatial, frequency, and strength of a natural disaster or phenomenon. The disasters include earthquakes, floods, flash floods, volcano eruptions, landslides, droughts, forest and land fires, and extreme waves and abrasion. Vulnerability represents socio-cultural, economic, physical, and environmental parameters that the hazards may affect, such as population density, GDRP per sector, number of housing and facilities, and forest area. Whereas the capacity analyses the region's ability to assess disaster risks, create and implement policies to prevent and mitigate disasters, and the region's ability during and after the natural disaster.

In general, the level of Indonesia's disaster risk varies

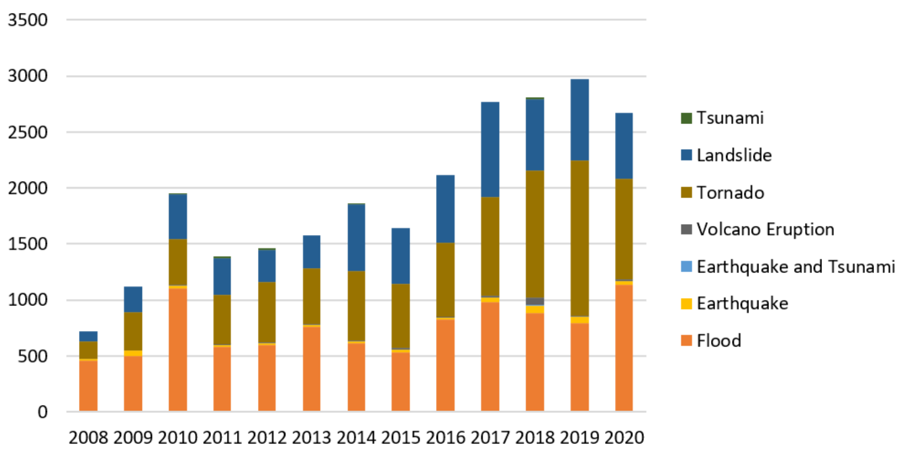

Figure 2.1. Natural Disasters Events in Indonesia 2008–2020
Source: BNPB (2021), authors' calculation

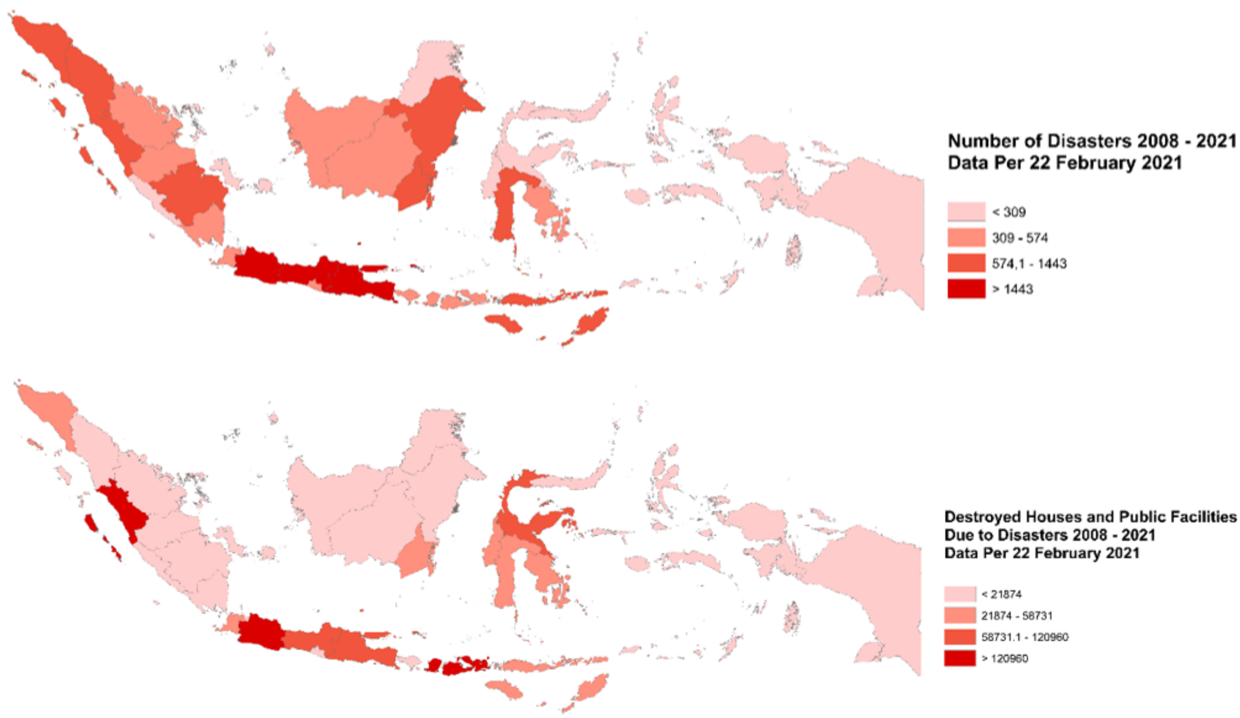

Figure 2.2. Number of Disaster and Damage from Natural Disasters 2008–2020
Source: BNPB (2021), authors' calculation

from moderate (261 districts) to high (253 districts) with no districts having low risks[2] (see Figure 2.3). The IRBI mapping shows that the majority of Sulawesi has high disaster risks, followed by Java and Sumatera. Meanwhile, Maluku and Papua have more districts with moderate risks. Moreover, the map also shows that most regions with high disaster risks are located near the sea. The high risks may be due to water-related disasters being more prevalent in these regions.

The mapping of disaster incidence and damage and IRBI may become a reference for the Government in calculating the disaster risk to plan Indonesia's infrastructure development regionally; as of now the utilization of the index has been mostly for disaster management. Between 2008–2020, 77% of natural disasters occurred in Java and Sumatra. High occurrence in these two islands entails a significant risk as 80.17% of Indonesia's 2019 GDP was contributed from the islands mentioned above. If climate change is left unmitigated, damage to these areas will be catastrophic for Indonesia's economy as a whole. Moreover, most of Indonesia's current infrastructure development is in Java and Sumatra, with more than 50% of national strategic projects built in the two regions. At the same time, the two regions are the most vulnerable to climate change which poses threats to the projects. If infrastructures being developed are not climate-resilient, Indonesia may bear high costs on climate change impacts. Thus, infrastructure construction must consider adaptation measures to face disaster risks in regional development.

2.1.1 Case 1: Floods in Greater Area of Jakarta

The Greater Jakarta Metropolitan area is home to nearly 30 million people and is Indonesia's political and economic

[2] BNPB defines the low risk region as having IRBI below 13, moderate risk is IRBI between 13–144, while high risk has IRBI higher than 144.

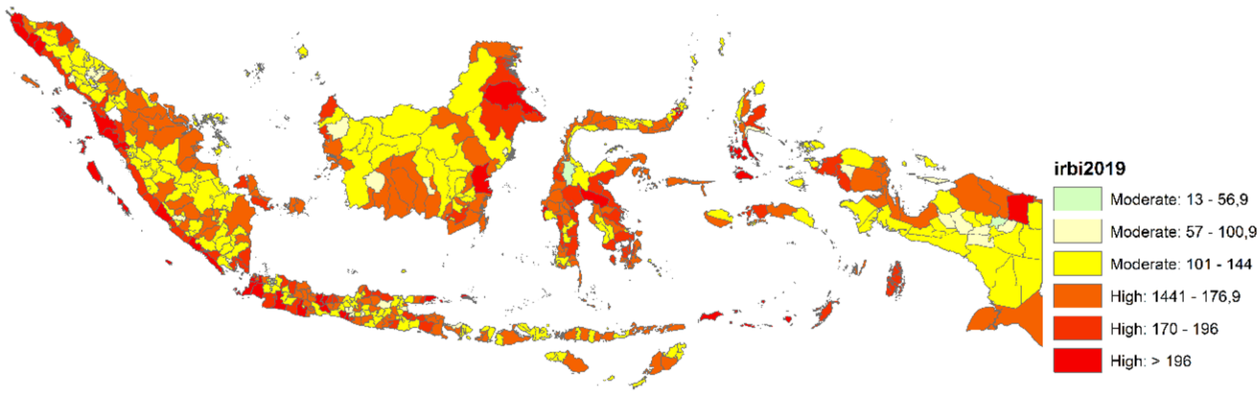

Figure 2.3. 2019 IRBI Map
Source: BNPB (2021), authors' calculation

center. The area contains the Special Capital Region Jakarta that contributes to 17% of Indonesia's GDP, the highest among all 34 provinces. Several parts of Jakarta are below sea level and the region is at risk of flooding, coastal erosion, and the threats of sea-level rise. Moreover, significant urban developments, including residential complexes, shopping malls, hotels, and industrial development, have led to increasing groundwater extraction that causes land subsidence (World Bank, 2019). Other risks contributing to the floods in Jakarta include insufficient drainage systems, poor waste management, environmental damage, and deforestation near river banks in Jakarta and Bogor (World Bank, 2016). Significant floods had occurred in Jakarta in 1996, 2002, 2007, 2013, and most recently 2020 (see Figure 2.4).

The 2007 flood in Greater Jakarta was one of the worst floods in recent years as it inundated 36% of the city. Estimating the damage to Greater Jakarta, by calculating the costs of impacts to housing, infrastructures, economy, social infrastructures, and cross-sectoral impacts, reaches up to IDR5.18–8 trillion in total, with 55% of the cost coming from the economy. The flood was estimated to reduce the economic growth of Jakarta, Bogor-Depok-Bekasi, and Tangerang by 0.59%, 1.33%, and 2.62%, respectively. The disaster also caused the death of 70 people, affected 2.6 million people, and displaced 340.000 people from their houses. On top of this, the economic losses due to loss of work and school days and health outbreaks of dengue fever and diarrhea increased the damage caused by the flood. Additionally, other large-scale flooding events in Jakarta also occurred in 2014 with an estimated cost of IDR5 trillion and in 2020 with an estimated cost of IDR960 billion despite being one of the least severe floods in the city in recent years.

The floods in Greater Jakarta have encouraged several infrastructure developments to increase resilience to climate-related disasters. The 2002 flood pushed for the construction of the East Flood Canal, which had previously experienced delays for 30 years and finally finished construction in 2010 (Octavianti & Charles, 2019). The 2007 flood had also initiated a river dredging project with the World Bank, with the GoI borrowing USD150 million. After a flood in 2013 that submerged the Central Business District, the government conducted a river canalization in a 19 kilometer stretch of Ciliwung River. Moreover, the government also launched a National Capital Integrated Coastal Development (NCICD), which included constructing a sea wall, a retention basin, and land reclamation in Jakarta Bay. Moreover, Octavianti & Charles (2019) have identified three reasons for the preferences in infrastructural approach to face the Jakarta floods: (1) high sunk costs due to decades of investment in flood mitigation infrastructure; (2) strong cultural constraints for policymakers decisions and; (3) unconscious bias to follow approaches from the colonial government to canalization projects.

2.1.2 Case 2: The 2018's Palu Earthquake-Tsunami-Liquification

Three million people currently live in Central Sulawesi, a province located in Eastern Indonesia. Central Sulawesi is categorized as a disaster-prone region. It is the location of the regencies of Banggai, Bangkep, and Parigi Moutong District, which all have a high risk of earthquakes, and Sigi, Tolitoli, Morowali, Poso District, and Palu City, which all have a moderate risk of earthquakes. The moderate earthquake risk is due to the area being located at the intersection of three tectonic plates, namely Indo-Australian, Pacific, and Eurasian plates. On September 28, 2018, an MW 7.5 earthquake occurred in Central Sulawesi, with an epicentre located about 70 km north of Palu City. Following the earthquake, soil liquefaction occurred, and an eight-meter tsunami struck the coastal areas of the regions. Thus, three major natural disasters occurred during this event (see Figure 2.5).

The National Disaster Management Agency (*Badan Nasional Penanggulangan Bencana*, BNPB) reported that the disaster caused a loss of 2200 lives and 68,000 houses. Damage in public infrastructures includes 176 health facilities and 1509 education buildings, while damage in economic infrastructures includes 13 marketplaces and 9,718 ha of agricultural land (UNDP, 2018). National Development Planning Agency (Bappenas) estimated IDR19.96 trillion in total damage caused by the disaster, with more than half coming from the housing sector, followed by the economy. Furthermore, Palu City and Sigi District bear respectively 44.9% and 37.3% of the total damage.

In 2018, Bappenas released the concept of "Build Back Better, Safer, and Sustainable for Resilient Indonesia" as

Figure 2.4. The 2020 Jakarta Floods
Source: *Arabnews.com* (2020)

Figure 2.5. The Aftermath of the 2018 Palu Earthquake-Tsunami-Liquification
Source: UNHCR Hong Kong (2018)

the basis of the reconstruction and rehabilitation efforts of Palu and other areas affected by the disaster to be resilient in events of future disasters. These constructions include creating houses and basic infrastructure to be earthquake, tsunami, and liquefaction-resilient, construction of basin and normalization of rivers, and also considering the spatial disaster risk in the reconstruction of Palu City and affected areas (Bappenas, 2018; MoPH, 2019). The tsunami in Palu also led to the construction of a seawall at Palu Bay to mitigate future tsunami events.

