Inter-American Development Bank

Lessons Learnt from Japan and Latin America and Caribbean Countries in Management of Hazard Resilient Infrastructure

A JICA-IDB Joint Research

Tsuneki Hori
Roberto Guerrero
Maricarmen Esquivel
Anri Hiramatsu
Chitralekha Deopersad
Mikio Ishiwatari
Taichi Minamitani

Environment, Rural Development and Disaster Risk Management Division

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The Inter-American Development Bank (IDB) is devoted to improving lives. Established in 1959, the IDB is a leading source of long-term financing for economic, social, and institutional development in Latin America and the Caribbean. The IDB also conducts cutting-edge research and provides policy advice, technical assistance, and training to public and private sector clients throughout the region. The IDB has been capitalizing on projects that support and demonstrate the impact of the creative and cultural industries with many operations that use culture, art, and creativity as tools for socio-economic development to improve lives.

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Lessons Learnt from Japan and Latin America and Caribbean Countries in Management of Hazard Resilient Infrastructure

A JICA-IDB Joint Research[1]

Abstract

The Latin America and the Caribbean (LAC) region is one of the most disaster-prone areas in the world. Disasters have increasingly devastated the development effectiveness of the LAC countries. Had infrastructure been constructed with additional measures to prevent collapses due to natural hazard impacts, the region would have saved in the long run a significant amount of the public, private and human capital allocated to repairs and reconstruction. A key question is: what are the factors involved in preventing infrastructure collapse due to natural hazard impacts and how might these measures be implemented? This paper discusses the LAC countries' sustainable infrastructure that has been shown to be resilient, continuing to operate without collapse even during hazardous events. The study reviews (i) the good practices for reducing vulnerability in Japan, (ii) the overall progress of LAC countries on disaster risk management, and (iii) the recent infrastructure damages due to disasters in LAC region and identifies lessons. Finally, using a comparative analysis of a selected case studies in LAC and Japan, the study identifies four approaches for hazard resilient infrastructure in the LAC region.

Key words: Hazard, Resilient Infrastructure, Latin America and the Caribbean, Natural hazards, vulnerability, disaster risk management, sustainable infrastructure.

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[1] Principal authors of the Inter-American Development Bank and JICA are: Tsuneki Hori (CSD/RND) – Co-lead author; Roberto Guerrero (CSD/RND); Maricarmen Esquivel (CSD/CCS), Anri Hiramatsu (CSD/HUD), Chitralekha Deopersad (CSD/RND), Mikio Ishiwatari (JICA) – Co-lead author and Taichi Minamitani (JICA). Other contributing authors are Ivonne Jaimes (CSD/RND) and Maria Retana (CSD/RND).

Acronyms

CEPAL (ECLAC)	Economic Commission for Latin America and the Caribbean
COPECO	Contingencies Permanent Commission
COSIPLAN	Infrastructure and Planning South American Council
CRED	Center for Research on Epidemiology of Disasters
DDI	Disaster Deficit Index
DP	Disaster Preparedness
DRA	Disaster Risk Assessment
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EIRR	Economic Internal Rates of Return
EIRR	Economical Internal Rates of Return
EM-DAT	Emergency Events Database
ENSO	El Niño - Southern Oscillation
ESCI	IDB's Emerging and Sustainable Cities Initiative
FP	Financial Protection
GDP	Gross Domestic Product
GEJE	Great East Japan Earthquake
GF	General Framework of Governance for DRM
GoE	Government of Ecuador
HQI	High Quality Infrastructure
IDB	Inter-American Development Bank
IGOPP	Index of Governance and Public Policies on Disaster Risk Management
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LAC	Latin America and the Caribbean
LDI	Local Disaster Index
MLIT	Ministry of Land, Infrastructure, Transport and Tourism of Japan
NOAA	National Oceanic and Atmospheric Administration
NPIS	National Public Investment Systems
ODA	Official Development Assistance
ODA	Japan's Official Development Assistance
ONI	Oceanic Niño Index
PIP	Public Investment Projects
PVI	Prevalent Vulnerability Index
RC	Post-Disaster Recovery Planning
RI	Risk Identification and Knowledge
RMI	Disaster Risk Management Index
RR	Risk Reduction
UNDP	United Nations Development Programme

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1. Introduction

The Latin America and the Caribbean (LAC) region is one of the most disaster-prone areas in the world. The Emergency Events Database (EM-DAT) of the Center for Research on the Epidemiology of Disasters (CRED) reports that the region has experienced more than 2,000 intensive disasters from 1970 to 2015 (EM-DAT, 2016); in total, these disasters affected more than 250 million people. Hurricanes, windstorms and flooding are the most common natural hazard events in the Caribbean; floods, earthquakes, and volcanic eruptions are the considerable hazards in South America, while Central America regularly faces the “full menu” of disasters (IDB, 2007). The most recent severe disasters in the LAC region include the Haiti earthquake in 2010 (which caused US$7.8 billion economic losses and 300,000 deaths); the Chile Earthquake in 2010 (US$30 billion in economic losses and 500 deaths); the Colombia floods in 2010-2011 (which caused US$5 billion in economic losses and 400 deaths); and the recent Ecuador Earthquake in 2016 (which caused US$3.3 billion on economic losses and 660 deaths) (SENPLADES, 2016). Even countries that historically have not been affected by repeated disasters, such as Argentina, Uruguay and Paraguay, have experienced several disasters over the last few years.

