Asia-Pacific
Economic Cooperation

Casebook of Infrastructure Build Back Better from Natural Disasters

Enhancing Rural Disaster Resilience through Effective Infrastructure Investment

APEC Emergency Preparedness Working Group

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Enhancing Rural Disaster Resilience through Effective Infrastructure Investment
Casebook of infrastructure Build Back Better
From Natural Disasters

TABLE OF CONTENTS

I Introduction

APEC economies, located on the Pacific Ring of Fire and repeatedly struck by natural disasters, have committed themselves to supporting growth through sustainable and resilient infrastructure development by encouraging investment in quality infrastructure and enhancing better connectivity between urban and rural areas. Critical infrastructure resiliency is one of the key areas in the APEC Disaster Risk Reduction (DRR) Framework adopted by APEC leaders in 2015. The framework facilitates collective efforts to build adaptive and disaster-resilient economies in the face of a "new normal" of increasing disaster risks due to social and environmental changes such as climate change and rapid urbanization. Additionally, the Sendai Framework for Disaster Risk Reduction 2015-2030 stressed the importance of ensuring the resilience of new and existing critical infrastructure to enhance disaster preparedness for effective response, urging economies to "Build Back Better" in post-disaster recovery, rehabilitation and reconstruction.

This casebook is the output of the APEC project "Enhancing Rural Disaster Resilience through Effective Infrastructure Investment (EPWG 01 2016)," aimed at facilitating quality infrastructure investment at the Build Back Better (BBB) stage. Focus is placed on non-metropolitan areas, including small and middle-sized cities, and rural areas facing growing demands for important infrastructure investments in the coming decades.

APEC project components

- Identify the best practices and challenges of rural infrastructure BBB.
- Organize an APEC workshop to examine and explore the good practices.
- Compile a casebook for promoting effective and resilient infrastructure investment.

The casebook compiles knowledge from three sources: first, case studies from six APEC economies, including Chinese Taipei, Indonesia, Japan, Philippines, USA and Viet Nam; second, discussions from the APEC workshop held on 17 September 2017 back to back with the Senior Disaster Management Officials Forum, SDMOF in Vinh City, Viet Nam; and third, additional inputs from many other economies.

1 Background

Quality infrastructure investment towards upgrading connectivity

Many APEC economies in the midst of economic growth and urbanization face an increasing demand for infrastructure investment. In order to foster regional and sub-regional connectivity, APEC leaders have reaffirmed the Da Nang Declaration, November 2017[1], the commitment to build a seamless and comprehensively connected and integrated APEC region by 2025 by reiterating the importance of quality infrastructure. APEC leaders have pledged to promote infrastructure in terms of both quantity and quality through adequate investment and strengthened public-private partnership, by encouraging collaboration and synergy among various connectivity initiatives and work on advancing economic development and integration of sub-regional, rural and remote areas in the region. This includes efforts to develop safe, secure, resilient, efficient, affordable and sustainable transportation systems.

1 The 25th APEC Economic Leaders' Meeting, Da Nang, Viet Nam, 11 November 2017
"Da Nang Declaration-Creating New Dynamism, Fostering a Shared Future"

More intensified policy efforts should be made to facilitate accelerating infrastructure investment, in particular, in rural areas and outside metropolitan areas facing progressive urbanization and sub-urbanization, which may lead to an increasing vulnerability. It is imperative to accelerate upgrading connectivity by encouraging infrastructure investment so that regions outside metropolitan areas could get better integrated in the economic and social development of the region, as well.

Insufficient investment in infrastructure may lead to weakening connectivity and increasing vulnerability, which may act as a brake on further growth. Nghe An province, Viet Nam, for example, endowed with high industrial potential and a population of more than three million, has seen severe impacts by natural disasters and also faces effects caused by climatic changes. Despite the DRR plans and scenarios targeting the people living near the coast line, as well as scenarios to prevent the plain areas from flash floods, the budget made available for infrastructure development to increase resilience has remained far from sufficient, as noted at the workshop. Many local governments in the APEC region face similar challenges of insufficient resources.

Both structural and non-structural measures are important for effectively promoting DRR; however, DRR policies with insufficient focus on structural measures are not likely to support sustainable economic development towards growth, as physical damages caused by natural disasters may be recurrent in the Asia-Pacific Region.

2 Recovery from natural disasters as an opportunity for investment

APEC region facing mega disasters

The APEC region, located on the Pacific Ring of Fire, has been repeatedly affected by mega-disasters. It saw more than 40 natural disasters resulting in the loss of more than two thousand lives throughout the 20th century, and already 10 such instances in the 21st century. As the population has been increasing and the region will become more and more densely populated, more lives could be lost. As our cities and regions have become increasingly better equipped with infrastructure, damages to that infrastructure will also dramatically increase. DRR authorities need to be well-prepared for effective recovery and BBB of infrastructure.

Table 1-1. Major natural disasters affecting APEC region (1900-2015)

Year	Economy	Natural Disaster	Killed*
1900	USA	Galveston Hurricane	6,000
1906	Chile	Valparaíso Earthquake	3,000
1906	Hong Kong,China	Typhoon	10000
1906	USA	San Francisco Earthquake	3,000
1906	Chile	Earthquake	3,800
1907	China	Tianshan Earthquake	12,000
1911	China	Flood	100,000
1912	China	Typhoon Wenzhou	5,000
1917	China	Yunnan Earthquake	1,800
1917	Indonesia	Bali Earthquake	15,000
1918	China	Guangdong Earthquake	10,000
1919	Indonesia	Mount Kelut Volcano Eruption	5,200
1920	China	Haiyuan Earthquake and Landslide	180,000
1925	China	Dali Earthquake	3,600
1928	USA	Okeechobee Hurricane	4,000
1933	Japan	Showa-Sanriku Tsunami	3,064
1935	CT	Hsinchu-Taichung Earthquake	3276
1937	Hong Kong,China	Typhoon	11,000
1939	Chile	Bío Bío Region Earthquake	5,648
1945	Japan	Typhoon Makurazaki	3,756
1945	Japan	Mikawa Earthquake	2,306
1947	Japan	Typhoon Kathline	1,930
1948	Japan	Fukui Earthquake	3,769
1959	Japan	Ise bayTyphoon	5,098
1960	Chile	Concepción Earthquakes	2,000
1970	Peru	Ancash Earthquake (the Great Peruvian earthquake)	70,000
1976	China	Tangshan Earthquake	250,000
1985	Mexico	Earthquake	9500
1988	USA	North American Extreme Heat Wave (1988-89)	5,000
1989	China	Flood and landslides (Sichuan Province)	2,000
1991	Philippines	Tropical Storm Thelma/Uring	5,000
1991	China	Flood in Jiangsu Province	1,900
1992	Indonesia	Flores islands Earthquake	2,100
1994	Russia	Flood	3,000
1995	Japan	The Great Hanshin-Awaji Earthquake	6,437
1995	Russia	Sakhalin Earthquake	1,989
1996	China	Flood and typhoon in seven southern provinces and five north and northern west provinces	2,800
1997	Viet Nam	Storm No 5 (Linda)	3,111
1998	China	Flood at Yangzu River Basin	3,700
1998	PNG	Aitape Tsunami	2,200
1999	CT	9-21 Chichi Earthquake	2,415
2004	Indonesia, Thailland, Malaysia and so on	Indian Ocean Earthquake and Tsunami	230,000
2005	USA	Hurricane Katrina	1,836
2006	Indonesia	Yogyakarta Earthquake	5,689
2008	China	Sichuan Earthquake	87,500
2010	China	Yushu Earthquake	2,968
2010	China	Haevy rainfall and mud flow (Yangtze River Basin region)	1,800
2011	Japan	The Great East Japan Earthquake	18,559
2012	Philippines	Typhoon Bopha /Pablo	1,900
2013	Philippines	Typhoon Yolanda/Haiyan	6,300

Source: Major natural disasters in APEC economies resulting in close to 2000 deaths or more. Death toll may include missing persons depending on data and economies.

3 Infrastructure and impacts of natural disasters

Natural disasters have significantly impacted APEC economies and affected key infrastructure supporting the economy and industries across the region, leading to disruption of economic activities and people's ways of life, thereby impeding efforts to recover.

In China, for example, the earthquake on 12 May 2008[2] (M. 8.0) that hit Sichuan province and surrounding areas, caused a horrific number of casualties (69,227 killed, 17,939 missing, 374,640 injured), and caused the most significant devastation since the 1976 Tangshan earthquake, in which at least 240,000 perished. The damage to infrastructure caused by the Sichuan Earthquake is estimated to be 185.1 billion yuan, 21.9% of the total damages amounting to 845.1 billion yuan. Damages to buildings amounted to 403.9 billion yuan, including 231.5 billion yuan (27.4%) to houses and 172.4 yuan (20.4%) to other structures.

Table1-2. Estimated damages by the Sichuan Earthquake, China

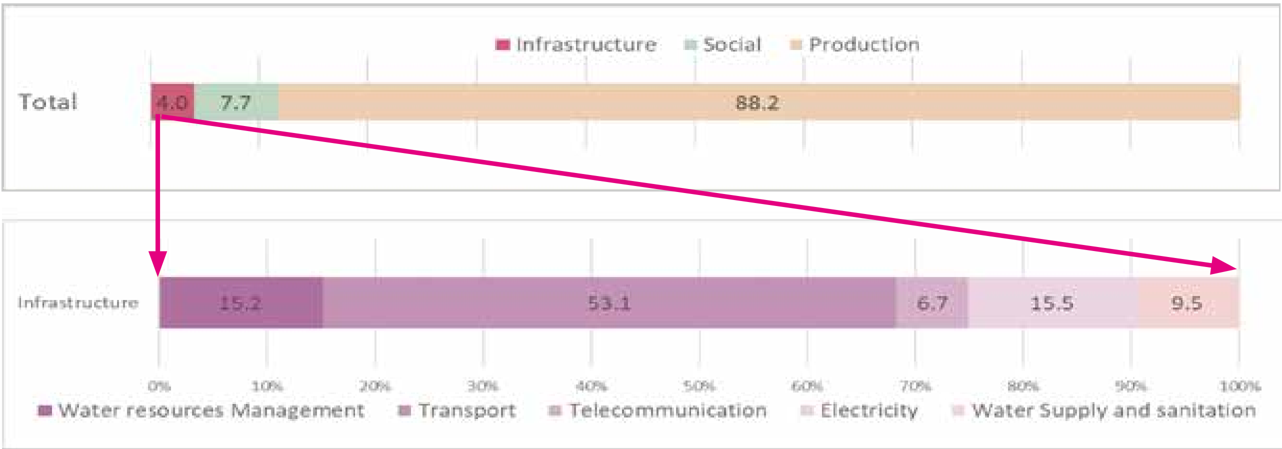
Item		Damages(billion yuan)	Share (%)
Infrastructure (roads, bridges, railways)		185.1	21.9
Buildings	Housing	231.5	27.4
	Other buildings	172,4	20.4
Others		256.1	30.3
Total		845.1	100.0

Source: Japan-China Economic Association (March, 2010) "Recovery from the Sichuan earthquake and economic development—report of recovery assistance cooperation project from the Sichuan earthquake (Japanese)"

In Thailand, the flood from July 2011[3] lasting almost half a year, affected the provinces of Northern, Northeastern and Central Thailand along the Mekong and Chao Phraya river basins, as well as parts of the capital city of Bangkok, resulting in 813 deaths, and 9.5 million people affected. The World Bank estimated the total damage and losses as THB 1.43 trillion (US$46.5 billion), with losses accounting for 56 percent of the total. Approximately 90 percent of the damages and losses were those of the private sector, mainly in manufacturing. Infrastructure damages and losses amounted to 4.0 % and in the social sector 7.7 % (76.2% of which is attributed to housing). Regarding types of infrastructure, transport infrastructure covers 53.1%, followed by electricity (15.5%) and water resources management infrastructure (15.2%).

2 GLIDE Number. EQ-2008-000062-CHN
3 GLIDE Number FL-2011-000135-THA

Figure1-1. Economic Damages and losses by the Thai Flood 2011



Source: World Bank (2012) "Thai flood 2011: rapid assessment for resilient recovery and reconstruction planning : Overview", Working Paper (69822)

In Indonesia, frequently hit by natural disasters, infrastructure is one of the critical policy issues.

Economic damage and loss by natural disasters

It is estimated that a major disaster in Indonesia could cost the economy up to 0.3 % of its GDP (BNPB, 2018(TBC). [4]

From 2004 to 2013, total losses of natural disasters reached IDR 126.7 trillion. This included the earthquake and tsunami of Aceh-Nias (2004), Yogyakarta and Central Java earthquakes (2006), the West Sumatera earthquake (2007), the Jakarta flood of 2007, the Bengkulu earthquake (2007), the West Sumatera earthquake (2009), the Mentawai tsunami (2010), the Wasior flash flood (2010), the eruption of Mount Merapi (2010), the cold lava of Merapi volcano (2011), and the Jakarta flood of late 2012 and early 2013.

Figure 1-2-1. Disaster damages and losses in Indonesia

Source: BNPB, material for the APEC workshop, 20th Sept. 2017, Vinh City, Viet Nam

4 ex. https://reliefweb.int/report/indonesia/indonesia-disaster-management-reference-handbook-2015

In the year 2016, economic losses caused by natural disasters amounted to IDR 747.2 billion (US$54.3 million), less than that of 2015 (US$108.9 million), thanks to fewer forest fires.

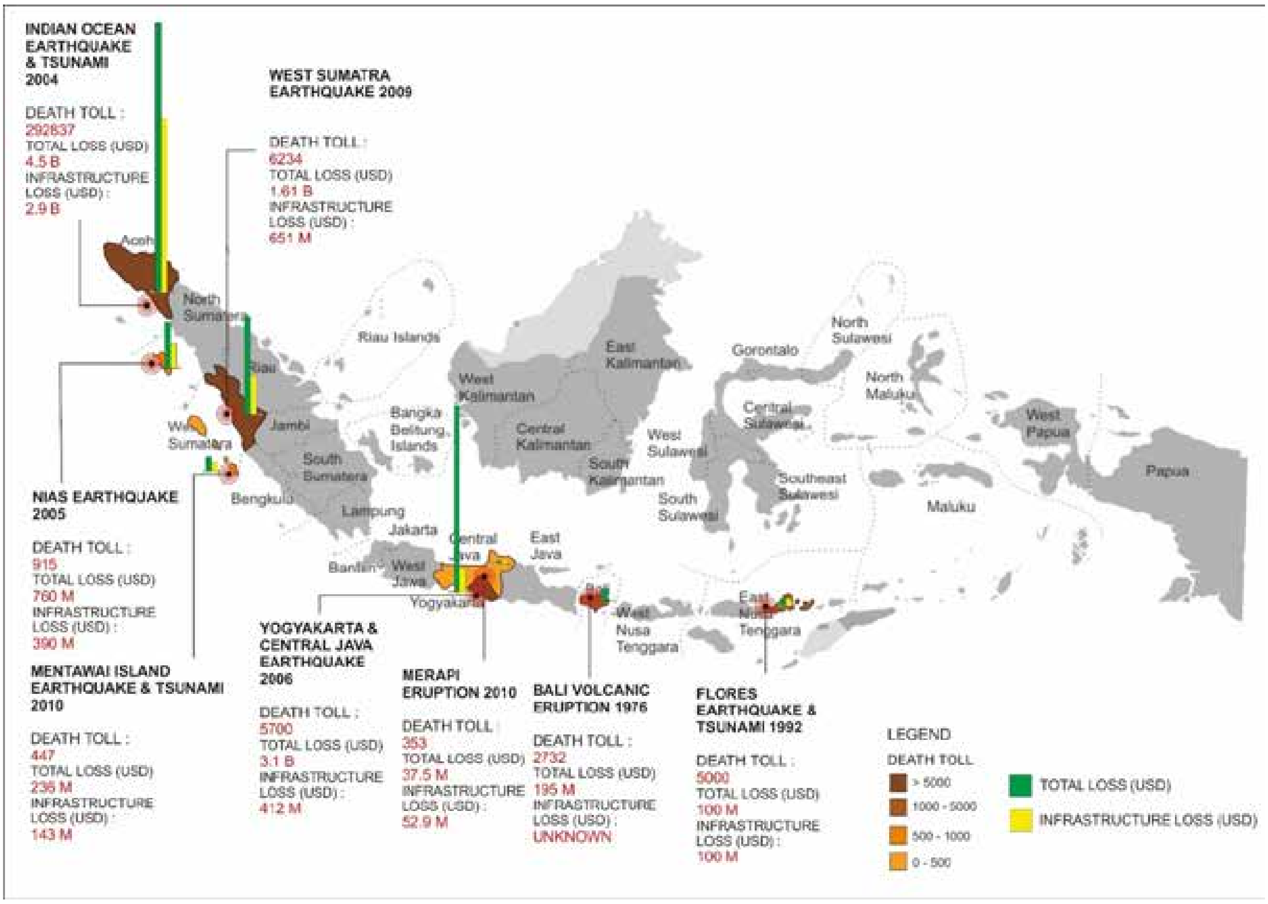
Cost for infrastructure recovery

2016: The needs for finance for post-disaster rehabilitation and reconstruction for the major disasters in the same year amounted to more than IDR 514 million.

Figure1-2-2. Post disaster rehabilitation and reconstruction, 2016

Source: BNPB, material for the APEC workshop, 20th Sept. 2017, Vinh City, Viet Nam

Figure1-2-3. Damages from major natural disasters in Indonesia since 1976



Source: BNPB, Indonesia, Retrieved from dibi.bnpb.go.id.

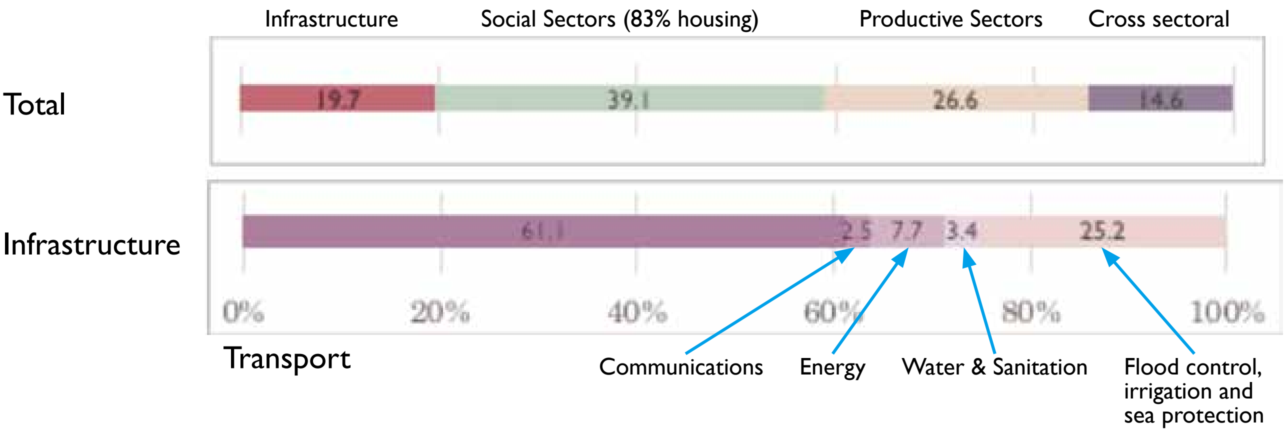
The Indian Ocean Earthquake and Tsunami in Indonesia

According to World Bank estimates[5], the damages and losses from the Indian Ocean Earthquake and Tsunami amounted to USD $4,451.6 million, including $2,920.4 million damages and $1,531.2 million losses. Of the total, 66% constitutes damages, while 34% constitutes losses in terms of income flows lost to the economy. The damage provides both an idea of the destruction of assets in the economy as well as a baseline for defining the program of reconstruction.

5 http://siteresources.worldbank.org/INTINDONESIA/Resources/Publication/280016-1106130305439/damage_assessment.pdf

Infrastructure damages and losses amounted to $876.8 million including $636 million damages and $240.8 million losses, constituting 19.7% of total damages and losses. The social sector amounted to 39% of the total, 83% of which is attributed to housing. Regarding the types of infrastructure, those for transport topped (61.1%) followed by those for flood control, irrigation and sea protection works.

Figure1-3. Damages and losses by the Indian Ocean Earthquake and Tsunami in Indonesia, estimated by World Bank



Source: World Bank, The consultative group on Indonesia January 19-20, 2005 "Indonesia: Preliminary damage and loss assessment –The December 26, 2004 natural disaster" A technical report prepared by BAPPENAS and the International Donor community

The impact of the 2006 Yogyakarta and Central Java earthquake[6] on public and private infrastructure was relatively limited, with the value of damage and losses estimated at IDR 397 billion and IDR 153.8 billion, respectively. The sector worst affected was energy with damage to the electricity transmission and distribution facilities estimated at a total 225 billion and losses at a further 150 billion from physical damage. In the transport sector, there was widespread but minor damage to roads, and localized damage to Yogyakarta's airport, and to mainline railway tracks and associated infrastructure. Total damage is estimated at IDR 90.2 billion. In the case of the West Sumatra earthquake, damages are estimated at IDR 21.6 trillion, equivalent to about USD $2.3 billion. Almost 80 percent of all damage and losses are recorded in the infrastructure sectors (including housing), followed by the productive sectors with 11 percent.

In the case of the Nias Earthquake 2005, most of the damage to infrastructure occurred to bridges, and there were fissures along the roads produced by subsidence and lateral spreading. Many bridges were displaced from their supports from 30 cm to 100 cm. One part of the newly constructed jetty at Gunung Sitoli, Nias, sank into the sea.[7]

In the Philippines, the reporting system for infrastructure damage covers roads, bridges, school facilities and other buildings. The largest damages were caused by Typhoons Ketsana and Pepeng in 2009 with losses amounting to PHP 27 billion. The two typhoons overlapped as they hit the "National Capital Region (NCR)", flooding the urban areas of Metro Manila and destroying roads and buildings. On the other hand, Typhoon Pepeng caused landslides and washouts in a mountainous region. These disasters were not detailed as cases for this report because most of the damage was in metropolitan areas.

6 http://documents.worldbank.org/curated/en/581581468041086975/pdf/407120ENGLISH01507190Yogya01PUBLIC1.pdf
7 https://www.eeri.org/lfe/pdf/indonesia_sumatra_northern_report.pdf

Table1-3. Disasters That Brought Significant Damages in Infrastructure in Philippines

Rank	Disasters, Year	Areas Affected	Damages on infrastructure Million Pesos
1	Typhoon Ketsana (Ondoy), Sept. 24-27, 2009 Typhoon (Pepeng), Sept. 30-Oct. 10, 2009	Luzon, NCR	6,600.189 20,435.459
2	Typhoon Haiyan(Yolanda), 2013, Nov. 6-9, 2013	Leyte, Visayan Region	12,055.240
3	Mt. Pinatubo Eruption, June, 1990	Central Luzon	7,680.000
4	Luzon Earthquake, July 16,1990	Baguio, Northern Luzon	6,845.000
5	Typhoon Bopha (Pablo), Dec. 1-9,2012	Northern Mindanao	6,836.923
6	Typhoon Fengshen (Frank),, 2008	Western Visayas	5,856.343
7	Typhoon Rammasund (Glenda), July 13-17,2014	Luzon, NCR	4,260.042
8	Typhoon Koppu (Lando), October 14-21,2015	Luzon, NCR	3,482.027
9	Typhoon Nock-ten (Juaning), July 25-28 ,2011		2,850.851
10	Typhoon Goni (Ineng), August 18-23,2015		2,333.560
11	Bohol Earthquake, Oct.15, 2013	Bohol, Visayas	2,257.337
12	Typhoon Nesat (Pedring), September 24-28,2011		2,094.817

Source: Office of Civil Defense, Philippines, 1980-2016 Report

Super typhoon Haiyan (2013) was the world's strongest recorded cyclone at landfall, with a wind velocity of 350km/hour. It caused PHP 12.055 billion worth of damage to infrastructure. It was said that not one structure was left standing in areas affected by a storm surge as high as 30 feet and reaching there kilometers inland. One of the facilities destroyed was the Tacloban airport. Its rehabilitation is included in the case studies (Case 1.3.5). The eruption of Mt. Pinatubo in 1990 destroyed infrastructure in four provinces of Central Luzon—Pampanga, Tarlac, Bataan and Zambales—through the ash-fall deposits and lahars that swept the region from 1991 to 1995. Heavy rains brought devastating lahars, eroding and burying communities, including roads, bridges and homes. The Luzon earthquake in 1990 affected Central and Northern Luzon, opening sinkholes along coastal communities and landslides in the mountain region. Tens of buildings were destroyed, particularly in the mountain city of Baguio. Another destructive earthquake occurred in Bohol in 2013, destroying heritage churches and other structures. .

In Viet Nam, over the past 20 years, natural disasters caused significant damages and casualties. It is reported that more than 300 people died or went missing due to natural disasters annually, with losses of 1-1.5 % of GDP (approximately USD $900 million).In 2016, for example, floods triggered by heavy rains that hit central coastal provinces in October, brought about economic damages amounting to $400 million, with 134 dead and missing as well as thousands of damaged roads and houses. The following table shows the 10 worst disasters over 20 years from 1997 to 2017 based on casualties, among which the estimated economic damages of three cases exceeded VND 4,000 billion, including the Great Flood of the central provinces in 1999 that caused almost VND 5,000 billion in damages.
The Great Flood of the central provinces (1999) is regarded as the largest flood ever recorded in Viet Nam up to that time. Floods impacted 10 provinces and cities of the central region and killed 595 people. Damage was estimated to reach nearly VND 5,000 billion.

The Mass Flood in the Mekong Delta (2000) killed 539 people, including more than 300 children. 9,457 houses were completely destroyed, and more than 62,000 households had to move their homes. Losses in production, livestock, infrastructure and natural ecosystems were also significant. Total damage was estimated at VND 4,600 billion.

Table1-4. Recent disasters in Viet Nam and damages

Name of disaster	Location	Year	Casualty	Economic damages (billion VND)	Note
Storm No. 5 (Linda)	Kien Giang province	1997	3111	4,474	A total loss of $385 million equivalent to VND 4,474 billion
August Flood	Northern provinces	1945	600		Casualty includes the number of missing.
The Great Flood	Central provinces	1999	595	5,000	
Mass Flood	Mekong delta provinces	2000	539	4,600	
Storm Chanchu	Central provinces	2006	266		Casualty includes the number of missing.
Flash Flood	Northern mountainous provinces	2008	256	3.229	The economic damage is that of property. Casualty includes the number of missing.
Mass Flood	Central provinces	2010	143		
Mass Flood	Central provinces	2016	134		Casualty includes the number of missing.
Mekong Flood	Mekong delta provinces	2011	89	4,400	
Hurricane No. 7 (Damrey)	Danang city	2005	68	3,500	The economic damage could be beyond VND 3,500 billion

Source: Viet Nam Disaster Management Authority, VNDMA, Ministry of Agriculture and Rural Development, "Report on Viet Nam Natural Disaster Prevention and Rescue"

In 2011, the Mekong River basin again experienced an extraordinarily large flood due to the combination of upstream rain and tidal flooding. The flood peak at Tan Chau was 4.86m; in Chau Doc it reached 4.26m (12/10/2011). The flood waters killed 89 people, damaged 176,000 houses, and caused the loss of 27,000 hectares of rice crop. The embankments and dykes at all levels were badly destroyed. Also damaged were a total of more than 250,000 meters of dikes and embankments, and more than 55,000 meters of "Provincial and National Roads". Total damage was estimated at VND 4,400 billion.

In Chinese Taipei, disasters throughout the 20th century and into the 21st century caused significant economic damages and losses, including the Hsinchu-Taichung earthquake (1935), the 9-21 Chichi earthquake (1999), the Kaoshiung-Meinong earthquake (2016), the 8-7 floods (1959), the 8-1 floods (1960), the 8-18 floods (1997), the 9-17 floods (2001), the 7-2 floods (2004), and the 8-8 floods (2009). The details of these disasters are listed in Table 1-5.
Regarding infrastructure, the major natural disasters that caused significant infrastructure damage include the following:

Table1-5. Earthquakes and typhoons affecting Chinese Taipei

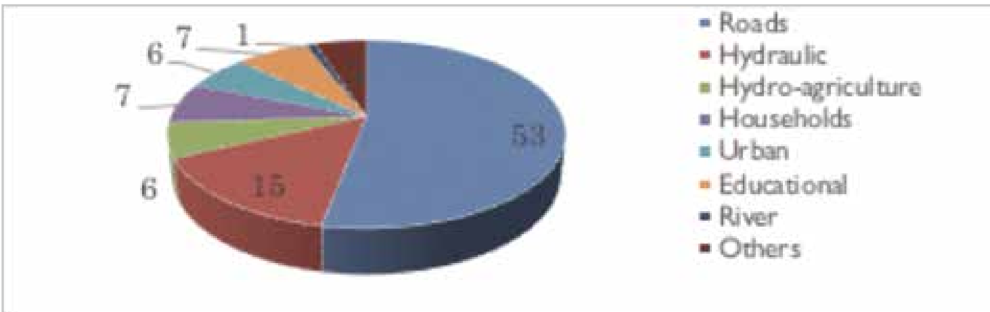
Earthquake	
1. The Hsinchu-Taichung Earthquake (1935, M7.1)	This earthquake caused 3276 deaths, 12,053 injuries, and about 55,000 houses to collapse. It is the most serious earthquake that caused the most casualties in the historical data.
2. The 9-21 Chichi Earthquake (1999, M7.3)	This earthquake caused 2415 deaths, with 30 people missing, 11,306 people injured, and about 110,000 houses collapsed.
3. The Kaoshiung-Meinong Earthquake (2016, M6.6)	This earthquake caused 117 deaths and 551 injuries. One building in Tainan city collapsed, killing 115 of the 117 victims. It is a special case that a single collapsed building caused most of the casualties.
Typhoon & Flooding	
1. The 8-7 floods (1959)	These floods seriously damaged the central and southern regions of Chinese Taipei. They caused 667 deaths and 942 injuries, leaving 408 people missing.
2. The 8-1 floods (1960)	These floods seriously damaged the central region of Chinese Taipei. They caused 104 people deaths and left 9890 houses destroyed and 50,194 people homeless.
3. The 8-18 floods (1997)	These floods caused 44 deaths and 84 injuries, with one person missing.
4. The 9-17 floods (2001)	These floods were caused Typhoon Nali which lingered over Chinese Taipei for over 49 hours, causing 112 deaths.
5. the 8-8 floods (2009)	The floods was caused by the great amount of rainfall that was brought by Typhoon Morakot. In the historical data, the damage from this disaster is second only to the 8-7 floods of 1959.

The 9-21 Chichi earthquake in 1999 brought about serious harm to human life (2,415 killed, 29 missing, 11305 injured), and also devastated homes (51,711 houses fully destroyed, 53,768 houses partially damaged) as well as infrastructure such as roads, bridges, dams, embankments and power facilities, pipelines, factories, hospitals, and schools. In addition, the earthquake led to huge landslides and soil liquefaction. The most severely damaged area is located in the center of Chinese Taipei. (See Case 1.1.2: Shihwei bridge and Case 2.5: Shihgang dam.)

The 8-8 floods were caused by Typhoon Morakot in August, 2009, dealing serious damage to the middle and the eastern regions of Chinese Taipei. In Pingtung county, an important north-south rail line was severely damaged when many of the railway embankments collapsed. In addition, in Kaohsiung county, many indigenous tribes in the mountains suffered from the most serious damages. (See Case 1.1.1: The No.20 provincial road.)

In Mexico, of the infrastructure impacted by natural disasters from 2000 to 2016, the majority was roads (53%), followed by hydraulic infrastructure.

Figure1-4. Mexico: Impact by type of infrastructure (2000-2016)



Source: Cenapred, Mexico, material for the APEC workshop, 20th Sept. 2017 Vinh City, Viet Nam

In the USA between 1980 and 2017, losses from weather-related disasters totaled over USD $1.5 trillion, and claimed 9,985 lives. The distribution of damage is dominated by tropical cyclone (hurricane) losses causing the most total damage ($850.5 billion, CPI-adjusted) and also the highest average event cost ($22.4 billion per event, CPI-adjusted). Tropical cyclones and flooding represent the second and third most frequent event types (38 and 28), respectively.

Table1-6. Billion-dollar events affecting the USA from 1980 to 2017 (CPI-Adjusted)[8]

DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	CPI-ADJUSTED LOSSES *(BILLIONS OF DOLLARS)*	PERCENT OF TOTAL LOSSES	AVERAGE EVENT COST *(BILLIONS OF DOLLARS)*	DEATHS
Drought	25	11.4%	$236.6	15.4%	$9.5	2,993[†]
Flooding	28	12.8%	$119.9	7.8%	$4.3	540
Freeze	8	3.7%	$27.6	1.8%	$3.5	162
Severe Storm	91	41.6%	$206.1	13.4%	$2.3	1,578
Tropical Cyclone	38	17.4%	$850.5	55.3%	$22.4	3,461
Wildfire	15	6.8%	$53.6	3.5%	$3.6	238
Winter Storm	14	6.4%	$43.1	2.8%	$3.1	1,013
All Disasters	**219**	**100.0%**	**$1,537.4**	**100.0%**	**$7.0**	**9,985**

Source: NOAA "National Centers for Environmental Information (NCEI)" U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

Among these losses, damage to infrastructures including transportation systems, ports, water systems, and electric grids make up a large proportion. The infrastructure costs of rebuilding the storm surge protection system in New Orleans after Hurricane Katrina totaled $14.5 billion (Table 1-7). The overall total for the storm's impact to infrastructure across the entire affected region was certainly much higher – some estimates for the total cost of Katrina reach $250 billion. In Hurricane Sandy, one estimate suggests the cost to housing and infrastructure was $33 billion (Table 1-7).

Table1-7. Infrastructure damages and losses in the USA by major, recent natural disasters

Natural Disasters (year)	Infrastructure damages	Source
Hurricane Katrina (2005)	$14.5 billion replacement cost for flooding protection system in New Orleans	"Billions Spent On Flood Barriers, But New Orleans Still A 'Fishbowl'," National Public Radio, 28 August 2016 https://www.npr.org/2015/08/28/432059261/billions-spent-on-flood-barriers-but-new-orleans-still-a-fishbowl
Hurricane Sandy (2012)	$33 billion housing and infrastructure replacement cost	"Hurricane Sandy's Rising Costs," New York Times, 27 November 2012 http://www.nytimes.com/2012/11/28/opinion/hurricane-sandys-rising-costs.html

8 https://www.ncdc.noaa.gov/billions/summary-stats

In Japan, direct economic damages by major earthquakes in the past are estimated as follows, including those on infrastructure. The Great East Japan Earthquake was the costliest, followed by the Great Hanshin-Awaji Earthquake.

Table1-8. Direct Economic damage by recent earthquakes in Japan

Past Earthquake in Japan	Source	Direct Economic Losses	
		JPY trillion	USD billion
2016 Kumamoto Earthquakes	Cabinet Office analyst	2.4-4.6	24-46
2011 Great East Japan Earthquake	Cabinet Office for Disaster Management	16.9	169
	Cabinet Office analyst	16-25	16-25
2004 Chuetsu Earthquake	Niigata Prefecture	1.7-3	17-30
1995 Great Hanshin-Awaji Earthquake	"National Land Agency, Cabinet Office", Hyogo Prefecture	9.6-9.9	96-99

Source: "Ministerial Conference Materials on Monthly Economic Report," 23 May 2016, Cabinet Office http://www5.cao.go.jp/keizai3/getsurei/2016/05kaigi.pdf, Calculated as 1 USD = JPY 110.