2.1.3 Case 3: The 2021's Seroja Tropical Cyclone in East Nusa Tenggara

East Nusa Tenggara is a province located in Central Indonesia and inhabited by a population of five million. East Nusa Tenggara, in general, is considered a region of moderate disaster risk with typical disasters include earthquakes, tsunamis, floods, and. Regionally, 11 out of the 21 districts in East Nusa Tenggara have high disaster risks, with Kabupaten Kupang possessing the highest risk, followed by Kabupaten Alor and Timor Tengah Selatan with the districts mentioned above being located in the eastern region of East Nusa Tenggara. In 2021, East Nusa Tenggara was hit by a tropical cyclone named Seroja and was considered the second most robust cyclone to hit East Nusa Tenggara after Kenanga Tropical Cyclone. Tropical cyclone events have been increasing in the last few years; however, a tropical cyclone at a scale of Seroja that impacted more than half of the districts in East Nusa Tenggara was relatively unprecedented.

The Seroja tropical cyclone, as of 15 April 2021, had caused casualties of 181 people, injured 258 people, and resulted in 47 gone missing (*Media Indonesia.com*, 2021). The disaster affected 122.232 households, equivalent to 428.986 people (nearly 10% of the population). Moreover, the disaster caused damage to physical assets, including more than 66.000 houses (17,124 units heavily damaged, 13,652 units moderately damaged, and 35.733 units lightly damaged) and 62,543 public facilities. The disaster also caused extreme weather in the area post-disaster, such as heavy rain and wind, to delays recovery efforts and posed the threat of another disaster (floods or landslides) to occur. Climate change has caused the increase of disasters that are correlated with extreme weather. As climate change continues, the number and the probability of climate-related and unprecedented disasters will increase. Given the possible condition, the GoI must incorporate considerations of climate risk in future infrastructure development.

2.2 Resilient Infrastructure Development Planning

2.2.1 National Development Planning

Indonesia has created several development planning that accommodates the disaster and climate risk faced by the country and infrastructure resilience. Those documents include the MoPH's National Action Plan for Climate Change Mitigation and Adaptation (*Rencana Aksi Nasional Mitigasi dan Adaptasi Perubahan Iklim*, RAN-MAPI), Bappenas 2014–2025 National Action Plan for Climate Change Adaptation (*Rencana Aksi Nasional Adaptasi Perubahan Iklim*, RAN-API), and 2020–2024 National Medium-Term Development Plan IV (*Rencana Pembangunan Jangka Menengah Nasional IV*, RPJMN IV). In general, these planning documents are in line to increase infrastructure resiliency and complement each other priority sectors (see Table 2.1).

The RAN-MAPI, which was established in 2012, elaborates explicitly on the four main sectors handled by MoPH in climate change adaptation efforts: water facilities, roads and bridges, engineering, and spatial planning. One of the targets in the roads and bridges sector, for example, covers the building of green property space as well as the supervision of national and regional roads that abide by safety and structural resilience principles. Another document, the RAN-API, established by Bappenas as a continuation of the 2009 Indonesia Climate Change Sectoral Roadmap (ICCSR), prioritizes four sectors: marine and coastal sector, water sector, agriculture sector, and health sector.

RAN-API selects the sector based on hazard assessments – with additional considerations made by involving the approach that is sensitive to gender, vulnerable groups, ecosystem, and financial mechanism. Regarding infrastructures, the planning aims to increase the resilience of vital infrastructures related to the four sectors so that the infrastructures will be ready to face various risks from climate change. The indicators used to mark the target differ according to the sectors. For example, in water sectors, the indicator used is the number of enhanced vital infrastructure around the river basins, especially in climate risk areas. As for the marine and coastal sectors, one of the indicators is the length of sea walls and other coastal protection structures constructed or upgraded in kilometers (km). These indicators are checked and evaluated by comparing the baseline condition with the condition in target years – so far being 2020 and 2024.

As for RPJMN IV, the document already defines the strengthening of infrastructure as well as disaster and climate resilience enhancement as two of its main development agendas. It then becomes an essential stage in the 2005–2025 National Long-Term Development Plan (*Rencana Pembangunan Jangka Panjang Nasional*, RPJPN) as it is the last stage that will affect the long-term plan's development targets – with the primary one being reaching a level of per capita income equivalent to upper-middle-income countries. The narratives in RPJMN IV that relate to infrastructure resilience towards climate change and disasters are explained directly in two of the seven development agendas, which are agenda number six and seven that are stated as "Strengthening Infrastructure to Support Economic Development and Basic Services" and "Building the Environment, Improving Disaster Resilience, and Climate Change", respectively.

In agenda number six, infrastructure development is prioritized to three focal points covering the infrastructure for Equitable Development, Economic Development, and Urban Development. The three focal points are sustained with the idea of mainstreaming the prioritization of disaster resilience. For example, to achieve the three focuses by improving basic service infrastructure in the form of decent, safe, and affordable housing, one of the approaches in this strategy includes enabling the environmental aspect, which strengthens the building standard and order becomes essential. Although, in this case, the standard as mentioned above is still not explained in detail further, this could lay sub-

Figure 2.6. The Aftermath of 2021 Seroja Tropical Cyclone
Source: *Tempo.co* (2021)

Table 2.1. Summary of National Development Planning Documents on Infrastructure Resilience

National Development Planning	Infrastructure-related Objectives	Priority Sectors/Agenda
National Action Plan for Climate Change Mitigation and Adaptation (*Rencana Aksi Nasional Mitigasi dan Adaptasi Perubahan Iklim*, RAN-MAPI)	Realizing public infrastructure development and spatial planning that are responsive to climate change	Water facilities, roads and bridges, engineering, and spatial planning
2014–2025 National Action Plan for Climate Change Adaptation (*Rencana Aksi Nasional Adaptasi Perubahan Iklim*, RAN-API)	Increasing resilience of vital infrastructures that are related to the priority sectors to face various risks from climate change	Marine and coastal sector, water sector, agriculture sector, and health sector
2020–2024 National Medium-Term Development Plan IV (*Rencana Pembangunan Jangka Menengah Nasional IV*, RPJMN IV)	Reducing the ratio of economic losses due to the impact of disasters and climate hazards by 0.3% to GDP in 2024	Strengthening infrastructure to support economic development and basic services (agenda no. 6) and Building the environment, improving disaster resilience, and climate change (agenda no. 7)

Source: Ministry of National Development Planning/Bappenas (2014,2020) & MoPH (2016))

stantial progress in taking into account the aspect of public housing resilience in Indonesia's infrastructure development agenda.

Furthermore, agenda number seven emphasizes the aspect of increasing disaster-and-climate resilience as a national priority due to high disaster risk coupled with the effects from climate change that Indonesia is exposed to. This priority is expected to anticipate and mitigate future greater loss and damage due to worsening disaster occurrences. The specific objective that RPJMN IV is trying to achieve, in this case, is to reduce the ratio of economic losses due to the impact of disasters and climate hazards by 0.3% of GDP in 2024. The strategies to achieve this objective are grouped into two categories, namely (1) disaster management (e.g., improvement of disaster-resilient infrastructure, rehabilitation, and reconstruction of disaster-affected areas, etc.) and (2) increasing climate resilience in four priority sectors according to RAN-API, which are marine and coastal, agriculture, water, and health sectors.

The RPJMN IV also covers other aspects related to funding to strengthen the implementation of the Money Follows Program. One of the strategic elements in the Money Follows Program that the RPJMN IV aims to enhance is in terms of expanding funding capacity as the current role of the Government in funding the development of most public utilities is still overrepresented[3]. At the same time, an estimate shows that Government funding can only cover about 20–25% of all development needs in the future. Thus, it is expected that greater involvement from non-government actors, such as State-Owned Enterprises (SOEs), community, and private sectors, can help to smoothen the infrastructure development through shared involvement between all stakeholders in the funding mechanism.

[3]See Appendix 3 for comparison between funding in Indonesia and Benchmark Countries in several sectors.

2.2.2 Regional Development Planning

Local governments in Indonesia have the authority to formulate their action plan that adapts to local conditions, risk, and vulnerability exposed by natural disasters and climate change at the regional level. With that in mind, these local-level planning documents are still different from the documents at the national level as they incorporate regional-specific characteristics. The similarity with the national-level documents, on the other hand, can be seen from the general objective of both documents, which is to enhance the resiliency of its region and people in dealing with disasters that are especially induced by climate change. Given the public availability and accessibility of both documents, Makassar City, South Sulawesi, and Kupang City, East Nusa Tenggara serve as examples of some existing local action plans in Indonesia to the rest of this subsection.

Makassar City's Regional Action Plan for Climate Change Adaptation Disaster Risk Reduction (*Rencana Aksi Daerah untuk Adaptasi Perubahan Iklim dan Pengurangan Risiko Bencana*, RAD API-PRB) has the vision of "A pleasant city of Makassar through vulnerability reduction and adaptation to climate change". This vision has two main concepts, which are a city that has "pleasant" condition and also "resilient". In the resiliency aspect, Makassar City tries to integrate a broad spectrum that covers the ability to understand the risks of climate-induced disasters, prevent the occurrences, as well as respond to the disasters so that the negative impacts on city life are minimized.

One of the strategies that Makassar City will go through to achieve this objective is improving its infrastructure and public services quality. Mentioning infrastructures through this plan, Makassar City is encouraged to acknowledge the vulnerabilities of its infrastructures, especially those in urban areas, because Makassar City has seen a growing urban population due to rapid urbanization rate that results in more pressures on suburban areas. In handling this issue, Makassar City has a related program of arranging canal areas to reduce the risk of flooding in residential areas along the canal. They also focus on vulnerable groups, such as the poor, by improving the resilience of urban poor to climate change vulnerability as their priority. Furthermore, Makassar City puts the greatest importance on post-disaster treatments by emphasizing the need to recover and rehabilitate infrastructures and social institutions in an accelerated manner. Another main issue in the infrastructure aspect highlighted in Makassar City's RAD API-PRB is the lack of infrastructure in vulnerable locations. To cope with this drawback, Makassar City establishes some Emergency Centers in disaster-prone areas to prepare better in the events of natural disasters or other climate-induced disasters. In addition, it also becomes essential for Makassar City to strengthen people's access to basic infrastructure services as an alternative way to increase its resilience.

As for Kupang City, its RAD API-PRB asserts more on improving the infrastructure resiliency that is more responsive to the most susceptible groups (such as the poor). In this case, Kupang City sees those groups as the most vulnerable ones to any kinds of disasters; hence, special attention is needed to be made towards them at each program that aims to increase the infrastructures' resilience. Several pressing issues surrounding disasters related to infrastructure development in the city of Kupang are flooding and drought. In the presence of climate change, these issues intensify and considerably threaten the well-being of citizens. Responding to the issues, Kupang City's RAD API-PRB has arranged some programs that could anticipate these occurrences, such as the development of polder and imbuing systems as well as the construction and normalization of urban drainage channels to reduce the risk of flooding. On top of that, the development of new facilities to source raw water to help support the needs of clean water during the dry season, especially for poor people who are more vulnerable to the condition, also acts as an effort to reduce the vulnerabilities of the people and the infrastructures in facing future increasing threats from climate change.

2.3 Regulatory Framework

In realizing the development of disaster- and climate-resilient infrastructures, Indonesia has established several supporting regulations to bolster the progress to achieve this agenda (see Table 2.2). The regulations are provided mainly by the MoPH, the ministry that implements infrastructure-related policies, as MoPH regulations. These regulations provide guidelines and standards for buildings to be disaster-proof (e.g., tsunamis) or buildings that accommodate green aspects to uphold environmental conservation and reduce climate change impact of infrastructure development.

2.4 Institutional Set-Up

2.4.1 Public Institutions

There are several central governmental or ministerial bodies whose work is vital to the issue of infrastructure resilience in Indonesia. MoPH is in charge of general infrastructure development, including sectors such as connectivity (toll roads, highways, national roads, bridges, etc.), water (dams, embankment, reservoirs, sanitation facilities, etc.), housing and settlements, including waste infrastructure, social infrastructure (education, sports, market, shopping centers, tourism), and lastly industrial complexes. MoPH creates policies and implements public works on infrastructure, including construction, regulation, management, implementation, guidance, and coordination. Given its direct relation to infrastructure, the work of MoPH is highly influential to the development and maintenance of resilient infrastructure in Indonesia. Additionally, some sectoral ministries also hold a stake in the quality of public infrastructures, which intersect with the work of MoPH itself. The ministries include the Ministry of Transportation, which manages public facilities such as airports, railway systems, and seaports, and sectoral bodies such as the Ministry of Energy and Mineral Resources (MEMR) and energy companies such as the National Electricity Company and the National Gas Company that manages energy infrastructure facilities. The National Standardization Agency designs and updates the national standards for infrastructure construction and disaster resiliency following international guidelines.