Disasters have increasingly devastated the development effectiveness of the LAC countries (IDB, 2007). Direct economic damage due to disasters in the LAC region have increased twelvefold from 1970-1979 to 2000-2009 (EM-DAT, 2016). The pace of the region’s increasing disaster damages and losses is much higher than the worldwide average (Stolton et al., 2008). This increasing trend of damage and loss in the LAC region is caused mainly due to the physical vulnerability of the infrastructure. For example, the result of the recent Ecuador earthquake in April 2016 reveals that almost two-thirds of the total US$3.3 billion damage was caused due to the complete or partial collapse of hospitals, schools, water and electronic facilities and housings (CEPAL, 2016a). Of the total US$120 million in damage and loss due to Hurricane Joaquin in The Bahamas, 74% was caused due to the damage of housings, roads and telecommunication facilities (CEPAL, 2016b). Across South America, disasters from 1980 to 2015 caused a total of US$3.8 billion in damages to transportation facilities (COSIPLAN, 2016). If the infrastructure had been constructed with additional measures to prevent collapses due to natural hazard impacts, the region would have saved significant public, private and individual capital that were otherwise allocated to repairs and reconstruction. Instead, this capital could have been invested in other high-priority and strategic sectors such as education, industry, or agriculture. A key question is: what are the factors involved in preventing infrastructure collapse due to natural hazard impacts and how might these measures be implemented?

This paper discusses the LAC countries’ sustainable infrastructure that has been shown to be resilient, continuing to operate without collapse even during hazardous events. The study first reviews good practices for reducing vulnerability in Japan, a country that has experienced numerous devastating disasters historically and has accumulated lessons and good practices deserving policy consideration. Japan recently materialized their disaster risk reduction [2] experiences in a concept called "high quality infrastructure (HQI)"[3]. Based on this notion, the study then reviews the overall progress of LAC countries on disaster risk management and identifies factors necessary to achieve hazard-resilient infrastructure in the LAC countries.

This study consists of five sections. Following this introductory Section 1, Section 2 reviews lessons and good practices related to HQI in Japan. Section 3 reviews overall progress and challenges of the LAC countries' disaster risk management policy framework and institutional performance. Section 4 focus more on project scale and reviews four case studies of recent infrastructure damage due to disasters and extracts lessons. Based on the good practices in Japan and the lessons in the LAC region, Section 5 discusses factors necessary for achieving hazard resilient infrastructure in the LAC countries. The last section concludes the result of this research with implications for next steps.

This report has been prepared under IDB – JICA joint technical research initiative proposed during the IDB Annual Meeting in The Bahamas in April 2016. The study was conducted during July 2016 – April 2017, primarily via desktop analysis and discussion among experts in the IDB and JICA.

2. High quality Infrastructure: good practices and experiences in Japan

Japan has repeatedly suffered from natural disasters including floods, earthquakes, and tsunamis throughout its history. The country started disaster risk reduction practices many generations ago, including the first dike system constructed in the Yodogawa River in Osaka in the 4th century. The community-based emergency preparedness has been organized for centuries in many places of the country. However, disasters continue to occur; the country experienced 215 major disasters from 1980 to 2015, which affected more than 4.6 million people according to EM-DAT (2016).

The country has accumulated the lessons from every major disaster, and utilized these experiences to improve its policies, laws, regulations and technical, institutional and community capacities. For example, the government formulated the first building code in 1924 following the Great Kanto Earthquake that killed more than 100,000 people in 1923, and has revised several times after that. It is important to note that each update of building codes requires a significant effort (e.g., policy reforms, institutional strengthening and laboratory engineering tests). Due to these updated building codes, and significant efforts in practice supporting these updates, buildings and infrastructure suffered only minimal damage during the strong main shock of the Great East Japan Earthquake (GEJE) of March 11, 2011, even though its magnitude was historically intensive (Mw 9.0).

[2] See IDB's Disaster Risk Management Policy and its Guidelines (http://www.iadb.org/en/about-us/sector-policies,6194.html) to clarify the definition of the two terms used in this paper: disaster risk reduction (DRR) and disaster risk management (DRM).

[3] Conceptualized by the national government of Japan, HQI refers to infrastructure that adds value in terms of safety and resilience against natural hazards. HQI allows for the continuous operation of socioeconomic activities even during the hazardous impact and reduces infrastructure's long-term maintenance cost.

Extracting from all experiences related to disaster risk reduction, the country has recently conceptualized these as a “high-quality infrastructure” to promote disaster risk reduction actions necessary in developing countries. Investments under the concept of high-quality infrastructure can ensure economic efficiency, reliable operation and safety against disasters during the life span of a project. High-quality infrastructure can additionally increase social and environmental value. This section introduces some examples related to high-quality infrastructure.

2.1 Reducing seismic risk in Japan – lessons from major earthquakes

The Great Hanshin Awaji Earthquake (Kobe Earthquake) occurred in Hyogo Prefecture on January 17, 1995. The earthquake caused over 6,400 casualties and economic losses at US$85 billion (Cabinet Office 2011). Major railways and highways, including bridges and elevated roads in Kobe City collapsed which impeded relief and rescue operations (Figure 2-1). The full reconstruction of highways took over 1.5 years to complete.