Regarding the Great East Japan Earthquake and the Great Hanshin Awaji Earthquake, estimates of infrastructure damages are as follows. Infrastructure damages, defined broadly to include buildings, were estimated at JPY 16.9 trillion for the former and JPY 9.6 trillion for the latter, while the public infrastructure damages including river management infrastructure, roads, ports, sewerage, airports and so on amounted to approximately JPN 2.2 trillion in both disasters.

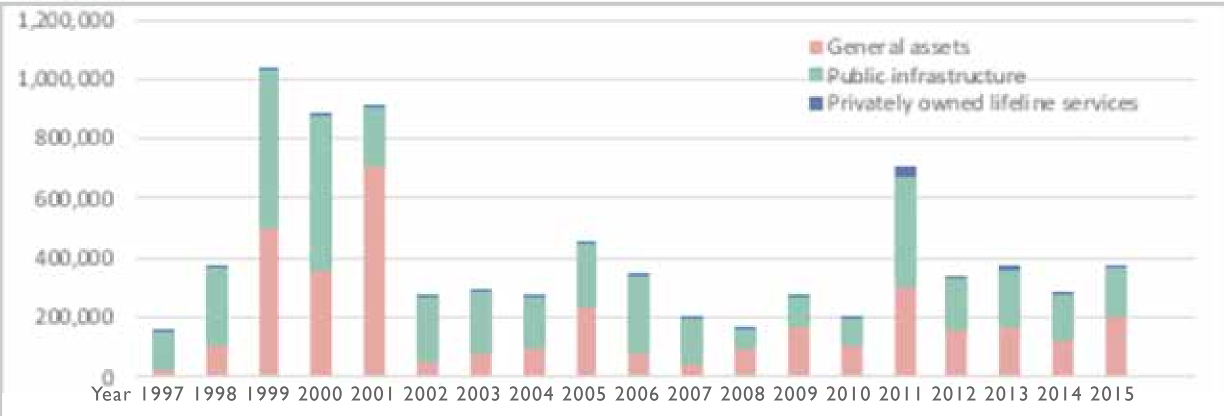
Table1-9. Infrastructure damages by the two earthquakes

Item		Estimated damages in JPY (with USD equivalents)	
		The Great East Japan Earthquake (2011)	The Great Hanshin-Awaij Earthquake (1995)
Total		JPY 16.9 trillion (US$163 billion)	JPY 9.6 trillion
Infrastructure	River management infrastructure, road, port, sewerage, airport, etc.	JPY 2.2 trillion (US$21 billion)	JPY 2.2 trillion
Lifeline facilities	Waterworks, gas facilities, electric facilities, communication infrastructure, etc.	JPY 1.3 trillion (US$13 billion)	JPY 0.6 trillion
Buildings	Housing and housing lots, shops, offices, factories and industrial machinery	JPY 10.4 trillion (US$100 billion)	JPY 6.3 trillion
Agriculture, forestry, and fisheries	Farm and agriculutral facilities, forests, fishery facilities, etc.	JPY 1.9 trillion (US$18 billion)	JPY 0.5 trillion
Others	School and education facilities, medical and welfare facilities, waste disposal plants and other public facilities	JPY 1.1 trillion (US$11 billion)	

Source: Cabinet Office, Japan (24th June 2011): "An estimation of infrastructure damages caused by the Great East Japan Earthquake" (Press release)

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) publishes annual economic damages by flood and water related disasters (See Figure 1-5). In 2016, total economic damages amounted to JPY 462 billion[9] : JPY 162 billion to general assets including housing, JPY 281 billion to public infrastructure, and JPY 19 billion to private-sector lifeline services including railways, water services, electricity and communication.

Figure 1-5. Economic damages by flood and water-related disasters, Japan (Unit: JPY millions)



Source: MLIT, Japan: "Flood statistical survey"

As the above demonstrates, APEC economies have seen significant economic impacts from natural disasters, although data is limited regarding infrastructure damages. Considering that production chains and supply chains are dependent on transport networks and basic services, indirect losses caused by infrastructure damages could become significant. They are not limited to large cities but also include non-metropolitan cities and rural areas, and extend beyond APEC economies. The world economy, as a whole, faces the risk of disruption to increasingly integrated and interlinked production and supply chains; global dependence upon these complex and tightly coupled systems could magnify the impacts of future natural disasters. Upgrading infrastructure resiliency is thus a precondition for achieving resilient supply chains and global value chains and for promoting sustainable growth of the world economy.

4 Learning from good practices of infrastructure BBB

The increasing frequency of natural disasters means that the government authorities in the affected regions and economies have little opportunity to discuss and plan recovery and BBB strategies during "peacetime". Rather, it is in the aftermath of disasters that DRR authorities in the APEC region have attempted to find feasible and affordable solutions for restoration, reconstruction and Build Back Better approaches to infrastructure by overcoming diverse challenges.

Recovery and reconstruction from natural disasters could, in fact, be a key moment of opportunity for infrastructure investment, especially for developing economies with growing needs for investments in higher quality infrastructure. Through the examination of successful examples, this casebook is intended to help guide and inform economies in need of infrastructure investment, planning and coordinating infrastructure recovery and Build Back Better approaches in close collaboration with the development authorities and the private sector.

9 Provisional figures

What is "infrastructure BBB"?

Exploring the concept of Build Back Better and that of infrastructure itself is a purpose of this project. "Build Back Better" in general is defined as follows, in the report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction established by the UN General Assembly:

"The use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment."

For the question "Is the concept of "Build Back Better, BBB" defined in the Sendai Framework well understood and integrated in Disaster Risk Reduction policies and infrastructure development policies in your economy?", most of the economies that answered our questionnaire survey chose "Very well understood and integrated", or "Largely understood and integrated", both at central and local levels. To take Australia as an example, the concept of Build Back Better is well understood; however, disaster risk reduction policies are structured in a particular way: Australia has focused on building resilience and promoting the integration of risk mitigation planning into all governments' future land use planning, infrastructure and community-based decision-making. Thus, there could be significant variations in understanding and promoting BBB economy by economy. The concept of BBB, as is the case in Australia, has been understood and integrated in DRR policies of individual economies in different ways under diverse contexts.

Taking into consideration the values of APEC and its policy priorities, in this case book focus is placed first on the effects of infrastructure recovery on local industries and economy. For example, the studies examine how reconstructed infrastructure has facilitated bringing rural products to regional and international markets by enhancing connectivity for the supply chain and global value chain.

Second, in this study, the DRR and development nexus will be highlighted in the context of BBB, as infrastructure development projects could be financed not just by disaster recovery budgets but also through various sources provided for development policies and other relevant policies. As infrastructure development projects may have wider scope of influence over the regional economy beyond the affected areas through the production and supply chain, an effect potentially lasting for decades, DRR priorities should be well integrated into relevant policies even in peacetime. Collaboration with the private sector as the user and provider of infrastructure will be another policy focus in considering infrastructure BBB.

Third, BBB can be achieved not just by the use of high technologies, but also by applying locally based or environmentally friendly technologies tailored for individually affected areas. Such solutions will also be highlighted here as an effective type of infrastructure BBB.

Table 1-10. Diverse types of Infrastructure BBB discussed at the APEC workshop

BBB Types	Cases
0. Immediate recovery	
1. Instauration of disaster-resistant infrastructure / enhancing capacity of the existing structure	• Earthquake-resistant, water-resistant , anti -tsunami structures • Instauration of emergency power supply • Introduction of structures to facilitate smooth recovery • Increasing redundancy by installing alternative facilities
2. Upgrading the function	• Use of cutting-edge technology vs. technology more adapted to the diverse conditions, less costly structures for maintenance • Realizing further links with local industrial clusters
3. Redefining and diversifying the function	• More environmentally friendly structures, "plant back better" • Infrastructure serves also as tourist destination • Improving scenic beauty
4. Planning & designing of recovery	• Relocation of infrastructure to the areas with less danger • Wider scope of planning and vision making for building new urbanised areas
5. Governance and finance or BBB	• Special fund facilitating immediate recovery • Effective organisation for smooth BBB • Collaboration with the Private sector
7. More effective and safer implementation of BBB works	• Use of construction technologies satisfying diverse demands for recovery
6. Installing facilities to support evacuation as an alternative/second best solution	• Installation of evacuation route, tsunami tower, and so on
8. Others	• Training of relevant human resources

Source: material for the APEC workshop, in Vinh, City, Viet Nam, 20th Sept. 2017

Which infrastructure will be studied in this project ?

The definition of infrastructure varies by economy. Moreover, the role played by the governmental sector and the private sector in regard to infrastructure development and relevant services provision is diverse among economies and infrastructure types. In this study, a wide scope of infrastructure BBB cases will be reported regardless of the strict definition of infrastructure in each economy.

Firstly, transport infrastructure will be examined through cases of the quick recovery of roads, followed by cases in which wide area road networks and connectivity were improved, and then BBB of ports, airports, and so on.

Secondly, cases of coast and river management infrastructures and other water resources development infrastructure will be examined.

Thirdly, cases of whole village relocation will be explored, including the development of community infrastructure. Some cases of housing/building recovery follow, although housing and buildings are rarely classified as infrastructure. In many disasters, housing damages are significant and residential reconstruction is given high policy priority. In rural areas, where large infrastructure had not yet been installed, structural reconstruction often largely means housing and building reconstruction. Lessons useful for community infrastructure recovery could thus be drawn from these cases.

Finally, funding policies that support infrastructure BBB and public-private collaborations facilitating infrastructure BBB will also be examined, further illuminating the core question of what infrastructure BBB actually is.

The project is principally to facilitate post disaster infrastructure development in rural regions and areas outside metropolitan regions which face increasing needs for infrastructure investment. Just to draw lessons learned for those regions, some cases from metropolitan areas are also presented.

II Good practices of Infrastructure BBB in APEC Economies

Chapter I will explore diverse cases of Build Back Better of infrastructure by types, including transport infrastructure at both communal and wide regional levels aimed at upgrading connectivity, as well as recovery of ports and other transport infrastructure. River management infrastructure, including sea dike recovery and water resources development infrastructure, will be analyzed. Village relocation will also be examined. Finally, examples of infrastructure recovery funding, collaboration with private sectors, and technologies facilitating recovery will also be presented together with additional considerations for "infrastructure BBB".

1 Transport infrastructure - towards upgrading connectivity

Section 1 focuses on transport infrastructure including roads, bridges and port facilities, which are essential to all economic activities, not just disaster management. These cases of post-disaster recovery of damaged infrastructure will help illustrate the concepts of critical infrastructure BBB in diverse situations.

1.1 Quick recovery of road transport

Immediate recovery of road transport is a starting point for smooth and effective recovery and BBB. In this subsection, four cases will be presented from Chinese Taipei, USA and Japan.

1.1.1 Chinese Taipei : Typhoon Morakot[10] and the No. 20 provincial road

The No. 20 provincial road is the main access road for many villages in the mountainous area of South Chinese Taipei and plays key roles for the local residents. It was significantly damaged and closed, however, after the typhoon Morakot in 2009. Its restoration was immediately undertaken by the Morakot Typhoon Post-disaster Reconstruction Council and the Directorate General of Highways, based on principles of environmental conservation, by adopting ecological engineering methods.

Pre-disaster situation

The No. 20 provincial road is a main access road that links Tainan and Taitung counties. The main road is 209.446km in its total length (Map1), the longest among all of the provincial roads, with two branches. Also known as "the Southern cross-island highway," the road crosses three mountains and three counties. Prior to Morakot, the road had greatly contributed to tourism, economy, and the industries of Tainan city, Kaohsiung city, and Taitung county.

Outline of the Infrastructure

Type of road: The southern trans-island highway.
Location: Between Tainan county and Taitung county.
The length of the road: Yujing to Degao, 172 km
Beiliao to Degao, 166.7 km
Jiasian to Degao, 150.5 km
Opened: November, 2014
Funded by: The Typhoon Morakot Post-disaster Reconstruction Council
Owner/Operator: The Directorate General of Highways

10 GLIDE number TC-2009-000150-TWN

Map1. Location of Provincial Highway 20

Impacts on infrastructure

Typhoon Morakot, struck the southern area of Chinese Taipei in 2009. The most serious impact of this typhoon was the floods caused by the enormous rainfall from August 6 to 10. The disaster is therefore known as "the 88 flood" (for 8 August), the economy's most serious flood since 1959.

Photo1-1 The Lidao bridge collapse

Photo 1-2 Reconstruction of the new Lidao bridge

After typhoon Morakot, the Lidao bridge was seriously damaged by landslides (as shown in Photo. 1-1). In July 2012, the new Lidao bridge was open to traffic (as shown in photo 1-2). It has improved the traffic on the No. 20 provincial road, and brought positive effects on both tourism industry and agricultural transportation.

Recovery and BBB projects chronology

The reconstruction of the No. 20 provincial road includes that of four damaged bridges, including the Taoyuan 1st bridge, the Shengjing bridge, the Salaawu bridge, and the Baolai 2nd bridge. In order to undertake the difficult reconstruction work, the Typhoon Morakot Post-Disaster Reconstruction Council was organized. It convened government agencies, such as the Directorate General of Highways and district offices, to enhance coordination so that the recovery work could be completed on schedule before the flood season. The reconstruction council continuously monitored the schedule.

Relevant authorities: The Typhoon Morakot Post-disaster Reconstruction Council, the Directorate General of Highways, and the district offices
Budget: approx. NTD 3,900,000,000
Recovery and BBB plan, and decision-making process:
- 2009: The reconstruction program was proposed by the Typhoon Morakot Post-disaster Reconstruction Council
- 2010: The Executive Yuan[11] provided the funding
- 2010: Start of the Project
- 2014: Completion

In October 12, 2011, the reconstruction council approved a special budget of 9.92 billion NTD, which had been proposed by the Directorate General of Highways for continuing the reconstruction plan for the provincial roads in Southern Chinese Taipei. The major reconstruction work was completed in 2014. The traffic conditions in Kaohsiung county have significantly improved, facilitating agricultural transportation, leading to more job opportunities for the local residents.

Effects on the local economy, industries and supply chain

The government has devoted NTD 39 billion to the reconstruction of the No. 20 provincial road. The new Lidao bridge was opened and improved the traffic on the No. 20 provincial road, and brought about positive effects for both tourism and agricultural transportation. In order to stimulate industrial recovery and local economic development, the reconstruction council also planned to develop five routes for the tourism industry in the affected area. The council devised a three-year program and allocated NTD 700 million in the Hairuei township for developing local industries, including maintenance of the mountain trails for tourists, consulting for retailers of local agricultural products, as well as quality agriculture development. The government hopes the development of the tourism industry could attract people to the affected area and stimulate the local industries towards prosperity.

Lessons learnt for APEC economies' infrastructure BBB

At the beginning of the reconstruction, the government devoted substantial funds to shorten the reconstruction schedule. The reconstruction council also integrated suggestions from the local governments to reconstruct the southern cross-island highway. The main goal was to keep the road clear during the reconstruction phase, and to minimize the impact to the environment. Ecological engineering methods were therefore adopted to implement the reconstruction work. In addition, the reconstruction plan also needed to satisfy the special requirements of agricultural transportation, improvement of the accessibility to indigenous communities such as Chingho and Fuxing townships, and also the development of tourism and local industries. The reconstruction of the No. 20 provincial road also reduced the traffic burdens on the South Bound Highway, and shortened the traffic time between Tainan county, Kaohsiung county, and Taitung county. This case demonstrates that the government initiative soon after the disaster accelerated the recovery work while also achieving regional development goals.

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11 The Executive Yuan is the executive branch of the ROC government, headed by the premier minister. In addition to supervising the subordinate organs of the Executive Yuan, the premier minister explains administrative policies and reports to the Legislative Yuan (Legislature) and responds to the interpellations of legislators.

1.1.2 Chinese Taipei: The 921 Earthquake[12] and Shihwei Bridge

Shihwei Bridge of the No. 3 provincial road located in the central region of Chinese Taipei, was destroyed during the 921 Earthquake, since it was located at the earthquake fault zone. A part of the superstructure of the bridge was destroyed. The bridge is an important access road that connects Miaoli county and Taichung county. In order to rapidly resume traffic access, a temporary bridge was set up, and the reconstruction work was immediately launched.

Outline of the infrastructure and the pre-disaster situation

Shihwei Bridge, located at 163km and 210m of the No. 3 provincial road, is an important link that connects Tungshih township, Miaoli county and Fungyuan section, Taichung county. The bridge, originally constructed in April, 1994, has four fast lanes and one slow lane in each direction. Total length is 75m, width 24m, and the radius of curvature to the center line of the bridge is 170 m.

Type: Road and bridge
Location: 163km and 210m of the No. 3 Provincial road
Opened: December, 2000
Funding: The Second Maintenance Office, Directorate General of Highways
Owner/Operator: The Second Maintenance Office, Directorate General of Highways

Impacts on infrastructure

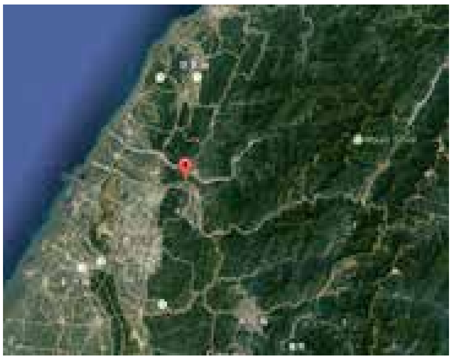
On 21 September 1999, the 921 Earthquake struck, which was the most serious earthquake in 100 years in Chinese Taipei. The epicenter was located at Chichi township, Nangtou county. The Richter magnitude scale reached 7.3. In total 2,415 people were killed, and over 110,000 houses were destroyed or partially damaged by the earthquake.

The earthquake caused serious damage to Shihwei Bridge: five spans of the superstructure fell, including the second and the third span of the northbound lane, and the third span of the southbound lane. One of the abutments was also squeezed by the soil and nearly fell over. The retaining walls of both sides of the embankments collapsed. In addition, part of the piers had obvious shearing cracks as shown in Photo 1. (Photo 2 shows the reconstructed Shinhwei Bridge.)

Photo 1. Damage to Shihwei Bridge due to the 921 Earthquake

Photo 2. High Damping Rubber(Shihwei Bridge)

12 GLIDE number EQ-1999-000321-TWN



Map 1. The location of the Shihwei Bridge

Photo 2. Reconstructed Shihwei Bridge

Infrastructure BBB investment
In order to catch up with the schedule of the emergency repair works, the general contractor and the construction supervisor held multiple charrettes. Since the steel bridge hoisting and the piping for electrical power, telecommunications, and water system are very complicated, it could have taken a very long time. The construction supervisor negotiated with the subcontractors for integrating their work (for example, the general contractor built up the steel bracket for the subcontractors so that they could save more time). After many negotiations and work rearrangements, the reconstruction was finally completed on schedule.

For immediate recovery, the following technologies were applied. High Damping Rubber (HDR) bearing to connect the piers and the superstructure was first imported as shown in Photo 2. The HDR isolators contain layers of rubber and reinforcing steel plates. These components let the HDR isolate the bridge/building/structure due to horizontal stiffness; they dissipate energy to reduce the horizontal displacement of the isolated structure with respect to the ground. The superstructure of the bridge adopted the design of continuous steel I-beam. Each beam was connected to fix the superstructure with steel plates, by using 52,000 high-tension bolts. In addition, the 30 High Damping Rubber bearings could move with the displacement caused by earthquakes and rapidly return to the original position, effectively reducing seismic damages. In both abutments, 20 sets of fall-proof devices which are made of high-tension steel bars, washers, and springs have been set up to prevent the superstructure from falling again. Shear keys are also set up in the steel beams to enhance the seismic performance.

Using such innovative techniques, the reconstructed bridge was completed on the original site in June 2000.

Relevant authorities: Directorate General of Highways
Budget: Total budget approx. NTD 70,060,000
Recovery and BBB plan, and decision-making process:
- -Sept.1999: The 921 Earthquake damages Shihwei Bridge
- -Oct.1999: Reconstruction project is proposed by the Directorate General of Highways.
- -Oct. 1999: Project is funded by Directorate General of Highways
- -Oct. 1999: Start of the project
- -Jun. 2000: Completion

Effects of infrastructure BBB and lessons learnt for APEC economies

The new design of the reconstructed bridge placed importance on safety as well as speed of recovery. It took eight months for recovery. The immediate recovery of local transport networks contributed to broader reconstruction and BBB of the economy of the affected areas.

1.1.3 The USA : Hurricane Irene[13] and federal highway infrastructure in the State of Vermont

Outline of the Infrastructure

Before: Vermont's highway infrastructure was standard for northeastern states, often damaged seasonally from the high use of salt to keep roads open throughout the winter. Vermont's highways were known to be vulnerable to flood waters, as many roads were built along the region's snaking rivers. Erosion of highway surfaces was considered a state problem, even pre-disaster.

After: Many small towns and villages were completely cut off from larger state or federal road networks, as large portions of Route 131 and Route 107 collapsed into the rivers below them, disrupting a significant amount of state and interstate travel. This also threatened the incoming fall foliage and snow sports seasons that the state greatly depends on for its tourist economy.

Type: Highways
Location: Statewide but in particular Route 131 & Route 107.
Opened: 1956 and 1939.
Funding: Initial investments covered by Vermont State government then covered in grant from US Department of Transportation, USDOT
Owner/Operator: The State of Vermont

Photo: Damage caused by flood waters from Tropical Storm Irene (2011-08-28) on the Ottauquechee River in Royalton, Vermont, which scoured the approach to the bridge on the northern shore of the river, as of 2011-09-07
Source: courtesy of Wikimedia Commons

13 GLIDE number TC-2011-000114-US

Photo: Homes and Vermont Route 107 (VT) 107 in Bethel, VT near the White River were damaged by quickly rising water during the Hurricane Irene flood event. photo credit: Ann Froschauer/USFWS
Source:courtesy of Wikimedia Commons

Pre-disaster situation

Before Hurricane Irene, the highways of Vermont served the same functions they do in other US states: providing access to an integrated local-to-federal road system for the travel of citizens and commerce. These roads are quite important to Vermont, as the state depends on the highways for its significant 'fall foliage' and mountain sports tourist seasons (valued at US$332 million in revenues, according to the New York Times). Additionally, Vermont depends greatly on the ability of the federal highways to connect the state's lumber, agriculture and animal products, and quarry industries with the domestic economy. Despite Vermont's inland position relative to the coastal areas affected by Irene, Vermont's vulnerability to flooding was a known reality. Yet little had been done to prepare for the magnitude of flooding that Irene would bring.

Natural disasters and the impacts on infrastructure

Early on 28 August 2011, after Hurricane Irene had run its course through most of the eastern seaboard of the United States, the storm hit Vermont. With many federal thruways built into cliffs overlooking snaking rivers or built on flatlands near bodies of water, Vermont's overlooked vulnerability to flooding became a reality. Hurricane Irene dropped 279.4 mm of rain on Vermont, resulting in three dead and one missing in the state, and 49 killed overall in the U.S. In Vermont more than 2,400 roads, 800 homes and businesses, 300 bridges, and a half-dozen railroad lines were destroyed or damaged. Local roads were poorly built for the purpose of surviving floods and accordingly many small towns and villages in Vermont were completely cut off from the outside world for days after the disaster. Federal Highways Route 4, 131, and Route 107 — among many smaller routes — were closed soon into the recovery process. In total more than 500 miles of roads were damaged. Major damages included 118 sections of state highway being closed and 34 bridges being closed, including many historical covered bridges.

Infrastructure BBB investment

The state of Vermont did not wait for a federal response. "National Guard" units from eight states participated, as did Department of Transportation crews from Vermont, New Hampshire, and Maine.

Hurricane Irene caused $733 million in damage to Vermont road infrastructure in total. The initiative for the repairs was taken entirely by the state government, which fronted all costs of repairing the highway infrastructure without any guarantee of federal aid, although it is apparent that some aid was expected eventually. The US Federal Emergency Management Agency (FEMA) did guarantee at the onset of the disaster that FEMA would cover eligible overtime labor costs accumulated from the speedy response. Recovery work started immediately after the hurricane and was completed within one year.

Effects on the local economy, industries and supply chain

The closure of any major transportation networks such as federal highways is going to have an effect on the local economy, but the effect of some parts of Vermont missing the 'fall foliage" tourist season cannot be overstated. As a progressive state, the service industry provides an enormous amount of taxable revenue that fuels social services. With this in mind the effect on the economy and population could have been significant if more of the 'fall foliage' and snow sports season were affected. Pragmatic efforts to partner with Google to create a live availability roadmap helped the effects of Irene to not be a complete loss for the service industry or other agricultural or extractive industries. Farmlands were affected significantly in the flatter areas of the state, particularly corn production. Widespread need for gravel and stone in the aftermath of the disaster could be interpreted as a boon for quarries in Burlington and other more mountainous areas in the states.

The effect on local economies specifically was significant, as outside of the federal roads the state government worked only to the most minimal levels to reconnect cut-off towns and villages. Other costs beyond this and damages on the small town/village level were costs that the townships themselves had to cover without guarantee of state or federal aid. Some places (e.g. Waterbury) were not able to front the significant costs, and formerly bustling towns were noticeably less bustling in the face of damaged infrastructure. While the efforts of the state government were impressive when it came to repairing the highway infrastructure, the economic effect on some smaller towns and villages was significant and potentially devastating.

Lessons learnt for APEC economies' infrastructure BBB

The repair of the Vermont State Highway infrastructure in the three months after Hurricane Irene is impressive and accordingly what this case displays as good BBB is how rapidly and completely the state made repairing the highways a primary goal, coordinating across state lines, and not waiting for federal assistance to begin work. Vermont partnered with Google to create a live updated map of the roads open in Vermont. This effort underlines how the state of Vermont was able to achieve an effective and efficient recovery while also insuring that the seasonal services they depend on at the local and state level were allowed to persist in some limited form, so as to prevent a complete loss.

A key lesson in this case for the more developed economies that comprise APEC is that a BBB project does not necessarily need to be anything but pragmatic. This case showed how efficient intergovernmental communication with other governmental agencies — federal, state, and local — can enhance a recovery operation. The use of "National Guard" reserve forces, construction crews from within and outside the state, and other governmental units was an impressive orchestration of ad hoc state power for recovery. Additionally the pragmatic use of forces at the state's immediate disposal was an equally pragmatic economic choice, without any federal guarantee and in the face of projected US$700 million cost. The state considered repairing its highway infrastructure — with or without federal aid — a necessary condition of recovery, regardless of cost.

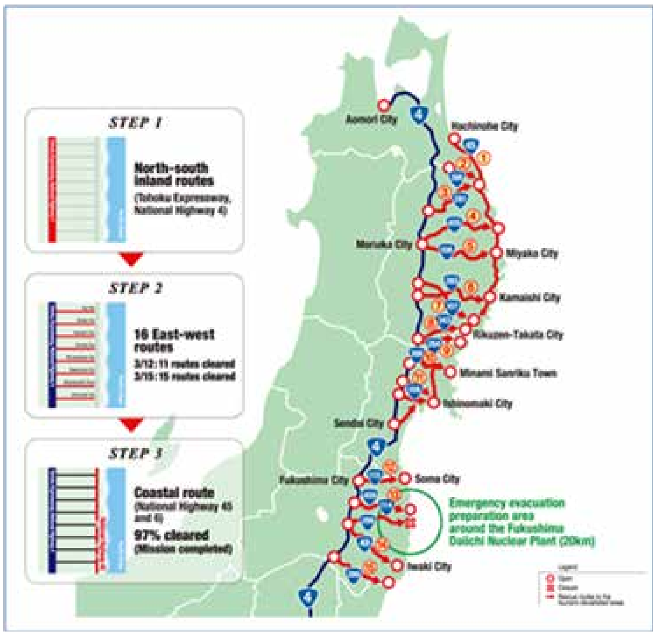
1.1.4 Japan : The Great East Japan Earthquake[14] and the immediate road networks clearance operation

Immediate clearing and securing of road networks in the heavily affected areas enabled immediate rescue operation and accelerating recovery process.

Outline of the Infrastructure

The Pacific coast of the Tohoku region, Japan, was connected by a wide range of road networks including the trunk roads of the Tohoku expressway managed by East Nippon Expressway Company Limited, and the "National Route 4". The four prefectures of Tohoku — Aomori, Iwate, Miyagi and Fukushima — are connected to the Tokyo Metropolitan region by these roadways.

Type: Expressway and "National Route"
Location: The Pacific coast of the Tohoku region
Funding: Tohoku Regional Development Bureau, Ministry of Land, Infrastructure and Transport, MLIT
Owner/Operator: Tohoku expressway (East Nippon Expressway Company Limited) "National Route 4"



Map 1. Road clearance operation "Teeth of Comb"[15]
Source: Tohoku Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Photo 1. Kotomoura, Rikuzen-Takata City (2011/3/14)
Source: Asia Air Survey Co.,LTD.

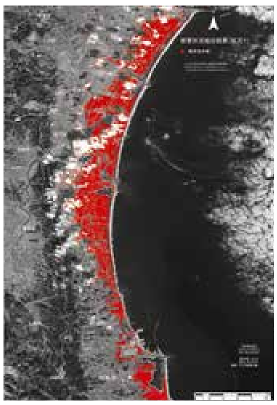


Photo 2. Inundated area by Tsunami
Source: Asia Air Survey Co.,LTD

Natural disasters and the impacts on infrastructure

An earthquake with a magnitude of 9.0 occurred around 15 km off the Sanriku coast around 14:46 on March 11. The scale of the main shock this time is the largest earthquake observed in Japan so far. Due to this earthquake the maximum seismic intensity of 7 was observed in Kurihara city, Miy-

14 GLIDE number EQ-2011-000028-JPN
15 http://infra-archive311.jp/en/s-kushinoha.html

agi prefecture. In addition, high tsunami such as 8.5 m or more in Miyako, 8.0 m or more in Funato, 7.6 m or more in Ishinomaki Ayukawa, 7.7 m or more in Soma, were observed in the Hokkaido region, the Tohoku region, and the Pacific coast of the Kanto region. According to the survey so far, it has been confirmed that the fishing port in Komoriba (Iwate prefecture Miyako City) recorded run-up heights over 30 meters. In addition to the huge tsunami, damage occurred in the vast area from the southern coast of Hokkaido through the northeast of Honshu including the Tokyo Bay and the southern part of Kanto region, due to seismic shaking and liquefaction phenomena, ground subsidence, dam breakdowns, and so on. A wide variety of infrastructure was damaged.
The earthquake and tsunami resulted in 18,449 people dead or missing, and total or half destruction of 400,827 buildings as of 2016. The government of Japan estimates the direct damage at JPY 16 trillion to 25 trillion, comparable to the total gross output of the three most damaged prefectures of Iwate, Miyagi, and Fukushima. According to estimates by the World Bank, the economic loss is the largest in the world's history.

Damages on the road networks and emergency road networks recovery
Due to the Great East Japan Earthquake, the "National Highway No. 45" on the Pacific coast was shredded, but the Sanriku coastal road that had been partially used in parallel with this survived the tsunami inundation. It served as a major detour route, together with the Route 45.
The Operation "Teeth of a Comb", named after the shape of the road networks, was a road clearance operation to secure rescue and relief routes networks extending from inland toward the Pacific coastal area of Tohoku. The Tohoku Expressway and the "National Highway Route 4" run through inland Tohoku from north to south, and a number of debris-covered roads connected the Expressway and the "National Highway Route 4" toward the coast. The inconceivably huge tsunami devastated the areas along the Pacific coast of Tohoku, leaving many areas isolated by debris-covered roads and washed out bridges. Immediately after the earthquake, the leaders and staff of the Tohoku Regional Bureau (TRB), MLIT, gathered in the Disaster Risk Management Office. Communication with the road and highway offices and branches was established immediately to gather information on the damage, and the strategy had been worked out. Operation Teeth of a Comb was immediately carried out to clear the roads and secure the Road of Life.

At the time of the Earthquake, however, 60% of the Sanriku coastal road had not yet been opened to traffic disaster, and, the road network connecting the Japan Sea rim region and the Pacific Ocean rim region had not yet been sufficiently connected.

The road clearance operation "Teeth of a Comb"

1. On the day of the tsunami, the TRB received almost no information about road damage from the Tohoku area. Nevertheless, the TRB confirmed that "National Route 4", running inland from the coastline, was not as severely damaged as expected. As the existing damage was not so critical for emergency vehicles to pass along, MLIT decided it would be the main axis for the road clearance operation.
2. MLIT assessed damages of the Tohoku Expressway, the only highway running north to south in the Tohoku region. Due to the heavy snow, most alternative routes passing the Ou Mountain Range were closed. The basic strategy of the road clearing was therefore to use the Tohoku Expressway and the "National Route 4" as the key access points from which to open lateral routes towards the Pacific coastlines.
3. Road selection was headed by the deputy director of the TRB Road Department. His team worked overnight on March 11 to select twelve roads from the fifty-five roads as the initial, primary access routes to reach the affected areas.

4. TRB liaison officers provided information on the roads managed by prefectural governments.
5. Before sunrise in the morning on March 12, the TRB director-general defined the twelve selected roads, named "the teeth of the comb" (kushi no ha). The access strategy focused not on the comb's axis, but on the lateral 'teeth,' which would subsequently open access to the worst affected areas. The TRB road recovery operation was therefore named 'Operation Comb'.
6. At 20:00 on March 12, one more road was added to the twelve original routes. Another three were added at 06:00 on March 13, making a final total of 16 routes.
7. It became evident during Operation Comb that the portion of "National Route 398" going towards Minami Sanriku across the Kitakami River would take too much time to clear. "National Route 108" and the Sanriku Coastal Road thus replaced the "National Route 398" as a better alternative route.

Effects on the local economy, industries and supply chain

Most of the roads became usable again, while there remained a lot of places in need of repair. According to the reconstruction agency, almost 99% of the "National Highways" were repaired by March 2012. In addition, the Joban expressway that was closed due to the nuclear accident has been completely re-opened since March 2015.

Figure 1 shows the average number of tons per month for each regional block by automobile during the year before the earthquake (March 2010-February 2011). Immediately after the earthquake, the average became extremely low in Tohoku (black line) compared to the rest of Japan (green line), yet since the fall of 2011, the Tohoku region exceeded other regions except briefly in mid-2012. This activity can be explained by the demands for logistics supporting restoration and reconstruction in the disaster-affected areas.