Bappenas serves the role of leading infrastructure planning. Bappenas formulates the long-term 20-years and medium-term 5-years National Planning Document and the National Action Plan for Climate Change Adaptation. Infrastructure development is a central issue in the current National Planning Document, while the National Action Plan

Table 2.2. Regulatory Framework of Climate-and-Disaster Resilient Infrastructure

No.	Regulation	Key Points	Implications
1.	Regulation of the Minister of Public Works and Public Housing No. 02/PRT/M/2015 regarding Green Buildings	• This regulation acts as a guideline to the conduct of green building operations	The concept of green buildings sustains the idea of disaster- and climate-resilient infrastructures since it includes the aspects of disaster and climate change mitigation that is manifested at each different stage of operations. In this regard, the mitigation aspects comprise the authorization of proper building functioning and also building maintenance and periodic inspections.
		• Includes the principles of green buildings, in which among those, it upholds the concept of sustainability, resource efficiency, environment conservation, waste management, and risk mitigation against disasters and climate change	
		• This regulation categorizes different buildings that are subject to green building requirements according to their respective category (e.g., mandatory, recommended, and voluntary) ○ The determinations of the category are based on: the height of the building, energy consumption, and other urgent considerations by the local government • The requirements for green buildings are applicable at every stage of building operation, namely (1) the programming, (2) technical planning, (3) construction, (4) utilization, and (5) dismantling stage	Moreover, the adoption of a green approach will also allow the buildings to adapt to the growing concerns toward water and energy conservation that relate directly to the issues surrounding climate change.
2.	Regulation of the Minister of Public Works and Public Housing No. 06/PRT/M/2009 regarding Guidelines on General Planning for Infrastructure Development in Tsunami Prone Areas	• The scope of this regulation contains, but is not limited to: Procedures for avoiding new developments in tsunami-prone areas, planning and construction of new buildings to reduce the impact of tsunamis, mitigating infrastructure structures against tsunami disasters by rebuilding and land-use planning, etc.	This regulation emphasizes the need to focus on infrastructure resilience in disaster-prone areas by highlighting specific aspects that are unique to the type of disaster associated with the location.
3.	Regulation of the Minister of Public Works and Public Housing No. 06/PRT/M/2007 regarding General Guidelines for Building and Environmental Planning (GBEP)	• One of the principles in the structuring of a building is to take into consideration the environmental aspect by addressing the issue of balance with the carrying capacity of the environment. In this case, in a land that is prone to natural disasters, the building density must be strictly controlled (up to 0 unit per hectare, if necessary) • In terms of the physical aspect, it is also required that the physical quality of the building design can meet user's comfort by taking into account local climate/weather	To minimize the loss from disasters or any climate-related occurrences, infrastructures must abide by the carrying capacity of the environment as well as climate characteristics of an area, so that these can adapt to the changing situations well.
4.	Regulation of the Minister of Public Works and Public Housing No. 29/PRT/M/2006 regarding Guidelines on Technical Requirements for Buildings	• One of the requirements needed to be fulfilled in constructing a building is to have the ease of connection to, from, and inside the building as well as the completeness of the building facilities, including in the event of disasters, to have a hazard warning system, emergency exits, and evacuation routes.	Basic non-structural infrastructure requirements (i.e., evacuation systems) should be integrated into a resilient framework to take into account unprecedented occurrences resulting from both disasters and climate change.

Source: MoPH (2006,2007,2009,2015)

for Climate Change Adaptation addresses the root cause of the increasing threat of climate change to infrastructures. Climate change, additionally, is also mainly addressed by the General Directorate of Climate Change Management (*Direktorat Jenderal Pengendalian Perubahan Iklim*) under the Ministry of Environment and Forestry. In terms of financing, the Ministry of Finance also has a specific directorate called the Center for Climate Change and Multilateral Policy Financing.

Another governmental institution that holds a significant role in the issue of infrastructure resilience is the Ministry of Agrarian Affairs and Spatial Planning, which covers the role of spatial planning along with Bappenas. Spatial planning is vital to infrastructure resilience as the development of infrastructures should consider the spatial risks associated with the area of development and land uses may also further affect the climate and disaster risks associated with threats to infrastructure resilience. The BNPB holds the responsibility for disaster risk and prevention tactics. BNPB organizes and coordinates early actions, which may keep the operational resilience of infrastructures and rehabilitation after disaster onsets, of which resilience aspect is important to incorporate. Additionally, the Meteorology, Climatology, and Geophysical Agency (*Badan Meteorologi, Klimatologi, Geofisika*, BMKG) also holds importance in supporting infrastructure resilience. BMKG monitors several climates, meteorology, and geophysical indicators that are useful in informing disaster risk and creating early warning systems.

As Indonesia applies a decentralization system, provincial and municipal governments also juristically have control over the development of infrastructures in their region. This level of autonomy applies up to the sub-district level (*Kecamatan*), where permits to build and certification requirements are filed. Aside from the main Governor's Office, which includes the Regional Secretariat (*Sekretaris Daerah*), related regional offices include the Department of Public Works (*Dinas Bina Marga/Pekerjaan Umum*), the Department of Public Housing and Settlement (*Dinas Perumahan Rakyat dan Permukiman*), the Department of Labor Work, Spatial, and Land Services (*Dinas Cipta Karya, Tata Ruang, dan Pertanahan*), the Department of Water Resources (*Dinas Sumber Daya Air*), and the Department of Food Security, Marine, and Agriculture (*Dinas Ketahanan Pangan, Perikanan, dan Pertanian*). Regional representation of national bodies involved in resilient infrastructure is the Regional Development and Planning Agency (*Badan Perencanaan Pembangunan Daerah*, Bappeda) and the Regional Disaster Management Agency (*Badan Penanggulangan Bencana Daerah*, BPBD).

2.4.2 Private Institutions and General Public

There are three main categories of actors related to infrastructure and its resilience aspect in the private and public-private sectors. First, financing actors that provide funds in the development of infrastructures. Examples of actors in this category include Indonesia Infrastructure Finance (PT. IIF), Sarana Multi Infrastruktur (PT. SMI), and Indonesia Infrastructure Guarantee Fund (IIGF/*Penjaminan Infrastruktur Indonesia*, PT. PII). Provincial development banks (*Bank Pembangunan Daerah*) also provide infrastructure financing, especially for regional governments. In some cases, private banks may also provide loans to build infrastructure, especially for housing settlements and property development. Financing actors can have a degree of influence over the resilience of infrastructures as they can require fund-recipient developers to maintain infrastructure standards that ensure resilience. The second category is the firms that possess the technicalities to build infrastructures. In regards to construction firms, there is a multitude of private and public partnership companies. Some examples include PT. Wijaya Karya, PT. Waskita Karya, PT. Adhi Karya, PT. Pembangunan Perumahan for public partnership companies, and PT. Agung Podomoro, PT. Jaya Property, PT. Pakuwon Jati, PT. Lippo Karawaci, for private housing and construction. Energy infrastructures, aside from those owned by the state, can be built privately, especially in upstream businesses. Examples of this are energy infrastructures that are controlled by energy companies such as PT. Adaro Energy, PT. Elnusa, PT. Medco Energi Internasional, PT. Bukit Asam. Last but not least, in the non-public sector are the consumers and general public, such as labors, buyers, investors, and workers. Independent housing settlements are quite widespread in Indonesia because most people cannot afford an architect, designer, spatial planner. As a result, many residential and independently-build buildings are built on any available lands with limited regard to resilience standards and considerations. Education and socialization at the grassroots level are critical to ensure the regulations prepared can be implemented. Without proper enforcement of the specified standards, infrastructure development will remain stagnant, unable to build resilience in the coming years.

3. Resilient Infrastructure in Indonesia: Key Challenges

Despite the progressive set-up of the GoI in terms of national and regional planning, regulatory frameworks, and institutions, Indonesia is still facing several challenges in building resilient infrastructure. This chapter generally describes these challenges starting from the suboptimal implementation of regulations and policies, continued by the limited capacity of institutions, both technically and financially. In the last part, this chapter will also dig deeper into some of the challenges faced by several sectors in building resilient infrastructure, based on Indonesia's Climate Change Sectoral Roadmap.

3.1 Regulatory and Policy Challenge

Indonesia already has several regulations and policies that address resilient infrastructure development. Firstly, standards related to infrastructure resilience, such as the construction quality of buildings which manifests in the Indonesian National Standard (*Standar Nasional Indonesia*/SNI), are already in place. In the last five years, updates on the standards have considerably taken place and include aspects of qualities that are adopted in developed countries. Secondly, spatial planning has been carried out under the responsibility of the Ministry of Agrarian Affairs and Spatial Planning and its subordinating regional-level bodies. Indonesia's spatial planning, in practice, already includes considerations of potential disruption risks due to disasters to a given geographical area.

However, adoption of the already existing infrastructure standards still faces challenges due to the relative absence, to some degree, of policy incentives to enforce such standards. Implementing resiliency standards to infrastructure projects produces cost increases, making developing resilient infrastructures less attractive financially from developers' perspectives, albeit the potential savings from reduced damage in the long run. With many policy incentives for government-related infrastructure projects, including public-private partnership (PPP) schemes, policy incentives to apply the standards to projects that are independent and smaller in scale are still limited. The lack of policy incentives to adopt resilient standards in infrastructure development leads to developers' hesitancy to adopt the standards as there is no means of offsetting the increasing financial cost implications.

Furthermore, challenges in the mainstreaming of resilient infrastructure regulations or policies also exist. Through the practice of decentralization law in Indonesia, both central and regional governments contribute to developing infrastructures in the country. It is often the case that the development planning of the central government does not align with regional development priorities. While the Government of Indonesia has planned the development of resilient infrastructures through RAN-API, not all regions across the country have RAD-API (Regional Action Plan for Climate Change Adaptation). Additionally, the emphasis on climate budget tagging still only presents at the national level, with only a few regions have climate action budget tags.

The next challenge is related to the current conduct of spatial planning, which has considerable key potential improvement areas. Although spatial planning in practice includes the risk of climate and disasters, spatial planning in Indonesia needs to also consider the possible environmental services – benefits that environmental spatial uses can provide – which may potentially also protect infrastructures from climate and disaster risks. Additionally, as spatial planning is conducted in part by regional-level governments, the degree of how much climate and disaster risks and environmental services influence spatial planning can differ between regional entities (provinces, districts, cities). A mechanism to ensure standardized assessments of these aspects are needed.

3.2 Institutional Challenge

3.2.1 Technical Capacity

There are two main challenges in the aspect of institutional technical capacities. The first issue is the limited supply of qualified human resources to support the development of resilient infrastructures. The issue is especially relevant to the case of regional governments and small and individual developers. It can hamper the ability of some regional governments to develop resilient infrastructures. A limited supply of professionals to assist in the conduct of spatial planning, implement resiliency standards, and carry out constructions can result in an environment that is unsuitable for the development of resilient infrastructures. In the case of small and individual developers, the lack of know-how also results in the development of infrastructures that are less resilient. In some cases, small and individual developers are not familiar with the application of resiliency standards and the consideration of climate and disaster risks.

The second issue is related to the capacity challenges in ensuring regulatory investment and transparent infrastructure project management. In terms of standards and guidelines, Indonesia has already applied the SNI for construction standards. Among them, several standards were explicitly made to mitigate disasters, such as SNI 1726: 2019 regarding procedures for planning earthquake resistance for building and non-building structures and SNI 2833: 2016 regarding bridge planning against earthquake loads. While regulations in the form of compulsory requirements of resiliency standards are in place, there are still issues in enforcing the regulations that render them ineffective.

For example, compliance with SNI is only implemented on certain types of infrastructure. Some of the infrastructures that are required to meet SNI standards are government buildings or major infrastructures such as bridges and main roads, most of which are planned by the government. Tall buildings in big cities also usually apply SNI for earthquake-resistant up to 7.5 SR. In addition to standard implementation, usually, such infrastructures have technicians who supervise their condition and conduct regular maintenance. The remaining infrastructure developments, such as private buildings, private infrastructures, and housing, are not bound by vigorous enforcement to implement SNI. Although this type of infrastructure also requires a permit from the local government, the implementation of these permits does not have strict enforcement and supervision. Many of the infrastructures already have permits but still do not meet the standards due to weak supervision. In fact, there are still many infrastructures that do not have permits.

Lack of standard fulfillment could happen because the application of infrastructure standards has not been explicitly regulated in the legislation. Buildings that have not implemented SNI are not bound by sanctions. Supervision of standards for private infrastructure is also still decentralized within local governments, so enforcement tends to vary according to local government capacities. Moreover, implementing infrastructure standards is still not optimal due to the lack of public awareness of the importance of resilient infrastructure. As a result, there is still no pressure from the community to implement resilient infrastructure development.