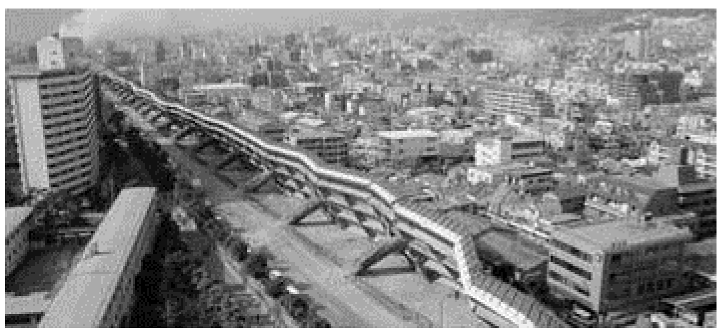

Figure 2-1. Kobe Earthquake. Source: http://www.bousai.go.jp/

Japan has experienced other serious earthquakes in the years following the Kobe Earthquake, including in Fukuoka in 2005 and Chuetsu-Nigata in 2007. Mega-earthquakes also took place historically in Tokai, Tonankai, and Nankai regions (pacific coast of central Japan). Based on the lessons from the Kobe Earthquake, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) along with highway companies jointly formulated a 3-year retrofitting plan to prepare for potential mega-earthquakes, especially for bridges. The ministry and highway companies retrofitted around 35,000 bridges throughout the country, completing this work in 2008. In the Tohoku region, MLIT retrofitted 490 bridges. Additionally, the East Japan Railway Company reinforced more than 17,000 bridge piers under the bullet train networks (called Shinkansen).

After the retrofitting work of this critical infrastructure was implemented, GEJE occurred in 2011. However, serious structural collapses of infrastructures were avoided and only five bridges collapsed under the force of the tsunami. Because damage was generally limited, the main highways and roads to the affected areas were reopened within one week of the event. Bullet train service (or Shinkansen) resumed 49 days after GEJE because of the East Japan Railway Company’s retrofitting works; this was much shorter than the experience of the Kobe Earthquake

(82 days). While these positive results were observed, it should be noted that serious damages occurred due to GEJE tsunamis, especially in the coastal areas, that took much longer to repair.

Multipurpose infrastructures contributed to reducing disaster damage and loss.
The direct economic damage due to tsunamis after GEJE is estimated at US$ 150 billion, which accounts for 3.5% of Japan's Gross Domestic Product. Despite these significant direct damages, the GEJE experiences still show that multifunctional structures are a cost-effective approach to reduce indirect disaster loss. For example, roads, expressways, and other public facilities largely contributed to reducing damage and losses caused by the GEJE by protecting tsunami waves and floods. These facilities also served as evacuation routes, evacuation areas, and base stations for emergency operations. Elevated highways in Sendai City protected houses from the tsunami waves. Roadside service stations and parking spaces alongside the highways, known as Michino-eki (meaning "station on the load" in Japanese), played important roles in disaster response (Figure 2-2). The roadside service stations, which were parking areas with public facilities, provided water and electricity for search and rescue teams and volunteers throughout the country. In sum, many public facilities and infrastructure could be functional to reduce disaster risks in addition to their primary functions.

Prior to GEJE, cost-sharing mechanisms for multi-purpose structures were established between disaster management local offices and road offices in Japan. The disaster management offices cover additional costs for hazard resiliency, such as the cost for raising road heights in road construction.

Figure 2-2. Roadside service station, "Michino-eki", during GEJE (left and center) and at normal time (right). Source: MLIT

2.2 JICA's contribution to reducing seismic risk

Japanese lessons on major earthquakes and practical measures to reduce its impacts are disseminated through the JICA projects. Among others, this paper introduces a case study in Istanbul.

Resilient bridge and tunnel to earthquake in Istanbul
Istanbul is a critical transport connection hub between Asia and Europe. Istanbul, a major city with a population of 13 million, is the commercial, financial and industrial center of Turkey. Due to rapid

economic development and population increase, the city suffers from chronic traffic congestion and heavy air pollution by exhaust gas. Transport infrastructures need to be developed in Istanbul, in particular, routes over the Bosphorus.

Turkey is a disaster-prone country and has suffered from frequent earthquakes, such as the earthquakes in the northwestern area in 1999, southwestern area in 2003, and eastern area in 2011. Because there is a risk that a large-scale earthquake will occur around the Istanbul area, infrastructure in the area must be sufficiently hazard resilient. Large-scale earthquakes are envisioned to strike the area with a frequency of 250 years (Yamamoto 2014).

Earthquake risks for bridges and tunnels were estimated with simulation software, and countermeasures were designed based on seismic engineering experiences in Japan. Japanese organizations, including the national and local governments, prioritized major highway's retrofitting activities due to the bitter experience at the Kobe Earthquake (in 1995). Urban highways were collapsed in Kobe and took significant time to rehabilitate. Major bridges over the Bosphorus, therefore, were retrofitted against earthquakes, and a railway tunnel was constructed with seismic structures 60 meters below sea level of the strait.

Seismic Reinforcement Project for Large-Scale Bridges in Istanbul

JICA begun a technical cooperation project in 2002 to formulate an urban master plan of Istanbul where earthquake disaster risks were taken into account. Utilizing the master plan as a blue print, a wide range of projects have been executed in Istanbul.