Figure1. Transport tonnage in Tohoku region and other regions
(One year average before the earthquake 100, 3 months moving average)

Lessons learnt for APEC economies' infrastructure BBB

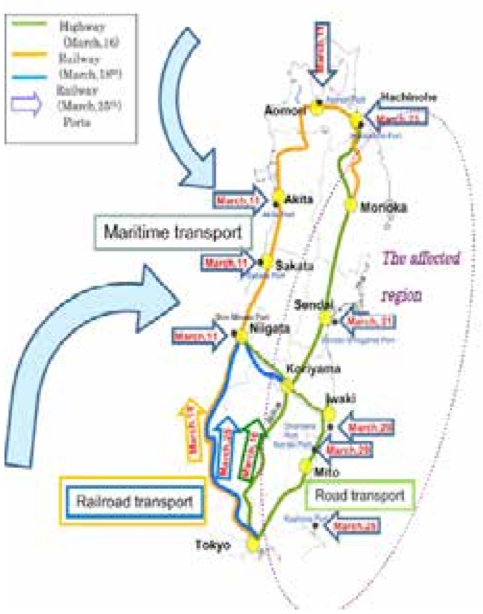
Immediate recovery of road networks

The road clearance operation "Teeth of a Comb" clearly demonstrated that immediate recovery of road networks is key for rapid and effective rescue and recovery operations. In Japan, other regions have drawn lessons from this experience and have introduced similar operations into their disaster management plans:

- The Chubu region could be affected by a massive earthquake in the Nankai Trough. The Central Countermeasure Strategy Council for the Tokai, Tonankai and Nankai Earthquakes announced a strategy for securing an immediate restoration support route called "Tooth of a Comb Operation, Chubu Edition" in March 2012, including life rescue support services within three days of a disaster, and emergency supplies transport assistance within seven days, by reaching from the inland to the coastal area.

- In the Kinki region, Wakayama prefecture has prepared for road clearance and restoration of the "National Road No. 42" located in the southern coastal areas.
- In Shikoku, the Committee for Shikoku Tonankai Nankai Earthquake Countermeasures has discussed routes for emergency operation.

Road networks development facilitating emergency operation
In addition to emergency operation plans, the concept of doubling road networks has been integrated in the regional development plans supporting road networks development, due to consideration of seismic risks. Infrastructure investment planning from a long term perspective and wider regional scope is a key to build a resilient region. "The National Spatial Strategy", revised in 2015 reaffirmed the importance of "territorial redundancy", or doubling key transport networks by learning from the lessons of the rescue and recovery operation after the Great East Japan Earthquake. Some regions have integrated this idea of dual road networks development into regional development plans.



Map2 Emergency transport networks in Tohoku

Reference

Tohoku Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan (2014) "Leading the first response to large-scale natural disasters—Lessons from the MLIT's Experience of the Great Eastern Japan Earthquake"

1.2 Upgrading connectivity — wide area road networks

1.2.1 Philippines: Mt. Pinatubo eruption[16] and alternative highways construction

In Philippines, after the massive eruption of Mount Pinatubo, construction of alternative road networks and improvement of existing ones commenced in the heavily affected provinces, including the Olongapo-San Fernando-Gapan Road & Highway, the Subic–Tipo Expressway and the Subic–Clark–Tarlac Expressway (SCTEX). The first project was the widening of a highway totally destroyed by the eruption. The second and the third were the new highways constructed as alternative routes to provide a better transport system in the disaster affected areas. Through these projects, connectivity of the affected areas has been significantly improved.

Pre-disaster situation

Before the 1991 Mt. Pinatubo eruption in Central Luzon, the transportation network from Metro Manila to northern Luzon was provided mainly through the North Super Highway (NSH) up to Mabalacat, Pampanga only. Western Luzon, particularly the provinces of Bataan and Zambales, was accessible through the Olongapo-San Fernando-Gapan Road, which is connected to the NSH.
Presidential decree No. 1062, issued by then-President Ferdinand Marcos on December 15, 1976, had mandated the construction and improvement of the Olongapo-San Fernando-Gapan Road in Olongapo City, Pampanga and Nueva Ecijais. The decree, "Appropriating Funds for Infrastructure Development, Synchronizing the Same With Previous Public Works Appropriations", allocated PHP 40,000,000 for the road project (PD No. 1062, 1976).

Natural disasters and the damages on the infrastructure

Mt. Pinatubo erupted on June 15, 1991, causing extensive damage. The data from the Office of the Civil Defense show that 850 people were killed and 23 missing. About 1.2 million people were affected and 110,000 houses were partially or totally destroyed. The ash-fall buried large tracts of land and caused the roofs of buildings to collapse. The lahars and flash floods wrought havoc on the infrastructure and the economic activities of Central Luzon. "Lahars destroyed and buried everything along their path: people and animals, farm and forest lands, public infrastructure, natural waterways, houses, and other facilities. Infilling of stream channels has caused overbank flows, drowning of areas behind natural impoundments, and other forms of flooding in low-lying areas" (Mercado, Lacsamana and Pineda, 1993).

The damage to crops, infrastructure, and personal property amounted to PHP 12 billion from 1991-1992. The business losses from 1991-1992 were estimated at PHP 491 million (US$18.4 million). The costs of caring for evacuees such as the construction of evacuation camps and relocation centers was at least PHP 2.5 billion (US$93 million) in 1991-92. An additional PHP 4.2 billion (US$154 million) was spent during the same period on dikes and dams to control lahars (Mercado, Lacsamana and Pineda, 1993).

16 GLIDE number VO-1991-000003-PHL

Infrastructure damages

The estimated damage to public infrastructure, as reported by the Department of Public Works and Highways (DPWH) Regional Office III was PHP 3.8 billion. The infrastructure subsectors affected and the cost of damages is shown in the table as follows. The gravest destruction on infrastructure was on irrigation and flood control systems, roads and bridges, and school buildings (Mercado, Lacsamana and Pineda,1993).

Table. Infrastructure damages

(US$1 = PHP 27.07)

Infrastructure subsector/ Facility	Damage Cost (in thousand pesos)
Transportation	1,149,908
Communication	13,215
Power and electrification	54,918
Water resources	1,568,642
Social infrastructure	1,045,708
Total	3,832,391

Source: Department of Public Works and Highways (DPWH) Regional Office III, Philippines

Project 1: The Gapan-San Fernando-Olongapo Road

The Gapan-San Fernando-Olongapo Road is one of the major highway systems in Luzon, connecting Manila with the western Luzon provinces. It passes through San Fernando, Pampanga and crosses over the Pasig-Potrero and Porac-Gumain Rivers.

When Mt. Pinatubo erupted, the whole stretch of the highway in Pampanga to Bataan and the two bridges were destroyed, isolating the two provinces. From 1991 to 1995, lahar flow destroyed the road network, making the permanent construction of road impractical. The infrastructural development prioritized right after the eruption was the construction of mega dikes along the two rivers to control the flow of lahars. After 1995 and towards 2000, more permanent infrastructural development for highways and bridges was implemented as a part of building up the provinces affected by the eruption.

Map of road networks

The Gapan-San Fernando-Olongapo (GSO) Road Widening Project (Jose Abad Santos Avenue) aimed at facilitating immediate relief from the inundation being experienced in Lubao, Guagua and Sasmuan, ensuring that transportation routes could be maintained during floods.

The project covers 18km of GSO road widening, including reconstruction of the 280m Santa Cruz Bridge and re-channeling of Porac Gumain River, all located in the Pampanga Province.

Project 2: The Subic–Tipo Expressway

The Subic–Tipo Expressway, a.k.a. the NLEX Segment 7, is a two-lane expressway approximately 8.8 kilometers in length, which traverses the provinces of Zambales and Bataan. The technical specifications are as follows:

https://www.revolvy.com/main/index.php?s=Subic%E2%80%93Tipo%20Expressway&item_type=topic

Technical specifications

Name: Subic–Tipo Expressway/Segment 7
Concession holder: NLEX Corporation
Operator: Tollways Management Corporation
Concession starting date: 1996
Concession ending date: December 31, 2037
Length: 8.8 km
Highway exits: 3
Lanes: 2 lanes (1 each direction)
Toll plazas: 2
Rest and Service Areas: one, northbound side just before freeport gate

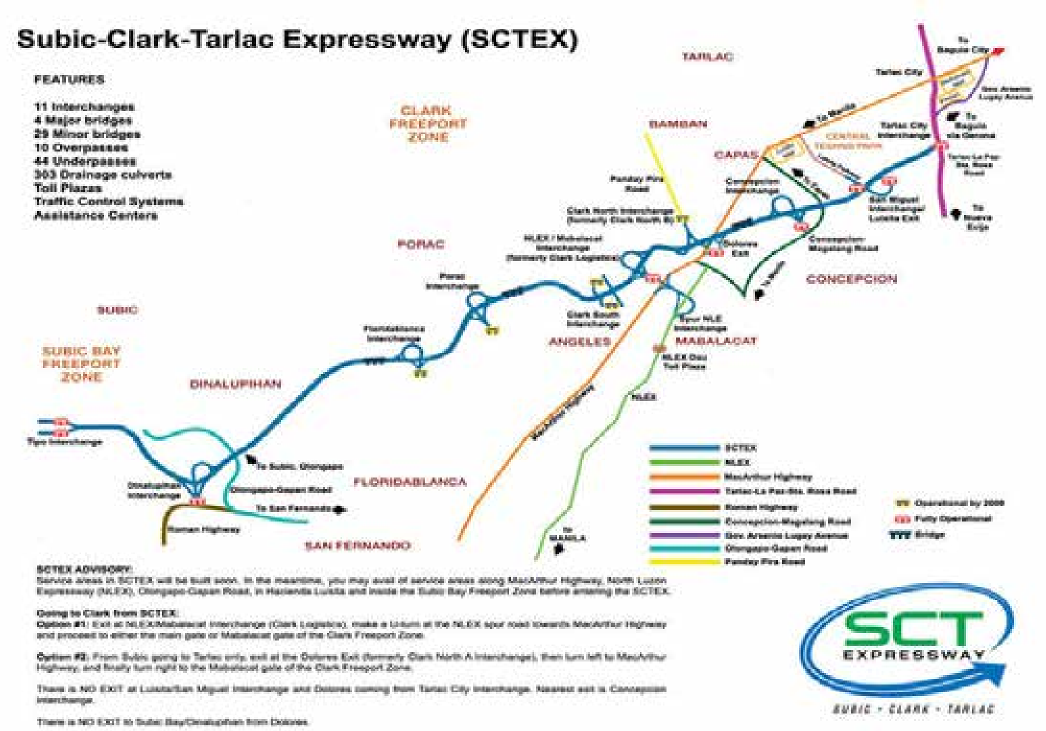

Photo. Subic–Tipo Expressway

Project 3: The Subic–Clark–Tarlac Expressway (SCTEX)

The Subic–Clark–Tarlac Expressway (SCTEX) is one of the highways that connects the provinces affected by the eruption, such as Pampanga and Zambales, with other provinces of Central Luzon. This is a 93.77-kilometer four-lane expressway built by the Bases Conversion and Development Authority (BCDA), a government-owned and controlled corporation under the Office of the President of the Republic of the Philippines. The project was started on April 5, 2005, and the highway was opened operationally on April 28, 2008. The construction of SCTEX provided more efficient transport among growth corridors in Cenral Luzon through the integration of economic activities in the Subic Bay Freeport, the Clark Freeport Zone, and the Central Techno Park in Tarlac. It fostered development of the municipalities served and connected major infrastructures such as the Seaport in Subic and the International Airport in Clark.[17]

17 http://www.trb.gov.ph/toll-road-projects/subic-clark-tarlac-expressway

The features of the SCTEX are shown below (http://www.gobaguio.com/get-to-baguio-faster-with-sctex.html#.WpY5ZryWbIV):



Pre-disaster situation

The Olongapo-Gapan Road served as the direct highway that linked the provinces of Bataan and Zambalez to the other provinces in Central Luzon and Metro Manila. The road therefore is crucial in the transport of the agricultural and sea products from the two provinces, as well as the entry of products from Metro Manila to supply the two provinces with basic needs products. The road served as the main highway for domestic buses and other public transportation that come from Bataan-Manila or Zambalez-Manila; as well as from Bataan/Zamabales to other provinces such as Pampanga and Nueva Ecija.

Before the disaster, the two new highways were not yet constructed, hence the affected provinces could be isolated if the Olangapo-Gapan road was not accessible.

Infrastructure BBB investment after the disaster

The Olongapo-Gapan road widening project is part of the continuing efforts of the government of the Republic of the Philippines to rebuild the Central Luzon that was heavily damaged by the Mt. Pinatubo eruption. The agency involved was the Department of Public Works and Highways (DPWH), with a project cost of PHP 1.5 billion.[18]

The Subic–Clark–Tarlac Expressway or SCTEX Project was implemented under the Bases Conversion Development Authority (BCDA). The project cost was PHP 27 billion, 85% of which was financed through funds borrowed by the government from the Japan Bank for International Cooperation (JBIC) .[19]

The highway has two major segments, the 50.5-kilometer (31.4-mile) Subic-Clark segment, and the 43.27-kilometer (26.89-mile) Clark-Tarlac segment.[20]

18 http://keasiainc.com/g.php?id=46

19 http://www.gmanetwork.com/news/opinion/kapuso-mo-jessica-soho/wp-content/uploads/2010/02/sctex_fullmap.gif

20 http://www.trb.gov.ph/toll-road-projects/subic-clark-tarlac-expressway

Effects on the local economy, industries and supply chain

The improvement of the roads and the construction of new highways have facilitated the transport of agricultural, industrial and supplies between the provinces. Travel time has reduced significantly as the traffic was eased by the alternative route that does not pass through the main or central districts of the towns. The construction of the new highways connected the main growth corridors in the region, stimulating and fostering growth of the economy. As the BCDA said, "it also created a portal by which Central Luzon can now trade directly with internal markets. Residents, traders and businessmen now have greater opportunities in investment, trade and employment as goods and services can now be imported from and exported to the rest of Asia and the world with more efficiency and less cost" (http://www.bcda.gov.ph/projects/subic-clark-tarlac-expressway).

Lessons learnt for APEC economies' infrastructure BBB

The case presents a good practice for improving the infrastructure to make it more responsive to the new conditions brought about by disaster. Prior to the disaster event, Olongapo-Gapan Road was the only road that connected the provinces of Bataan and Zamabales to other provinces of Central Luzon and to Metro Manila. With the widespread destruction of the major roads due to the lahar deposits covering the roads, reaching as high as 20 feet, and the destruction of bridges due to erosion as the lahar moved across the bridges and highways, the new roads and bridges had to be designed at a higher elevation and had to be resistant to potential lahar incursions.

The volcanic eruption and lahars have shown, too, that the provinces could be isolated from other provinces if the main road is destroyed. The case then shows the need to construct alternative roads, not only to facilitate traffic, but also to prevent a place from being isolated. The new highway that was constructed took a different route that was less vulnerable to lahar incursion.

The case of road improvement and road building in Central Luzon, particularly in Bataan-Zamabalez provinces, shows that responding to infrastructure damages due to disasters is a long-term agenda. The initial stage of reconnecting the isolated areas was an immediate response. However, the long-term plan of creating new roads was a "Build Back Better" approach that responded to the challenging conditions after the disaster.

The "Build Back Better" principle is illustrated in the case where the region that has been devastated by disaster can be rebuilt better by using an integrated networks of infrastructural development, particularly roads and highways. The rebuilding, therefore, is not only for the infrastructure itself but also for the recovery of the disaster-affected area.

References

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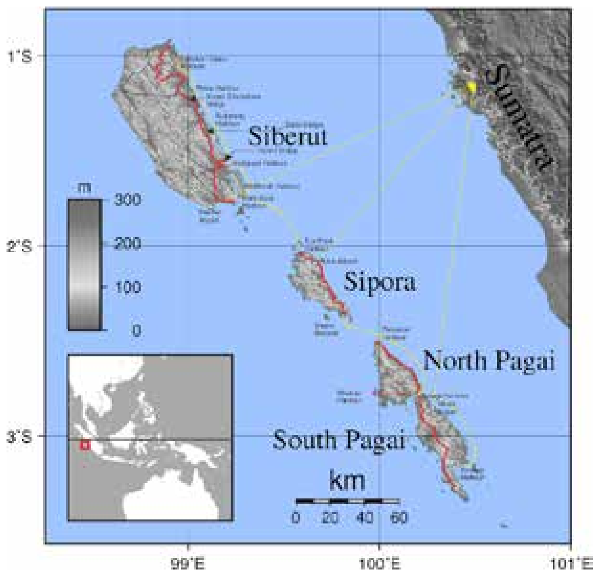
https://www.revolvy.com/main/index.php?s=Subic%E2%80%93Tipo%20Expressway&item_type=topic. "Subic–Tipo Expressway"

1.2.2 Indonesia: The 2010 tsunami and earthquake[21] and Trans-Mentawai road networks

Outline of the Infrastructure

The Mentawai Islands Regency Administration, West Sumatra, has developed a 349.3-kilometer Trans Mentawai highway, segmented across the four major islands, to ease the flow of people and goods. The main objective of this project is to improve transportation infrastructure between islands and districts and to increase people's welfare. It is also a part of the tsunami mitigation effort. In addition to the highway construction, the project also includes the development of piers for ferries to transport vehicles between islands. It is expected that the development of the Trans Mentawai will motivate people to move their houses from beach areas to higher ground so as to avoid tsunami. The roads will facilitate logistics in case of disaster. This project is the answer for the people. So far, it has been difficult to move around. All sections of the road in South Pagai and some sections in Siberut traverse production forests. Some parts of the highway also pass through the "Siberut National Park". The roads within the park may, for example, be used to access resort areas or may be constructed as inter-village lanes.

Name: Trans-Mentawai
Type: 349.3 km roads and bridges, 11 ports and 3 airport across islands
Location: Mentawai Islands, Indonesia (Siberut Selatan, Siberut Utara, Sipora and Siberut Island)
Project Period: 2011-2017
Funding: Central Government Budget, Provincial and Municipal Government Budget
Owner/Operator: Mentawai Municipal Government



Map 1: Trans-Mentawai

Infrastructure Details	
	Road width: 16 meters Length of Road: 349.3 km Number of Lanes: 4

21 GLIDE number EQ-2010-000213-IDN

The road connects sub-district centers with airports and harbors. Located on high ground, stretching along the coast to accommodate the need for evacuation routes and relief channels in the event of a disaster, and is expected to encourage coastal communities to settle in safer places along the road.

Photo 1. Trans-Mentawai Road on Siberut Island

Photo 2. Aerial View of Trans-Mentawai road splitting the village

Photo 3. The new bridge to Monga village, next to the old bridge

Pre-disaster situation

Based on the Decree of the Minister of Public Works No. 630 / KPTS / M / 2009 and No. 631 / KPTS / M / 2009 dated December 31, 2009, Mentawai Islands District had no "National Road". The Mentawai District had only 810 km of district roads spanning all four islands. Most of the local streets and roads were unpaved and the speed limit was Indonesia's lowest; volumes of traffic remained low. In the pre-construction stage, footpaths of dirt and boards could only be passed by pedestrians and motorbikes. In Sikakap District, the path could only be traversed during the dry season and at low tides, since the roads became muddy and easily flooded during rainy season. The South Siberut Sub-district, located in the upper reaches of the Rereiket River, could only be reached by boat (pongpong) through the river or by paths through hills or dense forests. In addition to the very difficult circumstances of citizens in terms of transportation and distribution of their crops, agricultural products were sold at very high prices. In addition, post-disaster assistance was also difficult and very slow. The only route for aid was via Padang with travel time to the islands in the Mentawai district about 3-10 hours, depending on the conditions of weather and the sea.

Photo 4. The Large bridges were damaged in the South Siberut village of sub-district in 2014

Photo 5. Bike and pedestrian bridge in the Nemnemleu Monga-Mentawai District of South Sipora

Photo 6. The connecting road of Limu-Mapinang Hamlet of South Pagai Subdistrict is muddy and impassable during the rainy season

Photo 7. Old Monga Bridge, made of wood with a width of 2 meters

Natural disasters and the damages on the infrastructure

The Mentawai Archipelago earthquake occurred on Monday evening, October 25, 2010, with a magnitude of 7.2 on the Richter scale, and the hypocenter of the earthquake 10 km deep, followed by tsunami waves as high as three to six meters 10 minutes after the earthquake. The quake and tsunami caused 509 deaths, 17 seriously injured, 21 missing and 11,425 injured.

Total damage and losses caused by the tsunami that hit Sikakap Island, Mentawai Islands District, was estimated to reach a total of IDR 348.92 billion. The largest damages and losses were in the economic sector, reaching a total of IDR 117.82 billion, followed by the housing sector with a total of IDR 115.82 billion, and cross-sector damages totaled IDR 79.44 billion.

Damages and losses in the infrastructure sector totaled IDR 19.16 billion and the social sector totaled IDR 16.66 billion. Although losses in the Mentawai infrastructure sector are only about 5.49% of the total loss, the sector is critical and contributes to the delivery of post-disaster assistance and rehabilitation. This low level of loss can be explained by the lack of investment in road infrastructure and bridges that existed prior to the disaster. Damage to infrastructure includes road damage (17.24 billion) and bridge damage (1.80 billion).

Infrastructure BBB investment

The 2010 earthquake in the South Pagai Sub District prompted the Trans-Mentawai proposal. Due to the lack of road connections within the island, earthquake-related information, damage, and new casualties were found by the Mentawai government 36 hours after the quake. The Regent of Mentawai, religious leaders and community leaders originated the idea of development of the Trans-Mentawai, with funding supported by the government and implemented by the public works department.

Trans-Mentawai is not only serves as the economic artery that connects the center of the sub-district in the district Mentawai, but also as a means of disaster mitigation and evacuation routes. To accomplish this, the Trans-Mentawai is planned to be built in the hill area so as not to be affected by a tsunami. These bridges are also constructed by taking into account disaster risk, such as the Monga Bridge made with piles with a depth of 28 meters into the ground, so that it may withstand the force of an earthquake. Trans-Mentawai has connected the area with the surrounding ports including Sibolga port, Enggano port, Bengkulu, Tanjung periok Harbor, and Jakarta.

In addition, the historical context of the Trans-Mentawai is the absence of land transportation that connects between districts in the Mentawai area, resulting in limited population mobility and low economic growth. The planning process incorporated the opinions of people who need roads for daily transportation and also for selling and distributing their products.

The quality of roads has also been significantly upgraded: Trans-Mentawai is a 20-meter-wide road network of asphalt and concrete rebar and uses standard road anchors, compared to the pre-disaster unpaved roads with wooden boards.

Effects on the local economy, industries and supply chain

Trans-Mentawai program is planned to connect all sub-district centers in the Mentawai islands. With the interconnected transportation, connecting routes within the island to ports and airports, as well as between islands, it is hoped that the community, especially in the agricultural sector, can market their products to other regions, thus improving the economy of the Mentawai Islands.

Although the project stands only 46.4% complete as of this writing (162 km of the planned 349.3 km), the impact of the opening of the trans-Mentawai road is already visible. With new roads and bridges connecting villages, shipping and selling agricultural products has become much easier and less costly, since local residents do not have to ship and sell products through ships, thereby increasing the competitiveness of agricultural products. This road encourages people to start farming alongside the Trans-Mentawai road, which implies that the crops harvested by the residents can be directly transported by the distributors to facilitate their sales. Simplifying distribution channels makes the distribution less costly, so that the farmers can sell their crops with more competitive prices, which in turn will improve the welfare of the community. In addition, local residents have started developing smaller roads that connect the Trans-Mentawai road with their villages, and alongside the smaller roads new settlements have followed.

Lessons learnt for APEC economies' infrastructure BBB

The construction of multi-year large infrastructure such as the Trans-Mentawai requires the commitment of stakeholders. The key for smooth implementation of Trans-Mentawai development projects include the leadership of the regent[22] with a vision of development that reflects the needs of the people, as well as comprehensive planning supported by community leaders and religious leaders. The Trans-Mentawai Road construction was eased by the possibility of utilizing the existing roads in the plan. Further, some of the road segments pass through land that is owned by plantation companies. This can be a win-win solution for both sides: the company will benefit from the

22 In Indonesia, the chief of the municipal governments is called "Regent".

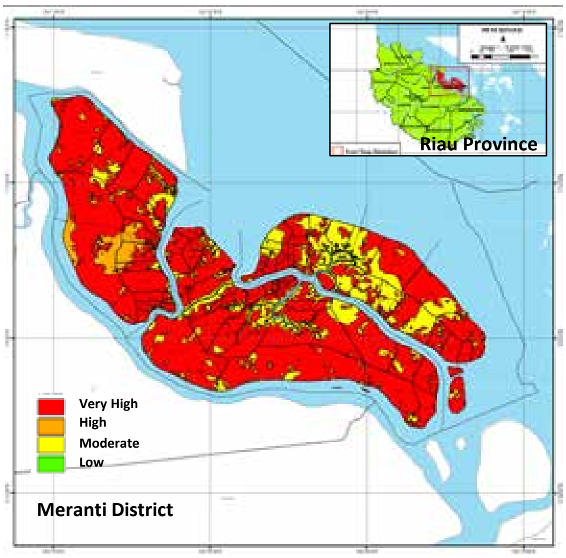
Trans-Mentawai road, since connecting to the district centers and harbors will improve the distribution chain, while the government could accelerate road construction with a smaller budget by using existing roads provided by the company.

The development of the Trans-Mentawai not only spurred the development of the area along the road, but also encouraged the inhabitants of the rural areas to work together to build tributary roads to the Trans-Mentawai to support their economic activities. The inhabitants have begun to farm and build settlements and houses near the Trans-Mentawai and its tributaries. By applying disaster risk considerations in local planning and superior road technologies enabling more disaster resilience, the Trans-Mentawai program has become a center for urban development, while ensuring that communities are built in a safer place from the tsunami disaster.

1.2.3 Indonesia: Peat fires, smoke, and canal blocking in Meranti

Pre-disaster situation

In the Meranti Islands District, Riau Province, located on the island of Sumatra, Indonesia, the widespread peat forests covering the district are increasingly being logged and replaced by plantations for timber and, in particular, oil palm. To produce oil palm, the water level in the swamplands must be lowered through drainage. Water loss on carbon soils causes a subsidence of 3-5cm per year for peat soil, so peatlands are sensitive to fires. Before the major forest fire in 2014, there were 487 canals in the Meranti Islands with a total length of 861,856km spread over seven districts. Sago is one of the main commodities of Meranti Islands Regency, the largest sago producer in Indonesia. It handles about 50% of the economy's sago needs, so it is crowned as the "National Sago Plantation Development Center". The Sago plant area reaches 60,000ha. Approximately 37,000ha is managed directly by the community and one private sago company is built on tidal land. Sago dominates 77% of the total production of the plantation sector. Total production of sago plant products in 2015 amounted to 198,000 tons. Sago plantation activities have been the livelihood of residents in peatlands since the 1960s.



Map 1 Hazard map of forest fire in Meranti Islands District.
Source: Klinik Tata Ruang Kabupaten Kepulauan Meranti, 2016

Photo1. Ditch in peatland leading to the river.

Natural disasters and infrastructure

El Nino-related fires in the Meranti Islands District since early 2014 have burned approximately 23,611.7 hectares of peat forests. The fires resulted in losses of up to IDR 1 trillion, covering a community sago palm plantation of 14,027.8ha, 5,847ha of rubber plantations, 3.2ha of coffee plantations, 136.6ha of palm plantations, 788ha of coconut plantations, Acacia plants covering an area of 1,000ha and groves covering an area of 1,809.1ha. Beginning in January 2014, rain ceased falling for 2.5 months, further drying peatlands already drained and degraded due to canal construction, facilitating the spread of peat fires. Such peat fires produce far greater quantities of smoke or "haze" than forest fires that burn only trees and surface brush. Smoke disasters in Meranti Islands District have become commonplace in the last 17 years. People inhale the smoke for months each year. Infants who were born in the area have been found to have decreased cognitive function due to the polluted smoke inhaled by their mothers during pregnancy. Peat fires also produce an increase in the poverty rate

Infrastructure BBB investment

Current peatland degradation requires the revitalization of degraded areas to reduce the social and environmental impacts of the fires. A three-pronged strategy was developed for peatland revitalization in the Meranti area: rehabilitation of water systems, revegetation of local crop species, and so on. Small dams that slow water drainage from the canals were constructed as an effective and efficient water revitalization solution by blocking the canal used to dry the land. This technique of "canal blocking" aims to allow peatland to be re-hydrated, reduce the risk of fire in the summer, provide the necessary water for dealing with the event of a fire, and isolate the fire so that it does not spread to other areas.

By planting sago trees that thrive in a wet peat ecosystem and also give economic benefits to local communities, local people were encouraged to keep their land hydrated by maintaining and monitoring the canal blocks regularly. Community-based approach is key to the success and sustainability of canal blocking operations in the area. Based on the results of investigations of ministries that came to the site with consultants from Gadjah Mada University and Riau University, there are at least three changes that occurred after the canals were blocked. In addition to sago growing greener, the channel water that was originally brackish or salty due to seawater incursion became more fresh.

Thus, the water canal can now be used as a source of clean water by residents. According to the data from KLHK, the number of burning "hotspots" in Riau Province was much reduced in the period from January to May 2015 compared to the same period in 2014. The ministry received reports that in 2015 there were only 1,893 "hotspots" in Riau, whereas in the previous year there were 7,271 hot spots. The data is also evidenced by the observation of the "National Disaster Management Agency (BNPB)" which observed the area from the air and found that the peatland in the area that was intersected by canals was wet and not burned.

In 2014, Indonesian President Joko Widodo inaugurated the canal blocking project at Sungaitohor Village, Meranti Islands District, together with a number of environmental and social NGOs for the prevention of forest and land fires. In total, the government of Indonesia allocated IDR 11 trillion, derived from standing funds from the "National Disaster Management Agency", Ministry of Forestry and Environment ministry funds, in collaboration with UNDP, and involving public funding schemes of public private partnerships with the Asia Pulp and Paper Group, to build canal blocking projects in wild-fire prone areas in Indonesia.

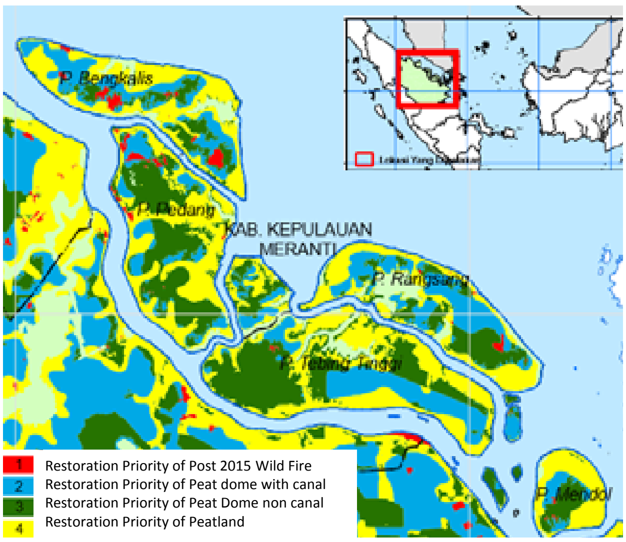
In Meranti Islands District, 23 out of 54 units of canal blocking in three canals have been built. Although the scale of wild fires in Meranti is not as severe as other areas, it was selected by the President because of its unique approach, achieving a high level of participation by the local community in preventing the wild fires by utilizing sago commodities.

The construction of canal blocking was technically planned by the Ministry of Public Works and People's Housing, State Owned Enterprise Cipta Karya, Spatial and Water Resources and technical personnel or people with expertise in civil engineering and water science, in coordination with consultants from the regional, provincial and state levels. In the planning process, the technical implementers of canal blocking development are Walhi (Wahana Lingkungan Hidup Indonesia) and the Center for Disaster Studies from the University of Riau in a context responsible for the Peat Restoration Agency, BRG. Walhi's role is to facilitate the community's understanding and involvement so that this activity is done by the community. UNDP provides financial support. While in the planning stage, the village began with deliberation about the form of canal blocking that would be built: what, how high, what kind of equipment and materials used, which workers, etc. This planning was made by local community groups who are used to working there and constructing canals.

Type of infrastructure: Canal Blocking
Location: Meranti Islands District, Riau Province, on the island of Sumatra, Indonesia
Funding: Central Government ("National Disaster Management Agency", Forestry and Environment Ministry), UNDP, PPP with Asia Pulp and Paper Group
Owner/Operator: Peat Restoration Agency and Sago Community

Photo 2. One of the canal blocking projects in Sungaitohor Village, Meranti Islands District

Source: Directorate of Forest and Land Fire Control. 2015



Map 2. Priority map of restoration in Meranti District

Source: https://brg.go.id/rencana-kerja-strategis/

Effects on the local economy, industries and supply chain

The canal blocking construction is to keep the peatlands from drying out by preventing the water collected in the rainy season from flowing to other places. With the availability of water both in wet and dry seasons, sago trees can grow more vigorously, which can be observed by the green leaves of sago throughout the year. One year after the construction of the canal blocking, sago in Meranti district was able to grow up to 15 meters. The growth in height of sago trees is significant —between 6-10 meters or about 40-100% higher than before canal blocking. The presence of canal blocks has effectively prevented intrusion of seawater, which is evidenced by the withering of brackish water plants such as berembang (sonneratia caseolaris[23]) and mangroves in areas with canal blocking. In addition, the canal blocking ensures the availability of clean water for daily life.

Canal blocking also allows the canals to be used as easy and reasonable transportation routes to bring sago commodities from plantations to sago industries. The canals can also be used as a source of clean water for sago processing industry activities. Compared to 2014 at the time of the forest fire disaster, sago production increased, with an increase in the number of families working in the sago plantation sector.

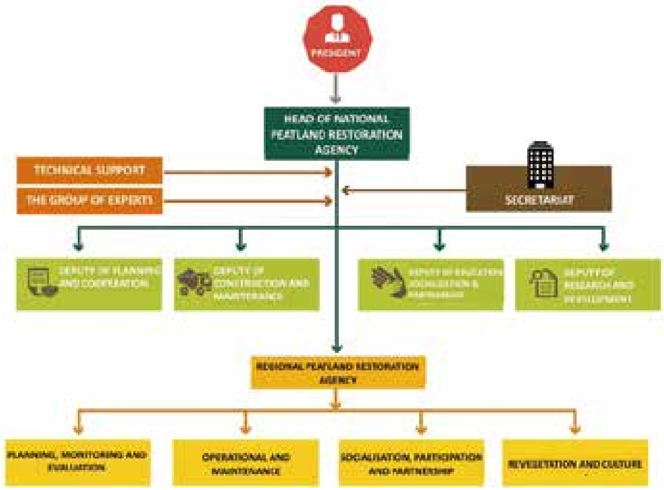
With peat that remains wet, the risk of fire is reduced by planting food crops such as sago that are not flammable. This is evidenced by the decrease of hotspots in some villages, such as the reduction of fire that occurred in the Tohor River Village. Ultimately Sungai Tohor, one of the districts in the Meranti Islands Regency, also made the first International Tropical Peat Restoration Laboratory in the world.

Lessons learnt for APEC economies' infrastructure BBB

The success of the synergy effects of forest fire prevention and increased sago production is explained also by the positive attitude demonstrated by the government in reflecting people's aspirations and adopting it in the government's program. This strategy ensures the acceptance of government infrastructure development projects in the community. The technical planning and implementation assistance provided by the government that is structurally and "tieredly"[24] coordi-

23 This tree is a type of mangrove growing up to 20 m in height and with a trunk reaching a maximum diameter of 50 cm. It grows in tropical tidal mud flats from Africa to Indonesia, southwards down to Northeast Australia and New Caledonia and northwards up to Hainan Island in China and the Philippines.