Lack of community pressures highly relates to moral hazards in regulatory enforcement, which allow parties to illegally be in-compliant with regulations. Additionally, less transparent management of infrastructure projects can contribute to this and other problems that can lead to a supposedly resilient development of infrastructure projects become sub-optimal. Disaster risks may become overlooked in determining the location of infrastructure development and not in line with spatial assessment and planning, which increases the proneness of infrastructure to climate and disaster risks. While this second issue may happen in almost all governmental entities, such regulatory and transparency enforcement can be easier to take place in an environment with less scrutiny. Possible settings that can be prone to this condition are at regional-level infrastructure development.

3.2.2 Financial Capacity

There has been no formal document so far that estimates Indonesia's financing needs specifically for climate- and disaster-resilient infrastructure. However, the value can be approximated using the financing need to fulfil the strategic plan of the MoPH for 2030.

Table 3.1 shows the total funding required to finance the plan reaching up to IDR3.651 trillion. Assuming that the estimated needs are based on business-as-usual (BaU) conditions, these values are then added with 3% of the investment value to incorporate the additional costs required to build resilience into infrastructure as estimated by Hallegatte et al. (2019). With this assumption, the total cost needed to realize the MoPH vision is IDR3,760.53 trillion.

Given the high financing needs and limited fiscal space, not all of the state's budget requirements will be funded. The MoPH estimates that around IDR390 trillion (or 46.54%) of the required funds for road and bridge construction and IDR854–996 trillion (or 20–30%) of the required housing development funds require private investment. Meanwhile, the state and regional budget will fully finance the financing

Table 3.1. MoPH Vision for 2030

Focus	Targets	Financing Needs in BaU Scenario (Trillion IDR)
Water Resources	Multi-function dam with a capacity of 120m3/capita/year.	1,423
Roads and Bridges	• 99% steady road • Toll road 2,000km • New road 3,000km • New bridge / flyover 70,000m	838
Human Settlement	• 100% drinking water service • 100% sanitation services • Reducing the area of urban slum settlements 4.4% (to 0 ha)	170
Housing	The housing backlog for low-income people at 3 million units, achieved through the construction of 4.88 million housing units	1220
Total		3,651

Source: MoPH's Strategic Plan 2020–2024 (2020). Modified

of water resources infrastructure and human settlement. In total, IDR1,244–1,386 trillion (or 34–37%) of the required funds for infrastructure development will be financed from the private sector. This figure can still increase if the resilience aspect has been incorporated into the infrastructure development plan. In order to meet such enormous financing needs, the GoI needs to explore various alternative financing and create a favorable investment climate to attract private investors.

BOX: Jakarta's Mass Rapid Transit System

In recent years, new development projects have been more attentive to the resiliency issue against disaster and climate change. Among them is Jakarta's Mass Rapid Transit (MRT) System, whose first leg started operating in March 2019 after an extensive partnership with Japan International Coordination Agency (JICA).

The design of the MRT considered flood data from the last 200 years. The gates of underground stations are equipped with stairs and flat flood barriers to stop water from getting in, which is vital owing to the below-river location of the stations. There are water pumps in underground station entrances coupled with runoff passages or water traps to the city drainage (*BeritaSatu.com*, 2021). Furthermore, the MRT's Operation Control Center (OCC) in its depot station of Lebak Bulus is in constant sync with the flood detection meters in Jakarta's West Flood Canal and Krukut river. When the water rises above the normal level, the MRT system is prepared to handle the worst scenario possible. Working together with the Provincial Government of Jakarta, Jakarta's MRT Company also ensures the drainage system around the station stays clean and well functioned (*AntaraNews.com*, 2020). Sealers are in place around the 1-meter-thick underground tunnels to prevent water from seeping in the cracks between wall panels. Meanwhile, stations and segments between tunnels have waterproofing membranes (Rachman, 2018). Additionally, the MRT is ready to handle earthquakes through a Standard Operational Procedure to stop trains when a shock ensues. MRT construction follows the 2012 SNI No.1726, which entails construction to withstand earthquakes up to 8.7 SR. It is a growth from the 2002 standard of 7 SR, but it made for an additional 2,56 trillion IDR in construction costs. However, the investment in resistance design is supposed to last earthquakes for another hundred years to come (*Kompas.com*, 2016). Jakarta's MRT has proven itself to be able to put up with natural disasters. In the 2020 Flood, MRT operations remain intact without any function being suspended, despite having 6km of the underground railway. Meanwhile, when the 2019 Banten Earthquake happens, MRT trains immediately halted for 10 minutes and 43 seconds after the OCC detected an earthquake through its sensors. It resumed once the shock subsided, and OCC immediately scoured the station for any casualties or physical impacts, none of which was fortunately found (*Suara.com*, 2019). With multiple key projects upcoming on the Middle Term National Plan, such as TransSumatera highways, Java speed trains, integrated main port network, the GoI must ensure that they all follow the same standard MRT construction did to ensure the trillion rupiahs of investment do not go to waste.

3.3 Sectoral Challenges

Adapted from the UNDP Dimension with modifications based on Indonesia's Climate Change Sectoral Roadmap, the six main sectors for infrastructure development to be considered are transportation, energy, water management, coast, health, and industry. In general, climate change can have an impact on changing temperatures, rising sea levels, variations in disaster patterns, and extreme weathers, such as heatwaves, droughts, and heavy rainstorms. However, the form and severity of impact on each sector will be different. Hence, there will be different challenges to overcome.

3.3.1 Transportation

There are several problems from the deteriorating climate quality for the transportation sector. For land-based transportation, higher temperatures make roads soften and expand, which creates rutting and potholes. Rail tracks, especially those made from metals, will stretch and buckle, while

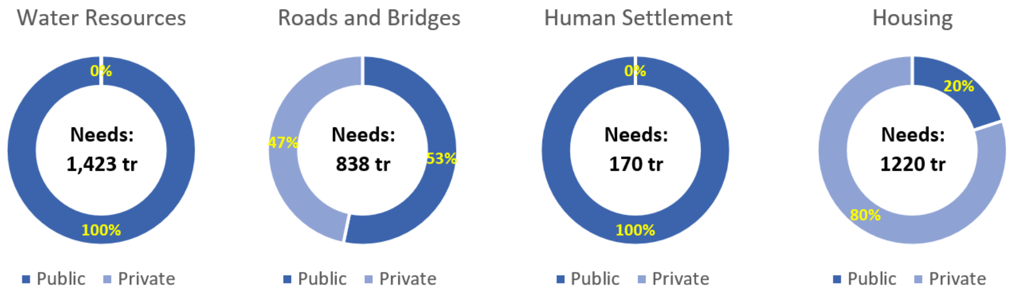

Figure 3.1. Financing Sources for the MoPH 2030 Vision
Source: MoPH's Strategic Plan 2020–2024 (2020). Modified

the joints of bridges will be more worn out. On the other hand, heavy rainstorms and the ensuing flood can disrupt land travel. Frequent exposure to flooding weakens the railways and roads, resulting in a shorter life expectancy. These extreme weathers led to more repairs and reconstructions, yet they limit building activities and exacerbate maintenance costs. For air transportation, since its performance hinges on weather conditions, heavy rain or storms can disrupt them, whereas major hurricanes and floods usually halt air travel. Airports may close because of ash clouds and smoke from carbon monoxide. Even if airports can remain open, climate events impair airstrips, runways, and airport structure. For water-based transportation, higher global temperature will melt sea ice, hence increasing sea levels and at the same time making inland canals shallower. Ships that are sensitive to the depth of a waterway and the extent of sea ice have to face weight restrictions and be built smaller, which alter their amount of cargo and shipping duties. Waterways have to be maintained regularly because flooding, and its runoff of debris and silt, make straits less accessible (EPA, 2017). Finally, non-physical direct impacts on transportation modes and travel methods should be regarded as a climate change aftermath. Adverse weather conditions, such as heavy rain, extreme wind, will push transporters towards automobiles. In turn, it increases travel time and reduces transport speed. The effect is particularly pronounced in peak travel periods, worsening the frequency, severity, and duration of traffic congestion across the system. Accidents are more likely to occur during adverse weather (Markolf et al., 2019).

For the GoI, which aims to encourage the infrastructure sector for inter-regional connectivity and networking, several challenges must be identified in tackling such problems. First, several existing transportation modes and facilities are not prepared with the mechanisms required to cope with climate change. Most railway systems are built in the 1900s during the Dutch Colonialization era, and it is poorly maintained. Highways and roads are constructed in the 1970s in Soeharto's administration. Airports, harbors, trains, and ships confront similar issues. Many facilities are approaching their capacity limits. Almost no upgrades have been made to ensure they are suitable to last against disasters and unknown climate impacts (Diez, 2018). Second, institutional efforts regarding climate change have only addressed issues to prevent losses in the first place, or mitigation efforts, without any plans about how the infrastructures respond to the damage, i.e., adapting to climate change. A majority of Indonesian transportation institution does not have a systematic roadmap related to climate change adaptation. Only 17% of them conducted any study on climate change impacts (Kusumaningrum, 2016). In part, this is because the transportation sector has neither a commanding agency nor clear institutional direction (Sitanggang & Saribanon, 2017). The current authorities are limited by administrative boundaries or their specific mode of transport, which poses a challenge seeing that transport affairs are an integrated system encompassing multiple cities and modes (Farda & Lubis, 2018).

3.3.2 Energy

Transmission substations, distribution grids, and power generators/transformers are all expected to be hit by weather damages. Interferences on the physical assets from natural disasters, such as erosion to the utility poles or floods in relay stations, can provoke short circuits and power outages. In the long run, the efficiency level of energy production decreases significantly from temperature variations. For instance, older power plants with lower physical robustness often rely on river water to cool the facilities, so when river water availability and temperature change, the generation ability is affected (Cortekar & Groth, 2015). At the same time, power plants are subjected to an overstress of demand. Previous evidence suggests that regional and seasonal demand shifts are the most critical, climate-induced change to the energy system. Cooling system spikes up in the summer while heat generators are sought after in the winter (EPA, 2017).

The energy sector also has to integrate massive volumes of renewable electricity into the current grids and systems. However, the production of renewable energy, either hydro, wind, thermal, or solar, is sensitive to weather and climate conditions. Precipitation and temperatures affect hydropower, wind speed and velocity changes affect wind generators, and cloudiness and rainfall make solar cells malfunction (IAEA, 2019).

Indonesia's energy sector has not been appropriately designed to mitigate or adapt to climate change. From the aspect of spatial planning, many energy plants are located in disaster-prone zones. Many steam-powered plants are located in earthquake risk areas. Other plants in development phases are also planned to be located in dangerous areas. The Panau coal power plant in Palu was in ruins from the 2018 tsunami, but it is still being rebuilt in the same place. Similarly, Sepang Bay in Bengkulu has been declared a high disaster risk zone by the Regional Disaster

Management Agency, but a coal power plant is still being built (*JATAM.org*, 2021).

Meanwhile, from the aspect of quality, there are still many energy infrastructures that have not included the resilience aspect in their construction. As a result, when a disaster occurs, the infrastructures are immediately disrupted. In 2013, a severe flood on the coast of Jakarta forced a power plant to close its operations for 12 days and turn off 546 units of distribution substation. The loss was estimated to reach USD15.3 million. Similarly, flooding in coal-producing provinces in South Sumatra and Kalimantan made the National Electricity Company's coal supply fell from two weeks to barely a week (Adhiguna & Hamdi, 2021). In 2011, West Java hydroelectric power plants were significantly disrupted by droughts, creating an estimated financial loss of 51.5 million USD (Handayani et al., 2019). Instead of transferring a massive amount of subsidy to the fossil fuel each year, the money would be better use to invest in a major refinery upgrade every year or a new refinery complex every four to five years, which would help them become more resilient (McKinsey & Company, 2020).

3.3.3 Water Management

Natural disasters and climate change affect water infrastructure in many ways. Firstly, storms and floods often bring power outages which affect the ability to treat and pump water. Secondly, events leading to floods can overwhelm water infrastructure, resulting in sewage spill-over and contamination of water sources through debris and silt (Piesse, 2016). Lastly, landslides and ground movement resulting from an earthquake can also damage less resilient water infrastructure. The impact of such disruptions may be massive. Transmission and distribution pipelines can be cut off, resulting in shortages in clean water.

3.3.4 Coast

Indonesia has the third-longest coastline in the world, reaching 54,716 km. Around 70% or 180 million people live on the coastline. However, Indonesia still faces many challenges regarding the resilience of infrastructure in the coastal areas. Multimodal nodes, like ports and harbors, are particularly exposed to rising sea levels because they are located at the open coast or low-lying estuaries and deltas (UNCTAD, 2020). Underground or below sea level tunnels are subject to inundation from sea level rise and storm surges. Transportation links in the coast often serve as critical evacuation routes, meaning when a disaster occurs, their reliability is crucial (EPA, 2017). Additionally, offshore power installations, especially wind, oil, and gas facilities, are impacted by sea-level rise, changes in ocean currents, and coastal erosion (IAEA, 2019). Storm occurrences on the coast become stronger as the sea level rises. With taller and bigger waves, profiles and structures near the shoreline are heavily attacked. At the same time, coastal erosion is often accelerated, and the shore is brought nearer to the sea, potentially removing protection from dunes and beaches. Disaster prevention facilities such as coastal dikes, water gates, and drainage systems, along with coastal protection structures such as seawalls, breakwaters, and groins, become less functional. The vulnerability of settlements in coastal regions, especially low-lying areas, is compounded by wind damage and tropical cyclones (IPCC, 2001).