JICA supported enhancing earthquake resistance of transport infrastructures in Istanbul by retrofitting major large-scale bridges from 2002 to 2012. The project covers investment loan for retrofitting works and consulting services including its earthquake risk assessment, engineering design, work implementation and supervision. The bridges of First and Second Bosphorus, and new and old Golden Horn, are heavily-trafficked structures with a traffic volume of approximately 400,000 vehicles a day (Figure 2-3). If these bridges collapsed due to an earthquake, Istanbul would be isolated from other areas, and transportation between Europe and Asia would be disrupted. Socioeconomic activities in the country and response operations to disasters would be seriously affected.

In this project, piers and other structures were reinforced, and shock absorbers and drop prevention devices were installed (Figure 2-3). This project contributed to mitigating damage and promoting prompt recovery in the event of disasters. Bridges were strengthened to function under the impact of more common earthquakes, which occur at a probability of 50% in 50 years, and avoid serious damage against rarer earthquakes, at probability of 2% in 50 years (Kitayama et al. 2010). In Japan following the Kobe Earthquake, the design concept of bridges was revised. Before the earthquake, bridges were designed to withstand against possible earthquakes during the project's expected life. Revised technical standards improved the structural stability so that bridges would not be damaged and endanger human lives even in case of a large-scale earthquake with low probability.

Figure 2-3. Second Bosphorus Bridge and facilities installed. Source: JICA

Bosphorus Rail Tube Crossing Project

A railway tunnel of 13.6 kilometers completed its construction, including the tunnel underneath the Bosphorus, in October 2014. JICA provided assistance for the construction of a tunnel that crosses the Strait through Official Development Assistance (ODA) loans totaling JPY 153 billion (equivalent to US$1.5 billion). The project contributed to the improvement of traffic conditions and the reduction of air pollution in downtown Istanbul. The tunnel shortened traveling time from 30 minutes by ferry to 4 minutes by subway.

Japan's latest technology and expertise in seismic engineering were used for building the 1.6 km section of the immersed tube tunnel that crossed underneath the Bosphorus Strait. Advanced design methods are used for crucial facilities to retain limited damage in Japan. Seismic waves at the construction site are examined through considering distance from epicenter and possible scale of earthquakes. Acceleration response spectrums are considered for structural design.

The project covers conducting site response analysis against seismic waves, designing connection portion between the immersed tube tunnel under the Bosporus Strait and boring machine tunnels in other sections, and implementing countermeasures against liquefaction. The railway tunnel is located 60 meters below sea level which is the deepest underwater immersed tube tunnel in the world. A seismic fault, that could potentially cause an earthquake of magnitude 7.5, is located 16 km away from the tunnel route. Seismic joints, which absorb displacement caused by earthquake shaking and ensure that the tunnel remains watertight, were installed at connection portions of tunnel segments. The shaking from the earthquake could cause soil liquefaction, leading to loss of strength in sandy soils. To prevent damage to the tunnel structure from liquefaction, the ground around the tunnel was improved by utilizing compaction pile grouting and replacement methods.[4]

[4] Compaction pile grouting: cement mix is injected into the ground so that the surrounding soils are displaced and densified.
Replacement: soft soils are replaced with densified soils.

2.3 Reducing flood risk in Japan – lessons from urban and rural flooding in Japan

Integrated approach to reduce urban flooding in Japan.
Increasing flood damage in urban areas became a serious socio-economic issue during the period of high economic growth in Japan from the mid-1950s. Migration from rural to urban areas contributed to the explosive growth of the Tokyo, Osaka, and Nagoya metropolitan areas. Large-scale housing development in hill areas reduced infiltration of rainfall water into the ground and accelerated runoff to rivers. Paddy fields, which used to serve as flood retardation ponds, were converted into residential areas. These development activities increased flood frequency and intensity, leading to damage growth in downstream low-lying areas. Urban development in flood-prone areas increased the value of exposed assets.

The Japanese Government initiated a new approach to urban flood management in 1979. The conventional engineering-oriented approach alone became insufficient to solve serious flood problems caused by rapid urbanization. Historically, Japan had long been conducting flood control works inside the river channels to allow more flood water to flow within the river and to flow out into the sea as quickly as possible. Therefore, Japan started a new approach conducting comprehensive measure interventions in the whole river-basins (not only within the river channels but also for whole river-basin area). The measures include flood risk assessment of the whole river-basins, structural works, such as widening of river channels, various measures distributed in the river basins as shown in figure 2-4, and non-structural measures, such as hazard maps, early warning and evacuation drills. The capacity of retarding floods is increased to reduce flood runoff to the lower stream. This new approach is regarded as the paradigm shift of Japanese flood risk management: “from channel to whole river-basin” (Kundzewicz and Takeuchi 1999).