24 "Tieredly" means in Indonesia being or arranged in tiers or layers. Peatland Restoration Agency works under the President. It consists of two main layers: "National Peatland restoration agency" is responsible for planning peatland restoration at the central level. On the second layer is the regional peatland restoration agency which is mostly responsible for implementation, monitoring, evaluation and promoting partnerships with local actors such as community organizations (e.g., WALHI), as well as reflecting local culture in the program.



nated under the Peatland Restoration Agency, enables the government to design, verify and supervise development projects in timely and efficient manner. Moreover, utilizing the simple, effective technology that can be delivered by the community, will facilitate increasing participation and an encouraging sense of belonging to the community. Utilizing the potential of existing canals in the planning area to build the canal blocking makes the construction faster and cheaper. This strategy is adapted to respond to the urgency of handling periodic disasters such as peat fires that require speedy response. Sago plantation that supports the villagers' livelihoods, which requires residents to keep their land wet, will encourage villagers to maintain the performance of canal blocking.

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1.2.4 Viet Nam: The 2015 flood[25] and upgrading of Tan Lap communal roads

Tan Lap-Ban Sen commune, Van Don district of Quang Ninh province, is located in an island with total area of 139km^2, home to 1200 residents. The communal road that had been frequently flooded was affected by a severe flood in 2015.

Pre-disaster situation

Before the flood in August 2015, the communal road provided access for hundreds of people of Ban Sen & Tan Lap communes to services such as school, a medical center and seafood farms. This road was also the way for tourists to visit the rural area. With the infrastructure systems in place, the people here made efforts to develop their seafood production, farming and tourism service. As shown by statistics[26], 75% of poor households gained wealth and obtained a better life.

Natural disasters and damages to the infrastructure

The commune was affected by a severe rain from July to August in 2015 and the land was flooded. After this historic flood, 30 rural houses were inundated two meters deep in water, mud, soil and stones. Their belongings were lost as well. There were more than 20,000m3 of soil and rocks pouring from the mountain. The communal road was severely damaged so the people could not go to work. Their life's activities were disrupted. The heavy rainfall from July to August 2015 seriously affected the infrastructure systems, and thus also farming and seafood production.

The Van Don district People's Committee was forced to mobilize youth volunteers and soldiers to help clear the mud, buy food, water, mosquito nets and so on for the emergency period. As estimated, total damages in the whole district of Van Don was VND 674 billion. The roadways were damaged and covered in rocks and boulders.

25 GLIDE number FL-2015-000098-VNM

26 Annual district social and economic report, Quang Ninh province, 2013

Outline of the Infrastructure

The communal road was constructed in 2015 and 2016, funded by the central government budget.

Type: Communal and rural roads
Location: Tan Lap & Ban Sen commune, Van Don district of Quang Ninh province
Funding: State budget
Owner/Operator: Van Don district People Committee
Road length: 1.5 km
The width of road section: 5.5m
Number of crossing culverts: 04

Photo1. Road damaged by the historic flood

Photo 2. Ban Sen commune in the flood

Photo 3. Urgent and rapid repair of the road in the disaster

Photo 4. The road under construction

Infrastructure BBB investment

Van Don district is an "island district"; the major road of Ban Sen commune and the rural road in Tan Lap–Ban Sen commune is thus vital for the households here. The only way connecting the outside areas to the rural area of "the island" is the roadways. When the roads were damaged by the flood (see photos), the priority for the Van Don district People Committee and the residents was to repair the road as quickly as possible.

The stakeholders who participated in the improvement of the roads include the district authority, the youth union, individuals and private companies. The monies for this project were mainly from the central government budget and partly sponsored by the private companies. Total budget amounted to VND 15 billion dong (US$680,000).

The roads were upgraded and improved from July 2015 to May 2016. The process was as follows:

- Right after the storm, individuals, youth volunteers and soldiers were mobilized to clear the mud and stones on the roads to quickly regain access.
- The district People's Committee made the project of "Repairing, upgrading the major road of Ban Sen commune and the rural road Tan Lap–Ban Sen commune, Van Don District, Quang Ninh province after the terrible flood in 2015" to obtain investment from the provincial budget.
- Consultants and contractors carried out the project.
- Projects were completed and handed over to the authorities

It followed the urgent instruction of the Prime Minister, No. 1192/CD-TT, dated July 28, 2015, and other legal regulations of Viet Nam as follows:

<The BBB plan and decision-making process>

(1) Urgent action for temporary recovery managed Van Don district People's Committee
(2) Summary report on the damage by the storm and flood, by Communal People's Committee
(3) Project budget approval by Quang Ninh authority
(4) Construction Economic Report (Including F/S report and detailed design in combination) approved by Van Don district People's Committee (project owner)
(5) Construction procurement approved by Van Don district People's Committee
(6) Construction work, acceptance and handover
(7) Commencing operation of the roads

This is the rural and island area, so all the community, local industries, and private sector paid attention and supported the recovery of the area.

Lessons learnt for APEC economies' infrastructure BBB

The urgent participation of all the stakeholders to identify solutions, particularly a better structure for the communal road, namely a concrete road instead of an unpaved road, can be regarded as a good practice. For the case of "the rural island area", located far from the central government and remaining under-developed, more DRR efforts need to be made by the local authority and people, such as training to cope with disaster and urgent recovery of the infrastructure.

Upgrading connectivity: lessons learnt

Immediate road recovery is the first step for BBB

The first group of four cases clearly prioritizing road transport recovery demonstrates the importance of immediate recovery of road networks. The cases also raise other important points of environmental consideration and close collaboration with relevant organizations. The relevant governments and authorities involved in those cases must have established good communication and collaborative relationships from the pre-disaster phase, which is a key lesson.

Road networks need to be planned and developed from a wider scope of perspectives

In the Philippines, post-disaster recovery provided a good opportunity for planning alternative transport networks that could also facilitate emergency transportation. The Trans-Mentawai in Indonesia (like the Great East Japan Earthquake) shows the value of developing road networks for a wider regional scope. The Trans-Mentawai not only increased connectivity but also generated economic benefits for the surrounding region, which is an excellent example of BBB through infrastructure reconstruction.

The last two cases focusing on local and communal road networks demonstrate the importance of local actors' participation in infrastructure recovery planning, which nurtures a sense of belonging by local stakeholders who use and manage local roads in daily life. On the other hand, collaboration among local authorities is critical for planning local infrastructure, as highlighted in the case of "canal blocking" in Meranti, Indonesia.

1.3 Recovery of port, airport and other transport infrastructure

1.3.1 Indonesia: The Indian Ocean Earthquake and Tsunami[27] and the deep-water ports in the Nias Islands

Nias island, located on the western coast of Sumatra, Indonesia is largely lowland, home to 750,000 people. The island was struck by the 2004 Indian Ocean Earthquake and Tsunami that claimed more than 100 local lives. In 2005, Nias was again affected by the 2005 Nias–Simeulue earthquake[28], and approximately 800 people lost their lives. The earthquake destroyed the wharf of Gunung Sitoli Port, the main entrance of Nias Island, which was nevertheless restored and upgraded through effective cooperation between the central and local governments and international organizations.

Pre-disaster situation

Gunung Sitoli Port, the main entrance of Nias Island, was first built in 1981 and functioned in 1983 as a class IV port. The wharf of Gunung Sitoli was also built and started operations in the same year. The main pier had a draft of about 12 meters and served as the main entrance for the entry of large ships carrying goods and merchandise from and to the island of Sumatra. Major items usually imported from Sibolga included rice, vegetables, medicines, salt, cloth and soap. On the way back, the ships load up with agricultural products in the form of raw materials such as rubber, copra, chocolate, banana, patchouli, and so on, to be brought to Sibolga. Activities at the harbor also encourage the creation of other economic activities around the harbor such as trading in the market, including coffee shops, food stalls, fruit sellers, bakeries, cigarette sellers and more. There are inns or lodgings and rental houses for the crew members, skippers and ship workers.

Before the disaster, the pier served an average of 40 docked ships each month. Although large ships might have been anchored in the port, the off-loading activities were unbearably slow. There were complaints about the delays almost every day, due to the narrow ship base where freight vessels and passenger ships were anchored. In general, the vessels used were wooden ships under 10 gross tons.

Outline of the Infrastructure

Type: Deep Water Port
Location: Nias Island, western coast of Sumatra, Indonesia
Opened: initially opened 1981; 2005, 2012 and 2015 opened after rehabilitation
Funding: Multi donor Funding, Government of Indonesia
Owner/Operator: PT. Pelabuhan Indo. I, Gunungsitoli Branch

27 GLIDE number TS-2004-000147-IDN
28 GLIDE number EQ-2005-000053-IDN

Photo1. Temporary wharf during 2005 Tsunami Recovery Port Redevelopment Program

Photo 2. Present Condition of Gunung Sitoli deep water port

Natural disasters and the damages to infrastructure

The 2004 Indian Ocean Tsunami disaster has changed the coastline of Nias. In some areas, the beach has shifted as far as 100 meters inland, while in other areas, the ground has risen as high as 2.9 meters. As a result, the majority of the infrastructure in Nias was severely damaged, particularly the port of Gunung Sitoli.

The port infrastructure was severely damaged: 12 large and small ports were destroyed, and over 1000 km of roads became impassable. Most of the victims were in urban areas due to the location of Gunung Sitoli, which is close to the epicenter. At the Port of Gunung Sitoli, in particular, the port facilities were not damaged either by the earthquakes or by the tsunami. Nevertheless, it had not been sufficiently firmly constructed. The wharf of Gunung Sitoli port was damaged by the lateral spreading of liquefied ground; as the result, the pile heads fractured and settled. The deck collapsed in three places. It was expected that with the heavy traffic that was using the wharf it would continue to deteriorate quickly and would have to be replaced or duplicated within the timeframe of the reconstruction program. All of the storage buildings and the offices, however, remained in good condition, as did the ferry terminal (UNDP, 2005).

Infrastructure BBB investment

As the port is vital infrastructure for the local economy, improvement projects had been approved by government and international organizations. The earthquake caused the wharf to collapse in three areas. It was feared that this would affect the smoothness of goods and services traffic for the recovery process. Accordingly, UNDP, supported by multi-donor funding, was planning the recovery of the new port and building two temporary wharves to support the recovery process. After 20 years of operation, the port was first renovated in 2005 by UNDP, after the earthquake.
The remote location of Nias island, however, slowed the progress of reconstruction. Sufficient quantities of building materials were difficult to obtain at an affordable price. An uncertain voyage

schedule worsened the scarcity of supply. Uncertain fuel inventories exacerbated inflation and hindered the rapid implementation of the reconstruction work, together with the great distance from the markets.

The project was undertaken by preparing detailed designs, environmental impact assessments and economic feasibility studies for port reconstruction. The project improved the functions of several ports through minor rehabilitation work and the construction of temporary wharves. All activities were well coordinated with the BRR, the Provincial, District and Municipal Agencies for Transport, and the Department of Sea Communications, and complemented similar work in other ports of Aceh Province. Activities were also based on close consultation with communities and representatives of local fishermen and other sea-related stakeholders.

	Before Recovery	**After Recovery**
Port Classification	Type IV	Type III
Area Connected	Sibolga	Sibolga, Padang, Singkil, Tanjung Priok
Dock Length	60 m	200 m
Number of Jetties	3 jetties	6 jetties
Ship Type	<10 GT	>10 GT
Other	No Lamps	36 Mercury Lamps

The new main jetty, 120m2, with six lines each 60 meters long, was built by reinforced concrete. The depth in the port and in the approach channel is 12m at the lowest tide. This port can accommodate a large ship of approximately 6000 DWT. The 20m-long ferry wharf was upgraded to three tons/m2 with 4-5m draft at lowest tide.

In January 2009, the opening of the 200m-long and 11m-deep jetty and trestle allowed the passenger ferry MV Lawit to resume its regular service, reconnecting Nias with Padang, Medan, and Jakarta. The new port facility became the island's main entry point for importing almost all basic commodities and manufactured goods from Medan and Padang. Before the 2004 earthquake approximately 60 freight ships had used the dock at Gunung Sitoli harbor every month, a 20 percent increase since the port reconstruction was completed in January 2009.

In 2012 and 2015, the port facilities were further improved by building additional 30m L-shape leaning container and passenger terminals to improve service and smooth the supply of goods and services from the port around to Nias. Since December 2013, the port has had container transport services, and expanded the trade reach of every regency in Nias Island with other islands, even up to Jakarta. The port has been much more crowded since it was rebuilt after the 2004 tsunami.

Late in 2016, a new Multi Donor Fund (MDF)-funded pier at the Gunung Sitoli port was completed, resulting in a major improvement in the flow of people and goods to and from the island.

The MDF project aims at planning new jetty developments. The jetty was built under the Infrastructure Reconstruction Funding Facility, and also funded by the MDF. The new pier also helps ease cargo congestion in the smaller and older jetty, which has long been overwhelmed by the average 120 ships it serves each month. The MDF's support for the construction of physical infrastructure at the Gunung Sitoli port is complemented by another MDF program focusing on improving management and technical skills of port employees across Aceh and Nias. Gunung Sitoli port employees have joined colleagues from 18 other ports in Aceh and North Sumatra in a training course on port operations and management, organized by the World Food Programme's Logistics Support Unit under the MDF's Sea Delivery and Logistics Program. The one-year course developed by the Singapore Maritime System includes 22 modules aimed at building capacity for modern port management. The course is held at Syiah Kuala University in Banda Aceh.

Effects on the local economy, industries and supply chain

This port is the entrance to Nias. As the island recovers from trauma and destruction, its inhabitants return to their livelihood as fishermen and as farmers of the island's two main commodities: copra and rubber. The commodities are loaded onto ships and taken to Sibolga, the nearest large island port. On the return journey, the same ships carry goods that are much needed by local residents.

Lessons learnt for APEC economies' infrastructure BBB

For smooth recovery of a key infrastructure, phasing of recovery process is a realistic strategy, as the construction of temporary wharves for quick recovery was the appropriate option to support post-disaster recovery activities in the affected areas, while recovery and expansion of the new port was planned at the same time. Investing in the quality and quantity of port facilities and services was initially to ensure the smooth recovery process, while presently it provides additional benefits to local governments and communities. It contributed to an increase in the gross domestic product up to 300% in 2012. Development and planning of the Gunung Sitoli harbor in cooperation with the central and local governments and international organizations has opened the horizons of local communities and local governments to further upgrade the importance of port as the spearhead of economic activity. The modernization of ports and the increasingly complex services accompanied by improved port management through managerial training ensures further contribution of the port to growth of local economy and industries.

1.3.2 Philippines : The 7.2 Earthquake[29] and Tubigon Port

Pre-disaster situation

The Tubigon port is located in the province of Bohol, Philippines, close to Cebu, a more developed province in the Visayas, and home to approximately 46,000 people in 2015. Several ferries cross the Cebu straight every day, including a fast craft and a Roro ferry that can carry vehicles. As such, the port provides a direct and inexpensive means of transportation among the residents of both Bohol and Cebu provinces. The users include domestic travelers, traders and business people in agricultural and retail enterprises. The capital city of Bohol is Tagbilaran, and the Tubigon Port is widely used even by the passengers from Cebu to Tagbilaran because of the accessible transport facilities between Tubigon and Tagbilarn City.

Natural disasters and the damages on infrastructure

A 7.2-magnitude earthquake struck Bohol and nearby provinces at 8:12 AM on 15 October 2013. The epicenter was plotted at six kilometers S24W (9.86 deg N, 124.07 deg E) of Sagbayan municipality at a focal depth of 12 kilometers. There were 211 killed, 877 injured and eight missing persons, while damages to major infrastructures, houses, government buildings, tourism facilities, properties and other businesses were estimated to cost billions of pesos (Bohol Province, n.d.)

29 GLIDE number EQ-2013-000134-PHL

The earthquake affected 30 municipalities and one city in Bohol province. The earthquake's impacts included surface rupture, ground shaking, liquefaction and landslides. Sink holes also appeared afterwards. A coastal uplift also caused the ocean to retreat about 50 meters back.

The 7.2 earthquake knocked down bridges, toppled buildings and churches, and terrified millions of residents. It caused widespread damages to buildings and infrastructure, notably roads, bridges, houses and icons of Boholano culture and heritage.

Photo. Cracks in the pier

Outline of the Infrastructure

Tubigon municipal port is the second largest and busiest port in the province of Bohol. It is served by six conventional vessels and two modern fast craft with a total of 20 trips daily to Cebu City. A roll-on/roll-off ferry is also operational making two trips daily (Tubigon Seaport, n.d.). The seaport has a total port area of 1,080 square meters. There is rock causeway 700 meters long by six meters wide that connects the port to the mainland. The pier is 126m x 8m with a berth of 120m. Prior to the earthquake in 2013, there had been rehabilitation work in the port as shown in the following technical specifications (Tubigon Seaport, n.d.):

Outline of the infrastructure

Type: Seaport for inter-island transportation
Location: Municipality of Tubigon, Bohol in the Visayas group of islands.
Opened: Rehabilitated in 2007
Funding: PHP 64 million by Philippine Government
Owner/Operator: The Philippine Port Authority.

Technical specifications

Two RORO terminals; width about 9m each
The depth or draft: 2.5m
Four clusters of fenders with seven pieces per cluster
Nine bollards
Seven cleats
Storage facilities and transit shed with an area of 200m2
Open storage and back-up area of 400m2
Five steel lamp posts inside and 5 posts at the causeway
A child care station at the passenger terminal

When the earthquake damaged the port, new technical designs and specifications were drawn to make the port more resilient to earthquakes. The improvements on the original design include the following (Elope, 2017):

- 25cm-thick concrete was upgraded to 30cm.
- Land capacity was raised from 13.5 tons per axle to 18 tons per axle

- Causeway durability was improved from 100% rock to 40% concrete and 60% rocks.
- The composite strength of the concrete pavement was improved from 3,000 psi to 4,000 psi.
- The reinforcement concrete piles were retrofitted and strengthened, both underneath and above the water surface. The damaged vertical piles were demolished and replaced with 15 cm pre-cast and 15 cm cast emplaced concrete.

Infrastructure BBB investment

The port recovery project involved the construction of a reinforced concrete pier extension of 1,188m2 as well as a port lighting system. The post-earthquake rehabilitation started in January 2016 and was completed in June, 2017. All the recovery work was quickly completed and all the port facilities have been brought back to service, which has facilitated recovery of the local economy. The project was funded by the Corporate Fund of the Philippine Port Authority. The infrastructure investment is described as follows: (PPA, n.d.; Elope, 2017).

Agency: Department of Transportation and Communication (DOTC), Philippine Ports Authority
Type of project: Repair/Rehabilitation of Municipal Port Talibon
Initial budget for rehabilitation: PHP 5.50 million
Budget for other rehabilitation projects: PHP 212.59 million

Effects on the local economy, industries and supply chain

The Tubigon port is close to Cebu City on another island, which is a growth center in the Visayan region. The continuous provision of services of the port is crucial, considering that the Tubigon port is a major choice of travelers bound for Cebu and vice-versa. There are numerous boats scheduled, and the travel time takes about two hours. Fast craft take only 45 minutes. This makes the Tubigon port popular due to the shorter time of travel compared to the Tagbilaran-Cebu route that takes about four hours. The cost of travel is also low, making it a popular choice among travelers.

Since the port is accessible to all other municipalities of the province of Bohol via land transportation, the exchange of goods from both the rural and urban areas is easily facilitated.

Lessons learnt for APEC economies' infrastructure BBB

The continuity of services to the public is an important life support system, especially in times of emergency and immediately after. In an archipelagic geography like the Philippines with more than 7,100 islands, inter-island transport system has to be constantly available.
Given this context, sea ports are a major infrastructure. The immediate rehabilitation and service improvements are a priority to ensure the continuity of the socio-economic well-being of the people and sustain the continued growth of the locality.

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1.3.3 USA: Hurricane Katrina[30] and the port facilities of Gulfport, Mississippi

Gulfport is the second largest city in Mississippi, USA, and home to a population of 72,000. The city was substantially flooded by Hurricane Katrina in 2005 and partially destroyed. The port of Gulfport sustained over $50 million USD in damages. The pre-Hurricane Katrina facilities of Gulfport, Mississippi began their development when the initial harbor was completed in 1902. The seaport developed over the next century largely as a niche banana port (see below), but also engaged with markets throughout the Atlantic region.

Outline of the Infrastructure

Type: Seaport
Location: Gulfport, Mississippi
Opened: Seaport initially opened 1902, 2017-2018 opening of the revitalized port facilities
Funding: United States Department of Housing and Urban Development
Owner/Operator: City of Gulfport
Physical: 2 piers, with a total of 11 berths (550–1100 feet long, with drafts of 20 to 36 feet deep), and warehouse space of 395,000

Map of Gulfport location

Aerial photo of Gulfport

Restoration Project Report

Source: 1. Map of Mississippi counties, courtesy of United States National Oceanic and Atmospheric Administration
2. Arial photo, courtesy of the Port of Gulfport, Mississippi

Pre-disaster situation

Before Katrina the port facilities at Gulfport were primarily used to import and store bananas, as the Port of Gulfport is the second largest importer of green fruit in the U.S. and served as the primary U.S. Gulf import and distribution center for both Dole and Chiquita. Other commercial goods from the Atlantic region also entered the local economy via the port facilities at Gulfport. Major imports included finished apparel, ilmenite ore, crushed limestone and general container cargo. Main exports included linerboard, fabric, general container cargo, project cargo and rolling stock. In addition to the macroeconomic benefits of the port facilities for medium-to-large family-run businesses, domestic and multinational corporations, the port also provided employment for 2000 local residents. While the coffers of the state of Mississippi and the government of Gulfport itself obviously benefited, calls were and continue to be made by economic justice organizations in the American South over the unequal distribution of the wealth generated by the port facilities — even in light of the BBB-style recovery.

30 GLIDE number TC-2005-000144-USA

Natural disasters and the damages on the infrastructure

In 2005 Hurricane Katrina hit with intensity in Mississippi on the Gulfport-Biloxi coastline; a reported nine-meter surge hit the coastline at the peak of the storm and destroyed 90% of buildings on the coast. The port facilities themselves were dramatically altered by Hurricane Katrina. Warehouses and cold storage locations were wholly flattened by the sea and the ruins thrown about onto the streets of Gulfport by high winds. The shipping cranes were knocked down and mangled beyond repair. Aerial photos of the site right after Hurricane Katrina reveal a barren pier. Nearby floating casinos were wrecked onto the beaches and their debris was scattered all about the coastline. Functionally, the pier was completed destroyed by the event in every way except the contiguity of the pier itself that the equipment and warehouses rested on. Rebuilding would be an effort nearly equivalent to producing a new seaport.

Infrastructure BBB investment

The recovery and revitalization of the port facilities at Gulfport was led by state and local officials but was given political credence via the support of influential state actors such as the governor, Phil Bryant. In the wake of the total devastation of the port facilities along with most of the Gulfport-Biloxi coast, Mississippi's state and local leaders envisioned a major revitalization project for the commercial infrastructure of the state. In this mode of thought the network of roads, bridges, and railways connected to specific economic entryways into the state became of primary importance, the port facilities at Gulfport being one such crucial economic point of entry.

Relevant authorities: Department of Housing and Urban Development, State of Mississippi and the City of Gulfport
Budget: Total budget amounted to approx. US$400-570 million
Recovery and BBB plan, and decision-making process:

May 2011	Final Release of Funds from HUD
April 2013	Fill Complete (+14 foot elevation)
June 2013	Wharf Upgrade Begins
March 2015	Acquisition of 116-acre inland port facility
April 2015	West Terminal Site Work begins
May 2015	Commercial small craft Harbor upgrade complete
Early 2018	Completion of the works ETA

After the destruction wrought by Katrina, acting Governor Phil Bryant in 2012 established a set of economic revitalization objectives, moving the project into the spotlight of political action post-Katrina. Public and private entities worked together closely to meet the magnitude of the project. Gulfport's port facility itself provided jobs to the local economy but less directly allowed the economic infrastructures tied together to exist. Its closure was a collapse of a huge economic "gate," and its recovery has been the restoration of that gate. According to the 2016 update on the reconstruction of the port: "Currently, 10 construction projects with a contract value of more than US$270 million are underway, and more than $57 million in construction contracts have been awarded during the 2016 fiscal year. During the 2016 fiscal year, a total of 294 jobs were created by the contractors and consultants."

Significant infrastructure upgrades open new economic opportunities for the city, the state, and the Gulf Coast. As the reconstruction has involved receiving funds from the US Department of Housing and Urban Development, another BBB outcome is possible, which is in more equitably sharing wealth creation. According to the annual report of the reconstruction process from 2016:

"HUD assistance or HUD-assisted projects shall, to the greatest extent feasible, be directed to low- and very low-income persons and business concerns located in the project area."
After the long process of recovery and revitalization is complete (2017-2018) the port will be upgraded in numerous ways. Gulfport's overarching objective with this recovery and revitalization project was to increase channel depth and to expand the storage and port facilities, all in an effort to bring in business from large Asian shipping companies. This economic development would bring back old pre-Katrina tenants and increase jobs for low and very low-income residents of Gulfport. The greater effect of all this development would be to foster further commercial development.

Effects on the local economy, industries and supply chain
The revitalization of the port facilities at Gulfport is an essential part of the economic recovery of Post-Katrina Mississippi. The first and foremost responsibility of this revitalization is to recapture the business lost due to the damages themselves, while improving and enhancing the facility. The restoration of the port facilities itself is largely premised on returning to pre-Katrina levels of use. Signings with multiple old partners and new partners in recent years confirm that the port facilities are re-attracting old customers and new customers, signifying the broadened economic motives of the port facilities in a post-Katrina world. The expansion of port facilities beyond previous measures is not intended only to attract the old tropical fruit producers, who regardless of expansion will use the port due to its historic use as one of the primary entryways into the US market and its close proximity to production sites. The expansions are aimed at attracting global shipping opportunities outside of the old customer base. So economically the repair of the port has literally begun to return the port to its pre- Katrina status, thus mending the local economy, industries and supply chains, in some capacity. However, the expansionary aspect of the project is intended to position the port and surrounding stakeholders for growth; thus, this BBB project returns itself to former glory and concurrently seeks to establish a new growth-oriented position for Gulfport.

1.3.4 Japan: The Great Hanshin Awaji Earthquake[31] [32] and the port of Kobe: two decades of BBB trajectory

Background
The 1960s saw a new innovative era of global container shipping, leading to a fundamental change of port infrastructure in Japan: Construction of deep-water container quays and relevant facilities. In 1983, the Japan Sea Earthquake (M.7.7, 104 casualties) struck northern Japan including Akita Prefecture, and 80 % of facilities including berths at the port of Akita were severely damaged by tsunami. Lessons from this earthquake urged the government to construct "high earthquake resistance quays" in major ports.

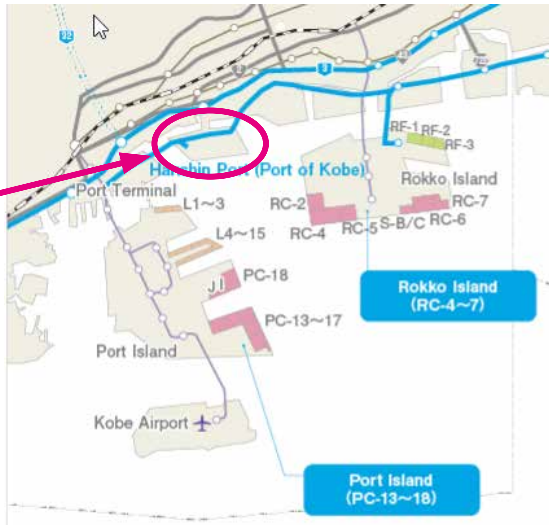
Damages to the port of Kobe by the Great Hanshin-Awaji Earthquake
On January 17, 1995, the Great Hanshin Awaji Earthquake (M 7.3)[33] struck the city of Kobe and surrounding areas and brought about extremely serious damages including 6,434 deaths, three missing and 43,792 injured. The Earthquake significantly impacted the transport infrastructure including the port of Kobe: caisson-type quays got considerably pushed out to the sea, and traditional block-type quay walls were totally destroyed. Quay gantry cranes also collapsed, and other buildings and facilities in the port area were heavily damaged, while the infrastructure that survived the quake included the Maya Wharf, with four quays constructed in 1967 and redeveloped in 1991 — including one of the first group of anti-seismic reinforced quays in Japan.

31 GLIDE number EQ-1995-000003-JPN
32 Kenji Ono (2017) Management for business continuity for survival of regions and companies
33 See also chapter 3 Column

<Outline of the Kobe port>Hanshin Port forms the largest logistics center in the Western Japan with container terminals, ferry terminals and various logistics-related facilities.

Figure: Port of Kobe area, facilities of Hanshin port, as of 2017

Photo: Maya Wharf



Source: City of Kobe
http://www.pa.kkr.mlit.go.jp/kobeport/pdf/know/shinsai_sokuseki.pdf

Port Island (PC-13 ～ 18)	A reclaimed island of 443ha. In 1970, container terminal PC1 (12m depth) came into operation followed by 11 berths. The northern area was completed in 1980, where convention centers and shopping malls as well as port facilities were located at the time of the earthquake in 1995. In 2009, the southern area of the island (the second stage development) was completed, which is equipped with six advanced deep water container terminals of 15-16m and 181ha port area and logistic areas. Containers moved to Rokko island and the terminals constructed during the second phase development; the first phase area has been redeveloped to be used as a green area and park.
Rokko Island (RC-4 ～ 7)	A reclaimed island of 595ha completed in 1992. High-standard container terminals 14–16m deep (4 berths) are located together with an air cargo terminal and other logistic facilities for Kansai Airport.

Source: Kobe-Osaka International Port Authority, Kobe City http://hanshinport.co.jp/en /facilities/

Infrastructure recovery from the earthquake

The Maya Wharf was back in use for ship calls within a couple of days after the earthquake, according to the report by the port authority. In the post-earthquake recovery plan, anti-seismic reinforcement works were built not only at the berths used for emergency relief transportation but also at the main container berths in the port as a whole.

Relevant authorities: Ministry of Transport (MOT. Currently Ministry of Land, Infrastructure, Transport and Tourism), Kobe City Authority, Kobe Port Corporation.
Budget: JPY 570 billion
Major milestones: Port rehabilitation plan prepared (at 14 days after the earthquake)
1st liner ship call (at 27 days)
Quay gantry crane operation resumed (at 62 days)
Port services fully recovered (at 464 days)

Technologies to restore damaged quay

New techniques were applied to facilitate recovery works from physical damages of the earthquake. The "steel jacket method" was applied for the first time in the port of Kobe to restore the damaged quays. The method contributed to quick recovery of quays under the physical constraints of limited recovery work space available.

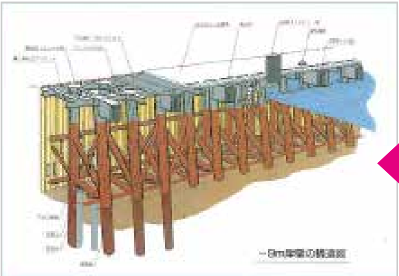


Photo and figure: application of the "steel jacket method"

Source: Earthquake recovery construction department, The Third Port Bureau, ex-Ministry of transport (Ministry of Land, Infrastructure, Transport and Tourism, MLIT) "Trajectory of Kobe Port recovery from the Great Hanshin Awaji Earthquake"(Japanese)

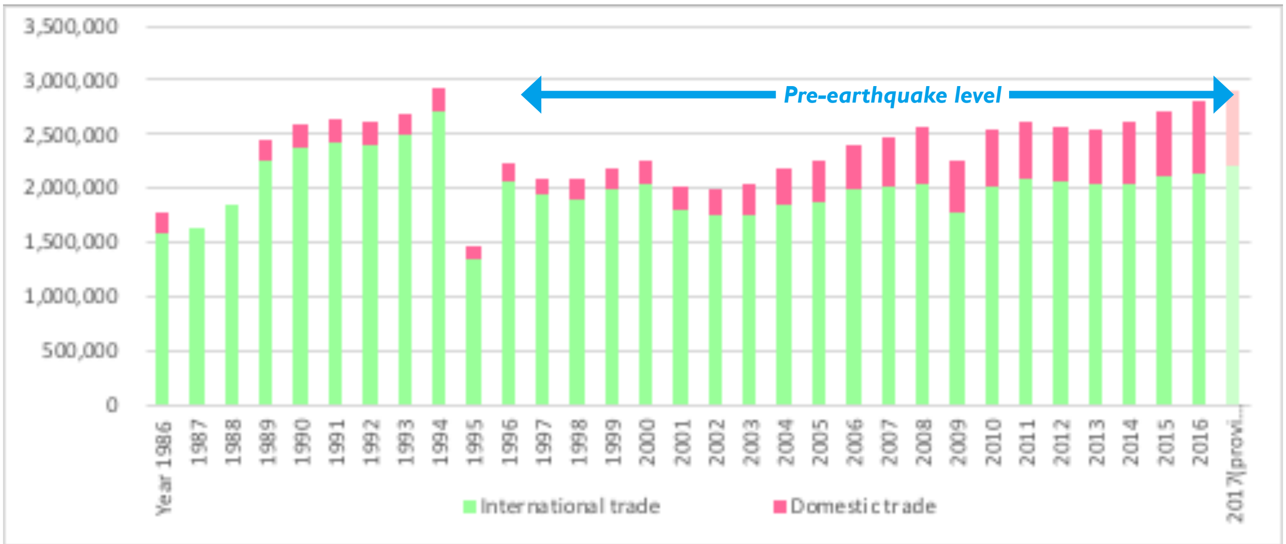
In total, JPY 570 billion was invested for recovery of the port for the initial 2-3 years after the earthquake, by port authorities including the ministry of transport (now the Ministry of Land, Infrastructure, Transport and Tourism, MLIT), City of Kobe, the Kobe Port Corporation (present Kobe-Osaka Port Corporation), the central government of Japan, and the semi-public Kobe Port Authority.

Two decades after the disaster — upgrading port management services

After the earthquake, although container cargo handling services resumed on the 8th day by using mobile cranes, the majority of the cargo handling services of the port of Kobe as an international distribution center were suspended. It took 62 days to resume the first quay gantry crane operations, 196 days to offer fully renovated berths, half a year to recover 50% of quay gantry cranes, and two years and two months until completion of all recovery work and the full re-opening of the port. Due partly to non-structural factors including classic practices of port management and services, however, some of the port clients and users did not come back to the port and have moved to emerging Asian hub ports such as Busan port.

According to Kobe city authority, for the year 2017, container cargos handled at the port of Kobe had largely recovered to the pre-earthquake level for the first time since the Earthquake, after almost two decades of trial and error to improve its services and operation as well as port infrastructure to catch up with the new global standards of 21st century port quality (such as 24 hours' services, and so on.

Figure: Container cargo handling at the Port of Kobe



Source: Kobe Port Authority (2016) "Kobe Port Overview". The data for 2017 is provisional.

Figure: A future vision of Kobe port

Source: Kobe Port Authority (2017) "A future vision of Kobe port"

At the occasion of the 150th anniversary of Kobe port's opening, Kobe City published a future vision of the port of Kobe and proposes a plan of further upgrading port infrastructure and services in the next three decades. Another stage of the long-term BBB of the port infrastructure and region's economy has been initiated 20 years after the disaster.

Lessons learnt for APEC economies' infrastructure BBB

Successful infrastructure BBB needs to be planned from a long-term perspective of infrastructure investment planning, while at the same time, quick recovery is also key, thus technologies that facilitate accelerated recovery are indispensable. In order to revitalize the local economy and industries dependent on the infrastructure, infrastructure-related services should be adapted to changing demands and in this regard, natural disasters could provide opportunities for change.