Unfortunately, the GoI has not addressed long-term resilience against the climate crisis. On the contrary, the GoI revolves around stop-gap measures and rapid construction. Rather than checking for local wisdom and traditional means that has last for decades, the GoI chose to invest hundreds of millions of rupiahs to upgrade drainage system in coastal cities, a common knee jerk reaction in disaster management. Promoting local community actions from the ground up and good governance should be the main spotlight in building long-term resiliency (Beagen, 2020).

3.3.5 Health

Like any other buildings, the health infrastructure is at risk of natural disasters. Essential infrastructure for emergency services and health care, like utilities, transportation, and communication system, is threatened by extreme weather and climate variations. Hospital supply chains may well be disrupted, prompting shortages of essential pharmaceuticals and medical devices. The shortages can bear deadly costs for compromised patients.

There are still many health infrastructures that do not meet the standards of resilience to natural disasters. As Indonesia still lacks the amount of health infrastructure, public health services may not be ready to equip disaster mitigation efforts into their infrastructure. Between 1990 to 2015, various natural disasters damaged 4,586 health facilities (Agustina et al., 2019). In fact, in the 2018 Earthquake in West Nusa Tenggara alone, 50 health centers and one public hospital were unable to provide medical services as they were severely wrecked.

3.3.6 Industry

Industrial and manufacturing complexes are major contributors to climate change. However, they are not immune to its effect. Climate impacts jeopardize plants, factories, and transportation modes. Heatwaves make cooling plants require more resources while intense storm increases the danger of shipping, either through air, land, or water. In addition, Indonesian manufacturing firms have to deal with disaster risks as well. There are hundreds of industrial zones located in disaster-prone regions. Damages to these industrial zones can reach trillions of rupiahs (*TRIBUNnews.com*, 2019).

4. Gap Analysis and Country Examples

To understand better the potential room for improvement in Indonesia's infrastructure resiliency, it might be useful to observe the best practice and examples from other countries which face the same problems. In general, we classify the aspects that influence resilient infrastructure development into three categories: regulatory aspect, institutional aspect, and sectoral aspects. For each aspect, we identify the gap in which it can be improved based on the best practices from other countries. We also provide an example from one developed country (Japan) and a developing country (Chile) of how they conduct the practice of implementing and improving the resiliency of infrastructure.

BOX: Anutapura Hospital (Palu) and Universitas Indonesia Hospital (Depok)

The outlook for the Indonesian health sector looks favorable. Awareness of resiliency starts to grow as evident in the reconstruction for Anutapura Hospital and the newly built Universitas Indonesia hospital. The Anutapura Hospital in Palu, Central Sulawesi, was demolished during the 2018 Palu earthquake. The bottom three floors were entirely buried, and the remaining two stories above ground were ruined. Medical equipment was destroyed, and 11 nurses were killed. Out of 550 hospital beds, only 50 are still intact (Sehat Negeriku Kementerian Kesehatan, 2018). One of the main causes of extensive damage is that the hospital was designed based on outdated standards with a lower resilient coefficient. In its reconstruction, the Ministry of Public Works intent to make it earthquake-resistant. Earthquake insulators as shock and tectonic energy absorbers will be installed in the hospital's foundation. A flexible plumbing and gas system is included as well. Local earthquake insulators are fixed in all surgery rooms and CT-scan laboratories. The insulators ensure medical staff and patients' safety and stability for medical equipment so any activities can be continued (*Kompas.com*, 2019). The reconstruction is estimated to cost IDR172 billion (*Kailipost.com*, 2019). Currently, Anutapura hospital has finished the first phase and is now on its second reconstruction phase (Direktorat Jenderal Cipta Karya, 2021).

On the other hand, Universitas Indonesia (UI) Hospital in Depok shows the progress the health infrastructure has. It is the first hospital in Indonesia whose structure is earthquake resilient. The hospital can withstand shock up to 9 SR, assisted by the resistance bearings on the structural base and foundation piling. Furthermore, each floor has fireproofed and smoke-free compartments in the event of a fire or extreme heat. Not only does the hospital able to mitigate disasters, but it also adapts to climate change. In the light of how energy-intensive the health sector is, the electricity, water and air filtration system in the hospital are energy-efficient and cost-effective because they are variable-based (RSUI, 2019).

With the growth of public health facilities reaching more than 5% each year, both hospitals can be an important encouragement for other infrastructure to follow suit, ensuring their resiliency to handle upcoming disasters and climate shocks.

BOX: Ministry of Public Works Green Building

In the midst of the increasing risk of climate change, the government has made various mitigation and adaptation efforts for infrastructure. In this case, the Ministry of Public Works' Green Building is one of the pioneering initiatives. The Green Building idea refers to a Green Concept Site and includes energy and water saving, CO2 minimization, and less material use. Moreover, the complex has to include a larger open green space, zero runoff, vehicle emissions restrictions, and integrated pedestrian sidewalks. It needs to have its own waste management unit and water harvesting, recycling, and reuse system. A rainfall catchment area must be directed towards drainage systems and underground water reservoirs. The excess water is used for gardening, urinal flushing, and cooling tower. The roof is completed with solar panels, which help reduce 50% of electricity costs. The entire design relies more on natural lighting during the day and automatic lighting that shuts down when no one is around. The building complex itself has received the Greenship Gold certification from the Green Building Council Indonesia (GBCI) as an energy-saving green building (*Bisnis.com*, 2017). The entire build cost 387.2 billion IDR, though there is an excess cost of 10–15% for the additional sustainability. However, it can save up to 44% of electricity and 63–81% of water use, depending on precipitation (*Bisnis.com*, 2013). The Ministry expects that the Green Building Complex could serve as an example of a sustainable business operation.

4.1 Gap Analysis

4.1.1 Regulatory Gap

Regulations are essential in sustaining the idea of climate- and disaster-resilient infrastructure because they can help in supporting and pioneering that very notion into reality. However, several regulatory gaps in Indonesia need to be addressed further to secure better economic development through resilient infrastructure building.

When we take as an example the regulations imposed in Japan, we can learn from them that in every regulation addressing the issue of disasters; they consistently implement the concept of 'learning from experience'. In this way, the Japanese regulations on resilient infrastructures always seem to re-update their contents to match the current, more extreme disaster occurrence so that future disasters can be mitigated more efficiently. For instance, the building code in Japan has been evaluated and updated continuously since the Great Kanto Earthquake in 1923 – which was considered to be the worst natural disaster to strike a quake-prone country at that time (Hammer, 2011) – to match any riskier and greater earthquakes in the future. This 'learning from experience' practice then proved to be helpful for them since it had successfully *prepared* them for the later and greater 2011 Great East Japan Earthquake. Indonesia, in this case, also has an exclusive infrastructure code for earthquake happenings (that is, Minister of Public Works and Public Housing Regulation No. 21/2007 regarding Spatial Planning Guidelines for Volcanic Eruption-Prone Areas and Earthquake-Prone Areas). However, the gap remains to exist because updates and renewals that should be adapted to the increasing threats from the disasters have not (or rarely) been realized yet. Adaptation is especially important if we also extend the discussion to involve the disasters commonly associated with climate change, such as floods, that need greater attention as they might be more unpredictable in the years to come – even spreading to areas that once never been flooded before.

Moreover, when we talk about a country's readiness to face increasing risks from natural disasters and climate change, it needs also to consider the importance of technical regulations for infrastructures that are considered critical. Critical infrastructures are infrastructures that are regarded to be vital in many aspects of people's lives and essential in maintaining normalcy in everyday lives (CISA, n.d.). Aside from buildings that entail homes, workplaces, and public facilities, utilizes are also as important to support livelihood. Utilities that are common in a country include electricity, water, sewer, and garbage facilities. Electricity, as an example, becomes more crucial nowadays as it is the energy source of most everyday tools and gadgets. Finland provides an excellent example in utility infrastructure resiliency by making electricity one of its regulation's focus on infrastructure resilience, thus preventing more extensive economic repercussions in the event of disasters. Its 2009 Electricity Market Act states that the electricity network should be designed, built, and maintained in a way that by 2028, disturbances due to disasters, such as storm, can be contained not to surmount six hours in a population-dense area and 36 hours in other areas (OECD, 2016). This kind of regulation is carefully crafted to adapt to changing climate and more extreme disasters that will be beneficial in the coming years – which is why the Act plans to cover up to 2028. In this aspect, Indonesia also needs to start thinking about crafting regulations to encompass more infrastructure types, given how threats are becoming even more intense and frequent in the present time.

4.1.2 Institutional Gap

As a country with a decentralized governmental form, infrastructure-related problems can be both central and local government problems in Indonesia. Despite the responsibility of the central government in some national-wide projects, the central GoI has also passed responsibilities to local governments, which include public works, healthcare, education, culture and social affairs, labor, environmental protection, land, citizenship, and investment. However, in the current condition, infrastructure development has not been provided equally between provinces and municipalities in Indonesia. For example, in the province of Papua, only 29.6% of villages had access to roads that are passable throughout the year in 2014; thus, not all villages and sub-districts in Indonesia have access to transportation infrastructure (OECD, 2018). Resilient and better infrastructure development can provide many socio-economic benefits and play an important role in developing local economic conditions. However, based on the OECD report, the infrastructure developed by local governments tends to be in worse condition compared to the central government. Additionally, local or regional and central governments in Indonesia still lack smooth cooperation and coordination, with the existence of a high degree of red tape in Indonesia (Indonesia Investments, 2017).

Indonesia can learn from Japan's experiences as one of the most natural-disasters affected countries by optimizing the role of government, especially for local government's role, in building resilient infrastructure. Until now, central governments still play a main role in infrastructure projects, compared to local governments. By improving coordination and mainstreaming resiliency with other local organizations or private entities in infrastructure planning, monitoring, and maintenance, infrastructure development efficiency and quality may increase, as Japan has successfully done in their flood problems. Moreover, the other important part is that the central government and local government need to have a clearer division of responsibilities to make it easier to maintain and develop infrastructure in the future.

Indonesia can also learn from how the government of Chile created a research, development, and innovation (R&D+*i*) body that is specifically appointed for managing resiliency towards disaster called The Commission of Research, Development, and Innovation (R&D+*i*) for Disaster Resilience (CREDEN). CREDEN focuses its research on creating strategies for disaster resilience roadmap. It was formed as a collaboration between various stakeholders ranging from government bodies to civil bodies (NGOs). With that, CREDEN acts as an integrated commission that develops capacity in dealing with disasters. In Indonesia itself, research and development (R&D) in the disaster management field is still mostly managed by several universities that have their own research centers (BNPB, 2010). It is not lacking, in a sense, that there is no effort to improve R&D in this field in Indonesia, but the effort could be improved by forming an R&D center that is more integrated. This integrated R&D center can act as a one-stop body that collects first-hand knowledge on the development of disaster-related issues and how to mitigate, adapt, and rehabilitate from them, as well as for gaining relevant information for future investments needed in the field of disaster management. This is precisely what has been done in Chile's CREDEN that has brought them to their own success.

After having qualified institutions, Indonesia also needs to have adequate funds to ensure that the programs planned to deal with disasters can be realized properly. Unfortunately, infrastructure investment in Indonesia has been small over the past few years as it is constrained by the limited fiscal budget space of the governments and other bottlenecks (Breuer et al., 2018). A large infrastructure gap might lead to limited foreign direct investment flows as the distribution costs increased, lower industry competitiveness, and lower macroeconomic conditions. Despite the infrastructure gap, the central government's spending was crowded out by large energy subsidies, which accounted for more than one-fifth of the total budget or three times higher than the budget allocation for infrastructure (Carter et al., 2016). According to the IMF report, GoI needs infrastructure investments up to USD323 billion (32% of GDP) in order to close the infrastructure gap. Moreover, Indonesia has also struggled with high logistics costs despite a better ranking in the Logistics Performance Index, which lowers its competitiveness, investor appetite, and foreign direct investment flows. At the same time, Indonesia is still in an under-investment and poor asset management condition (Ray & Ing, 2016). Indonesia can also learn from Chile regarding significant improvements in the financial market in the number of participants, the variety of products, and the financial market depth. The consolidated credit information of banks and non-banks would bring a better credit rating and limit the negative impact of credit faults in the country.

Despite the introduction of the public-private partnership (PPP) scheme in infrastructure projects, the implementation of PPPs has been slow due to complex regulation and lack of coordination.