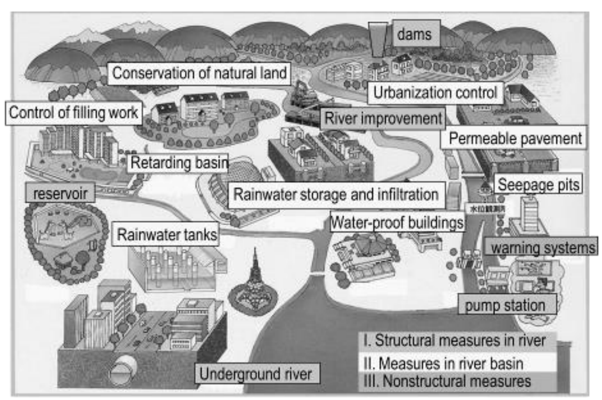

Figure 2-4. Concept of urban flood management, Source: MLIT

Because it is difficult to acquire lands for ponds or reservoirs in densely developed urban areas, multifunctional facilities are alternatively developed in the river basins. Lands owned by the municipality governments, such as school grounds and sports facilities, have been used for the retarding ponds in case of flooding (Figure 2-5). Local governments, by their ordinances, require private companies and developers to construct retarding ponds to offset run-off volume increased by residential development. Rainfall infiltration facilities and permeable pavements are also installed. The local governments identify preservation zones for agricultural and natural lands, and regulate land use. Also, the governments control development activities, such as landfill, so as not to increase flood discharge. The governments encourage residents to construct houses with raised floors to avoid inundation.

Flood damage in urban areas was substantially decreased because of the comprehensive flood risk management approach. The Japanese government invested 3.7 trillion JPY (approximately US$ 37 billion) in 17 selected urban rivers in Tokyo, Osaka and Nagoya metropolitan areas. It is estimated that damage of 12.7 trillion JPY (US$ 127 billion) was avoided as a result (Ministry of Land, Infrastructure, Transport and Tourism 2004). Benefit-cost ratio for the total investment, therefore, is calculated at 3.4.

Figure 2-5. Alternative use of retarding pond in urban area. During normal (left) and flooding (right), Source: MLIT

Green growth in Kobe

The city, located at the foot of the Rokkosan Mountain Range, has repeatedly suffered from urban floods (Figure 2-6). Urban management in Kobe City is regarded as a good practice, especially in terms of urban flood management adopting the comprehensive flood risk management approach. The approach includes land use regulation, forestation, and structural measures. When Japan started to modernize in the late 19th century, people living in this area had cut down most trees in Rokkosan Mountain Range to use wood for fuel. A forestation program, therefore, was started to mitigate flood risk in 1902, and currently the mountain range is covered by forests. The MLIT and Hyogo Prefecture Government have constructed over 1,000 check ("sabo") dams to control debris and floods since 1895. Flood damages have shown a constant decrease due to these preventive measures. For instance, 695 people were killed and around 130,000 houses collapsed or were inundated because of urban floods and debris flows in 1938. Damages were significantly lower during the floods of 1967, which caused only 98 deaths and 38,305 collapsed or inundated houses (Rokko Sabo Office 2009).

In addition to floods, the city of Kobe experienced the Kobe Earthquake in 1995, during which 34 people died from landslides. Following the Earthquake, MLIT and local governments established the "green belt" program to enhance urban resilience to multiple hazard events. The program was focused not only on hazard resilience but also for citizen's increasing social or recreational value that consisted of (i) structural measures of check dams and slope protection works, (ii) forest reserve, (iii) prohibition of housing construction and urban development in greenery reserve areas, and (iv) community participation activities in afforestation and education.

Figure 2-6. Kobe City.

Examination of structures constructed in river area

When electric companies or authorities construct new dams or hydropower facilities in Japan, they need to obtain an approval from river offices. The river offices of national or prefectural governments have a mandate of managing flood disaster risks and examining any new structures to be constructed in river areas from a perspective of managing flood risks. Improper design of the structures would increase flood risk. The MLIT formulated technical guidelines for constructing structures, such as dams, barrages for water intake, bridges and parks in the river areas. According to these guidelines, the river offices have the mandate of ensuring the safety of dams and barrages, monitoring structures, facilities of flowing floods, communication equipment and others. Also, the river offices conduct routine inspection on the structures once every few years during the operation period.

The river offices require other organizations to strictly follow the guidelines, including requirements in construction of structures such as dams, barrages, bridges, dykes, pumping stations and gates. Bridges and weirs are constructed in compliance with the minimum requirement of span lengths. For example, construction of the new runway at the Tokyo Haneda Airport at the river mouth of Tamagawa River was subject to careful examination by a MLIT river office for potential risks of disturbing the flood flow of the river. As a result, a bridge-type runway was selected in consideration of flood risk mitigation (Figure 2-7).

Figure 2-7. Tokyo Haneda Airport in consideration of flood risk mitigation. Source: Ishiwatari M.

2.4 JICA's contribution for reducing flood risk Tietê river basin depollution project in Brazil

The São Paulo metropolitan area is one of the economic centers of Brazil, where production accounts for 20% of the national GDP. The area has a population of 20 million, which comprises 50% of the population of São Paulo's State. The Tietê River runs through the metropolitan area. The area has rapidly sprawled, and the urban area covers 40% of the river basin.

Almost every year, flooding dam ages highways and commercial and residential buildings in the metropolitan area. Flooding often disturbs traffic on the Marginal Tiete Road along the river (Figure 2-8). The road connects the metropolitan area with important facilities: Santos port and the São Paulo-Guarulhos International Airport, and plays a crucial role in urban transport in the area with a traffic volume of approximately 900,000 to 1 million vehicles a day. The cost of traffic disturbance due to flooding is estimated at some US$4 million per day (JICA 2009a).