1.3.5 Philippines: Super Typhoon Haiyan[34] and the Tacloban Airport

Outline of the Infrastructure: before the disaster and after BBB

Tacloban airport provides the link between the provinces and cities in the Eastern Visayas and Metro Manila. As such, it plays a vital role in the socio-economic development of the region. Like any domestic airport, it services all sectors such as the agriculture, industrial and service sectors. Rural areas from the provinces benefit from the airport since their products can be delivered faster via air transport.

Type: Domestic airport linking the region and the provinces in Eastern Visayas to Manila and other cities such as Cebu and Iloilo in the Visayas.
Location: City of Tacloban
Opened: The Tacloban Airport in Barangay Costa Brava, San Jose district, was constructed in the 1960s. The airport was later renamed after former House Speaker Daniel Z. Romualdez. The Tacloban airport serves the entire eastern Visayan provinces.
Funding: Central government
Owner/Operator: Civil Aviation Authority of the Philippines (CAAP)
Runaway: 2,138 m.[35]

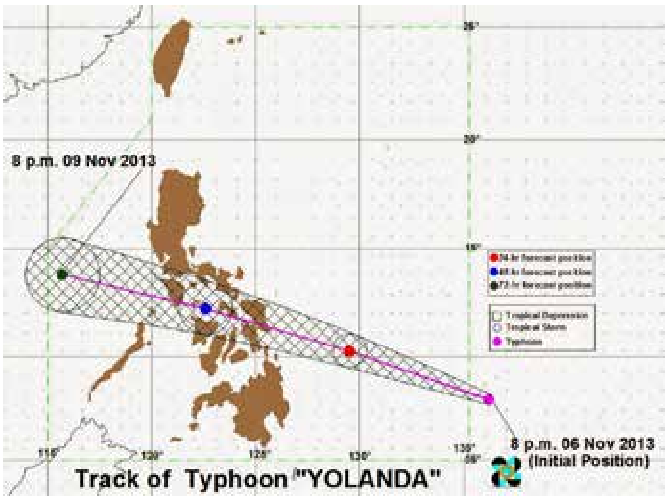
Natural disasters and the damages to infrastructure

Typhoon Haiyan, known domestically as Yolanda, had a wind speed of 300 km/hr and caused storm surges of over four meters and had a reach of three kilo metres in some areas. The strong winds and the storm surge destroyed more than 90% of the structures where they passed through. The official death toll was around 6,200. The geographic areas and persons affected by the typhoon are as follows:

NUMBER AFFECTED

❑ Regions	9
❑ Provinces	44
❑ Cities	59
❑ Municipalities	578
❑ Barangays (Villages)	12,122
❑ Families	2,581,677
❑ Persons	12,191,201

❑ Dead : 6,190
❑ Missing : 1,785
❑ Injured : 28,626
(NDRRMC, cited in Lagmay, 2014)



Source: Philippine Atmospheric Geophysical and Astronomical Services Administration, PAGASA (2013). Track of Typhoon 'Yolanda".

34 GLIDE number TC-2013-000139-PHL
35 www.airports-worldwide.com/philippines/daniel_z_romualdez_philippines.php

The airport was totally destroyed by Typhoon Haiyan/Yolanda on November 8, 2013. Located on a peninsula, the storm surge hit the airport from both sides as the direction of the surge moved from the east to the west and back. The airport building was totally destroyed and the runway was inoperable right after the disaster. Only choppers could land; it took weeks before the airport was able to have improvised facilities that would enable domestic flights to resume.
A year after the typhoon, the runway was still under repair. The airport had a very limited number of passengers that could be accommodated by the flights. Local officials said that Tacloban City was losing three-fourths of passengers coming in and out of the city because the airport could not accommodate jets. "It's definitely taking a toll on the economy not of only Tacloban City but the entire region." (Romualdez, 2014).

Photo 1: Devastation on the structures

Photo 2: A cargo ship was carried inland by the storm

Infrastructure BBB investment
The airport rehabilitation was completed in January 2015 for the gateway. In addition to the physical reconstruction, the Japan International Cooperation Agency (JICA) provided rescue and fire-fighting vehicles to facilitate immediate response during accidents involving aircrafts. The Japanese government through JICA donated JPY 237 million worth of equipment to support rehabilitation of Tacloban Airport. The equipment consists of fire-fighting vehicles for emergency response, x-ray baggage inspection systems, and walk-through metal detectors that will improve Tacloban Airport's security capabilities and resiliency in cases of natural disasters.[36]

Concerning the construction of a new airport, then President Benigno Aquino III proposed moving the airport to a place away from the sea. However, the local executive opposed this plan and pointed out that the key to the recovery of the airport is the building of a "more resilient structure."
Efren Nagrama, civil aviation area manager at the Tacloban airport, said that officials wanted to "fast-track" the repair of the runway and finish it by the first week of December, 2014. They vowed to repair the Tacloban airport as soon as possible, especially before January 2015, when Pope Francis was expected to come to the city.

Relevant authorities: Civil Aviation Authority of the Philippines (CAAP).
Budget: PHP 44 million ($979,334.41)

Improvements made on the Airport
- Refurbished passenger terminal building
- New safety and security equipment like four x-ray machines and four walk-through metal detectors
- Rehabilitation of the airport's administration and project management office
- Resurfaced tarmac to accommodate large aircraft starting January.
- Reconstruction of the airport's fire station and perimeter fence

36 https://www.jica.go.jp/philippine/english/office/topics/news/160226.html

Although the airport has been rehabilitated to a state better than it was before, it is currently undergoing further reconstruction within the same area. One major consideration in designing the structure is making it more resilient to storm and storm surge. The new structure is a two storey-building.

The reconstruction of the new airport will cost PHP 1.06 billion. The funds will be used for:
- rehabilitation of shore protection
- improvement of existing terminal building and other activities

Effects on the local economy, industries and supply chain
The improvement in the airport facilities has improved services for domestic flights, thus creating greater opportunities for socio-economic development. More flights and more passengers have been accommodated. The beneficiaries of the improvement extend beyond the city of Tacloban. Passengers and traders from other, less developed municipalities of the province also benefit from the airport as this is the only airport that they can use for air transport of their goods and products.

Lessons learnt for APEC economies' infrastructure BBB
Airports are life-support facilities in times of emergencies. Right after Typhoon Haiyan, the Tacloban airport was closed and this hampered the delivery of relief services and humanitarian workers. Only choppers could land and take off from the airport. Before the disaster, the airport had a lot of areas for improvement. Although there had previously been a plan to improve the old airport, the plan was not implemented. The total destruction of the airport by Typhoon Haiyan provided the opportunity to rebuild the airport with better facilities, including the runway, the offices, the passengers' lounges and other support services. The impact of the disaster triggered the construction of a new airport complex that has better facilities and more resilience to possible hazards.

1.3.6 Japan: The Niigata-Chuetsu Earthquake[37] and the shinkansen's Urgent Earthquake Detection and Alarm System (UrEDAS)

Background
At the occasion of the opening of the shinkansen "bullet train" in Japan, in October 1964, the Railway Technical Research Institute of Japan Railways had started developing an automatic train control system in case of earthquakes to achieve a higher level of safety for the high-speed train. Prior to the opening, the Niigata Earthquake occurred in June 1964, followed by another earthquake, Oigawa Earthquake (M6.1) in April 1965, half a year after the opening. Due to the Oigawa earthquake, all the Shinkansen trains running in service stopped; no accidents, including derailment, happened while the railroad tracks were affected. Soon after the opening, the bullet trains were running at moderate speed for safety. It was recognized, however, that an earthquake could have triggered train derailment.

Outline of Urgent Earthquake Detection and Alarm System, UrEDAS
The Urgent Earthquake Detection and Alarm System (UrEDAS), is a railway safety system that can issue an alarm immediately and reduce the speed of trains, or stop them, once earthquakes are identified, in order to minimize the damages. The time lag between the shaking at the epicenter and at other areas could be used to benefit the areas located far from the epicenter.

37 GLIDE number EQ-2004-000114-JPN

Niigata Chuetsu earthquake

UrEDAS has been equipped for the Tokaido line of the shinkansen since 1992. Thanks to the continuous efforts of improving UrEDAS, the alarm could be issued one second after the primary wave of the earthquake. This occurred after the Great Hanshin Awaji Earthquake in 1995, the Miyagiken-Oki Earthquake in 2003 and the Niigata-Chuetsu Earthquake in 2004. When the Chuetsu Earthquake occurred late in the afternoon on 3 October, a bullet train left Ueno station, Tokyo, for Nagaoka city, Niigata prefecture, running at 200 km/h. It suddenly braked, since a quake was identified by UrEDAS soon after the Earthquake. Although several cars were derailed, there were no deaths or injuries among the 154 passengers, two train crews and a train shop person, thanks to UrEDAS. This system has been continuously upgraded and applied not only to bullet trains but also for ordinary lines. The safety system supporting key transport infrastructure has been significantly improved by learning from the lessons of the past disasters.

Photo. Shinkansen derailed by the Chuetsu earthquake
Source: East Japan Railway Company https://www.jreast.co.jp/safe/jishin.html

Lessons learnt for APEC economies' infrastructure BBB

In addition to strengthening the physical structure of infrastructure, relevant systems for operation and management are also important to upgrade infrastructural resilience. Also, training the operators of infrastructure and disseminating information to users and customers need to be integrated with infrastructure recovery and development planning.

2 Water and waste management infrastructure

Embankments of rivers and the seas are often severely impacted by natural disasters. Millions of dollars are invested for upgrading or recovering sea dikes or river embankments every year. In this sub-chapter, BBB cases of the sea and river management infrastructure will be explored, followed by water management infrastructure. Community-based technologies will be spotlighted.

2.1 Viet Nam: Upgrading the sea dike system in western Ca Mau province

Ca Mau is a province with three sides facing to the sea as a peninsula, with a long coastline of 254 km and 87 gates to the sea. There are seven major river estuaries and more than 10,000 km of canals. The Ca Mau's coastal area is directly affected by two tidal regimes: the tide and the uneven tide of the East Sea and the West Sea, respectively. There were large mangrove forests to protect the coastal land from erosion and landslide. The dike system in the west of Ca Mau province was built more than 10 years ago to protect the coastal land from erosion and salinization, and to keep the alluvial soils for mangrove planting.

Ca Mau is impacted seriously by climate change, with the most striking impact being the increased occurrence of landslides. According to surveys of functional departments in the province, from 2007 up to now, about 80% of Ca Mau coastline has been affected by landslides. On average, every year the sea encroaches about 15m, sometimes even up to 50m. About 300 hectares of protective forest are swept out to the sea each year. At these rates of erosion, it is estimated that by year 2100 Ca Mau will lose 56% of its mangrove area, or more than half of the mangrove area of the economy. Due to the impacts of natural disasters, more than 100km of sea dikes will have been seriously impacted by landslide (CPC, 2017).

Photo 1. Landslide at West sea dike, Ca Mau province, southern Viet Nam
Source: PMUARDW, 2017

Rach Dinh sea dike embankment is one component in the project of building and upgrading the West sea dike system of Ca Mau province, with funds from the central government (approximately 90%) and the provincial government. Total capital investment was VND 26,284 million (about US$1.2 million). The project was started in April 2013.

Recovery process

Since 2009, the goverment has provided strategies to reinforce and upgrade the sea dike systems along the middle and south coastal zones of Viet Nam.[38] Considering the situation of the west sea dike system under the impact of climate change, the government of Ca Mau province has approved

38 Decision No.667/QD-TTg, dated 27 May 2009, to approve the program of upgrading the sea dyke systems from Quang Ngai to Kien Giang province; Decision No. 1397/QĐ-TTg, dated 25 September 2012, to approve the irrigation system for Mekong river delta, 2012 -2020, in the context of climate change and sea level rise.

the investment in constructing and upgrading the sea dike system in the west of Ca Mau. The key objective was to construct a breakwater a bit offshore to reduce waves and prevent the erosion of silt in order to grow back mangroves.

The Ca Mau Provincial People's Committee took the initiative for directing the project implementation. The local authorities at district and commune levels were also involved in the upgrading process. Local construction companies and related private sector entities were also involved actively during the process of constructing and ugrading Ca Mau's west sea dike system. In the project of upgrading Rach Dinh sea dike, low–cost technology was applied to create a soft dike embankment with high resistance to sea waves.

Details of the applied technology

New technology was applied in which two rows of D300 centrifugal concrete piles with length of 7m and 10 m were put down interlaced. The distance among piles is 0.4m and 2.3m, vertically and horizontally. Elevation of embankment was + 1.6m. The top of the embankment had horizontal and vertical reinforced concrete braces, 30m by 30m cross-section area. Inside, it was filled up to the top with embankment stones. The bottom of the dike was tiled with cajuput (PMUARDW, 2017).

Photo 2. Low cost and "soft" technology applied for sea dike embankment (Source: PMUARDW, 2017)

BBB impacts

This type of sea dike embankment helps to protect Ca Mau sea bank from collapse and erosion. Alluvial silt is retained for sedimentation facilitating the local "mám" trees' growth for mangrove forest development. Compared to standard concrete designs, this "soft" embankment, suitable and adaptable to the current situation of climate change, reduces the waves impacting the beaches and prevents the sea banks from erosion and collapse, and at the same time preserves the nutritive muds for planting mangrove.

This technological solution requires a total investment of VND 30 million per meter of length. This is a simple construction solution that reduces the total investment of sea dike upgrade by 25%, compared to standard concrete embankments. The cost of the embankment technology is lower than traditional concrete and more stable. Still, it costs about US$ one million per kilometer, which is still significant. About 24km of sea dike was reinforced under this project.

Photo 3. The mangrove forest after the dike was constructed Source: PMUARDW, 2017

In addition, the private sector was involved in reinforcing the sea dike. In particular, some parts of the beach were leased by investment companies (FLC group, VINGROUP). They proactively invested in embankment to protect their properties (resorts, houses) and also to protect the general beach. Their involvement allowed them to develop tourism that would provide an economic base to protect many of the seafronts and their ecosystems.

2.2 Viet Nam: Biological technology for the Thanh Mai stream bank, Ban Phat village, Bac Kan province

The Thanh Mai stream is a branch of the Cau river in Bac Kan province, the northern, mountainous province of Viet Nam. The catchment area of the Thanh Mai River at Ban Phat is about 59.7 km2 and the annual average flow is approximately 1.6 m3/s. The area along the Thanh Mai stream is agricultural land where local villagers cultivate rice and vegetables.
Before upgrading the Thanh Mai stream's dike, a large amount of land along the stream's banks had been affected by landslides and floods, threatening the rice fields and cultivated areas of local people. The main stream was flowing directly against the bank, causing bank erosion and damaging the road connecting Ban Phat village to the Thanh Mai People's Committee's headquarters.

Photo 4. Land erosion and sliding at the banks of Thanh Mai stream near Ban Phat village, Bac Kan province Source: MARD-PMU, 2016

The project of upgrading dike systems using biological technology against Thanh Mai stream bank's erosion (Cho Huyen district, Bac Kan province) is one of the pilot case studies of the technical aid project "Improve the rural infrastructures for north mountainous provinces in Viet Nam to respond to climate change".
The project was mostly funded by Asian Development Bank (ADB), which accounted for 78.2% total investment, and the rest was funded by the central government budget with 22.8%. The project managing agency was the Development Project Board of UNDP. The owner/operator was the Agricultural Project Management Board (APMB), Ministry of Agriculture and Rural Development (MARD).

Recovery process
The project that started from 2014 was operated by APMB and MARD. Diverse stakeholders participated in the implementation process: the local authority of Cho Moi district and Ban Phat commune, experts from MARD, local villagers of Ban Phat, and representatives of APMB and UNDP.
A series of surveys on all local plants were undertaken to evaluate and to choose the most suitable trees that met the technical requirements: long and strong roots, easy to grow and no negative impact to the environment.

Technical details
The embankment was composed of rocks reinforced with local plant piles at the lower part of riverbank. Different local trees (si, puou) and imported vetiver grass were used on the upper part of the riverbank. During the construction, there was less intervention to the river pathway and the natural shape of the upper riverbank was kept as much as possible. In addition, the project utilized local labor, especially women, for planting the local trees. The cost was only 10-20% of conventional pre-cast concrete embankment.

(a) (b)

Photo 5. Recovery steps: (a) Reinforcing the stream bank with local tree piles and rocks, (b) Local trees were planted in the upper part of the stream bank Source: MARD-PMU, 2016

(a)

(b)

(c)

(d)

Photo 6. Biological dike after (a) one month, (b) three months, (c) one year and (d) two years
Source: MARD-PMU, 2016

BBB impacts

This is an effective and low-cost method for preventing erosion of riverbanks. It can be applied for stream banks in remote areas where financial resources are limited. The green embankment not only helps protect the bank from erosion but also maintains the natural green view of these mountainous areas. This biological method has been applied for riverbank protection in Bac Kan, and Son La provinces, as well as mountain road slopes in Son la and Thai Nguyen provinces.

2.3 Viet Nam : Sea dike erosion recovery in Hai Duong area, Huong Tra township, Thua Thien Hue province

Hai Duong Dike is an important infrastructure in Huong Tra township in the central area of Thua Thien Hue province. The dike's length of reinforcement is 730 km; the width of the dike's road section is 5.0m; the length of sturdy embankment on the dike is 50m; three roads connect to the dike at total length of 190m, cross section 1.5m. Huong Tra town is located in a coastal area; the economic condition is thus mainly based on aquaculture and tourism. The sea dike was constructed to

help local economic activities.
Before a storm eroded the dike in late 2013, the dike and its road served for hundreds of people of Huong Tra township as transportation route and protection dike for the residential area as well as the Tam Giang lagoon and aquaculture farms. This road was also the way for tourists to visit the coastal area, as well.

After the sea dike was severely damaged and eroded, many households lost their aquaculture farms and properties. The Thua Thien Hue provincial People Committee issued urgent instructions to move hundreds of households to safer areas. The road to nearby Con Dau commune was flooded and the whole commune was isolated. So far, there has been no publicly detailed estimation, but the erosion of the dike could have formed a new sea inlet, which would threaten the life of people and stop aquaculture production.

The Thua Thien Hue People's Committee urgently mobilized the people and soldiers to implement recovery work and immediately initiate a new project to improve the dike. The funding for this project was from the provincial budget. Total budget was about VND 49 billion (about US$210,000) (NDPC Hue, 2017).

Recovery process
The dike and its roads were reconstructed from May 2014 to October 2014 just before the storm season came, following the urgent instruction of the Prime Minister No. 142/2009/QĐ-TTg, dated December 31, 2009, and other regulations of Thua Thien Hue province and central government:

The BBB plan and decision-making process was as follows:
(1) Urgent action for temporary recovery managed by the provincial authority
(2) Summary report on the damage by the storm and flood by Huong Tra township's People Committee
(3) Project budget approval by the provincial authority of Thua Thien Hue
(4) Construction Economic Report (including feasibility study report and detailed design in combination) approved by the provincial authority of Thua Thien Hue.
(5) Construction procurement approved by Project Management Unit, PMU
(6) Construction work, approval and handover
(7) Start the operation of new roads

A key for the smooth recovery could be explained by participation of different stakeholders including government authorities, individuals and soldiers in the urgent recovery of the dike.

(a) Dike damaged by the storm

(b) Urgent and temporary repair of the road by soldiers and private citizens

(c) The dike under construction. The PMU and provincial authority are inspecting the work.

(d) Completion

Photo 1. Recovery process of Hai Duong sea dike (Source: NDPC Hue, 2017)

Lessons learnt for infrastructure BBB
In this case, four aspects were critical, including:

(i) Urgent participation of all sectors;
(ii) A better structural solution for the dike and its roads;
(iii) Close direction and steering of leaders in response to natural disasters; and
(iv) Application of proper technologies to meet the multiple demands including protection of people's lives and improvement of transportation.

2.4 Japan: The 1982 Nagasaki Flood and bridges designated as cultural heritage

1982 Nagasaki Flood

The City of Nagasaki, located north of Kyushu island, Japan, has been repeatedly affected by heavy rainfall including that of 23 July 1982 (record precipitation: 187 mm/h), which killed 299 (37 by flood, 262 missing, 5 injured) and damaged or inundated as many as 40,000 houses. The city is characterized by steep slopes which are susceptible to landslides, debris flow and slope failures along upper streams in 9,240 areas. In 1982, main highways and roads were shut down by mud, debris, cars, etc., which disrupted emergency vehicles and recovery work. Public transportation was disrupted and more than 1500 cars were left on the roads, while about 20,000 cars were damaged. Water entered into underground spaces of facilities, paralyzing power supplies for hospitals, hotels and department stores. The city had seen practically no flooding for 190 years, leading to poor river maintenance prior to 1982.

The city was famous for the stone bridges over the Nakashima River built in the 17th century, including the oldest stone arch bridge in Japan, designated as an Important Cultural Property. Six of these ten important tourist attractions were severely damaged by the heavy rainfall in 1982.

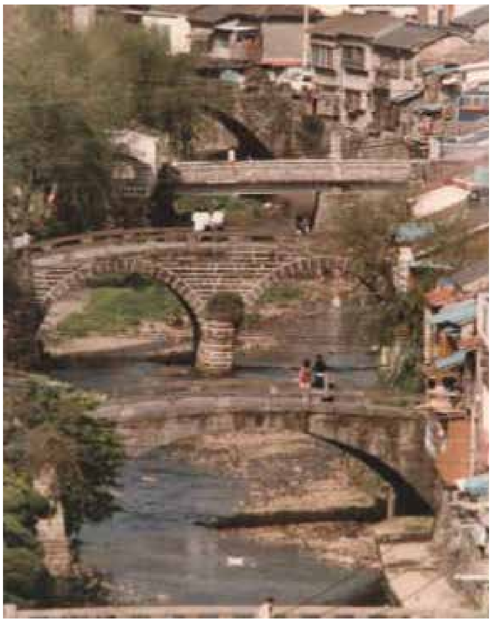


Photo 1. Megane Bridge

Photo 2. Damaged Megane Bridge

Nagasaki Prefecture planned and undertook the Nakashima River improvement by upgrading existing dams, and construction of head-race tunnels and culvert bypasses so that the scenic beauty of the stone bridges could be protected. The budget amounted to JPY 7.27 billion. The local authorities made efforts to coordinate opinions among residents and achieved a balanced solution satisfying both goals of disaster prevention and conservation of cultural properties by constructing the bypass waterways on both sides of the bridge. Sabo, Erosion control and landslide projects were also undertaken, including emergency work to prevent secondary disasters, sediment-related work to prevent debris flows, landslides and slope failures, and installation of sediment control dams (Budget: JPY 20 billion).

Under the recovery plan, in order to intensify flood control, three dams in the Nakashima River were reinforced: the oldest concrete dams of Nishiyama Dam (1903, 1.5 m3), Hongochi Kobu Dam (1891, 0.6 m3), and Honochi Teibu Dam (1903).

Lessons learnt and BBB effects

Nagasaki prefecture successfully achieved two goals of cultural heritage preservation and safety from flooding by coordinating the solution with citizens and stakeholders, while promoting comprehensive flood control measures.

2.5 Chinese Taipei: The 921 earthquake[39] and Shihgang Dam in Taichung County

The Shihgang dam is the weir located at the lower Daja river, managed by the Central Region Water Resource Office. It provides water for all of Taichung city. The dam was fully designed by domestic engineers and did not rely on foreign engineering techniques. It is a concrete gravity dam which was finished on 10 October 1976 and began operation in 1977.

Total capacity: 3,380,000 m^3.
Catchment area: 1,061 km^2 (410 sq m^2)
Reservoir area: 0,645 km^2 (0.249 sq m^2)

In addition to drinking water, the reservoir also provides water for industrial and agricultural use, and it adjusts the volume of the tail-race from hydraulic power plants. The Shihgang dam therefore plays an important role in the economy of the local area.

The 921 Earthquake happened on 21 September 1999. The epicenter of the M7.3 earthquake was located at Chichi township, Nangtou county. The quake caused 2,415 casualties and over 110,000 totally destroyed or partially damaged houses. This earthquake is the most serious one in the recent 100 years in Chinese Taipei. After the 921 earthquake, the terrain nearby the Shihgang dam changed rapidly; the uplifts and shifts of the terrain caused serious damages to the dam, the gates, and the water channels (see Photo 1a). This made the reservoir lose its function, leading to water shortage in Taichung city. By the collaboration between the Water Resource Agency and the Central Region Water Resource Office, the Shihgang dam was fixed under emergency (see Photo 1b). Total budget amounted to approximately NTD 3,500,000.

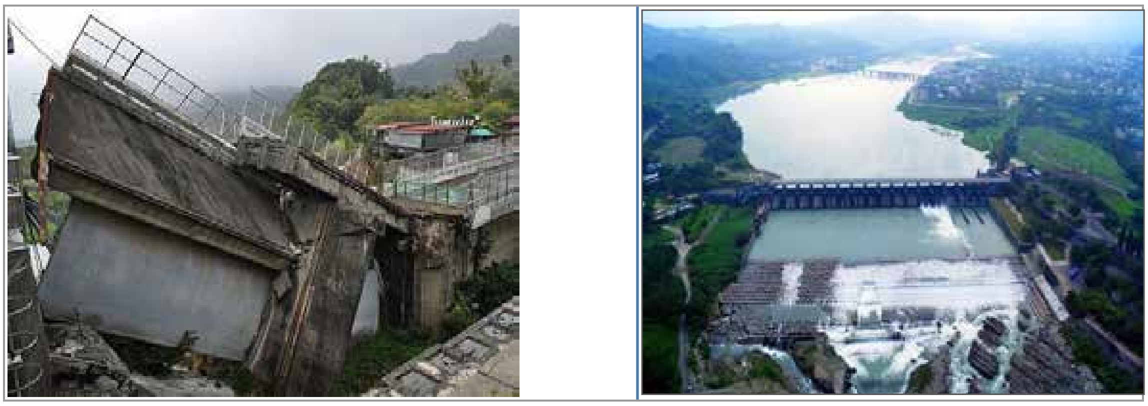


Photo 1. Shihgang dam: (a) after the earthquake and (b) after reconstruction

Recovery process

The Water Resource Agency proposed the reconstruction plan and funded the project initiated in 1999; the whole project was fully completed in 2010.

The purposes of reconstruction were twofold: stabilization of the water barrier facilities, and recovery of the water reservoir. The important engineering characteristics are as follows:

(1) To reconstruct the gate of the Shihgang dam, which suffered from the geological changes causing an inconsistency of elevation, increased the difficulties of both design and construc-

39 GLIDE number EQ-1999-000321-TWN

tion, and there are few similar cases.

(2) The government collected many suggestions from environmental groups, academic experts, and public opinions on the reconstruction. A fish ladder was set up in the side of the dam, which improved the ecological diversity and contributed to the conservation of the Daja river, especially for an endangered maculate fish species.

With the collaboration between the Water Resource Agency and Central Region Water Resource Office, an emergency repair construction project was launched to solve the water shortage problem in Taichung city. After the emergency work, the Water Resource Agency also scheduled a three-phase reconstruction plan to repair the minor functions of the Shihgang dam and the reservoir. The project was launched immediately after the 921 Earthquake. In December 1999, the Shihgang dam started to block water again. By the end of 2000, the emergency repair work was completed, although during the following ten years, the Shihgang dam was used only for improving the water supply. In 2007, the renewal of the electrical and piping systems of the dam started, followed by the mechanical reconstruction in March 2008. In September 2010, the gate of dam was also renovated. At the end of the same year, the fish ladder construction was completed, and the Shihgang dam was fully repaired.

BBB results

The Shihgang dam is a multi-purpose hydraulic construction, including adjustment of the tail-race volume from the hydropower generators as well as water supply for drinking, agriculture and industry. For the agricultural use, two of the existing ditches were widened to provide water for two new irrigation areas of Chelungpu and Dadushan. For the drinking water supply, the water resource of the whole Taichung city (including the industrial area in Taichung Harbor) was supplied by the Daja river. The water is piped from Shihgang dam to the water purification plant, and then transported to the Taichung city for consumption.

2.6 Indonesia: The Indian Ocean Tsunami[40] and waste management infrastructure

Banda Aceh, a growing city, is the capital of Aceh Province, the most western province in Indonesia. The Civil Registry Office recorded that Banda Aceh Municipality (BAM) had a total population of 223,446 in 2010, spread over nine sub-districts and 90 villages. Given the average waste generation of 0.7 kg per capita, BAM generates approximately 155 tons of waste per day. Spatial Planning of 2011-2029 forecasts that its population by 2029 will be as many as 482,131. The final disposal site of Gampong Jawa was opened in 1994 on an area of 12 ha. The Detail Engineering Design (DED) was provided by the Ministry of Public Works (PU), which already stipulated the technical provisions of a sanitary landfill. However, after the construction the landfill operation did not follow the criteria of sanitary landfill operations and maintenance; lack of funding led it to become only a controlled landfill. The soil was not covered on a regular basis, thus there were many fires. Similarly, the leachate ponds were also available, but not properly operated. The leachate must be pumped periodically from the control box to the leachate pond, which is costly.

The earthquake and tsunami in 2004 damaged an area more than 1,000km long with total damaged area of 12,345km2. The disaster left 110,229 dead, 12,135 missing, and 703,518 displaced. Damaged roads amounted to near 300km, including 120 affected bridges, and the services of 14 ports were

40 GLIDE number TS-2004-000147-IDN

suspended. That left the districts and the municipalities disconnected and the distribution of goods disrupted. A large amount of funds were allocated for the development and improvement of the infrastructure of Banda Aceh City, especially, after the tsunami. Local governments faced the challenge of handling the enormous quantities of rubble and debris resulting from the disaster. More than one million cubic meters in total, which is equivalent to the volume of a 0.5m-thick sediment layer covering an area of 10km long and 200m wide. Over 73,000 hectares of land were damaged and an estimated 26,000 hectares of wet farm land and paddy fields remained unusable due to tsunami debris and silt. Since the damage was so vast, BRR (the Rehabilitation and Reconstruction Body) targeted agricultural land clearance as one of its priorities to support livelihood in the agricultural sector.

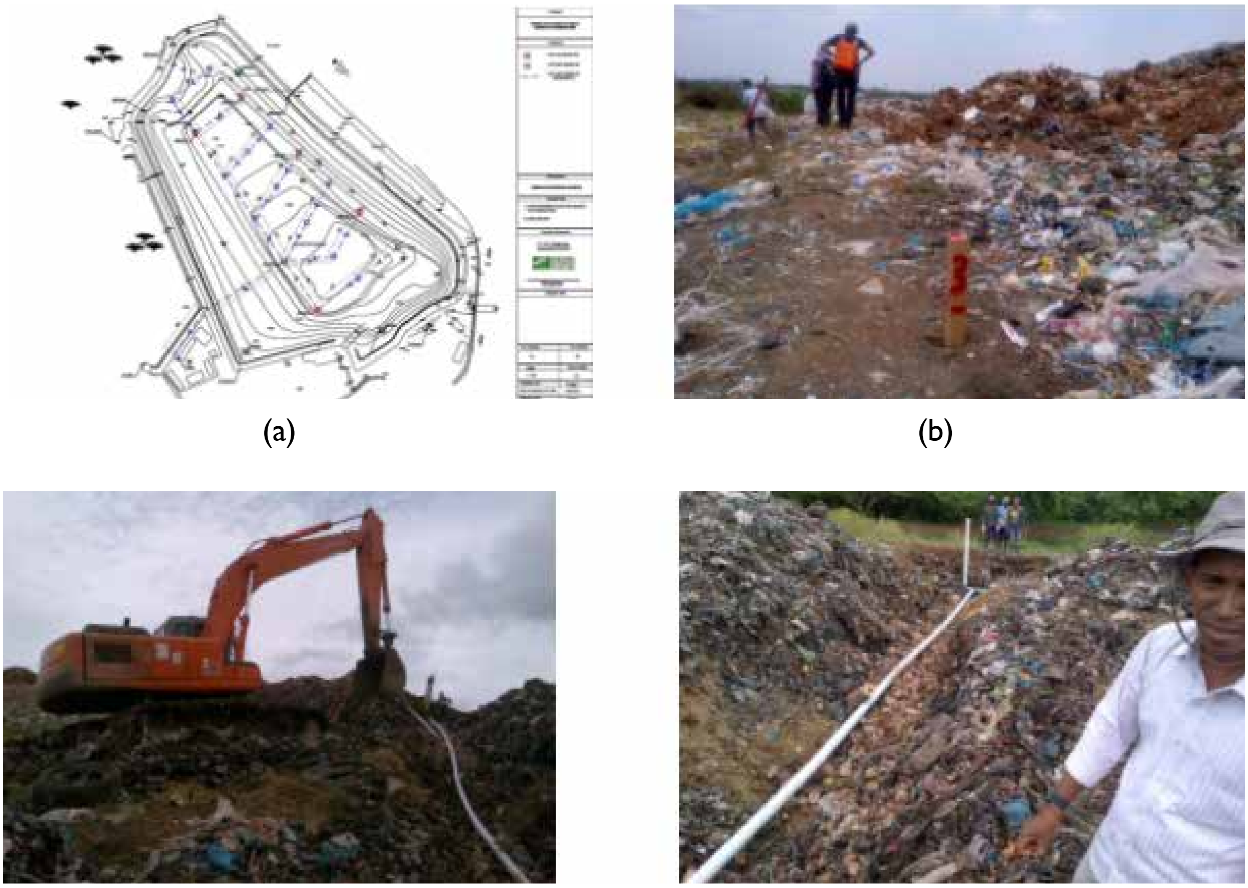
The Tsunami Recovery and Waste Management project (TRWMP) was implemented by the UNDP, which first helped clear rubble and waste from the tsunami-devastated areas (mainly urban areas), thus making urban reconstruction possible. Thanks to this project, an improved municipal solid waste management system was established, which contributed to significantly improved environmental management and improved livelihoods. It was implemented from December 2005 to December 2012; the grant amounted to US$39.4 million. Following its initial push to remove tsunami waste from devastated urban areas, the TRWMP developed its agenda to construct better landfills and to lay the groundwork for their sustained operation to improve waste management standards, an important contribution to improving environmental management more broadly. A substantial portion of funding for TRWMP was not only used to finance infrastructure (mainly landfills), but also to build district government capacity for solid waste management, to clear debris in the immediate aftermath of the tsunami, and to develop livelihood programs to aid social and economic recovery.

TRWMP consisted of three main components: (1) capacity building for better environmental management, (2) construction of better landfills than had existed before the disaster, and (3) creating livelihoods especially for disaster victims and women. The scope of the TRWMP, implemented by UNDP, initially included the demolition of damaged buildings, clearing of tsunami waste as well as its utilization (e.g., extraction of recyclables, reuse of timber for building or furniture making, use of timber for firing brick kilns, etc.), and rehabilitation of the main waste dump site, Gampong Jawa in Banda Aceh for temporary use. More important for the long term, the project established a regional sanitary landfill, which will be managed by a newly established technical implementation unit (Unit Pelaksana Teknis Daerah or UPTD). The provincial government finances 50% of the operating cost, and Banda Aceh City (30%) and Aceh Besar District (20%) the remainder.