Indonesia has the potential to increase private investment participation in infrastructure. However, the government needs to improve regulatory and institutional quality, such as uncertainties and transparency of the projects. One lesson learned from Chile is that a stable and certain PPP framework can increase investors' appetite and participation in financing infrastructure projects. Moreover, in 2019, The Asian Development Bank (ADB) has also approved a loan to help catalyze private sector investments in infrastructure projects (ADB, 2019). It became one of the solutions to help filling Indonesia's infrastructure financing gap and supporting the development of resilient infrastructures. The improvement of PPP schemes and increase of availability-payment (AP) PPP schemes could transform the underlying risks of infrastructure investment to the party best placed to manage them between the government and the private entities (Ray & Ing, 2016).

4.1.3 Sectoral Gap

• Transportation

As a country with a high number of municipalities, accessibility is fundamental for sustainable development, especially in rural and remote areas. However, as discussed in chapter 3, Indonesia's public transportation development is still far from sufficient, especially the connectivity between rural and urban areas. Most rural areas in Indonesia still rely on road-based transportation (Leung, 2016), and some areas still do not have proper connectivity access (OECD, 2018). To improve transportation infrastructure, GoI can learn from other countries' transportation systems, such as Japan, which have a modern, secure, punctual, and well-organized transportation system (Yudhistira et al., 2015). One way to measure connectivity is to evaluate the Rural Access Index (RAI) that measures the proportion of the rural population within 2 km of an all-season road via rural household surveys (Avery et al., 2017). The 2006 RAI data shows that there is a vast inequality of access in Asia, where the lowest rural access was found in Myanmar with 23% access, and the highest rural access was found in Japan with 99% access. The data indicated that not only Japan has a modern transportation system, Japan also developed its transportation to connect and reach the rural areas within the countries. The Japanese government is not only focused on the road network (such as expressways, national highways, prefectural roads, and municipal roads), but also focused on other networks, such as railways and airports. Since the 1870s, Japan has built its first railway and is still developing its railway until now, seen from the various railways from a conventional railway to high-speed railway (Shinkansen) with high punctuality (Shibayama, 2017). Filling the gap of transport connectivity in Indonesia is considered crucial to strengthen the resiliency from disasters. In times of disasters, a well-connected infrastructure could facilitate better first-response and damage control. Furthermore, good connectivity is critical in minimizing the loss, both in terms of physical and economic damage from disasters.

• Energy

Indonesia is still facing issues regarding renewable energy usage and non-climate-resilient infrastructure conditions. The high risk of flooding could threaten the energy supply, in terms of electricity, to the flood-prone areas. Indonesia can learn from Japan's experience which has been improving its power plants resilience for natural disasters. After the Fukushima Daiichi nuclear disaster in 2011, the government of Japan and the private sectors in Japan has reformed their safety requirement. The new safety requirement significantly raised the assumption level of natural disasters and reinforced the measures for extreme events (Murakami & Anbumozhi, 2020). Tokyo Electric Power Company (TEPCO) also selected and evaluated 44 natural hazards and narrowed them down to 11 natural highly probable natural hazards in Japan. Based on the evaluated natural disasters, Japan improved their safety upgrades, such as tide wall or watertight door or drainage systems for tsunamis were implemented in the nuclear power plant (NPP) areas. Moreover, in 2011, Higashi Matsushima was severely hit by a tsunami. As a response to the disaster, Higashi Matsushima has become the poster child for smart, resilient communities in Japan (Beath, 2018) and has become the first microgrid community in Japan. The government builds a mini-grid solar power using the form of batteries for the electricity, and it has been set up within the city. In the time of the disaster, the mini-grid will provide full power that can be last for three days using the stored electricity as a substitution of national power. Through this mini-grid solar power, people still can access electricity even though the national power plants are shut down or disrupted due to the disaster.

• Water Management

Despite Indonesia's status as a marine country, Indonesia is still facing a water crisis, especially in terms of its safe and clean water supply as well as irrigation problems in agricultural areas. Besides the water crisis, Indonesia is also facing a threat to its infrastructure due to the high risk of floods in most areas. However, in Japan, the government manages the flow rate of water and there is significant non-consumptive use in the Tone-Gawa River system where the 22 dams in this river system are mainly used for flood control, generation of hydroelectric power, agriculture, etc. (OECD, 2015). In addition, Japan's efficient water management systems have supported Japan's economic growth (JFS, 2010). Japan uses water-saving technologies, which result in highly efficient water resource management, through membrane technology and technology for earthquake resistance and leakage prevention. To maintain its water availability, Japan tries to reuse and recycle its water to save water resources, reduce environmental impacts, and reduce the costs and energy involved in water management (Takeuchi & Tanaka, 2020). The same strategy has been used in Singapore, where the government developed an R&D project to develop recycled water processing the sewage water through a 3-phase purification process and other advanced treatment until the water is drinkable (JFS, 2010). Moreover, concerning the high exposure of natural disasters, Japan faces the same water management problem as Indonesia, which is floods. However, Japan had a major flood management program consisting of a wide range of water facilities and control systems to protect people from floods. According to the Ministry of Land, Infrastructure and Transport in Japan, the project has included the development of embankments, retardation basins, floodways, pumping stations, and other projects across Japan. Better water management, especially in the rural areas of Indonesia can also help the resiliency of the agricultural sector and MSMEs in Indonesia. GoI can implement all the efforts and development of Japan's water management to ensure the availability of safe water and maintain the resilience of its infrastructure.

- **Coast**

In terms of coastal conditions, the high risks Indonesians are facing need to be solved as it is important for the economy. As one of the longest coastal countries, Canadians are also facing disaster risks due to climate change and its negative impact on their infrastructures. In Canada, the majority of core public infrastructures are owned by provinces, territories, and municipalities. According to the Government of Canada (n.d.), Canadian provinces, territories, and municipalities across the country are investing in green infrastructure to reduce greenhouse gasses as well as enhance resilience to floods. For example, Toronto's Don Mouth Naturalization and Port Lands Flood Protection Project aims to provide critical flood protection to Toronto's eastern waterfront. Toronto's Green Roof Strategy is also developing green roofs to improve stormwater management, mitigate heat island effects, reduce greenhouse gas emissions, and improve air quality. The Canadian government also structuring the 2019–2022 Federal Sustainable Development Strategy (FDS) consists of 13 aspirational goals, one of which is to create healthy coasts and oceans (Environmental and Climate Change Canada, 2019). In terms of port effectiveness, Indonesia can learn from Singapore, which has the busiest transhipment hub in the world (Mindur, 2020). According to Maritime Singapore, the port of Singapore is capable of handling up to 1,000 ships per day in 10-minutes intervals. In 2019, to increase its effectiveness, Singapore's Maritime and Port Authority (MPA) has launched a one-stop portal for maritime regulatory and port services transactions as the new digital tool for its port (World Maritime News, 2019).

- **Health**

Furthermore, Indonesia's healthcare infrastructure has yet to be ready to tackle climate change and natural disasters, especially in rural areas. According to Bloomberg Covid Resilience Ranking, Singapore and South Korea are in the top 5 of the rank, with the resilience score 79.4 and 73.8, respectively (Chang et al., 2021). In mid-2021, Singapore is planning to stretch its inoculation efforts as new virus strains continue to emerge. The fast government response and strict government measures during the pandemic give Singapore a 0.2% 1-month fatality rate. In terms of their readiness for the pandemic, although their hospital bed ratio (2.6–2.8 per 1,000 people) is still below OECD countries' average (4.7 hospital beds per 1,000 people), the effective TTT (test-tracing-treatment) efforts and aggressive containment are most likely be the key to a low number of Covid-19 infections in Singapore (Ansah et al., 2021). Meanwhile, from other countries in Asia, Indonesia can learn from South Korea which has a high hospital bed ratio, at 11.5 per 1,000 people. Moreover, the resilient health infrastructure in terms of hospitals is also important, especially in Indonesia that has high exposure to natural disasters. Despite the development of the earthquake-resistant hospital in Universitas Indonesia, Depok, the government needs to increase the development of resilient hospitals, particularly in disaster-prone districts. As discussed before, Japan is not only developing earthquake-resilient water management systems but also building earthquake-resilient hospitals which increase their health infrastructure resiliency, which is regulated by the government (Suganuma, 2006).

- **Industrial**

The high number of MSMEs and the importance of their role in the Indonesian economy need to be maintained to prevent them from risks. One of the risks to MSMEs in Indonesia relating to infrastructure is that they are facing climate risks which increase their vulnerability (Neise et al., 2021). Furthermore, locations of industrial zones in Indonesia are also disaster-prone. In terms of industry and disaster risk, Japan can be an excellent comparison to Indonesia's current state. Although the manufacturing and transportation sectors have been one of the leading industries in Japan and play a critical role in its economy, SMEs are also driving the industry (World Bank, 2020). Currently, minimizing the environmental impacts of industries is a critical agenda in Japan. Japan has been working on developing its resilient industry through policies and institutions that target industry competitiveness. National and local governments in Japan are taking a role in catalyzing the Business Continuity Plans for both corporations and SMEs to identify the potential disruptions from natural disasters. Moreover, the Japanese government is also utilizing technology, such as big data technology, to enhance the resilience of industries against disasters (World Bank, 2020). Through the help of big data, the Japanese government can understand more clearly the risks of disasters and prepare for their impact on people, business, and infrastructure.

4.2 Country examples

4.2.1 Developed Country: Japan

Japan is already well-known as one of the most vulnerable countries to suffer from disasters due to its natural conditions (Hayashi, 2010). Disasters, both geophysical and climate-change-induced, are affecting Japan drastically each year. Climate change has particularly posed a greater risk to Japan because it has contributed to the increased frequency and intensity of extreme weather events (Case & Tidwell, 2008). Anticipating those, Japan has managed to build "high-quality infrastructure". How are they doing that?

The key action from Japan's resilient infrastructure is learning from experience. Nearly all of its policies, technical, institutional, and community capacities are improved through accumulated lessons from every sizable disaster (Hori et al., 2017). First, in terms of geophysical disaster, the Japanese government has made continued renewals over the years to its building code created in 1924 as a response to the damage caused by the Great Kanto Earthquake (7.9 MW). It is done by evaluating past earthquakes to test buildings' resilience to conform to more risky earthquakes in the future. The effort had come to fruition when the 2011 Great East Japan Earthquake (9.0 MW) happened and only resulted in minimal damage to the buildings and infrastructures. For non-geophysical disasters, Japan also shows a great example of reducing urban flooding problems due to high rural-urban migration. The Japanese government enacted a more comprehensive approach that did not just treat the areas within river channels but also the whole river-basin area because they knew river channel treatment was not enough (Kundzewicz & Takeuchi, 1999). This approach then includes structural (i.e., widening river channels) and non-structural measures (i.e., hazard maps, early warning, evacuation routes). Further, the local government's role in Japan cannot be denied since they also require private companies to construct water-catchment areas to compensate for their activities that disturb water penetration. All these efforts had resulted in a significant drop in flood damage in most metropolitan areas, even after more than 30 years since it was first initiated.

All those approaches that have been practiced in Japan seem possible to be applied in Indonesia to improve the resiliency of its infrastructure. First, in terms of building code, Indonesia already has its own standard under SNI. Improvement in this aspect can be made in terms of updating the standard over time in order for the infrastructures to be able to face more significant risks exposed by increased natural disaster occurrences as well as higher vulnerability due to climate change. Furthermore, Indonesia can also learn from Japan's comprehensive approach in dealing with flooding by not just considering the structural aspect of the infrastructure itself, but also the non-structural aspect that completes the disaster mitigation efforts. For this matter, the local governments in Indonesia can strengthen the partnerships with other local governmental organizations, such as *Dinas Lingkungan Hidup*, to support the implementation of the aforementioned comprehensive approach as well as the enforcement of adequate land use permits that uphold the provisions as stipulated in *Analisis Mengenai Dampak Lingkungan* (AMDAL).

In order to fill the funds needed for building resilient infrastructure, the Japanese government developed a public-private partnership (PPP) scheme to increase infrastructure development. In the PPP concession scheme in Japan, banking organizations are taking parts as a lender that provide a loan, investment, or mortgage for the private operators. Moreover, to further promote the PPP development, the Japanese government also promotes concessions in airports, water, and sewage projects through the Private Finance Initiative Act (the PFI Act) (World Bank, 2017). The Japanese council also established a guideline for the PPP/PFI scheme that under the guidelines, a public authority needs to consider PPPs/PFIs when they make decisions on construction, renovation, operation, and maintenance of public facilities (Sato & Okatani, 2016). As the infrastructure projects are closely related to high risks, such as force majeure, the government also creates a risk-sharing scheme between them and private entities under the PPP scheme. The standard contract in many PPP cases for the risk-sharing scheme between those two entities is the "1% rule", where the private operator will bear up to 1% expenses of the investment cost when the facility is damaged, and the government usually bears more than 1% damages. However, in the case of the "1% rule" is not applied, the risk-sharing between the two entities will be examined after discussing the damages.