JICA financed a flood-capacity improvement work from 1997 to 2006 in the Tietê River Basin (Figure 2-8). Using Japanese experience of river improvement, flood situations were simulated and channel works were designed. The flood capacity of the river was substantially improved from once-in-two year flood to once-in-100 year flood, and flood damage decreased significantly. The economic benefit of avoiding flooding is estimated at US$108 million per year (JBIC 2008).


Figure 2-8. Flood in February 1983 and structures constructed after JICA contribution. Source: JICA

Comprehensive flood mitigation for Cavite Lowland area in the Philippines

JICA supported the Philippines to mitigate flood risk with consideration to climate change effects in the river-basin and Manila metropolitan area from 2007. The JICA projects cover risk assessment, investment planning and financing mitigation measures. Cavite Province is facing pressures of rapid urbanization of residential areas, and has undergone intensive industrialization since the 1990s. The population of the province has increased by more than 5% annually and flood damage becomes more serious as urban and housing development progresses.

There are synergistic effects between climate change and urbanization in terms of increasing vulnerability to floods. Houses are being constructed in risk areas where flood inundation would become more severe because of climate change. It is projected that the number of houses inundated would double or triple by 2050. JICA predicted precipitation extremes by a statistical downscaling method, which was created based on the subset of the global climate models for the IPCC fourth assessment report. Flood volumes of 10-year return period would be increased by 24% - 48% by 2050 according JICA study in 2009 (JICA 2009b).

The projects utilized the Japanese experience of the comprehensive approach especially for urban flooding. In addition to conventional channel works, the following measures were proposed and are currently being implemented:

a) **Off-site flood retarding basins**: The retarding basins were planned as the key structural measure. Flood water is stored at the basins' adjoining rivers. The capacities of the retarding basins can be expanded as flood risks increase. Considering continuous increase of flood risks, embankments were not selected as the key measure because embankments cannot be easily raised in urban areas once completed.
b) **Land-use regulation**: Regulating developing activates was proposed to reduce damages to property in risk areas. In addition, water infiltration will be secured by land-use regulation in upstream areas.
c) **Early warning and evacuation**: Early-warning and evacuation systems are crucial to save human lives under an uncertain and changing climate. A series of public consultations were conducted to share information on flood risk with communities and to formulate community-based action plans of flood risk management.

Flood risk reduction in Nepal

Nepal is prone to natural disasters including landslides and floods caused by heavy rains during the rainy season. 80% of its territory is located in mountainous area where geology is fragile because of active tectonic processes and the high angle of slopes. Crucial infrastructure, such as hydropower plants and highways, have been damaged by disasters, posing a severe threat to the sustainable development of the country.

JICA supported disaster prevention works against flooding and landslides around the Kulekhani Hydroelectric Power Plants to ensure safe and efficient operation of the plants. Kulehkani No. 1 Power Plant, with a capacity of 60 megawatts, and Kulehkani No. 2 Power Plant, with a capacity of 32 megawatts, were constructed under Japan's Official Development Assistance (ODA) loan during the 1980s. These two hydropower facilities were the largest power plants in Nepal, which accounted for approximately 31% of the domestic power generation capacity. The Kulekhani Power Plants suffered repeatedly from severe floods in 1984, 1986, and 1993. In particular, the 1993 flood, which was caused by rainfall of up to 80 mm per hour and 540 mm over a 24-hour period, seriously damaged the penstock line, head pond, and power station generator. Moreover, power generation from the plants had to be halted (JICA 2003).

The disaster prevention projects include the construction of soil erosion control ("sabo") dams upstream of the reservoir (Figure 2-9), the slope protection works for water transfer facilities, the blockage works for the water intake facility, and the monitoring equipment.


Figure 2-9. Sabo dam in Nepal. Source: JICA

These works are effectively protecting the plants from flooding. Heavy rains in 2002, during which the daily precipitation ranged from 325 mm to 455 mm, amounting once in 100-year probability, the power plant operations experienced no significant disruptions. The annual inflow of sand into the reservoir was greatly reduced from 4.8 million m^3 in 1993 to an annual average of 290,000 m^3 between 1996 to 2002. Further, the life spans of the power plants and reservoir were extended from 15 years to 50 years by the project. The operation rate of power plants was also increased to 99% from 80% prior to the project, and this contributed to stable power supply in Nepal.

These projects have shown these are economically viable. The economic internal rates of return (EIRR) were calculated at 16.9% and 23.5% by comparing with and without scenarios (JICA 2001; JICA 2003).

Institutional capacity development for continuous flood risk management in Nepal
JICA supported another program in Nepal to develop flood and landslide management capacity through grant technical assistance programs. The program continued for two decades. The programs included (i) training for government engineers and practitioners for construction and maintenance of the flood risk reduction measures, (ii) developing technology for low-cost and eco-friendly methods of disaster risk reduction by using local materials (Figure 2-9), (iii) sharing of disaster information and disaster mitigation technology, (iv) developing database on disasters and (v) raising awareness of the public and the government on disaster risk reduction.

At the beginning of the programs, the government established a technical center, which became the Department of Water Induced Disaster Management. This department plays a leading role in implementing disaster risk reduction projects, its maintenance and mainstreaming DRR in other infrastructure projects. The Japanese experience shows that establishing the leading agency for flood management is crucial in coordinating, implementing and maintaining DRR measures.