Table 1. TRWMP budget and actual spending (US$ million)

Component	Budget (including interest)	Spent until June 2011	% Budget Used
1a. Clearance of tsunami waste	} 18.5	} 18.5	} 100%
1b. Local government capacity building			
2. Landfills	16.9	16.8	100%
3. Livelihood program	3.5	3.6	100%
Monitoring	1.5	1.5	100%
TOTAL	40.4	40.4	100%

Source: MDF-JRF Secretariat, 2012



(a) (b) (c) (d)

Photo 1. Construction of land field for waste management

(a) Site plan of methane gas pipes,
(b) Field survey for DED and bench marking
(c) Excavation of the piles of waste, and
(d) pipe placement (Source: Yayasan Kemaslahatan Ummat (YKU), 2015).

Technology details

The TRWMP constructed new landfills for municipal waste to improve technical specifications that had never been implemented in Indonesia before the tsunami. Specifications included site selection, sealing the bottom of the waste deposition cell, collection and primary treatment of leachate (effluent), and final treatment of leachate in a quasi-natural reed bed. Sufficient land for future expansion has also been set aside adjacent to the landfill. The TRWMP facilitated the establishment of a joint secretariat between two local authorities, including Banda Aceh City and Aceh Besar District, to manage the newly constructed regional landfill at Blang Bintang. The joint secretariat forms the embryo of a dedicated agency to be established in the future. TRWMP trained over 600 local government sanitation department staff in improved techniques for solid waste management, especially the improved operations to be introduced in the newly constructed landfill sites.

After the tsunami, it was considered critical to design a regional landfill immediately. In 2006, a masterplan was developed to replace Gampong Jawa Landfill, (GJL) as its capacity was insufficient. However, before the construction, in anticipation of need, BAM acquired nine hectares of land around the landfill area, bringing the total of GJL to 21ha. The Feasibility Study and Detailed Engineering Design (DED) were then prepared by Arcadis and UNDP, and GJL was constructed by the government through the Rehabilitation and Reconstruction Body (BRR). Although ultimately the construction was not implemented in accordance with the DED, GJL was built in 2008 and went into operation in early 2009.

The transition of controlled landfill into sanitary landfill was conducted to anticipate the provisions in "National Act No. 18/2008 on Solid Waste Management", which in Article 44 requires all districts to provide an open-dumping closure plan no later than one year after the enactment of the Act, and to close the open dumping at a maximum of five years after the enactment.

Table 2.Project details

Item	Blang Bintang Regional Landfill	District Landfill
Total Area	200 ha	6-7 ha
Area developed under the project	35 ha	5-6 ha
Population served	450,000	180,000
Estimated lifetime	Up to 50 Years	15 Years
Total Cost	US$ 7.0 Million	US$ 1.0 Million

Source: MDF-JRF Secretariat, 2012

BBB results

This is a case of infrastructure BBB for the following reasons:
Disaster debris was used for reconstruction work. Tsunami waste and debris brought about by the tsunami has been used for recovery and operation of infrastructure. After the tsunami, more than one million cubic meters of debris was cleared in urban areas, which were used as recyclable materials for 100 km of roads rehabilitation, 55 ha of daily cover at landfills, and for manufacturing 12,000 units of wooden furniture.

Recovery work generated local employment. In 2005, TRWMP paid the wages for 400,000 days of temporary labor in a cash-for-work scheme that facilitated debris clearance, street sweeping and drainage clearance. Over the full period of cash for work (2005–2008) the average daily number of participants was 1,451; approximately 254 ha of tsunami-impacted agricultural land was cleared and has been recovered for productive use, which has benefited 946 households.

Recovery work created business for local small-to-medium-sized enterprises (SMEs). TRWMP supported 164 SMEs, 109 of which were continuing their business three years after the support; waste recycling SMEs created employment for 2,400 people, further benefitting 11,800 indirect beneficiaries; (UNDP Indonesia, 2013). In all, US$1.34 million was distributed as small grants supporting start-up business capital and operations; 72,121 tons of waste were recovered for recycling over the period of NGO support (2005 to 2010); roughly 67,000 tons of recycled and recrafted materials sold successfully in the market (Source: UNDP Indonesia, 2013).

DIKE Furniture, a local furniture maker, for example, used tsunami-recovered lumber to make desks, tables, chairs and cupboards used at school, home and offices. This local carpentry business successfully continued after TRWMP ceased its financial and organizational support.
The waste arriving at GJL is re-sorted by types and the selling price. At least 50 stalls of junk shops operate in BAM, and more than 20 tons of recyclable materials are sent to Medan every day. While most of the green waste is processed by shredding machine in GJL as described above, other "3R" activities (Reduce, Reuse, Recycle) are undertaken in BAM, such as household-scale composting.
Approximately 1,000 households engage in this activity. Schools also engage in micro-scale composting. In schools, in addition to composting, waste sorting is also conducted through the "waste bank" program. Eight School Waste Garbage Banks helped to teach children about recycling and income-generating activities at school. Medium-scale composting is also being developed in the sub-district of Ulee Kareng to compost organic waste from the markets.

Lessons learnt
Rapid debris cleaning after a tsunami is essential to be addressed so that recovery programs can be implemented effectively. This requires a lot of work that can be done by involving disaster victims, which directly generates immediate income to help livelihood recovery. TRWMP is planned in several stages, tailored to the needs of the post disaster period and also the future. The comprehensive plan ensures the sustainability of income generation not only after the disaster but beyond the recovery period. Livelihood creation oriented around extending the lifecycle of debris — such as waste separation, used goods sales, waste banks, etc. — is not only economically profitable for society, but also contributes to a better and more sustainable environment and reduces the burden of post-disaster waste disposal. Advanced technologies along with improvement of government capacity in post-disaster infrastructure recovery can ensure the self-sustaining operation of infrastructure after the government-supported recovery period ends. Nevertheless, the regional landfills in the Blangbintang has not yet been operating. Every year the city government allocates IDR 900 million for operational contributions, which could not however be disbursed due to the absence of clear policy regarding the operational funding responsibilities of the landfill. The transfer of infrastructure assets to local authorities might be divided into several phases and integrated into the program planning, so that it could smoothly be transferred and ensure the operation of the infrastructure assets after the end of the recovery program.

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2.7 Philippines : Typhoon Uring and slit dams in Ormoc city

The City of Ormoc, located in the province of Leyte in the Eastern Visayas of the Philippines, home to a population of 200,000, was devastated by a typhoon in 1991, resulting in about 6,000 fatalities due to flash floods. Only 3.3% of Ormoc's watershed was classified as timberland. The rest was alienable and disposable land, meaning open to private use for commercial sugarcane and coconut plantations, lowland rice field irrigation and pastures. Within the city is Isla Verde, a delta of alluvial deposits, which was heavily populated despite high risks of inundation (Olan, 2014).

Disaster impacts

Typhoon Uring (international name Thelma), one of the worst disasters in the Philippines before Typhoon Yolanda (Haiyan) also struck Eastern Visayas, caused intense flooding and landslides in the area, killing more than 6,000 people, in Ormoc, Leyte, on 5th November 1991. The typhoon affected Viet Nam as well, and the total estimated damages amounted to US$19 million, based on 1991 values.

The high death toll and massive damage could be attributed to the combined effects of unusually heavy rain, the damming of rainwater in the upland areas, and the proliferation of illegal settlers along the riverbanks. In addition, there were accounts that attributed a landslide that washed away huge logs to illegal logging activities on the mountain. According to the provincial government, the disaster happened at exactly 12:00 noon, and within 30 minutes the entire Ormoc City was devastated (Bangkok Post, 2017).

Infrastructure development after the disaster

After the disaster, the local government of Ormoc City carried out restoration work by repairing damaged dikes and replacing destroyed bridges. However, it lacked the financial resources to carry out crucial flood mitigation measures. In 1993, a survey project for flood mitigation in Ormoc City was started through the assistance of the Japan International Cooperation Agency (JICA). From 1997 to 2001, JICA constructed four new bridges and three slit dams to reduce the danger of landslides and floating trees. JICA also widened the rivers by creating an entire diking system, and provided other protective infrastructure to improve drainage of the city's two major rivers. The project was funded by a JPY 3.321 billion grant (JICA, 2014; Bangkok Post, 2017).

Through this project, a "Flood Mitigation Committee" was established that promoted disaster response efforts at the local level. JICA also commended Ormoc's effective management and maintenance of the flood mitigating structures, demonstrating that community cooperation can maximize the benefits of the infrastructure.

The bridge construction and widening of rivers required the displacement and relocation of some of Ormoc's citizens. Consultation meetings were organized together with JICA to explain the necessity of the project to the local residents. City officials emphasized the necessity to widen the rivers and the importance of flood control measures to protect the community as well as the residents' own lives and property. The city acquired a resettlement area and provided compensation to those who were relocated. Once basic services were provided (electricity, water supply, etc.), the residents were resettled (Bangkok Post, 2017).

In addition to these measures, the city reforested the upland areas which had previously been utilized mainly for sugarcane and rice plantations. Since the 1991 typhoon, the local government has continued reforestation projects every year. In September 2013, the Department of Environment and Natural Resources (DENR) named Ormoc Bay as a water quality management area, which has designated the watershed and its tributaries, and is expected to lead to formulation of a comprehensive management program to protect the waters (Olan, 2014).

Results and lessons learnt

In 2003, Ormoc City was struck again by an equally devastating typhoon. Thanks to the slit dams, no casualties were recorded, as the residents were protected from landslides and floating trees. Likewise, when Typhoon Yolanda/Haiyan struck the Philippines in 2013, the two main rivers did not overflow and the number of casualties in Ormoc was significantly reduced, compared with that of Uring, proving the effectiveness of the flood control infrastructure (JICA 2014 b). The successful case of Ormoc demonstrates that in the APEC region, which is repeatedly struck by typhoons, critical infrastructure investment is a precondition for sustainable development as well as DRR. And for this purpose, effective and timely communication with aid agencies is a key. Another important lesson is that community cooperation maximizes the benefits of infrastructure investment.

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3 Village relocation

Whole village relocation has been attempted in several economies, despite the difficulties. A relocation project could involve development of a set of community infrastructures including community roads, water facilities, sewerage systems, parks, schools, and so on, and could be seen as a type of infrastructure BBB.

3.1 Chinese Taipei: Typhoon Morakot and Laiyi township relocation, Pintung county

The Laiyi township is located on the west side of the central mountains of Chinese Taipei, where the average altitude of the township is higher than 300 meters. In Laiyi, there are mountains, rivers and valleys which create an undulating topography. The climate type is tropical monsoon climate. In the township, most of the residents are Paiwan people, who are one of the indigenous peoples of the island. The township is also the most densely populated indigenous village in Chinese Taipei, and is therefore critical to the Paiwan culture and industry.

Disaster impacts

From 6 to 10 August in 2009, Typhoon Morakot struck the southern part of Chinese Taipei. The most serious impact of this typhoon was the floods caused by the enormous rainfall. The disaster is therefore known as "the 88 flood". It was the economy's most serious flood since 1959.

After the disaster, several villages including Laiyi village, Yilin village, and five to seven neighboring villages of the Danlin in Laiyi township, Pingtung county, were classified as unsafe areas, and the residents had no choice but to relocate. The central and local governments negotiated with the residents and selected South Bank Farm as a permanent housing area for settling the dislocated Paiwan residents. The permanent housing area was renamed as "the new Laiyi tribe" by the residents.

In order to support industrial development and to pass on their culture, the reconstruction council established "the retail center of the new Laiyi tribe" (see Figure C) for promoting local industry (such as handicrafts) and providing working opportunities. The tourism industry can also promote the industrial development and the sustainable operation for the new Laiyi tribe. This project was funded by government agencies, the Red Cross of the Society of the Republic of China, and the Tzechi foundation. Red Cross was actively involved in the project implementation. Total budget was about NTD 1.6 billion.

Recovery process

By 2010 the reconstruction project was proposed by the reconstruction council and the revised plan was funded by the government agencies, the Red Cross Society of the Republic of China, and the Tzechi foundation. Phase one project started in 2010 and completed in 2011, followed by the phase two project that was completed in 2012.

Table 1. The number of new constructed houses

Area	Type A (46.2)	Type B (92.4)	Type C (112.2)	Total
Phase 1	0	112	120	232
Phase 2	16	32	10	58

The government acquired the farm site from a sugar corporation by land expropriation. The total area of the site developed by the Red Cross and Tzechi foundation was 24.88 ha, and the infrastructure and facilities were supported by the council of indigenous peoples and planned by the construction and planning agency.

The permanent houses were funded and constructed by the Red Cross Society, including 122 units of 92.4 square-meter houses and 111 units of 112.2 square-meter houses. The project started on July 10, 2010, and finished on August 20, 2011. In phase two, the construction of 58 permanent houses was funded by the Tzechi foundation. The reconstruction was divided into two phases because the original site of Laiyi township was struck by another typhoon in 2010, and wider areas were classified as dangerous. Therefore, more residents were determined to relocate to the new site, and more permanent housing units were required. The county government acquired support from the Tzechi foundation for phase two of the reconstruction plan. The second phase started in June, 2011, and completed in January, 2012.

A site of 24 ha was developed to settle 223 families from the Laiyi village. The reconstruction and settlement plan was finished within two years with the collaboration between the government, NGOs and civic groups. In addition to settling the refugees, the government also provided working opportunities and facilities by establishing a production and marketing center on the site. This center featured indigenous handicraft industries. With the operation of the production and marketing center, the refugees could also develop their traditional culture and handicraft skills by making souvenirs for the tourism industry.

In addition, the reconstruction committee also made use of the subsidies to enhance hydraulic engineering for agriculture. Irrigation water from the original township was rerouted to the new site for agricultural use. Although the residents have been relocated to a new site, by using the same water resource they can keep the memories of their original lands.

BBB impacts

During the reconstruction project, the reconstruction council placed importance on villagers' demands for local industries and job opportunities, and implemented projects to promote agricultural development and tourism as well as local indigenous society and traditional culture.

A community center and a center for local retailers were constructed in the area funded by both government agencies and the Red Cross society, beginning operation in 2012. The retail center features the specialty of the Laiyi township, which is taro. In addition, many other facilities supporting the village life were also established to enhance the living functions, including community offices and kindergartens. Landscape improvement work was also implemented.

3.2 The USA: Kickapoo River Floods and the village of Gays Mills community and commercial infrastructure[41]

The Village of Gays Mills was struck by back-to-back floods in August 2007 and June 2008. Both floods were greater than 500-year flood events, which resulted in substantial losses to residences and businesses within the Village.

The village of Gays Mills, located in Crawford County, Wisconsin, home to a population of almost

41 "Long-Term Community Recovery Plan" Crawford County, Wisconsin, November 2008
http://www.emergencymanagement.wi.gov/recovery/docs/2015/long-termrecovery/Village_of_Gays_Mills_Recovery_Plan_2008.pdf

525, emerged from the creation of a sawmill by James B. Gay in 1847. Between 1848-1865, families moved to the village to work at or establish similar mill operations. At the turn of the century Gays Mills' connection to numerous rail transportation networks allowed its agricultural and light industrial products greater access to the local and federal economy, resulting in a small yet bustling town. Since the 1940's Gays Mills has found itself without a rail connection and increasingly beset by the problems of the American town in the post-industrial era. Facing a declining and aging population, high unemployment and low income, Gays Mills' future was bleak prior to the flood events of 2007-2008.

The town faced flooding disasters before, some 11 times in the last 100 years. Between 1935-1976, a variety of programs and government interventions via the US Army Corps of Engineers and congressionally authorized projects attempted to plan for flooding events; however, often these assessments could not be executed in time, or at all, due to lack of resources (e.g., 1938 preliminary studies and 1976 "Alternatives for Flood Reduction and Recreation in the Kickapoo River Valley"). In 1962 the Kickapoo River Valley Flood Control Project constructed a series of earthen water management structures and in 1975 the construction of a dam that was three-quarters completed was halted due to concerns over long-term costs. In 1978 the valley experienced a major flood event, causing some US$10.5 million in damages. A study by a regional planning and engineering firm advised either the construction of a levee or a partial relocation, neither of which were ever implemented (FEMA, 2008).

Impacts on infrastructure

Although Gays Mills experienced a significant flood on August 18-20, 2007, it was soon struck by another river rise of 6.23 meters on June 10, 2008. Both these events were considered greater than the "500 year" (i.e., annual 0.2% chance) flood event measurement, making them particularly catastrophic in the village's 100+ year history of flood management.

The 2007-2008 flooding events resulted in significant damage to the community, substantially damaging 60 homes and devastating local businesses in the downtown as well as those attached to the Kickapoo valley's economic network. The flood's impact on roadways gravely interrupted the villages' commercial connections but the main damage was the potential loss of residents who were customers of the historic downtowns' commercial enterprises. Gays Mills housed some 625-650 inhabitants before the 2007-2008 flooding of the Kickapoo River, most of them in the downtown area. Nearly 90% of the downtown area was inundated by the floods, but 2008 in particular damaged a significant amount of the basic housing: 108 homes, 53% of which were substantially damaged, along with street infrastructure and the businesses operated by those home owners. In total, 40 homes were completely lost in the disaster.

Previous planning efforts that had never been implemented before the 2007-2008 flooding event jump-started the conversation that would lead to Gays Mills, in effect, being relocated a mile north of the original downtown area on the east and west sides of Highway 131.

Recovery process

In 2008, the Gays Mills Long Term Community Recovery Team led an intensive three-month long planning process in consultation with local, state, and federal officials. The result was a Long Term Community Recovery plan that "reflected a community vision for recovery" (FEMA, 2008). The relocation to a new site was considered carefully with four options. In 2010, relocation sites were purchased in North Mills Dudgeon, multiple funding streams acquired, and an Economic and Recovery Coordinator position was established. The construction started in 2011.

Sustainable design sought to reduce negative impacts on the environment and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability were to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments. Sustainable building design principles included the ability to (i) optimize site potential, (ii) minimize non-renewable energy consumption, (iii) use environmentally preferable products, (iv) protect and conserve water, (v) enhance indoor environmental quality, and (vi) optimize operational and maintenance practices (FEMA, 2008).

Photo and map of Gays Mills, Wisconsin

Photo: Flooding of Gays Mills, Wisconsin, Courtesy of United States Federal Emergency Management Agency[42]

BBB results

The BBB approach at Gays Mills was heterogeneous in nature: multiple funding streams were to be acquired; multiple community perspectives variable to the location of the floodplain were to be explored; and a disjointed economic landscape had to be negotiated. However perilous the situation at Gays Mills can seem, the industry that has long dominated the area, apple harvesting, has remained largely untouched, unlike the town that is closer to the river and not perched on the hills. The installation of geothermal and solar systems funded by the United States Economic Development Administration exerts some influence on the energy economy, as do the repairs and improvements to the local highway infrastructure. In addition, the rehabilitation of the commercial and housing centers is an important and direct improvement to the economy. The most recent efforts at Gays Mills focus on keeping business moving through the town and keeping rent costs low. More expansive and expensive projects have been postponed in an effort to establish this new population of settlers, which the town sees as the key to local growth. While the macroeconomic supply chains remain intact, we see that to continue existing, the place called Gays Mills needs to re-emphasize the microeconomic supply chains of housing, food, gas, and community to spur true growth.

42 "Long Term Community Recovery Plan", Nov. 2008
https://dma.wi.gov/DMA/divisions/wem/recovery/docs/Village_of_Gays_Mills_Recovery_Plan_2008.pdf

Lessons learnt

The recovery of Gays Mills is a great example of community and private support interacting with organizations at the state and federal level. While communication troubles did occur, these happened over the pragmatic realities of the situation and the nature of state and federal funding flows, rather than fundamental disagreements about goals, values or roles. However difficult these obstacles were, Gays Mills has not been marked by a sour political reality following the disaster. Although the community was clearly devastated, a dominant narrative of local vs. state or state vs. federal did not emerge. Gays Mills serves as an example of the power of multiple funding streams to enact a potentially decades-long relocation project for a relatively microscopic portion of the population.

An invaluable lesson of the BBB project at Gays Mills is related to the proactive establishment of a constructive 'new normal'. The constructing of this new normal was a process that directly involved the community. For APEC economies it is essential to learn that a 'new normal' cannot be constructed from the vision of a planning board. Plans must meet the on-the-ground reality of disaster to form a democratically acceptable form of recovery. Federal and state levels of government power could expedite future recoveries by enacting and designing more reflexive programs, which would — among many productive outcomes — lead to disaster recovery systems that operate both within and outside the community in measures beyond what 'integrated communication' can deliver.

3.3 Village relocation as an alternative for BBB

Village relocation projects have also been implemented in other economies as a solution for recovery and building resilient residential areas.

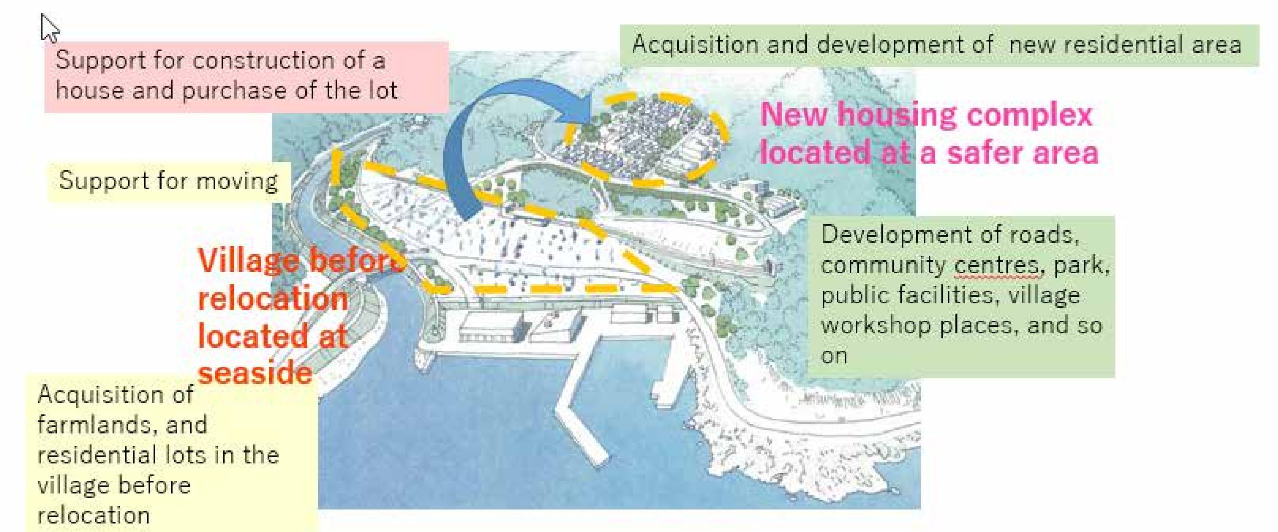
In Australia, after the Queensland flooding from November 2010 to March 2011[43],resulting in 35 deaths, an AUS$18 million community relocation project called Strengthening Grantham was established to provide vital community infrastructure including water supply, sewerage and roads, at a new residential development on higher ground in the town of Grantham; this development allowed residents to relocate to areas that are better protected from flooding[44].

In Japan, a scheme facilitating collective relocation for DRR purposes from natural disaster hit areas and potentially struck areas has been made available since 1972. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) supports the local governments' land acquisitions and development of new residential areas for relocation, while individual residential lots are sold or rented to the relocating residents. In this scheme, community infrastructure development in the new village, such as community roads, water facilities, and so on, is also supported. For the residents, interest for bank loans to purchase new houses and lots is supported. Local governments purchase housing lots in the village before relocation and apply building restrictions so that the high-risk areas will never be used as residential areas.

43 GLIDE: FL-2010-000259-AUS

44 Queensland Reconstruction Authority "Rebuilding Grantham together — Development scheme: Grandtham Reconstruction Area" https://www.statedevelopment.qld.gov.au/resources/guideline/qra/rebuilding-grantham-dev-scheme.pdf

In the tsunami-affected areas after the Great East Japan Earthquake, more than 300 collective relocation projects from coastal areas to hilly areas are underway.



Source: Cabinet Office/MLIT, Japan (Provisional translation by ADRC)

Many economies have attempted whole village relocation projects to disaster-resilient locations as an alternative, despite the complicated coordination and consensus-building process required. Development of a destination area could involve installing a full set of community infrastructure. Relocation provides an important opportunity for building new residential areas or villages equipped with updated infrastructure, which can be seen as a type of infrastructure BBB.

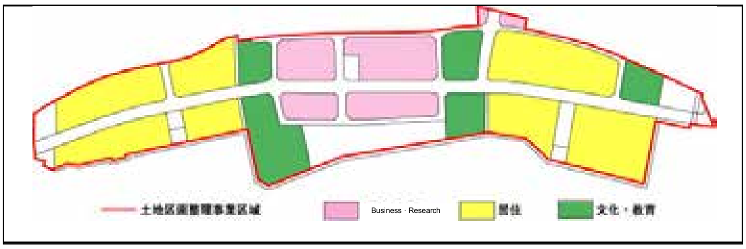
Column: The Great Hanshin-Awaji Earthquake (1995): redevelopment of affected urban areas (HAT Kobe), Japan

Post-disaster urban redevelopment can provide an opportunity for fundamental changes of the disaster hit areas, almost equivalent to relocation. The waterfront urban center development project, HAT Kobe, after the Great Hanshin Awaji Earthquake in 1995 (See case 1.3.3), was a symbolic project of BBB in Kobe. (HAT = "Happy Active Town".) In this area, international organizations, museums and shopping centers have replaced steel industries, leading to a fundamental change of the nature of the area and diversification from an industrial zone to a cultural and touristic area.
The case of Kobe could not be classified as non-metropolitan; however, some areas already saw aging of population. In this regard, the recovery of Kobe shared similar challenges with rural areas in Japan facing extreme aging and population outflow.

Redevelopment project

The HAT Kobe redevelopment project was regarded as a symbolic project of Kobe City Reconstruction, integrally carrying out land readjustment, harbor renovation and housing improvement, by converting the industrial complexes greatly affected by the earthquake.
The development plan of this area had already been discussed in 1992, well before the Earthquake. After the earthquake caused catastrophic damages to extensive areas of the city, urban reconstruction became a priority for the municipal authority. The need for a large supply of housing was especially urgent. Within months, the new, Eastern city center development project was thus defined as the leading project of Kobe city's reconstruction plan, a symbolic project of recovery. In addition to the fundamental infrastructure, facilities for various functions such as research, education, cultural facilities, a disaster prevention hub, and housing, were planned to be located in an area of 120 hectares. These facilities were designed to serve a population of 30,000 population and a workforce of 40,000 by providing 10,000 units of housing.

Aerial photo of HAT KOBE after the earthquake
Source: Asia Air Survey CO., LTD



Layout of the reconstruction of HAT KOBE
Source: Hyogo Prefecture

Zoning for the area was changed from industrial to urban (public) use. Major infrastructure to be constructed included: the new, east urban center line and nine other roads, four pedestrian walkways, parks and green space. Two private railway stations were renovated in the area as well. The redevelopment plan promoted four priorities:
Safety, such as anti-seismic water reserves, earthquake-resistant water tanks, and common ducts for utility tunnels;
Environment, including green rooftops, community air-conditioning and heating, and beautiful roadside trees;
Welfare, such as pedestrian steps, slopes and elevators friendly to everybody; and
Vitality, including central zone construction of diverse facilities, private companies, parks and " harbor walks", etc.

HAT Kobe is characterized by an accumulation of DRR related organizations, including the Disaster Reduction and Human Renovation Institution (DRI), commemorating the earthquake, andAsian Disaster Reduction Center (ADRC), which has been located there since the opening of the area. In 2017, the Graduate School of Disaster Resilience and Governance, University of Hyogo, opened as well. Other organizations and international organizations with facilities in HAT Kobe include: the World Health Organization (WHO), the Japan International Cooperation Agency (JICA), a Red Cross hospital, a prefectural art museum, a prefectural medical center, and many regional offices of various international organizations.

BBB impacts

HAT Kobe area is a case of post disaster redevelopment by changing the nature of an area from an industrial zone to a cultural and environmentally friendly area attracting tourists and foreigners, which also contains convenient and modernized residential facilities for comfortably housing large numbers of displaced people. The whole area has been built back better by diversifying the functions. After two decades, however, HAT Kobe now faces aging of residents living in the housing constructed for the disaster-affected. Soon after the earthquake, elderly households were given priority for reconstructed housing. Aging and weakening ties among residents have now become a challenge of the area. In order to revitalize the communities, variety of efforts have been made in close collaboration with NGOs and local governments. Thus, BBB of the area has not yet been completed.

4 Lessons for infrastructure from innovative reconstruction of housing and buildings

While this project primarily focuses on infrastructure, some important lessons can be drawn from cases of housing reconstruction for infrastructure, especially vis-à-vis community-based approaches.

4.1 Chinese Taipei: Typhoon Morakot and Dabang elementary school in Alishan township

The Dabang elementary school was established in 1904. It was the first elementary school in Chinese Taipei with over a 100-year history. The reconstructed Dabang elementary school adopted a special design. The shape of the campus reflects the "node of life", which is an important symbol of the Tsou tribe. In addition, the campus also keeps many of the historical remains, such as temples, trails, and stairs, which help preserve the culture of the Tsou tribe. The indigenous culture integrated in the campus also reflects their educational philosophy.

The Dabang elementary school is located on Ali Mountain, and integrates nature, ecology, and humanity, including the local indigenous culture. In the school, they teach not only modern subjects, but also the tribal language, spiritual ceremonies, and the conventional arts. The school also implements the indigenous culture education in summer camps. Therefore, after it was damaged in a typhoon, the reconstruction of the Dabang elementary school was also helpful for rebuilding the culture and the arts (including industrial) of the Tsou tribe.

Typhoon Morakot, which struck Chinese Taipei in 2009, caused torrents of water and mud to rush down the mountain to the river valley adjacent to the Dabang elementary school. It caused the slope around the campus to collapse, so the buildings became adjacent to a cliff. In addition, the original campus buildings were too old and insufficiently constructed to withstand seismic impacts. The campus buildings had already been condemned and were going to be relocated. The project started in 2013 at the Alishan township, Chiayi County, funded by the TVBS Foundation. Total budget was approximately NTD 131 million (MTPRC, 2013).

Technical details

Reconstruction targets included the main campus buildings, the indoor sports field, the library, and the faculty dormitory. In addition to the teaching facilities, construction work also focused on the grounds and environmental engineering. The design concept of the campus reflects the symbol of the indigenous tribe's harvest god.

The reconstruction plan integrated the indigenous culture into the campus design, and combined traditional culture with modern buildings, presenting a good practice on cultural preservation in campus reconstruction (as shown in the photo).

Photo. Reconstruction of Dabang elementary school

Source: MTPRC, 2013

Recovery process

Relevant authorities included the Typhoon Morakot Post-disaster Reconstruction Council, the Directorate General of Highways, and the Ministry of Education. The process began with the initial project proposal by the Reconstruction Council in 2009. Construction started in 2010 and was completed in 2013.

Since the Dabang elementary school is located in a mountainous area, the conservancy regulations and assessments are especially strict. The construction plan suffered from many difficulties, such as the inconvenience of material transportation and the abrupt climatic changes in the mountain's area. The access road collapsed twice, forcing the reconstruction to be temporarily suspended. Therefore, the reconstruction council needed to collaborate with the Directorate General of Highways (DGH) since the DGH was in charge of fixing the road so that the reconstruction of the campus could be continued. After 24 project meetings and numerous discussions and investigations over two years, the construction of Dabang elementary school's new campus was finally completed on 7 May, 2013.

BBB results

The reconstructed campus that has integrated the indigenous culture in the campus design, and mixed the modern building design with the traditional culture, illustrates a good practice of cultural preservation in architectural reconstruction. The reconstructed campus is not only an educational facility but also the cradle for recovering the culture and industry of the local indigenous people (MTPRC, 2013).

4.2 Viet Nam: Flood-resilient housing in the central region

Located in the tropical monsoon climate zone, the central regions of Viet Nam are often impacted by heavy rains during the rainy season. The heavy rain often causes flooding in many provinces, especially in Nghe An, Ha Tinh and Quang Binh provinces. Many houses are submerged by floods and the local residents have to suffer through terrible conditions. Every year, the flood disasters result in human losses, significant damage to housing and infrastructure, and severe crop and livestock damages. The severest one was in 1999 with 595 people dead or missing, resulting in a total economic loss of VND 5000 billion, followed by damage from a strong storm in the central provinces in 2010, with 134 people dead or missing.

(a)

(b)

Photo. Flooding in (a) Huong Khe, Ha Tinh province and (b) in Tan Hoa valley, Quang Binh province

Source: vnexpress, 2016

Therefore, on 21 November, 2013, the "Flood resilient housing project" was initiated as a community-based project for the purposes of providing designs, building safe houses and developing sustainable livelihoods for the poor people in the areas affected by natural disasters and climate change. The project called for the cooperation of individuals and organizations, domestically and internationally. The project was initiated by some young and active people from a variety of fields. They raised funds from such sources as the community, the private sector, NGOs, and famous people's contributions. The idea was that 50% of the funding would be covered by the project, and 50% would come from local homeowners. The project period was from 2014-2016.

The project applied different housing designs depending on different topographical areas which tend to have different impacts from natural disasters, described below. The pilot areas were in Ha Tinh and Quang Binh (Phuong My and Phuong Dien commune, Huong Khe district, Ha Tinh province, Tan Hoa valley, Quang Binh province). Each house cost about VND 70 million (approx. USD 3,000).

Technical details

Several housing models were used for severely flood-affected areas:

1) Model of individual floating house

Location applied: for Tan Hoa valley with water level raising from 4m–14m during the floods.

1. Using light material: local wooden wall (gõ tràm), aluminum roof
2. Wooden beams and columns
3. Empty tanks to make house floating

Photo 2-1.Floating house model

2) Model of brick house connected with floating house

Location applied: Huong Khe–Ha Tinh province.

The floating portion of the house has steel pillars at all four corners. During flooding, the pillars act as rails. The floating portion can move up to 10m high, keeping people safe from rising water.

The model is designed to be suitable for flood or storm situations while maintaining conventional, modern building form.

Photo2-2. Combination of brick house and floating house model modern building form

3) Model of house with place for livestock

Location applied: very low areas of Huong Son, Duc Tho, Ha Tinh province (where water raises 2.8-3.2m and flooding lasts 7-15 days).

Outside staircase for livestock goes up during flooding.

This model has a mezzanine to contain straw and dried grass for livestock while easy to be cleaned.

Photo 2-3. Model of house with place for livestock

Photo 2-4 and map. Location of flood-resilient houses that were built and the real houses applied Source: Kenh14.vn, 2016

Low elevated house

High elevated house with place for livestock

Floating house

BBB results

This project has important benefits for the local economy since it has provided a safe living environment for local peole and reduced a remarkable amout of damages and losses in terms of human beings and the economy.

With the contributions and support from different sources, local residents have benefited by only having to pay 50% of construction costs for their flood-resilient houses.

The flood-proof housing models meet the criteria of being low cost yet highly effective, using simple technology and quick construction to save time, money and energy for the society.

In conclusion, the project was considered successful as it was a community-based project that met the demands and real conditions of the community. It mobilized different sources from the community without waiting for government support. In particular, it was an initiative by young, active and enthusiastic leaders, which resulted in the participation of all stakeholders in the selection of suitable solutions. Finally, it used modern communications for spreading information and calling for contributions widely, which also had more influence in the community. In these regards, some lessons for infrastructure BBB could be drawn from these housing cases.