4.2.2 Developing Country: Chile

Chile is considered the most exposed country to natural disasters, with 54% of its population and 12.9% of its territory exposed to three or more types of hazards (Dilley et al., 2005). Given the fact, Chile leads the OECD countries with the largest%age of GDP spent on disaster losses with a figure of almost 1.2% or more than USD2,800m per year (De La Llera et al., 2018). This condition is exacerbated by severe climate events ranging from flash floods and landslides to extreme cold waves with heavy snowfall.

Chile responded to these issues very well. Since 1928, Chile has updated the construction rules after almost every notable disaster in its history, especially earthquakes, accompanied by a constitution and/or institutional changes. Recently, the Government of Chile created the National Commission of Research, Development, and Innovation (R&D+i) for Disaster Resilience (CREDEN). The goal was to develop a comprehensive R&D+i strategy by collaborating with more than 80 experts representing different stakeholders from academia, public and private sectors, NGOs, and the armed forces. In 2016, CREDEN successfully translated the strategy into an R&D disaster resilience roadmap. The realization of such a strategy demands much investment, amounting to USD914 million in 20 years. However, it is expected to have a benefit-cost ratio of 2.32 and annual savings of USD106 million (De La Llera et al., 2018). Such practice could be implemented in Indonesia as well. Currently, Indonesia already has a special agency that deals with disasters, the National Disaster Management Agency (*Badan Penanggulangan Bencana Nasional*/BNPB). In this regard, BNPB could act as an initiator in forming an R&D+i commission for various stakeholders to design a comprehensive climate and disaster resilience roadmap jointly.

Moreover, Chilean local governments also play an essential role in the risk reduction part of the infrastructure (Valdivieso & Andersson, 2018). The local governments can guide local development through regulations, plans, and actions, also create a responsible budget and administrative autonomy for local welfare and development. Studies found that Chilean municipal organization has been improved in terms of accountability, transparency, and internal coordination, thus stimulating the local government's role in Disaster Risk Reduction (DRR). In addition, many local governments in Chile are making a decision that is coordinated with the central or national government's decision (Valdivieso et al., 2017). Valdivieso & Andersson (2018) found that municipal capacities, organization, leadership, and multilevel governance relationships can affect the local governments' decisions in infrastructure DRR. Moreover, municipal council members' coordination with other external organizations and national funds could help municipal finance their infrastructure projects, including the local environmental disaster risk management (EDRM) (Valdivieso et al., 2017).

Chile's substantial financing needs for disaster resilience are matched by their robust PPP framework. Regarding this, The Economist Intelligence Unit (2019) has ranked Chile first in Latin America in the capacity to do public-private partnerships (PPP). Chile is also named the most attractive investment infrastructure market in Latin America by the Third Global Infrastructure Investment Index (Arcadis, 2016). The secret recipe for Chile's success in PPP is their regulatory framework in concession. They establish a clear, transparent, and fair concession process so that the private sector can know the criteria for evaluating the offer. The framework is also stable and predictable, providing certainty to private investors regarding the low risk of government expropriation and clearly stated compensation for any unilateral changes. In addition, investment and trade tax policies can also prevent foreign capital investment from leaving the country (Hill, 2011). Thanks to its good investment climate, as of 2020, Chile is able to absorb a total investment of USD14,884 million for its concession plan for the period 2019–2023 (Mansilla & Vassallo, 2020).

5. Conclusion

The threat of disasters and climate change is getting more imminent as the day goes by for Indonesia. By nature, Indonesia is located in the ring of fire, where almost 90% of worldwide earthquake events occur. Furthermore, Indonesia is one of the most disaster-prone countries that frequently face a range of hazards. As suggested by Bündnis Entwicklung Hilft (2020) World Risk Index, Indonesia is ranked 40^{th} among 181 countries in terms of vulnerability towards natural disasters. Indonesia is one of the most vulnerable countries to seismic, tsunami, and volcanic risk exposure. For instance, the risk of earthquakes in Indonesia is ten times bigger than in the United States (Arnold, 1986). On average, there are five from 127 volcanoes that show an activity increase (e.g., eruption) across Indonesia each year. In addition, Indonesia has experienced 177 tsunamis in history (*CNBC Indonesia.com*, 2018). Findings by World Bank (2019) suggest that more than eight million people are directly affected by disasters in Indonesia. On average, natural disasters have led to the death of 954 people, the destruction of 120,918 houses and 4,745 public facilities every year over the last five years.

Following this situation, Indonesia must prepare the infrastructure to be more resilient in the face of disasters. We classify the challenges faced to improve the resiliency of infrastructure in Indonesia into three broad categories; regulatory and policy challenge, institutional challenge, and sectoral challenge. In terms of regulatory and policy aspects, the main challenge is enforcing resilient infrastructure standards. Standards related to infrastructure resilience, such as the construction quality of buildings that manifests in the SNI, are already in place. However, the adoption of standards for the existing infrastructure still faces challenges due to the relative absence, to some degree, of policy incentives to enforce such standards. Furthermore, challenges in the mainstreaming of resilient infrastructure regulations or policies to regional planning also exist. This challenge is also related to the current conduct of spatial planning, which has considerable key potential improvement areas.

Secondly, the institutional challenge in developing resilient infrastructure include technical and financial capacity. For technical capacity, the first issue is the limited supply of qualified human resources to support the development of resilient infrastructures. A limited supply of professionals to assist in the conduct of spatial planning, implement resiliency standards, and carry out constructions can result in an environment that is unsuitable for the development of resilient infrastructures. In the case of small and individual developers, the lack of know-how knowledge also results in the development of infrastructures that are less resilient. In some cases, small and individual developers are not familiar with the application of resiliency standards and the consideration of climate and disaster risks. Another issue of technical capacity is in ensuring regulatory investment and transparent infrastructure project management. For financial capacity challenge, the main issue is the high financing need required for resilient infrastructure and limited fiscal space of GoI. Thus, resilient infrastructure cannot be fully funded by the state, while at the same time, the alternative financing is fairly limited.

The last challenge identified in building resilient infrastructure is sectoral specific issues. The sectoral challenges include, but not limited to, transportation, energy, water management, coast, health, and industry. For the transportation sector, the main issue is the deterioration of physical infrastructure quality due to low maintenance, which shorten the life expectancy of built infrastructure. For the energy sector, Indonesia's energy sector has not been properly designed to mitigate or adapt to climate change. From the aspect of spatial planning, many energy plants are located in disaster-prone zones. Many steam-powered plants are located in earthquake risk areas. In terms of water management, many types of disasters (e.g., floods and storms) has often led to the damaged facilities, which creates a condition of water shortages in the impacted areas. For the coast aspect, Indonesia still faces many challenges regarding the resilience of infrastructure in the coastal areas, which are inhabited by 70% or 180 million people. Multimodal nodes, like ports and harbors, are particularly exposed to rising sea levels because they are located at the open coast or low-lying estuaries and deltas (UNCTAD, 2020). In terms of the health sector, many health infrastructures do not meet the standards of resilience to natural disasters. As Indonesia still lacks the amount of health infrastructure, public health services may not be ready to equip disaster mitigation efforts into their infrastructure. Lastly, Industrial and manufacturing complexes are major contributors to climate change. However, they are not immune to its effect. Plants, factories, and transportation modes are jeopardized by climate impacts. Heatwaves make cooling plants require more resources while intense storm increases the danger of shipping, either through air, land, or water. In addition, Indonesian manufacturing firms have to deal with disaster risks as well. There are hundreds of industrial zones located in disaster-prone regions.

In general, Indonesia may learn certain lessons regarding resilient infrastructure development. The lesson includes a continuous learning process in the event of disasters and research and development to improve infrastructure standards, a comprehensive approach of infrastructure development, optimizing local government coordination and contribution in resilient infrastructure development, strengthening financial tools and instruments for resilient infrastructure financing, and improving the resiliency of critical infrastructure. These several aspects will enable resilient infrastructure development and reduce disaster and climate change risks in Indonesia.

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APPENDIX

Appendix 1

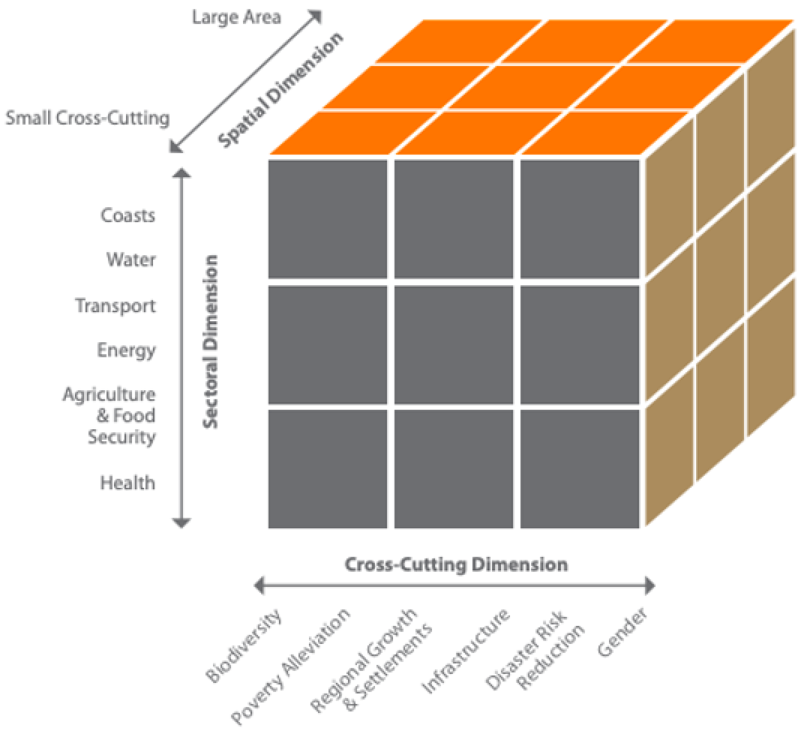

Figure A1. Adaptation Cube (Spatial, Sectoral, and Cross-cutting Dimensions of Climate Change)
Source: Kay in UNDP (2011)