Figure 2-10. Low-cost technology for land slide protection, Source: JICA

Under the JICA programs, collaborative systems among organizations concerned in DRR were formulated. A supervising committee, including the electric authority and the road department, was set up to guide the programs. These organizations dispatched engineering staff and staff from a wide range of organizations received training. The department shared disaster information, such as risk maps, research papers, and newsletters, and conducted seminars of disaster risk management with the organizations at the local level as well. Countermeasure works against landslides and floods, which are applicable to hydropower plants and sites, were developed through pilot programs.

2.5 Summary

DRR investments pay off. While the countermeasures against natural disasters seems costly, the investment pays off. JICA and Japanese DRR projects show economic benefits and robust internal rates of return (Ishiwatari 2016). Infrastructure projects should include the cost of countermeasures against natural disasters. These may cause to decrease economic viability from a short-term perspective. However, these pay off in a long-term perspective.

Infrastructure designs must be based on proper risk assessment. Disaster risk should be carefully assessed and be incorporated in the design of infrastructure. Without proper consideration, these structures would be damaged and furthermore increase flood damages in neighboring areas by blocking floods or changing flood courses.

Public facilities and infrastructure can function as multipurpose infrastructure to reduce disaster loss and damages. Roads, expressways, and other public facilities contributed to reduce damage and loss in GEJE by providing multiple protections against flooding, and by serving as evacuation routes and base stations for emergency operations. Organizations for disaster risk management and other public sector organizations should coordinate to ensure that their structures are multifunctional whenever possible.

Critical infrastructure should be designed to continue to operate even in case of extreme events. The failure of critical facilities, such as a large-scale dam, oil refinery, or industrial facility, can have a cascading effects, multiplying the destruction and leading to irreversible human, social, economic, and environmental impacts. Also, public facilities, such as schools, disaster risk management centers, and hospitals, are expected to play various roles in disaster response.

Critical infrastructure should be carefully designed against the risks of all natural hazards even at extreme hazard events.

Prepare for uncertainty. Climate change and other changes in a society may increase disaster risks. Ideally damages should be evaluated against the worst-case scenario, and contingency plans should be prepared for such a scenario. Even simple assessments, such as confirming a structure's safety against recorded disasters, are useful in preparing for disasters.

Disaster risk management organizations need to take the lead role in mainstreaming DRR in infrastructure sectors. These organizations should enhance capacity of examining infrastructures to be constructed by other organizations from a DRR perspective. If bridges, hydropower plants, and urban facilities are constructed without proper measures against disasters, the structures can be easily damaged by earthquakes, flooding, and landslides. Also, these structures may deteriorate disaster damages by disturbing flowing floods and landslides. Technical advice for design or plan is useful in developing infrastructure that is resilient to natural disasters. Approval processes by the disaster management organizations for resilient structures should be established.

3. Current Progress of National DRM Frameworks for high quality and disaster resilient infrastructure in Latin American and the Caribbean

This section assesses the overall progress in terms of national framework and its performance related to disaster risk reduction in LAC countries. Specifically, this section reviews the result of three technical studies developed by the IDB: Index of Governance and Public Policies on DRM (iGOPP), Status of Incorporation of DRM in National Public Investment Systems (NPIS study), and Disaster Risk Management Index (RMI). Through the review of these studies, this section identifies key challenges for better planning for disaster resilient infrastructure.

3.1 Index of Governance and Public Policies on DRM (iGOPP)[5]

Methodology

The Index of Governance and Public Policies (iGOPP) measures the current condition of public policy and regulatory framework on disaster risk management (DRM) including the climate change context at the country level. iGOPP consists of a total 241 indicators grouped by six

[5] The Bank developed a methodology of Indicators of Disaster Risk and Disaster Risk Management (the Indicators). Currently the Indicators include five sub-indicators including: Disaster Deficit Index (DDI), Local Disaster Index (LDI), Prevalent Vulnerability Index (PVI), Risk Management Index (RMI) and Index of Governance and Public Policies on DRM (iGOPP). DDI, LDI, PVI and RMI were originally developed in 2004 through the Technical Cooperation financed by the Japan Special Fund: ATN/JF-7906/07-RG "Information and Indicators Program for Disaster Risk Management" (See IDB (2008) for details). iGOPP has been additionally developed in 2012 through the Technical Cooperation RG-T2064 financed from the Bank's Multi-donor Disaster Prevention Fund contributed by the government of Canada, Japan, Korea and Spain. Among these five sub-indicators, RMI and iGOPP include the aspect of the hazard resistant infrastructure and meet the objective of this study.

components[6], and each of these indicators are assessed with a binary scale of progress (yes or no, or whether legal, responsible institution and budgets exists or not). Within the six components, the following three components comprise a total of 74 indicators that address the subject of disaster resilient infrastructure: risk identification and knowledge (RI), risk reduction (RR) and disaster preparedness (DP). For the purposes of this document, these selected 74 indicators are identified as the "Infrastructure iGOPP."