5 Policies, tools and technologies facilitating infrastructure BBB

Efficient recovery and BBB are supported by DRR policies and governance as well as by technologies. Chapter 5 explores good practices presented by APEC economies: firstly, funding of infrastructure recovery (5.1), secondly, collaboration with the private sector (5.2), and thirdly, a few cases of technologies facilitating recovery work (5.3).

5.1 Funding infrastructure recovery and BBB

How to finance recovery of infrastructure from natural disasters is a key concern to promote BBB of infrastructure. Many of the economies stress that a key challenge for them is insufficient funding available to plan or build more resilient infrastructure, as well as difficulties in land acquisition and other issues. Diverse solutions have been explored to accelerate and finance recovery work. In the case of large-scale disaster in particular, the government should urgently estimate and satisfy the huge demands of financing recovery, restoration, reconstruction, and BBB. This requires well-desiged mechanisms to prepare a sufficient budget in advance.

5.1.1 Philippines: Infrastructure recovery scheme

The recovery of infrastructures in the Philippines is generally a function of the Department of Public Work and Highways (DPWH). The DPWH has an office and annual budget for the recovery of roads, bridges and other facilities affected by disasters. The department is a member of the "National Disaster Risk Reduction and Management Council", which is the economy's highest policy-making body on matters pertaining to disaster risk reduction and management (DRRM). The Philippine Disaster Risk Reduction and Management Act of 2010 (RA 10121) was passed to strengthen the Philippine disaster risk reduction and management system. It provides a DRRM framework and plan for institutionalizing DRRM by adopting a comprehensive DRR approach.

In compliance with RA10121, the Philippines has a "National Disaster Risk Reduction and Management Plan (NDRRMP) (2012-2028)". The NDRRMP serves as a guide for achieving sustainable development through inclusive growth while building the adaptive capacities of communities. The NDRRMP includes a plan for infrastructure development toward increasing the resilience of vulnerable sectors and optimizing disaster mitigation opportunities. It outlines the activities of sectors aimed at strengthening the capacities of the central government and local governments together with partner stakeholders.

From the central level, the DPWH, as a department, wields institutional mechanisms for DRRM and recovery of infrastructures affected by disasters. Department Order No. 69 issued on Dec. 11, 2010, created a committee to study and formulate action plans to strengthen the DPWH Disaster Preparedness and Response Mechanism. In 2012, the DPWH formulated the "Disaster Risk Reduction and Climate Change Adaptation Plan" that served as a guide for DRR and climate change adaptation for the infrastructure sector.

At the local level, each Local Government Unit (LGU), such as a city, municipality or province, has a Master Development Plan that lays down the infrastructural development programs for the area. There is also a DRRM Office (DRRMO) in each LGU that draws up the plan for DRRM, including recovery of areas affected by disasters. The DPWH, as the central office, coordinates with the LGU Engineer's Office on identification and planning of infrastructural projects for DRRM, including recovery.

5.1.2 Mexico: FONDEN

In Mexico, which has been repeatedly struck by earthquakes, the Mexican Natural Disasters Fund, FONDEN[45], was established in the late 1990s as a mechanism to support rapid rehabilitation of federal and state infrastructure affected by natural disasters. FONDEN strives for reconstruction activities to avoid recreating vulnerabilities. FONDEN were originally intended only for rehabilitation and reconstruction of the following:

1) Central, state and municipal governments' public infrastructure,
2) Housing for the low-income population,
3) Forests, nature conservation areas, rivers, and lagoons satisfying certain conditions.

Photo: People working on a building damaged by the earthquake of Sept.7, 2017 of M 8.2[47]

Source: Televisa News, Mexico, Material by CENAPRED, Mexico, for the APEC workshop, 20th Sept., 2017, Vinh City, Viet Nam

In recognition of the importance of ex ante DRR efforts, from the beginning of the 21 century the Mexican government has allocated resources for designated prevention measures. Nevertheless, the key purpose of FONDEN remains reconstruction. As directed by the Federal Budget and Fiscal Responsibility Law, at the beginning of each fiscal year an amount not less than 0.4% of the annual federal budget[46] is reserved for FONDEN, FOPREDEN, and the agricultural fund for natural disasters. Additional resources may be transferred from other programs and funds, such as surplus income from the sale of the Petroleum, in case the default amount is not sufficient. FONDEN funding can be used to rebuild infrastructure at higher standards, based on the "Build Back Better" principle, and also to relocate public buildings and/or communities to safer zones.

5.1.3 Peru: FONDES

The Fund for Interventions before the Occurrence of Natural Disasters (FONDES) is a fund that is presently being consolidated as Peru's main emergency fund, which can support subnational governments and provide necessary resources for the timely execution of interventions in the areas affected by natural disasters. The ultimate purpose of the FONDES is to protect the population and restore the basic infrastructure damaged by a natural disaster. Moreover, when an intervention is financed by FONDES, it will generate employment for the affected people as well.

FONDES evaluates the requests of subnational governments that declare themselves in a state of emergency, and guides those who need the fund. By gathering information from those subnational governments that are exposed to natural disasters, FONDES could provide funds for disaster mitigation interventions to protect the population and public infrastructure.

45 El Fondo de Desastres Naturales de Mexico
http://www.proteccioncivil.gob.mx/work/models/ProteccionCivil/fonden/images/ResenaLibroFonden.pdf
46 equivalent to around US $ 800 million in 2011
47 GLIDE number EQ-2017-000128-MEX

The application of FONDES

In Peru, FONDES was originally established in the middle of 2016 and it was regulated in Law No. 30458 with the purpose of financing pre-disaster prevention, rehabilitation and reconstruction for better infrastructure recovery so that infrastructure can continue to function properly in case of another natural disaster in the future. In other words, it is aimed at financing a BBB approach to infrastructure recovery.

In May 2017, the Ministry of Economy and Finance, with Supreme Decree No. 132-2017-EF, approved the creation of the Multi-Sectoral Commission of the FONDES responsible for prioritizing investment projects, reinforcements and other kind of investments that do not constitute "projects", including preparation of technical files for the execution of future projects, optimization interventions, enlargement interventions, emergency activities of rehabilitation, and others, in case of the occurrence of any natural or man-made disasters.

In the same way, Supreme Decree No 132-2017-EF defines the organization regulations and functions of the Multi-sectoral Commission of FONDES. The institutions that constitute the Multi-sectoral Commission include the Minister of Economy and Finance as president, the Minister of the Environment, and the Minister of Defense. The "National Institute of Civil Defense, INDECI", acts as the Technical Secretariat of the Multi-sectoral Commission of the FONDES.

The Technical Secretariat engineers who specialize in disaster risk are responsible for the reviews, authorization and prioritizations of the requests made by subnational governments. Likewise, the Technical Secretariat of the multi-sectoral commission of FONDES is in charge of coordinating the meetings of the Multi-sectoral Commission, where requests of interventions that require financing by FONDES will be submitted, examined and selected.

Recent good practices funded by FONDES

A good practice of infrastructure BBB financed by FONDES throughout 2017 includes, for example, riparian defenses with rock formations in critical areas to protect the population and land of the department of Lambayeque, la Libertad, Ancash, located close to Lima, Piura and the Tumbes region, in northern Peru.

Drainage works such as terraced structures for retarding the flow of flash floods and mudslides, on the rehabilitated rural road to the district of Lincha (see the following photos), were financed by the FONDES. This kind of intervention protects the rural road from the runoff of the rain through the ravines.

Drainage works such as canals and culverts on the rural road to the district of Tupe (see photos) were also financed by the FONDES.

It might be better to have an asphalted road, but it is not economically sustainable. Therefore, FONDES has financed these kinds of interventions (see photos above and below) that reduce the impacts on exposed zones of unpaved, rehabilitated rural roads.

Gabions have been installed with funds from FONDES to help channel the runoff at the source of the ravines and avoid damages to the town, District of Tupe.

Photo. Rock casting work in the District of Tumbes protects the slope from erosion and scouring.
Source: INDECI, Peru

All these structures in the areas affected by the El Niño Southern Oscillation (ENSO) on January and February 2017 have been achieved thanks to the FONDES resources by focusing on the Build Back Better approach.

5.1.4 Australia: NDRRA [1]

In Australia, state and territory governments are responsible for emergency management, and for providing disaster recovery assistance to affected communities following a natural disaster. Disasters can result in large-scale expenditure by state and territory governments in the form of disaster relief and recovery payments and infrastructure restoration. To assist with this burden, the Australian Government provides financial assistance to state and territory governments in certain circumstances under the Natural Disaster Relief and Recovery Arrangements (NDRRA). NDRRA assistance may be used for emergency assistance to individuals, communities, small businesses, primary producers and not-for-profit organizations, and for the restoration of eligible infrastructure.

The level of financial assistance provided by the Australian Government under the NDRRA depends on the type of assistance provided and the level of eligible expenditure incurred by a state within a financial year. The Australian Government can provide up to 75% of eligible state expenditure incurred in response to certain disasters, and is predominantly in the form of a reimbursement payment. In order to calculate the level of reimbursement, individual state thresholds are used which take into account the capacity of a state to fund its disaster recovery assistance costs.

In this way, the NDRRA operates as a financial safety net for the states when they experience frequent and/or severe natural disasters. As the nature, scale and frequency of natural disasters increase, so too does the cost of assistance provided and the Australian Government's liability under the NDRRA.

Good practices of NDRRA funding
The NDRRA allows for jurisdictions to claim expenditures associated with rebuilding their disaster-damaged essential public assets back to the same condition that they were in prior to the disaster. The NDRRA also allows a modest level of flexibility for states to rebuild those assets using contemporary methodologies and materials in certain circumstances. For example, if the damaged

[1] https://www.disasterassist.gov.au/Pages/fact-sheets/disaster-arrangements.aspx

asset is a two-lane timber bridge and the extent of the damage to that bridge means it is to be demolished and replaced, the NDRRA allows states to claim expenditure associated with using contemporary methodologies and building materials to replace the two-lane timber bridge with a two-lane concrete or steel bridge. In addition, in response to Queensland tropical cyclones Oswald (2013), Marcia (2015) and Debbie (2017), the Australian Government has provided NDRRA funding to the Queensland Government for their local governments to rebuild their damaged essential public assets back to a more disaster-resilient standard.

The NDRRA does not prevent states and their local governments from building resilience back into their damaged assets following a disaster, or building new, more resilient infrastructure before a disaster hits, or building resilience into existing infrastructure that has not been damaged by a disaster. Asset owners are responsible for deciding how best to manage their assets to withstand the impacts of future natural disasters, and how best to fund any resilience activities undertaken as a result.

5.1.5 Japan: Inter-ministerial fund for promoting emergency projects for DRR

In Japan, in order to support restoration of disaster-struck public infrastructure to the pre-disaster status, the government designates the natural disaster as a "disaster of extreme severity" or "regional disaster of extreme severity" and provides additional fiscal support for the restoration based on the "Act on Special Financial Support to Deal with the Designated Disaster of Extreme Severity", in case the funding necessary to restore designated types of public infrastructure is estimated to exceed a certain amount of the tax revenue of the affected local governments.

In addition to this general scheme, an inter-ministerial fund for project coordination has been made available since 2005, to facilitate recovery work as well as pre-disaster infrastructure development to increase resilience. This fund, established after learning from the lessons of a series of heavy rainfalls and typhoons in 2004, is budgeted at the beginning of individual fiscal years without defining the recipients and target projects. It supports local governments affected by natural disaster or severe transport accidents throughout the fiscal year, by allocating funds necessary for public works without waiting for the annual budgeting process for the succeeding fiscal year. This fund can be allocated for either post-disaster recovery or pre-disaster preventive measures to reduce risks and increase the resilience of unaffected public infrastructure.

Compared with other public investment funds, this fund could be spent not only to reconstruct infrastructure to its pre-disaster state, but also to upgrade the resilience of infrastructure specifically targeted for a Build Back Better approach.

Presently "the National Spatial Development Policy Bureau", Ministry of Land, Infrastructure, Transport and Tourism (MLIT), is in charge of coordination and allocation of the fund for local governments in close collaboration with Ministry of Finance and other relevant ministries. Projects normally funded by the Ministry of Agriculture and other ministries are also eligible, as the fund is to facilitate inter-ministerial projects. The idea of the inter-ministerial project coordinating fund comes back to the similar fund for development projects allocated by the former "National Land Agency" attached to the prime minister's office that had been in charge of overall inter-ministerial coordination for regional development.

In fiscal 2017, JPY 13,438 million was allocated for 44 projects including projects for the areas affected by the heavy rainfall following Typhoon No. 3, Nanmadolan, that had hit northern Kyushu island in July, resulting in 35 deaths. Soon after the typhoon, in Asakura City, for example, a series of projects for widening river channels and installing a new erosion-control dam were rapidly initiated by using this fund to increase resilience of the river basin area.

Photo. Typhoon damages at the Chikugo river basin area, July 2017[48], Asakura City, Fukuoka prefecture

DRR-related projects including recovery work could involve more than one ministry, which could make the decision-making and budgeting processes complicated. This inter-ministerial fund has facilitated the initiation of various projects that should be implemented through close collaboration by several ministries and local governments.

Column: Hometown tax donation program facilitating recovery (Japan)[49]

Apart from the ordinary budget for DRR, the Hometown Tax donation system has become widely used to support disaster-struck local governments in Japan.

The Hometown Tax donation system (Furusato Nozei) started in 2008. It allows residents to divert a proportion of their income tax payments to other prefectures or municipalities of their preference, which could be their own hometown or another place they love. Tax payers living in metropolitan areas could thus contribute to their hometown.

In June, 2008, inland areas of Tohoku, in Iwate and Miyagi prefectures, were struck by an earthquake, the Iwate-Miyagi Earthquake (M7.2), which caused landslides in the affected areas, leaving 17 people killed, six missing and 462 injured. Many people made donations to support the local governments in the earthquake-affected areas through this system that had just come into force the same year.

This Hometown Tax donation system, originally targeting regional development, has been widely used for supporting disaster-affected local governments, which need to simply inform the Hometown Tax authority to start making appeals for contribution. This scheme can be used to support local-scale disaster-hit areas in addition to mega-disasters that could attract widespread support relatively easily.

5.1.6 Viet Nam

In Viet Nam, DRR policy and finance is managed mainly by the Ministry of Agriculture and Rural Development (MARD) in close cooperation with the Ministry of Finance and provincial People's Committees. The principal source for financially supporting DRR is the state budget in addition to provincial budgets and financial contributions from the private sector.

48 GLIDE number FL-2017-000082-JPN

49 https://www.furusato-tax.jp/saigai/

Procedure for supporting recovery from natural disaster damages

In Viet Nam, practically no annual budget is preliminarily allocated for recovery from natural disasters. Once a disaster happens, individual provinces allocate the budget for recovery, including infrastructure restoration[50], as follows:

1) The Chairmen of People's Committees of provinces prepare:
    a. A report on the damage caused by natural disasters, the need for relief, assistance and proposals on remedies is sent to the Central Steering Committee for Natural Disaster Prevention and Rescue and concerned ministries and branches, pursuant to the Law on Natural Disaster Prevention and Control.
    b. The report on the local budget reserved for natural disaster reduction is sent to the Ministry of Finance.
2) The Ministry of Finance sums up the reserved budget of provinces, classification of local groups on budget capability, and a report on the central budget reserved for NDR.
3) The head of the Central Steering Board for Natural Disaster Prevention and Rescue sums up the damages and the needs for recovery and restoration in the affected provinces, proposing the Prime Minister to provide funding for the provinces/localities to overcome the consequences of the disasters.
4) The Prime Minister decides the financial support for the affected localities on the basis of the proposal made by the head of the Central Steering Committee for Natural Disaster Prevention and Rescue and the opinions of the Ministry of Finance and related agencies.
5) In case of emergency, the Ministry of Finance makes advance payments from the state budget to support the damaged localities pursuant to the Prime Minister's decisions.

Disaster Preparedness Fund

At the provincial level, the Disaster Preparedness Fund is widely used as an important and effective tool for post-disaster recovery.[51] The Disaster Preparedness Fund was first founded in 2008 by several provincial governments in the central area, which is most severely affected by disasters. During the initial three years, the fund mobilized nearly VND100 billion from the private sector, supporting local floodplains in 14 coastal central provinces from Thanh Hoa to Binh Thuan. So far, the Central Disaster Prevention Fund has handed over 11,000 emergency relief gifts; financed 87 community-based houses[52] for disaster prevention and control; planted more than 100 hectares of mangrove forest to protect dikes; and trained rescue teams at the village and commune levels. Each province has its own way to raise its Disaster Prevention Fund.

Disaster preparedness funds can also be spent for restoration of infrastructure, although the amount of funds in many cases may be insufficient to cover the full costs of infrastructure recovery. Infrastructure restoration, which could be a long process, has thus been mainly financed by the central government.

50 Decision No 01/2016/QĐ-TTg by Viet Nam Prime Minister issued on Jan 19, 2016 on procedure of supporting finance for provinces for NDR.
51 Decision No 36/2015/QĐ-UBND by HCM city's PC dated on July 24, 2015 on management, collection, use and liquidation of the city's Disaster Prevention Fund, Viet Nam
52 Multi-purpose houses built in flood resistant area, which could accommodate community residents in case of severe storms.

The contribution rates regulated by Ho Chi Minh City's People's Committee, including the annual contribution rate for independent-accounting economic organizations and citizens in the city, are stipulated as follows:

1. Private Enterprises:
   The compulsory contributions for one year are two tens of thousandths (2/10,000 = 0.02%) of the total value of assets currently available in Viet Nam according to the annual financial report or the total production and business capital of the enterprise. VND 500,000, up to VND 100,000,000 shall be accounted into the production and business expenses.
2. Citizens: From 18 years old to 60 years old and from 18 years old to 55 years old, the contribution rate is once per year as follows:
   a) Cadres, civil servants and officials in the agencies, organizations and armed forces who are paid wages, as well as managerial officials in state enterprises, shall pay one day of salary per person per year at the basic salary level after taxes and insurance payable;
   b) Laborers in enterprises shall pay one day of salary per person per year based on the regional minimum wage;
   c) Other laborers, except for subjects defined at points (a) and (b) of this clause, pay VND 15,000 per person per year.
3. Others: Provincial governments encourage organizations and individuals to voluntarily contribute to the Fund.

Infrastructure BBB and funding
Availability of funding is the key for infrastructure BBB. In Australia, in order to facilitate immediate reconstruction, a certain amount of funding is annually reserved without designating specific purposes, which can be allocated without complicated approval procedures once a disaster happens. The "Build Back Better" principle, as already applied in recovery funding in Mexico through FONDEN and in Peru through FONDES, is applicable also to pre-disaster prevention work. In Japan a fund facilitating inter-ministerial collaboration is reserved in addition to ordinary budgets for infrastructure restoration sector by sector. Institutionalizing collaboration with development authorities as well as financial authorities is a precondition for BBB of infrastructure, as suggested by the Philippines' experiences.

5.2 Infrastructure BBB and collaboration with the private sector

APEC's DRR framework recognizes the essential role of the private sector, stressing that sustainable development highly encourages collaboration between the public and the private sector in recognition of their shared responsibility towards disaster resiliency. Many efforts have been made APEC-wide to promote the continuity of businesses and MSMEs and to increase supply chain resiliency together with private sector partners.

In addition to non-structural DRR efforts such as promoting business continuity plans, it will be worth exploring the possibilities of effective collaboration with the private sector toward structural measures such as critical infrastructure investment, both for users of infrastructure and for provide/operator providing relevant services
At the phase of post-disaster infrastructure BBB, closer collaboration with the private sector is highly expected by member economies, as discussed at the workshop and as raised in the cases and in diverse contexts:

- Private sector as main provider/operator of infrastructure and relevant services
- Private sector participation in infrastructure development and management for business
- Private sector participation in infrastructure BBB construction work
- Corporate social responsibility and non-profit activities for supporting affected areas
- Participation in the process of planning recovery as infrastructure users & stakeholders

Private sector provision of infrastructure and relevant services
The private sector provides infrastructure and lifeline services in many APEC economies, including power generation, gas services, telecommunications and so on, although such cases are not studied here. Natural disasters could provide opportunities for private sector companies to start infrastructure-related services. In Japan, for example, the electricity wholesale supply business that had been reserved only to a few companies was opened up in 1995, allowing many private companies to start power generation businesses. After the Great East Japan Earthquake triggered the disaster of the Fukushima Nuclear Power Station, all nuclear power plants in Japan stopped operating, as a safety measure, resulting in power shortages. Private companies in heavy industries provided gas turbine-generated electricity to power supply utilities. In Tohoku after the Great East Japan Earthquake, a steel industry company initiated power generation projects based on renewable energy, facilitating recovery of the affected region's economy. The Great Hanshin-Awaji Earthquake hit areas where heavy industries and steel industries were located, which then achieved a miraculously quick recovery. In the process of restructuring over the last few decades, some areas where ironworks were located have been converted to power generation plants that could provide electricity for the surrounding areas in case of disasters, a kind of BBB by learning from experience. Disaster has provided momentum for changes in their business while contributing to resiliency of energy provision in the area.

Private sector participation in infrastructure recovery and business development
In Viet Nam, the Goverment often calls for and encourages private participation in infrastructure investment. In general, the Law on Natural Disaster Risk Prevention and Reduction (2013) encourages organizations, households and individuals to invest in DRR work, and encourage enterprises to buy business insurance for natural disaster risk. The law supports enterprises engaged in investment and production in natural disasters-impacted areas. It also adopts policies on exemption and reduction of enterprise income tax on contributions to natural disaster prevention and response. In addition, as raised in the previous sub-chapter (see 5.1.5), in 2008, the Central Disaster Preparedness Fund was founded in the central area of Viet Nam, which mobilized substantial monies from the private sector.

As the cases of collaboration after disaster show, the private sector invested in the project expanding Le Trong Tan, Cam Le district, Da Nang city. A private company, Danang Central Investment Jsc., joined the project under the Built-Transfer contract with the Department of Transportation, Danang. The project aimed at increasing connectivity among residential areas, mining industrial zones, universities (e.g., Duy Tan University, and the University of Sports and Physical Education), and military zones (for the Air Defense Force), by upgrading unpaved roads to asphalt, ensuring the safety of transportation and preventing the formation of mud and buffalo–shaped holes due to flash floods.

In the case of Ca Mau province (Case 2.1), recently affected by landslides, local authorities along 16 km of coastline applied low-cost technologies to sea dike enforcement by working with private partners to develop tourism projects, which also protect mangrove forests. Despite some good practices, in Viet Nam, private sector participation in DRR-related projects for profit is limited due to low levels of expected gain and insufficient incentive mechanisms. Local governments remain unable to address infrastructure backlogs and are confronted with growing public debt. More incentive mechanisms enabling wider participation by the private sector are necessary.

In Japan, the Great East Japan Earthquake in March 2011 accelerated privatisation of the affected Sendai Airport. The international gateway of the Tohoku region, Sendai Airport is located 1.2 km from the coastline. Its passenger terminal building was totally inundated by the tsunami. In December, Miyagi prefecture proposed a plan to privatize the airport in order to restore the facilities and improve its business performance. After discussions involving both public and private sectors, in 2013 the government published the basic scheme for privatization, followed by Airport Operation Guidelines in June 2014. The philosophy behind this idea is to facilitate revitalization of the surrounding areas affected by the earthquake with the capital and management skills of the private sector, for more effective operations of the runways and terminal buildings. The Sendai International Airport Co., Ltd has thus been established under the concession system. It is the first privatized company among local airports in Japan. The new company manages and operates the terminal building, freight terminal building, railway, runway and apron that had been separately operated by a semi-public corporation and the government. The number of passengers at Sendai Airport was 3.1 million in 2015 before privatization, while in 2016 this number increased to 3.16 million.

Sharing expertise by participating in infrastructure BBB reconstruction

Collaboration with private sector expertise is important, as discussed at the workshop, in order to apply technologies necessary for recovery construction work. Private companies play an important role in developing and applying high technologies and in training human resources for these purposes. For example, unmanned construction technologies (Case 5.3), used in areas affected by volcano eruptions or in the earthquake affected areas with risks of landslides, have been developed and maintained by the private sector so that they could be employed when necessary.

Non-profit activities by the private sector in the process of infrastructure BBB

In Viet Nam, the private sector has contributed to recovery of infrastructure through non-profit activities, as reported in the case of the post-disaster rural road improvement project at Ban Sen – Tan Lap commune, Van Don District, Quang Ninh province (Case 1.2.4). Local roads were severely damaged in the flood affecting Tan Lap Commune in 2015. The local stakeholders who participated in the subsequent road improvement included the district authority, the youth union, individuals and private companies. The private companies provided monies for the repair work in addition to the state budget as the main source of funding. In the case of flood-resilient housing in the central regions (Case 4.2) the funds were raised also from the private sector.

Local industries as users of infrastructure

Private companies in affected areas have been involved in infrastructure recovery and BBB processes as important users of the target infrastructure. In Indonesia, after the Mentawai Archipelago earthquake in 2010, a Trans-Mentawai road network was planned. The project required the commitment of stakeholders for several years. The smooth implementation of the construction work depended on smooth acquisition of land owned by plantation companies, for example. Authorities worked to find win-win solutions for the relevant parties and successfully built better distribution chains so as to facilitate development of the rural economy in the area along the road. Close collaboration with the local private sector from the early stage was one of the key elements of this success. In Chinese Taipei, when major natural disasters occurred, the government integrated resources and suggestions from diverse stakeholders, including industry, academia, and local governments, to facilitate the reconstruction work. As studied in the cases described in this report, the government could encourage the private sector to participate in the reconstruction plan, to promote private participation in public construction projects. In the case of Laiyi township, affected by the Typhoon Morakot disaster in 2009, a relocation project was supported by the government agencies, the Red Cross of the Society of the Republic of China, and Tzechi foundation. The plan integrated opinions from the local businesses. The reconstruction council prioritized villagers' demands for local industry and job opportunities, implementing projects to promote agricultural development and the tourism industry as well as local indigenous society. Infrastructure recovery projects should be planned by reflecting on the needs of local industries as users of the target infrastructure. Private sector and non-governmental organizations will help identify the needs of people who might otherwise be neglected by government.

For further collaboration toward infrastructure BBB

Private sector investment in infrastructure BBB, in particular, will remain a key concern. Cases in the previous chapters demonstrate that governmental sectors in many of the economies face challenges with insufficient funding for infrastructure BBB, which may require co-funding with diverse sources of support, including participation by the private sector. In addition to funding, the private sector could provide expertise and human resource networks necessary for effective infrastructure development and management.

In order to provide incentives for the private sector, firstly, it is necessary to demonstrate advantages of the investment, in particular the business benefit for the companies involved, including those throughout the supply chains. It is also necessary to demonstrate middle and long-term socio-economic benefits for the affected region and economy, although this may be a challenge in many cases. For the questionnaire survey targeting APEC economies asking "How could we collaborate more closely for 'BBB of infrastructure' with the private sector including SMEs, local industries that use infrastructure for their business, and those providing infrastructure and relevant services?" Four economies said that private sector inclusion in consultation meetings for related policy making is important,[53] and two economies answered that incentive measures such as tax exemption or low interest loans could be useful.[54]

In Australia, the federal government works closely with the Australian Business Roundtable for Disaster Resilience and Safer Communities (ABR)[55]. The ABR seeks to promote a greater emphasis on mitigation, improved decision-making, and greater awareness and education about the costs, impacts and risks of natural disasters and extreme weather events.

In a questionnaire survey undertaken by the Tokyo Chamber of Commerce and Industry asking important DRR measures. Improving earthquake resistance of infrastructure was the measure that topped the results, with two thirds of the responding SMEs (Figure 5-1). In another question asking about the important role of DRR infrastructure (Figure 5-2), however, the number of respondents answering that they well understood the role of infrastructure remained limited (22.8%). These questions relate only to infrastructure directly targeting DRR. Other infrastructure supporting supply chains and economic activities, as studied in this casebook, should also be more resilient.

53 Australia, Chile, CT, Indonesia, Philippines

54 Philippines, Peru

55 Six organisations with an interest in disaster resilience comprise the ABR: the Australian Red Cross; Insurance Australia Group (IAG); Investa Property Group; Munich Re; Optus; and Westpac Group.

Figures. Questionnaire survey on DRR for SME by Tokyo Chamber of Commerce and Industry

Figure 5-1. DRM measures to be intensified

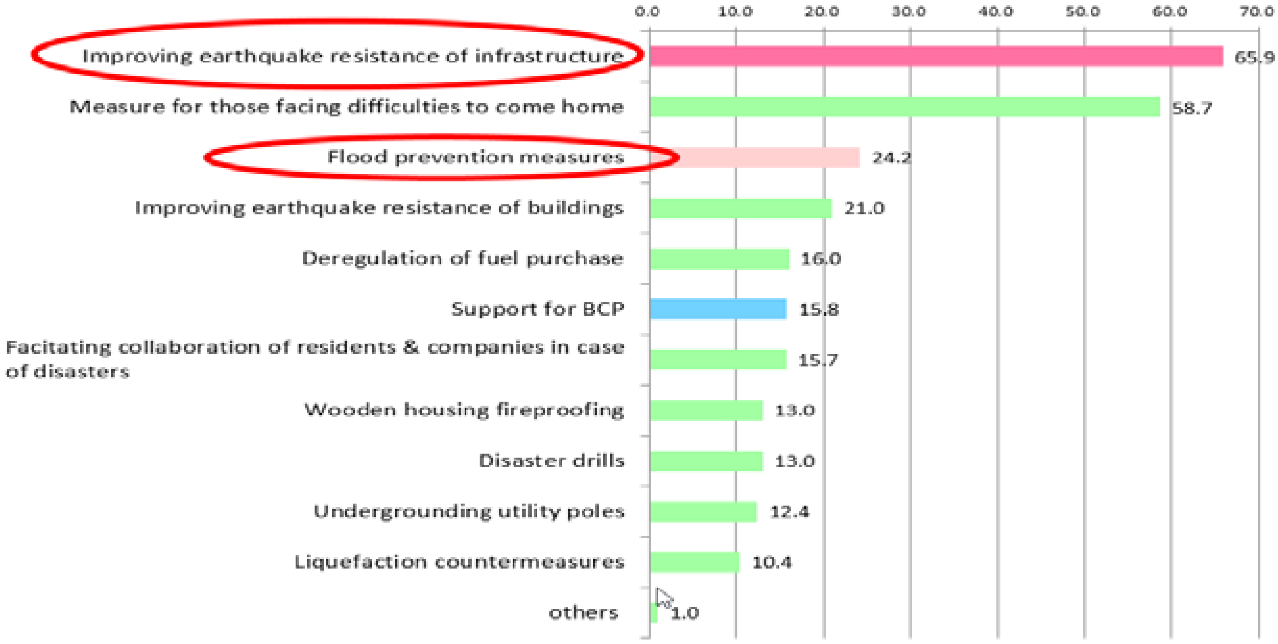
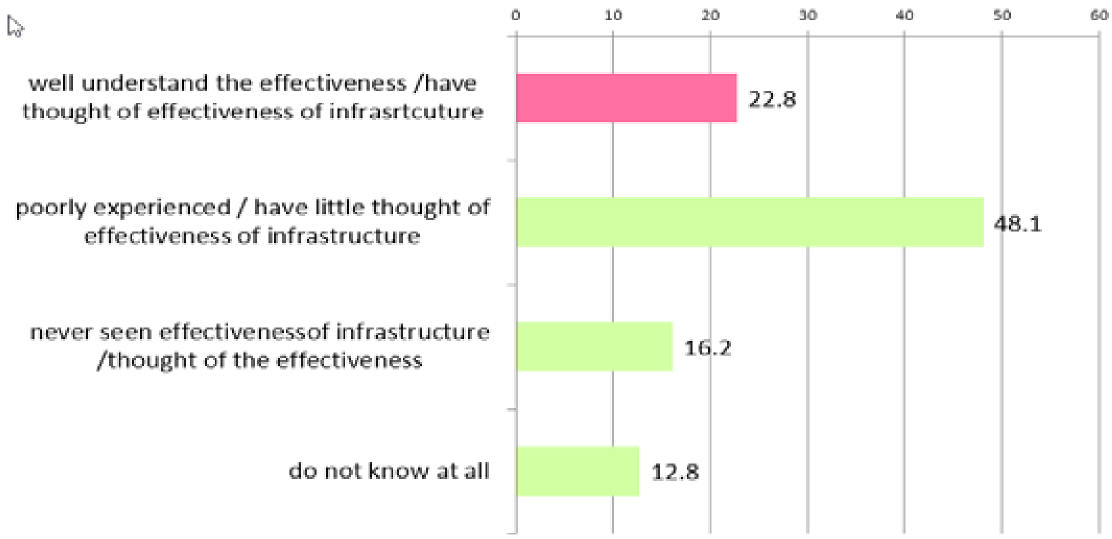


Figure 5-2. Importance of infrastructure is not sufficiently understood

Q: Have you ever thought that installed infrastructure including dams, barriers, dikes, levees, flood gates, drainage pumps, or upgrading of earthquake resistance are effective to reduce risks?



Source: Tokyo Chamber of Commerce and Industry, "Questionnaire survey on DRR", June 2017[56]

The private sector is one of the important users of infrastructure. Closer collaboration with the private sector in infrastructure investment policy-making is essential, and incentive measures for wider participation need to be further explored. The phase of recovery from natural disaster should be an opportunity to bring the public and private sectors together in common cause.

56 Questionnaire survey annually conducted by the Tokyo Chamber of Commerce and Industry since 2014, targeting 10,000 companies located in Tokyo, of which 1,539 answered the 2017 survey. Two thirds of the responding companies are SMEs with less than 99 employees. http://www.tokyo-cci.or.jp/page.jsp?id=102640

5.3 Technologies facilitating infrastructure recovery work

Smooth restoration and BBB of infrastructure depends on technologies supporting recovery work as well as fiscal resources, collaboration with stakeholders, and many other factors. In APEC economies, it may be difficult to continue reconstruction during the typhoon, monsoon and flood seasons, as reported in the case of the No. 20 provincial road in Chinese Taipei (Case 1.1.1). Maintaining safety in recovery operations in the affected areas is also indispensable. It is worth sharing the cases of infrastructure recovery in which technologies were applied for policymakers' post-disaster recovery planning processes.

5.3.1 Japan: Unmanned construction technologies accelerating reconstruction of the Aso Bridge damaged by the Kumamoto Earthquake[57] and Landslides in 2016[58]

On 14 and 16 April 2016, earthquakes struck the middle of Kyushu Island, in southwestern Japan, measuring a 7 (the highest level) on the seismic intensity scale of the Japan Meteorological Agency (JMA). The quakes caused 137 deaths in Kumamoto prefecture, including those who passed due to injury or stress after the disaster, and 8,329 houses were totally destroyed in Kumamoto and Oita Prefectures.

Damages on infrastructure
The Kumamoto earthquakes severely affected roads and bridges, including "National Route No. 325" and the Aso Bridge (Minami-Aso Village, Aso County, Kumamoto Prefecture).

In the Aso Ohashi district, due to the main shock, a large section of hillside collapsed, 700m long and 200m wide. The area below was devastated, including "National Route No. 57", the JR Houhi Main Line, and the Aso Bridge over the Kurokawa river ("National Route 325"). The Aso Bridge had been constructed in 1970 as part of "the National Route No. 325" bypass, branching from "National Route No. 57" to Nango Valley (Minami-Aso Village, Takamori Town). The bridge was 205.96m long, 8m wide, and rose 76m above the Kurokawa valley bottom. At the lower part of the collapsed slope, the JR Houhi Line had been running parallel to Route 57. The collapse is located between Tateno and Akamizu stations, and the span of track between Higo Otsu and Aso stations remains disconnected so far.