Appendix 2. Natural Disaster Incidence and Damage by Natural Disaster Type

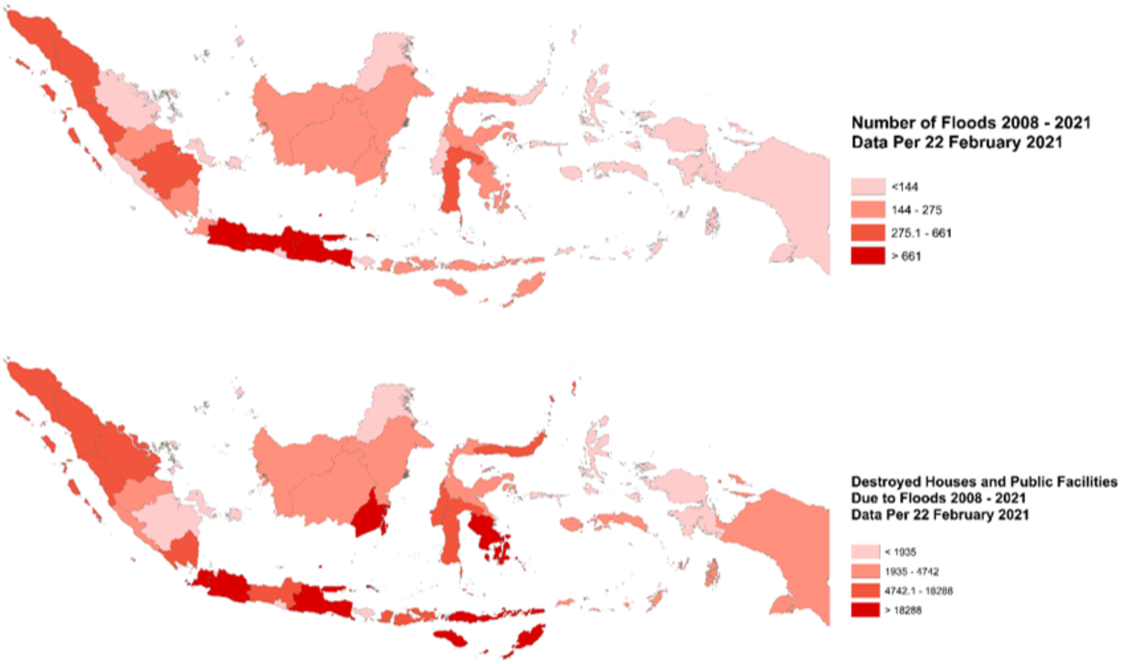

Figure A2. Flood

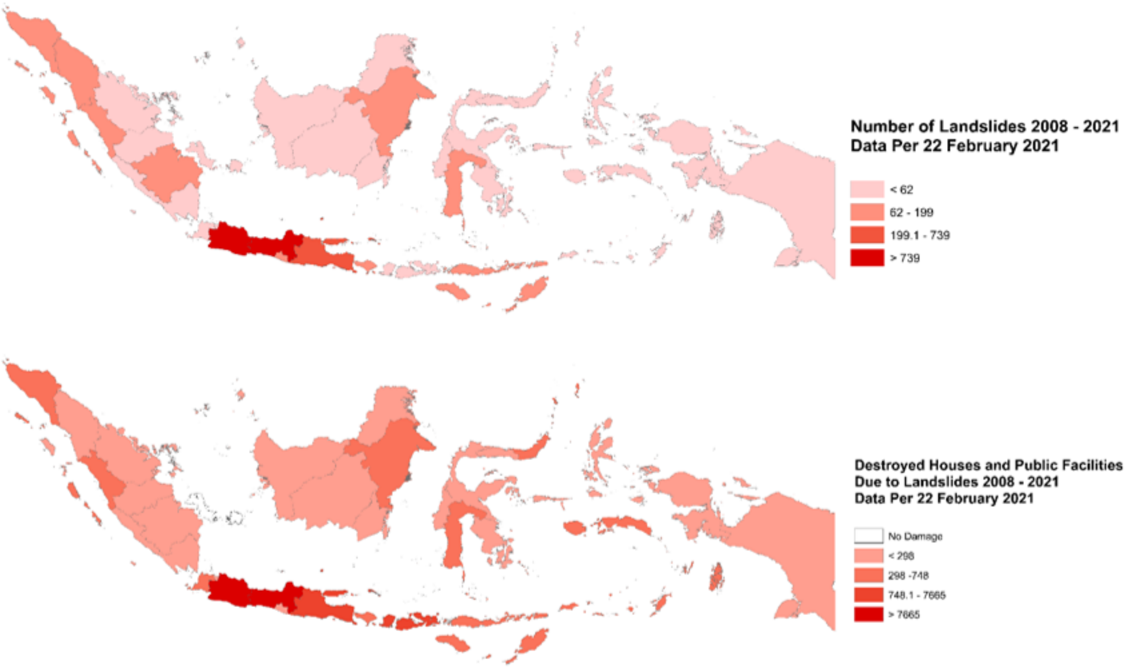

Figure A3. Landslide

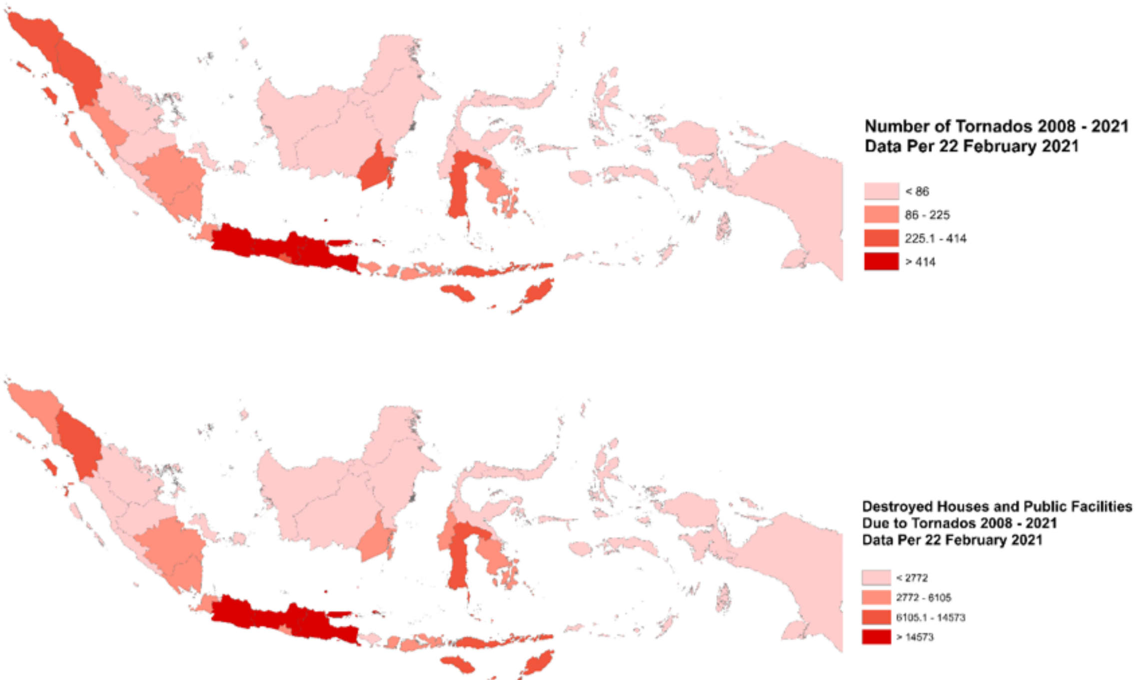

Figure A4. Tornado

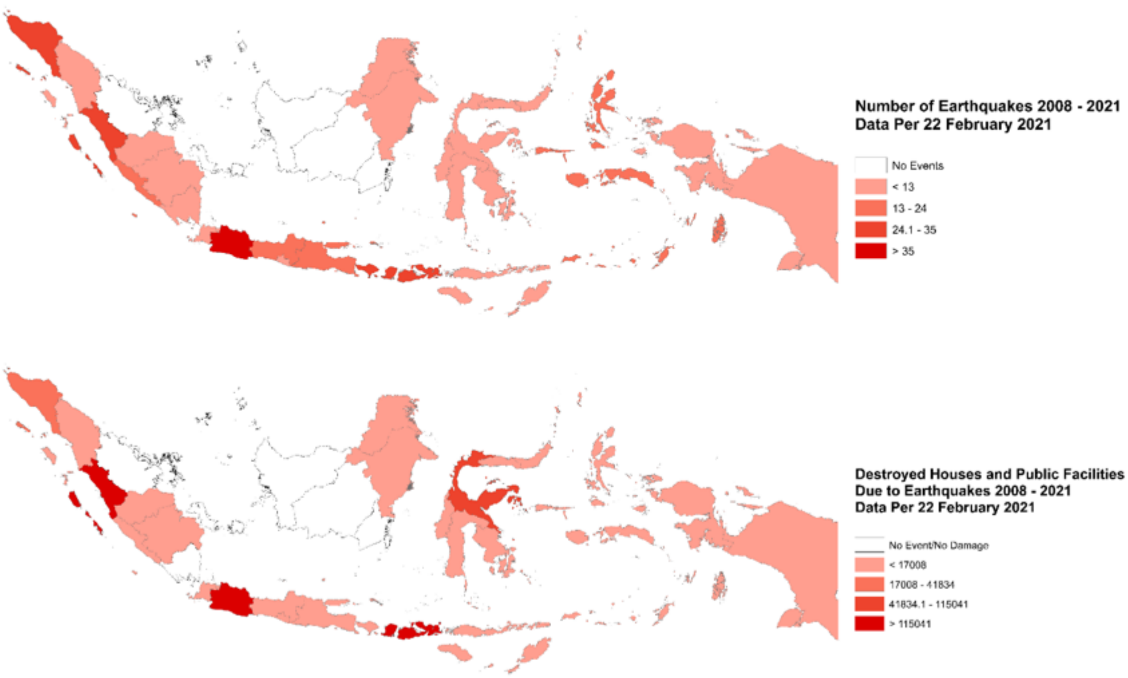

Figure A5. Earthquake

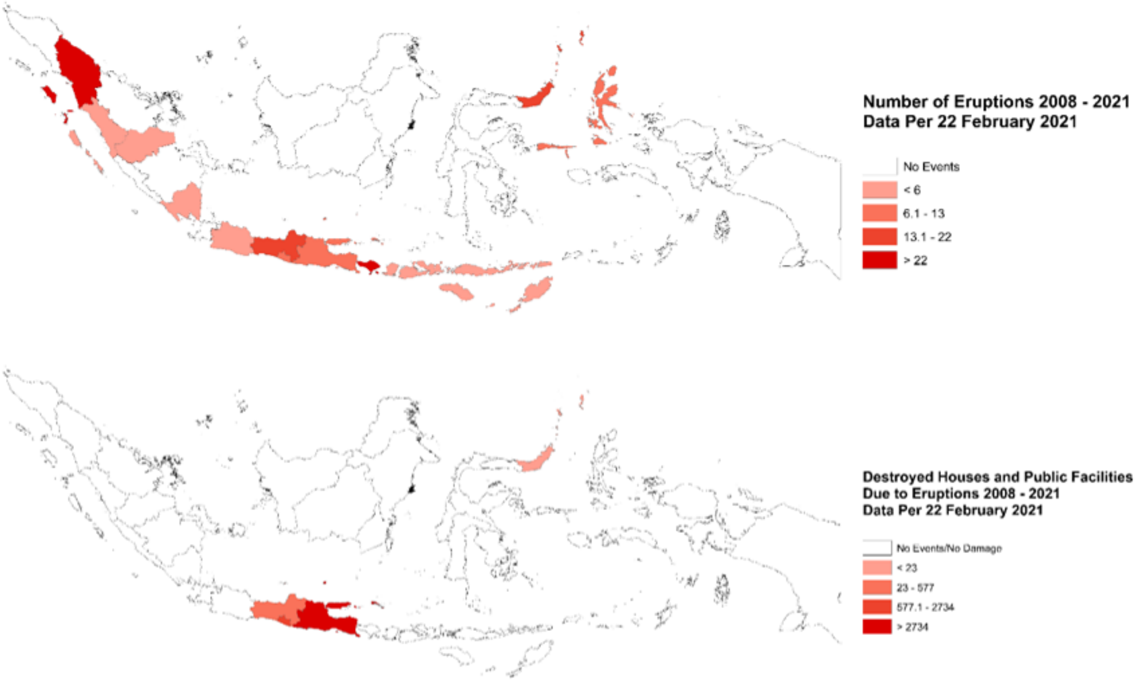

Figure A6. Volcano Eruption

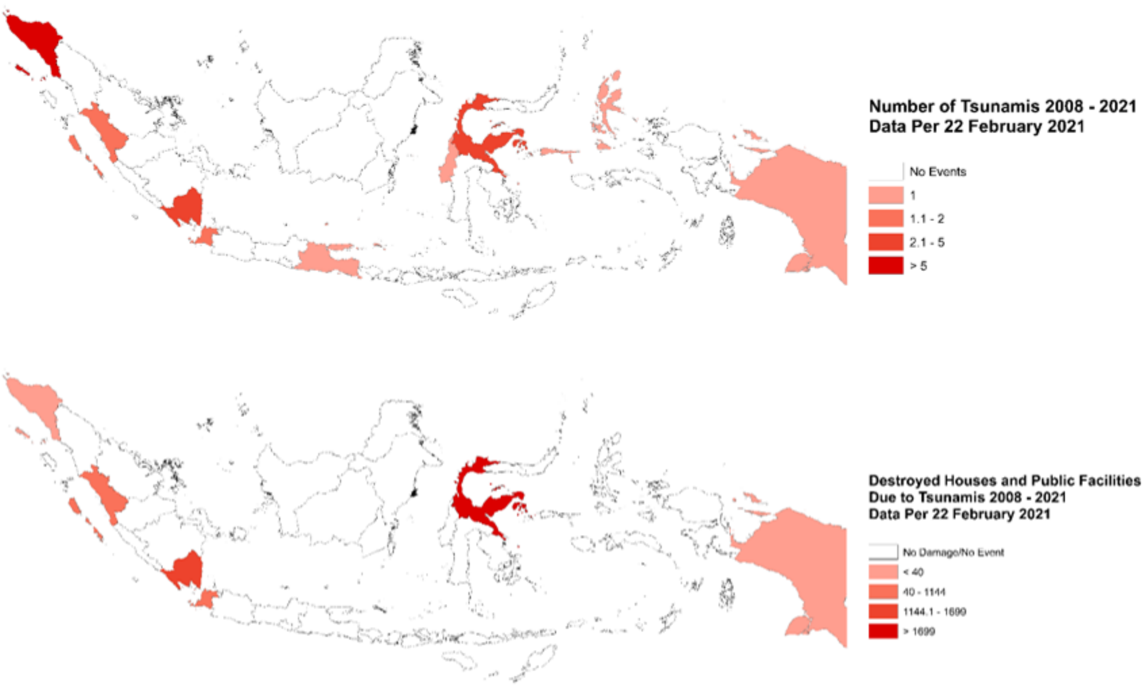

Figure A7. Tsunami

Appendix 3

Table A1. Funding Comparison between Indonesia and Benchmark Countries (China-India-Malaysia-Philippines-South Africa-Thailand-Vietnam) for Projects Starting in 2015–2019 (% of funding per sector)

SECTOR	Government		SOE		Private Entity		Government-Private	
	Indonesia	Benchmark	Indonesia	Benchmark	Indonesia	Benchmark	Indonesia	Benchmark
Airport	81%	54%	4%	NA	0%	32%	14%	14%
Harbor	60%	30%	8%	NA	1%	30%	31%	39%
Housing	2%	7%	0%	NA	93%	10%	5%	83%
Water and Sanitation	61%	60%	0%	NA	7%	30%	32%	10%

Source: Directorate of Development Funding Allocation, Bappenas & McKinsey, Team Analysis

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