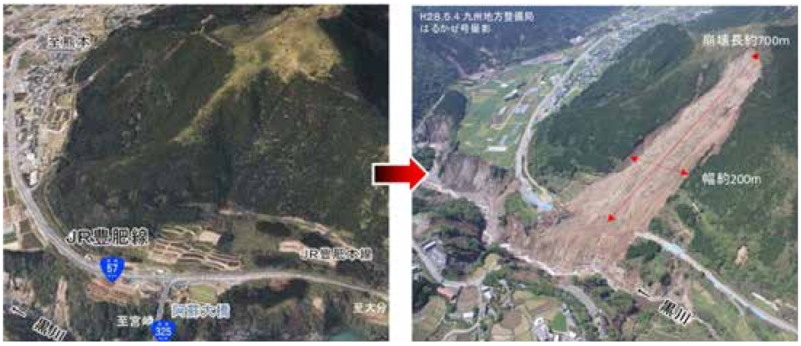


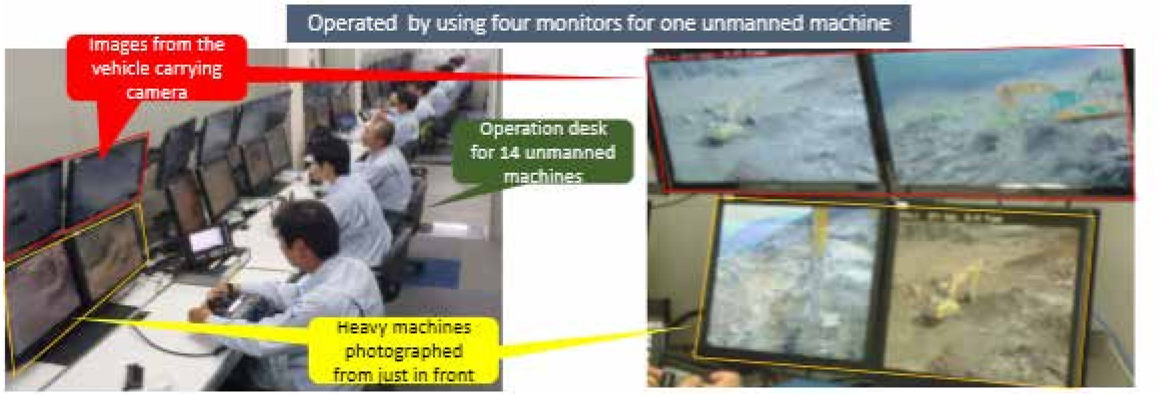
Photo. The situation before (left) and after (right) the earthquake
Source: Kyushu Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Application of unmanned machine
Since Aso Bridge directly supports people's daily lives and is widely used by tourists, its immediate recovery was imperative. Landslides occur in this area, and the unstable earth and sand remain dangerous since a heavy rainfall could trigger or accelerate further collapse. In order to avoid a secondary disaster from the slopes, and to accelerate reconstruction, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) directly conducted the recovery work by applying unmanned methods to remove the loose sand left on the slopes.

57 GLIDE number EQ-2016-000033-JPN
58 Cabinet Office of Japan, "Report on the 1990-1995 eruption of the Mount Unzen" (2007, Japanese)

- Speed of construction: For quick restoration of the transport infrastructure, it was necessary to accelerate preparing the construction environment for manned recovery work.
- Safety during construction: Due to many cracks remaining on the slope around the collapsed area, and risks of further collapse triggered by aftershocks, unmanned operation by remote control was imperative.
- Nature of the affected site: At the site of the Aso Bridge, volcanic ash-like viscous soil was abundant. Such soil can easily become liquefied into mud similar to a lahar. Moreover, debris sediment remained scattered on the long and steep slopes of the hillside. It was thus necessary to continue monitoring changes in the slope situation, where gullies could develop inside the collapsed area, leading to further collapse of the surrounding area.

Photo: Operation of the unmanned machine for construction works



Source: Kyushu Regional Development Bureau, MLIT, Presentation material for the ADRC Study Visit to the affected areas by Kumamoto Earthquakes , December, 2016

Outline of Measures

The slope disaster prevention measures of the Aso Bridge district can be roughly divided into three types: earth retaining embankments, earth removal work (rounding construction) and monitoring and measurement.

The earth retaining embankment and the removal of earth from the head of the landslide were both achieved through unmanned (remotely operated) construction techniques. Earth retaining embankment is a temporary structure for securing the safety of the restoration work such as protecting traffic infrastructure etc. The falling rock from the upper part of the slope is captured at the lower part. The installation position was checked from images taken by an unmanned aerial vehicle (UAV). The same technique was used to monitor the local conditions such as the angle of the collapsed slope and the accumulation of the collapsed earth, and so on, keeping in mind the limits of construction by the unmanned machine. In addition, based on the results of a falling rock simulation, the embankment was constructed in two rows with a height of 3m in the upper row and a height of 5m in the lower row. As a result of this arrangement, the embankment became a structure capable of roughly capturing the unstable earth and sand remaining on the slope. Furthermore, by securing the minimum width (5 m) in the unmanned construction, it was possible to utilize the top end width as a construction access road, which was necessary for future construction and maintenance.

The wireless remote operation of bulldozers, caisson drilling machines and backhoes had been tried experimentally since the 1960s, and the first unmanned operation had been implemented after the volcanic eruption of the Mount Unzen in 1990. In order to accelerate recovery work and debris flow countermeasures in the danger zone where streams of heated rocks and volcanic ash could arrive within several minutes, the former Ministry of Construction started exploring unmanned operation of the machines. In 1993, the ministry invited technological proposals from private companies, implemented tests in 1994, and implemented six technologies at affected areas in 1998. The test revealed that unmanned operation could be implemented effectively but it took one week for the operators to become accustomed to the work. This technology was applied to other areas that saw volcano eruptions, including Mount Usu in 2000 and Miyake island in 2002. With these experiences, it was then coupled with intelligent construction (i-Construction) methods, development by unmanned survey using GPS, and other innovative techniques.

5.3.2 Japan: The Great East Japan Earthquake and installation of conveyer

Rikuzen-takata city in Iwate Prefecture was severely affected by the Great East Japan Earthquake in 2011. Two housing area development projects are underway, one by relocating affected residents to a hilly area, and another by elevating the base level of low altitude areas for a new residential area so as to reduce the risks of tsunami.

In total, approximately 7.8 million cubic meters of earth and sand are required for these projects. In order to shorten the period necessary to implement them, a huge conveyer machine, 2,970m long, was installed, which could transport 5,500 tons of dirt per hour. The conveyer transported 20,000m3 of earth and sand per day to develop the new residential areas, and the project is scheduled to be completed approximately six years earlier than expected.

As seen in Chapter 2.1, immediate recovery is as important for BBB as safety and quality. Diverse and innovative methods of construction that can accelerate work while maintaining safety and quality need to be explored and shared.

Towards the future: Infrastructure supporting information and communication technologies (ICTs)

In this casebook, cases of diverse transport infrastructure, river and water management infrastructure, and so on, have been studied, while many other types of infrastructure remain to be covered, including those for power generation, gas and water supply, sewerage, and communication, which are indispensable for emergency operation. Communication satellites, which may sometimes be neglected as a type of infrastructure, support emergency operations. Data centers have been developed by learning from the experiences of natural disaster.

Column: Communication satellites as ICT infrastructure supporting BBB

After Typhoon Haiyan struck the Philippines in 2013, wireless technologies were the only communications options left for the relevant authorities. Images from earth observation satellites have been widely used for DRR purposes. After the Great East Japan Earthquake in 2011, a communication satellite supported emergency communication in the affected areas.

The Japan Aerospace Exploration Agency (JAXA) has established a broadband communications environment using the Wideband INternetworking engineering test and Demonstration Satellite (WINDS) "KIZUNA" to facilitate disaster measures targeting the areas affected by the Great East Japan Earthquake. With this support, high definition teleconference systems, Internet protocol telephones, radio LANs (local area networks), and other means were made available to share and disseminate disaster information. With this experience, JAXA has concluded agreements on disaster prevention using communication satellites with multiple disaster prevention agencies and local governments.

The KIZUNA Wideband Internetworking engineering test and Demonstration Satellite (WINDS) was jointly developed by JAXA and "the National Institute of Information and Communications Technology (NICT)" and launched on February 23, 2008. It is designed to support the development, testing and demonstration of new technologies, thereby contributing to the formation of an advanced information-and-communications-network society without gaps in data availability through operation in conjunction with ground-based infrastructure. KIZUNA follows an orbit above the equator at 143 degrees east longitude, and is equipped with multi-beam antennas featuring fixed multi-spot beams covering Japan and Southeast Asia and an active phased array antenna (APAA) that covers a wide area with its scanning beams. Its switching equipment enables signal switching on board the satellite itself.

Photo: Internetworking Satellite "KIZUNA" (WINDS)

Source: Japan Aerospace Exploration Agency http://www.jaxa.jp/projects/sat/winds/index_j.html

The Great East Japan Earthquake and damages to ICT infrastructure

In Japan, most local governments depend on fixed telephone lines and mobile communications provided by major telecommunication companies building public networks and others. The Great East Japan Earthquake and the tsunami that struck the northeast part of Japan resulted in the collapse, submersion and loss of equipment in structures that were supposed to be used as base stations and relay stations. The disaster also caused disruption of underground cables and pipelines, collapse of utility poles, and damage of overhead cables, leading to significant damages to communication networks. Also, due to the prolonged disruption of the commercial power supply, many services stopped after storage batteries became depleted. Fixed communication networks including NTT East, KDDI, and Softbank Telecom were also damaged and disrupted.

Communication satellites as an ICT infrastructure for DRR

JAXA offered communication lines to the disaster-struck areas in Iwate Prefecture by using KIZUNA. A portable VSAT (very small aperture terminal) unit installed at the Iwate Prefecture Disaster Countermeasures Office (part of the Iwate Governor's Office) was connected by KIZUNA with portable USAT and VSAT units installed at the local disaster countermeasures offices in the cities of Kamaishi and Ofunato. Additionally, the High Data Rate VSAT (HDR VSAT) at the Tsukuba Space Center was designed to connect with public Internet networks, and connections were established from these support bases. In addition to the portable VSAT/USAT test stations, the support bases were also equipped with an all-in-one unit of disaster-related equipment and supplies, such as peripheral communication equipment (including an L3 switch and a TCP accelerator, housed in a general-purpose rack), a videoconference system, and equipment for connecting wireless LAN access points.

Videoconferencing equipment installed at the support bases was used for information sharing by disaster countermeasures offices. At the Prefecture Disaster Countermeasures Office, a variety of officials and staff engaged in support activities, including prefectural government employees as well as staff dispatched from other prefectural governments and government ministries and agencies (e.g., the Cabinet Office, the MLIT, the Ministry of Health, Labor and Welfare, the Ministry of Internal Affairs and Communications, the Fire and Disaster Management Agency, and the Japan Self-Defense Forces (JSDF)). Accordingly, daily liaison meetings were held at the Prefecture Disaster Countermeasures Office, to share information on urgent needs of disaster victims, status of search operations, and to solve problems toward immediate recovery. Local disaster countermeasures offices and the Prefecture Disaster Countermeasures Office were connected by a videoconferencing system via KIZUNA so that local office representatives could participate in

the liaison meetings held by the prefectural government from their offices. In this way, the videoconferencing system supported real-time information sharing with the prefectural government and other governmental bodies.
Internet services: Wireless LAN access points were set up at support bases to connect to public Internet lines by linking to HDR-VSAT installed in Tsukuba, using KIZUNA. At the Prefecture Disaster Countermeasures Office in Morioka City, a wireless LAN access point was set up in the room next to the disaster countermeasures office (where the videoconferencing system was installed). Pre- and post-earthquake images from the Daichi satellite (PALSAR and AVNIR), showing coastal areas, were downloaded at high speed from the Daichi Bousai WEB via KIZUNA for use in planning debris removal work and to help visualize the status of removal progress. At the local disaster countermeasures offices in Kamaishi and Ofunato, a wireless LAN access point and three Internet-enabled laptops were installed in the entrance lobby, which was open to the public. These units were used by disaster victims and individuals dispatched to coastal areas by various organizations.

Lessons learnt:

The video conference system critically contributed to communication for emergency rescue and recovery work. The advantages include high-quality voice and image clarity compared with web conference systems previously used by the Iwate Prefectural Government, and the capacity for real-time transmission of videos captured from helicopters above coastal areas, and other resources. Internet services were used from March 20 to April 24, by 538 people. On average, 18.6 people per day used the services in Kamaishi, and 43.1 in Ofunato. The laptop usage rates at the support bases exceeded 50 percent almost all day long, indicating high demand for Internet services.

Column: Tokai heavy rain in 2000 and data centers, a 21st century infrastructure

On 11-12 September, 2000, Nagoya City, Japan, together with its surrounding areas, was affected by a severe rainfall due to warm and humid air associated with Typhoon No. 14. The rain amounted to 567 mm, equalling one third of average annual precipitation in a period of approximately 24 hours, which caused 10 deaths and 115 injuries in four prefectures, including Shizuoka, Gifu, Aichi and Mie. The severe rain impacted highly urbanized areas and a broad range of urban infrastructure including roads and subways.

In this disaster, many computers used in both the public and the private sectors were submerged, resulting in significant replacement costs and the loss of important data. Due to learning lessons from this experience, data centers were subsequently built in areas located far from city centers for regular backup and disaster recovery services.

Photo. Inundated Nishi-Biwajima Town

Source: Chubu Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism

http://www.cbr.mlit.go.jp/shonai/tokai_gou_15yrs/photo_gallery/index.html

Today, hyper-scale data centers are widely located throughout APEC economies, supporting computer systems and associated devices including backup power supplies, which might be assumed to be a kind of urban infrastructure. In Japan, due to the experience of the Tokai heavy rainfall, both public and private sectors have started to use data centers placed mainly outside of city centers, making them a new kind of infrastructure for the 21st century.

III Challenges and ways forward

1 Infrastructure BBB: Lessons learnt

Infrastructure recovery and BBB varies depending on infrastructure types, disaster types or economies and other conditions. In this APEC project, almost 30 cases have been provided from APEC economies, including those which participated in the APEC workshop. (See "Table: Infrastructure BBB cases in APEC economies studied in this casebook" at the end of this chapter.)Many important lessons could be drawn from the studied cases, which are widely applicable and worth sharing among all member economies.

Immediate recovery as a starting point for BBB
Immediate recovery of key infrastructure is a precondition for the whole recovery process, especially that of roads used for rescue operations, as demonstrated by cases from Chinese Taipei, Japan, USA, and Viet Nam. Shihwei Bridge, an important road destroyed by the 921 Earthquake that struck Chinese Taipei in 1999 (Case 1.1.2), was successfully restored in eight months through close collaboration with contractors who applied cutting-edge construction technologies. Due to the Typhoon Morakot in 2009 that affected wide areas of southern Chinese Taipei, bridges of the No. 20 provincial road collapsed (Case 1.1.1). Quick decision-making by the government to devote significant resources into the road and bridges' restoration facilitated a smooth recovery and also redevelopment of local tourism industries. In Japan, the immediate clearing and securing of the trunk road-networks in the heavily affected areas, begun on the very day after the Great East Japan Earthquake, greatly contributed to accelerate rescue operation and the overall recovery process (Case 1.1.4). In the USA, the initiative of the State of Vermont enabled the immediate recovery of highways in three months due to the Hurricane Irene in 2011, by considering the effect on the local economy (Case 1.1.3). In Viet Nam, the sea dike in Thua Thien Hue Province, which served also as a local road, had been affected by erosion but was immediately recovered through broad stakeholder participation as well as the strong initiative of authorities (Case 2.3). In the Philippines, Tubigon Port, affected by the 7.2 Earthquake, 2013 (Case 1.3.2), was restored and port services restarted in just 504 calendar days.

These cases demonstrate that quick recovery was supported by the close communication among the relevant authorities, enabling urgent decision-making and consensus-building among relevant authorities and communities, immediate allocation of funding, and application of the appropriate technologies to accelerate recovery work. (See also 5.3 "Technologies facilitating infrastructure recovery work", and Case 1.3.5).

Recovery from disasters as an opportunity to plan transport network upgrades
Post-disaster recovery sometimes accelerates infrastructure development aimed at regional economic development, as presented in the case of road improvement and alternative highways construction in the Philippines (Case 1.2.1), and the case of the Trans-Mentawai road networks in Indonesia (Case 1.2.2). In the Philippines, the Mt. Pinatubo eruption brought about a widespread destruction of the major roads and bridges (Case 1.2.1); the authorities were thus forced to design new, alternative roads and bridges more resistant to lahars, which ensured the accessibility of rural provinces. The existence of redundant routes ensures that rural areas will not be isolated, even during future disasters. As suggested in the case of Trans-Mentawai, Indonesia, master plans are important for effective recovery and BBB of infrastructure. Recovery projects need to be integrated into the development master plan, as reconstruction will take years. A master plan can

be used as a tool for facilitating coordination among relevant stakeholders. In Japan, the immediate road networks clearance operation after the Great East Japan Earthquake (Case 1.1.4) has reminded authorities of the importance of alternative roads, for the concept of redundancy, and the idea of doubling road networks was clearly defined in the "National Spatial Strategy", revised in 2015, stressing the importance of dual road networks for upgrading spatial resilience. Other regions have then integrated similar ideas of doubling road networks in individual regional development plans.

Infrastructure BBB contributing to development of local economy

In APEC economies, post-disaster infrastructure recovery has been planned by aiming not just at recovery of infrastructure but also BBB of the local economy. The Trans-Mentawai road networks development project, planned and implemented after the Mentawai Archipelago Earthquake in 2010, Indonesia (Case 1.2.2), has successfully connected rural areas, including four major islands, by improving road networks which support the local economy. Before the disaster, the absence of inter-district land transportation in the Mentawai area had slowed the region's economic growth due to limited mobility. The Trans-Mentawai highway was thus planned to connect the areas to the potential markets for their agricultural products, which encouraged the rural inhabitants to build houses and farms near the roadsides. The road recovery construction work directly benefited the affected areas by creating temporary job opportunities, which accelerated recovery. The authorities effectively collaborated with private companies which provided land alongside existing roads for the improved road by the Trans-Mentawai development, leading to a win-win solution: the local private sector has benefited from the upgraded accessibility. And the recovery of the Port of Gulfport, Mississippi, which had been devastated by Hurricane Katrina (Case 1.3.3), was also promoted as an essential part of the economic recovery of the region.

Planning stage by stage recovery as a realistic solution

As restoration and BBB of large infrastructure could be a costly process lasting a decade or even longer, immediate reopening was imperative to jumpstart the process. Planning a stage by stage recovery could be a realistic alternative to satisfy various needs sometimes contradicting each other, as shown in the case of Super Typhoon Haiyan/Yolanda and the Tacloban Airport, Philippines (Case1.3.6). After the typhoon, in order to facilitate delivery of relief supplies at the first stage, authorities gave priority to resume airport operation, and then a new airport was designed and built with better design and facilities more resilient to natural disasters, for the future. Also, in the case of Alternative Highways Construction after the eruption of Mt. Pinatubo, Philippines (Case 1.2.1), at the initial stage re-connecting the isolated areas was an immediate response, while the long-term plan of creating new roads was attempted as a BBB strategy. And in the case of the Nias Islands, Indonesia (Case 1.3.1), temporary wharves were constructed while construction of the new port was planned at the same time.

Community-based infrastructure BBB

Infrastructure BBB can be achieved not just by applying cutting edge and huge scale infrastructure. Infrastructure tailored for the local reality and economy could benefit by involving the local community in maintaining and improving the infrastructure in their daily life, which will ensure its safe and sustainable management. Many cases are reported from Viet Nam by using low-cost and environmentally friendly technologies well-adapted to the affected rural areas. In the case of Ca Mau province, recently affected by landslides damaging the long coastal lines (Case 2.1), local authorities applied low-cost technologies, including a "soft" embankment of rocks and concrete, to reduce the impacts of sea waves and protect mangroves. The use of such technologies contributed to reduce the construction cost. For the case of Thanh Mai stream embankment (Case 2.2), low cost biological technology was applied. In Indonesia, a small-scale infrastructure, as reported in the case of smoldering peat fires and canal blocking in Meranti (Case1.2.3), has been successfully undertaken through community involvement. A community-based infrastructure management model could provide sustainable solutions for regional development and BBB if sufficient opportunities and alternatives are made available for local authorities to choose the best solutions adapted to local reality. In the case of Viet Nam and the Philippines, training for maintaining infrastructure is already integrated in the recovery projects. Finally, the case of the slit dams in Ormoc city, constructed after Typhoon Uring (Case 2.7), shows that community cooperation can maximize the benefits of infrastructure investment.

Cultural aspects and diversification of the role of infrastructure

In the process of recovery, cultural aspects can be integrated as an important value-added component of infrastructure BBB. The Dabang elementary school building complex, damaged by Typhoon Morakot in Chinese Taipei (Case 4.1), was reconstructed by integrating indigenous culture with modern building design as a symbol of the local industry and culture, which has ultimately contributed to preserving traditional culture and local identity. In the case of the 1982 Nagasaki Flood in Japan (Case 2.4), the prefectural government successfully achieved the twin goals of cultural heritage preservation and safety from flooding by coordinating the solution with citizens and relevant parties. And in the case of the reconstruction of Kobe City from the Great Hanshin-Awaji Earthquake, industrial areas were partially converted to a culture-and-arts zone by constructing museums and other facilities which can be seen as a kind of BBB by changing and diversifying the nature of the area.

Inter-governmental/ministerial collaboration

Infrastructure recovery and BBB process is supported by close inter-governmental and inter-ministerial collaboration, as demonstrated in the case of Hurricane Irene and federal highway infrastructure in the State of Vermont, USA (Case 1.1.3). Efficient inter-governmental communication enhanced a BBB recovery process. Intensifying the DRR-development nexus will become increasingly important for the purpose of effective investment in critical infrastructure BBB. At the same time, effective collaboration with the private sector, highly expected by member economies, also needs to be explored (Chapter 5.2).

APEC-wide knowledge-sharing towards infrastructure BBB

As suggested in the case of the 921 Earthquake and the Shihwei Bridge in Chinese Taipei (Case 1.1.2), recovery work should consider safety and disaster resistance by applying appropriate technologies adapted to individual cases under diverse constraints such as the duration of the work, cost, and so on. Collaboration with the private sector is important for the purpose of sharing knowledge and expertise for planning recovery processes, and for sharing technologies that enable immediate and smooth recovery (Case 1.3.5, from Japan). Unmanned construction technologies used in the areas with risks of landslides, have been maintained and developed by the private sector so that the technologies could be used when it becomes necessary. The private sector takes an important role in applying high technologies and human resources training and development for this purpose. Guidelines are useful to enhance and facilitate infrastructure BBB, as suggested by the Philippines. That economy's Department of the Interior and Local Government (DILG), for example, published a handbook for designing and building safer public infrastructure[53], which demonstrates new approaches in building more resilient structures to protect communities against the adverse effects of extreme weather disturbances. APEC-wide information-sharing regarding good practices of infrastructure BBB will be useful to facilitate critical infrastructure investment in the process of recovery and reconstruction.

53 The technical handbook, "Designing Resilient Structures: Mainstreaming Disaster Risk Reduction and Climate Change Adaptation."

2 Challenges of infrastructure BBB

BBB has been largely well understood among DRR organizations; however, achieving infrastructure BBB requires overcoming many challenges, including administrative, organizational, financial, and technical challenges.

Need for immediate recovery vs. BBB

Immediate recovery is important for the affected and local economy, especially infrastructure supporting basic lifeline services; however, it takes time to plan and coordinate recovery and BBB, as this involves consensus-building among stakeholders as well as securing and obtaining resources. BBB will require good planning from longer perspectives and wider scope views, which takes time. Long-term recovery without proper planning is not likely to achieve BBB smoothly, but in the short term, authorities cannot leave affected populations in an uncertain and unsafe situation for too long. Prioritizing and phasing the recovery process must be further explored.

Time constraints and timing

For recovery planning, timing is extremely important. Authorities are expected to set up priorities for recovery of infrastructure that can support residents' livelihoods in a timely manner. In the case of rebuilding a market in Indonesia, local merchants had already moved to another market to support their livelihood. Coordination with diverse stakeholders in planning infrastructure can be time-consuming. When local stakeholders are not sufficiently involved in the project coordination process, authorities are likely to face some resistance or at least lower levels of acceptance.

Natural and geographical constraints

Another constraint facing many APEC economies is that emergency reconstruction work should, in many cases, be completed before the monsoon, typhoon or flood season starts, as noted in the case of the No. 20 provincial road and the Dabang elementary school, Chinese Taipei (Case 4.1) and the case of Aso Bridge, affected by the Kumamoto earthquake in Japan (Case 5.3.1). In the case of Dabang elementary school, it was located in a mountainous area, and faced difficulties in transporting construction materials, especially with the abrupt changes of weather in the mountains. In Viet Nam, the sea dike in Thua Thien Hue province, which had also been used as a local road (Case 2.3) was urgently recovered before the storm season, thanks to the government initiative and the broad participation of local stakeholders. The Philippines saw multiple hazards taking tolls on the countryside, such as lahars that occurred more than once annually, thus destroying early recovery efforts.

Financial constraints

Many economies suggested that the most important challenge for infrastructure BBB is insufficient funding available to build sufficiently resilient infrastructure.

Financial constraints include budgeting process and timing as well as insufficient resources. Some economies have established systems to finance recovery work by reserving funds in anticipation of natural disaster damages, while in other economies, practically no budget is allocated for recovery of infrastructure before a disaster happens. In addition, restoration to the pre-disaster state of infrastructure could be financed by the central government while improving or modernizing, and BBB could not easily be financed due to the principles of building back to the pre-disaster status. Another challenge authorities may face is to choose either a high initial cost but low maintenance cost solution or low initial cost solution requiring higher maintenance and lifecycle costs.

Immediate availability of information
Infrastructure recovery and the BBB process will require a broad range of knowledge: technological solutions adapted to the damages, flow and timing and limitations of funds available, and possibilities to collaborate with the private sector, for example. To restore the gate of the Shihgang Dam, affected by the 921 Earthquake in Chinese Taipei (Case 2.5), authorities faced geological changes causing inconsistency of elevation, and difficulties in selecting the design and construction method. Infrastructure restoration and BBB requires a wide range of technical specialists as well. Central governments often need to serve as a source of technical assistance by organizing committees (for example) comprised of experts from relevant ministries, in order to muster all the necessary expertise for BBB.

Difficulties in land acquisition
Many economies suggest that lack of land slots available for rebuilding infrastructure is a challenge. Land acquisition can be a long process delaying recovery.

Addressing inequality and achieving balance among the affected
BBB of an infrastructure may generate inequality of access to newly developed and better infrastructure among the affected, or between the affected and the non-affected. In case of large-scale disasters, for example, prioritization among many infrastructure projects and consensus-building could be an important challenge to address this issue.

Governance challenges for BBB
It may be difficult to pre-plan for recovery in economies where large natural disasters are not frequent. Organizational arrangements for recovery are not always well institutionalized, due partly to the sporadic and rushed nature of recovery. Some economies pointed out weakness or absence of law, regulations, or guidelines, for post-disaster reconstruction. In addition, politics may play an important role in decision making for recovery and BBB of infrastructure, potentially hampering speedy rehabilitation. Bureaucratic procedures may also delay recovery processes, due to a government's rules and requirements in project planning, budgeting and project implementation.

3 Ways forward

Compared with infrastructure investment decision-making during ordinary periods, post-disaster infrastructure BBB generally needs to be undertaken under pressing needs. To achieve BBB beyond simple restoration, time for discussion and consensus building among stakeholders may be limited under a post-disaster situation, while a special budget for reconstruction and development could be provided.

Compared with metropolitan areas, rural and non-metropolitan areas, as highlighted in this casebook, have not yet been well equipped with modern infrastructure. Although horrific, disasters may present opportunities to update old structures or to construct new infrastructure. While rural and non-metropolitan areas may face technical challenges for construction due to geographical and climatic constraints, as seen in the case of Chinese Taipei, land for building infrastructure may be acquired more easily than would be possible in highly developed urban areas.

Natural disaster as a driver for long-term planning

The cases demonstrate that post-disaster situations could be a key moment of important decision-making for investment in infrastructure and resilience, if the relevant authorities and stakeholders are prepared for it. In the Philippines, disaster provided an opportunity to improve infrastructure more adapted to emerging conditions, while in Indonesia, the Trans-Mentawai road networks were successfully planned and developed after the earthquake in 2010. Furthermore, post-disaster infrastructure investment improving connectivity could trigger further growth of local industries and economy. Strengthening the nexus of DRR policy and regional development policy is a key for effective post-disaster investment in critical infrastructure. Various possibilities of infrastructure improvement should be discussed, examined and shared among relevant stakeholders before disaster strikes. Important infrastructure BBB plans will often not be suddenly supported in the difficult moments just after a disaster. The strategy of territorial redundancy was already defined in Japan's "5th Comprehensive National Development Plan" of 1998. Based on this idea, the resiliency and redundancy of road networks in Japan has been gradually improved, eventually enabling the successful operation of "Teeth of a Comb" after the Great East Japan Earthquake in 2011.

Small is smart: advantages of locally based infrastructure

Many cases demonstrate that "small is innovative", including community-based and locally managed cases of recovery from Viet Nam and Indonesia. Small infrastructure designed and tailored for individual communities can be more resilient and easily restored. Highly developed modern infrastructure could actually yield more significant damage, once affected, compared with small scale, locally manageable infrastructure. Up until the 1950s, major ports, for example, had been equipped with limited structures aside from breakwaters; it is not easy to find records of severe infrastructure damages to ports caused by natural disasters in the early 20th century. In the 21st century, strikes on large modern infrastructure will often result in significant damage, and since modern transport infrastructure is intensively networked and complex, damages and losses can be huge. Rural areas have an advantage in that it is possible to build small and smart infrastructure, locally manageable and more resilient, by applying cutting-edge technologies that could become more easily affordable.

Towards creative recovery

After the Great Hanshin-Awaji Earthquake, the idea of creative recovery was proposed, which already implied the concept of Build Back Better. Despite the budgetary principles of restoration back to original status, the affected local governments in Hyogo made maximum efforts for creative recovery. With that experience, for the post-disaster recovery from the Great East Japan Earthquake, the idea has been further enhanced and shared with others. The importance of DRR investment needs to be re-identified by all stakeholders. Public and private investment in DRR through non-structural as well as structural measures is essential to improve resilience, including a BBB approach to post-disaster recovery of critical infrastructure. Individual APEC economies may directly face a limited number of mega-disasters. For many government DRR authorities, working for recovery from a mega-disaster would thus be the first experience in their careers. It would thus be useful to share APEC-wide experiences of recovery from diverse disasters to prepare for an effective Build Back Better strategy for infrastructure, since the APEC region has historically endured many large-scale disasters (as listed in Chapter 1).

Table. Major good practices of infrastructure BBB studied in the casebook

NO.	Economy	Disaster type and name		Infrastrucrtue type and location		BBB type
1.1.1	Cinese Taipei	Typhoon	Typhoon Morakot	Road	No. 20 Chinese Taipei Provincial Road	Immediate recovery
1.1.2	Cinese Taipei	Earthquake	921 Earthquake	Bridge	Shihwei Bridge	Immediate recovery
1.1.3	USA	Hurricane	Hurricane Irene	Highway	Federal highway in the State of Vermont	Immediate recovery
1.1.4	Japan	Earthquake	Great East Japan Earthquake	Road	Road networks	Immediate recovery
1.2.1	Philippines	Volcaon eruptio	Mt. Pinatubo eruption	Road and highway	Highways	Transport networks planning and development
1.2.1.1	Philippines	Volcaon eruption	Mt. Pinatubo eruption	Road and highway	Olongapo-San Fernando-Gapan road & highway	
1.2.1.2	Philippines	Volcaon eruption	Mt. Pinatubo eruption	Road and highway	Subic–Tipo Expressway road & highway	
1.2.1.3	Philippines	Volcaon eruption	Mt. Pinatubo eruption	Road and highway	Subic–Clark–Tarlac Expressway (SCTEx)	
1.2.2	Indonesia	Earthquake	Mentawai Earthquake	Road	Trans-Mentawai road networks	Transport nework planning, revitalization of local economy
1.2.3	Indonesia	Peatland fires	Meranti peatland fires	Canal Blocking	Canal Blocking in Meranti	Locally based technology
1.2.4	Viet Nam	Flood	2015 floods	Community road	Tan Lap Communal roads	Locally based technology
1.3.1	Indonesia	Tsunami	The Indian Ocean earthquake and tsunami	Port	Deep-water ports in the Nias Islands	Stage by stage recovery of infrastructure
1.3.2	Philippines	Earthquake	7.2 Earthquake	port	Tubigon Port	Immediate restoration
1.3.3	USA	Hurricane	Hurricane Katrina	Port	Gulfport, Mississippi port facilities	Revitalization of local economy and industries
1.3.4	Japan	Earthquake	Great Hanshin Awaji Earthquake	Port	Port of Kobe	Technologies for quick recovery, upgraded anti-seismic structures, long-term BBB
1.3.5	Philippines	Typhoon	Super typhoon Haiyan/Yolanda	Airport	Tacloban Airport	Airport facility upgrades
1.3.6	Japan	Earthquake	Chuetsu Earthquake	Railway	*Shinkansen* "bullet train"	Upgraded infrastructure safety
2.1	Viet Nam	Landslide	2007 landslides	Sea dike	Sea dike system in western Ca Mau province	Application of low cost technology
2.2	Viet Nam	Landslide	Landslides casued by floods	Embankment	Thanh Mai stream embankment	Application of biological technology
2.3	Viet Nam	Erosion	2013 acute erosion	Sea dike	Sea dike in Hai Duong area	Immediate recovery by wide stakeholder participation
2.4	Japan	Flood	1982 Nagasaki Flood	Bridge	Bridge	Preservation of cultural heritage
2.5	Cinese Taipei	Earthquake	921 Earthquake	Dam	Shihgang Dam in Taichung County	Ecological consideration
2.6	Indonesia	Tsunami	Indian Ocean Tsunami	Waste managemen	Waste management infrastructure	Rapid cleanup and use of disaster debris, local job creation
2.7	Philippines	Typhoon	Typhoon Uring	Slit dam	Slit dams	Upgraded technology
3.1	Chinese Taipe	Typhoon	Typhoon Morakot	Village relocation	Laiyi township relocation	Whole village relocation
3.2	USA	Flood	Kickapoo River Floods, 2007–2008	Village relocation	Village of Gays Mills community relocation	Whole village relocation with commercial facilities
3	Australia	Flood	Queensland flooding 2010–2011	Village relocation	Village relocation	Whole village relocation
3	Japan	Earthquake	Great Hanshin-Awaji Earthquake	Urban redevelopment	Urban redevelopment of (HAT Kobe)	Diversification of the purpose of infrastructure development
4.1	Chinese Taipe	Typhoon	Typhoon Morakot	Elementary school	Dabang elementary school in Alishan township	Support for indigenous culture
4.2	Viet Nam	Flood	Central region floods	Houses	Flood resilient housing in the Central regions	