The specific criteria assessed in the Infrastructure iGOPP are whether each country has: (i) rules to identify critical buildings and infrastructure; (ii) rules to incorporate vulnerability reduction measures in project planning and implementation; (iii) building codes with anti-seismic designs and specific construction regulations to protect critical infrastructure against hazard events; (iv) regulations related to land use planning to identify hazard risk areas, (v) mechanisms to assign budgets to implement risk reduction measures, (vi) mechanisms of audit or inspection during and after construction; and (vii) emergency or contingency plans in each sector in case of disaster. The targeted infrastructure for this index includes the following sectors: Agriculture, Environment, Health, Housing, Education, Tourism, Transport, Water and Sanitation, Telecommunications and Energy.

Similar to the original iGOPP, the Infrastructure iGOPP score[7] ranges from 0 to 100 with the following classification criteria: (i) a score of 91-100 denotes an *outstanding* level of governance conditions for sustainable infrastructure; (ii) 71-90 reflects *very good level*; (iii) 41-70 reflects a *good level*; (iv) 21-40 reflects an *incipient level*; and (v) 0-20 reflects a *low level*.

Results

Table 3.1: Summary of the result of the Infrastructure iGOPP in 15 countries. Overall, there are significant opportunities to enhance the national DRM policy framework for ensuring disaster resilient infrastructure in the studied countries. Only four out of 15 countries studied are classified as *good* governance condition to implement disaster resilient infrastructure, five countries are classified as *incipient*, and six countries are classified as *poor.* The results of each component are as follows:

[6] The six components are: General Framework of Governance for DRM (GF), Risk Identification and Knowledge (RI), Risk Reduction (RR), Disaster Preparedness (DP), Post-Disaster Recovery Planning (RC) and Financial Protection (FP). See https://publications.iadb.org/handle/11319/6717 for details. To date, IDB has applied iGOPP in 15 LAC countries: Argentina, Bolivia, Chile, Colombia, Costa Rica, the Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, México, Panama, Peru, Uruguay and Venezuela.

[7] The Infrastructure iGOPP first measures 0-100 in each component and with the specific weights of each component (RI 35%, RR 50%, and DP 15% base on the number of indicators in each of the component) and then, obtains its total value (RI+RR+DP with each specific weights).

Table 3.1. Infrastructure iGOPP scores (total and each component) in 15 countries

Country	Total	RI	RR	DP
Peru	51.8	46.6	53.1	59.3
Mexico	51.6	61.7	57.3	12.8
Costa Rica	41.7	40.4	50.4	18.7
Colombia	41.7	33.7	53.0	25.5
Honduras	29.3	23.3	35.0	25.5
Chile	28.9	29.5	35.8	6.8
Venezuela	24.5	29.0	25.2	12.7
Guatemala	23.4	14.0	29.6	25.5
Bolivia	21.2	23.3	22.6	12.7
Argentina	19.4	13.5	23.6	19.5
Dominican Republic	19.4	16.6	23.8	12.7
Panama	15.8	5.2	22.6	18.7
Jamaica	14.1	3.1	20.7	18.7
Haiti	13.3	10.9	19.4	0.0
Uruguay	13.0	18.1	13.6	0.0
Average (0 - 100)	**27.3**	**24.6**	**32.4**	**17.9**

The results of each component are as follows:

Risk identification and knowledge (RI). The average RI score of the Infrastructure iGOPP was 24.6 points, meaning an *incipient* level of governance conditions to promote and implement risk identification necessary for disaster resilient infrastructure. In fact, the results vary among the countries from the highest (61.7 points, in Mexico) to the lowest (3.1 points, in Jamaica). 11 countries (73%) have some rules to define critical infrastructure that were either recently created or created after 2003. Noticeable sectoral disparities were found in the mechanism to assign responsibility for sectorial risk analysis. 11 countries (73%) assign responsibilities for the environmental sector to implement risk analyses and eight countries (53%) assign responsibilities for the agricultural sector. However, only five countries (33%) assign responsibilities for the water and sanitation sector, four countries (27%) assign responsibilities for the transportation sector, three countries (20%) assign responsibilities for the education sector, three countries (20%) assign responsibilities for the energy sector, two countries (13%) assign responsibilities for the tourism sector, and no countries assign responsibilities for the telecommunication sector. Overall, it was difficult to identify financial resources to implement disaster risk analyses - at least three countries (20%) assign it for the environment and housing sectors.

Risk reduction (RR). The RR score of the Infrastructure iGOPP varied from a high of 57.3 points in Mexico to a low of 13.6 points in Uruguay, with an average of 32.4 points, categorizing the study countries as an *incipient* level of governance conditions for risk reduction. Overall, 11 out of 15 study countries already have building standards that incorporate seismic hazard risk consideration in their development projects. Two of the countries, however, have not updated their standards in more than 10 years. Four countries lack specific regulations that standardize the construction of critical infrastructure, protecting infrastructure against hazard events. 13 out of the 15 countries do not mandate risk reduction measures to be incorporated during planning and construction process of development projects.

Noticeable sectoral disparities also persist in sectorial disaster risk reduction regulations; in the agriculture (9 countries), health (11 countries) and housing sectors (8 countries), legislation explicitly defines responsibilities to reduce disaster risk. Most of the study countries, however, does not assign the same kind of responsibilities in the transportation and the water and sanitation sector. In nine out of 15 study countries, there are regulations on development planning and land use to specify a hazard risk area. Overall, in housing (six countries), environment (five countries), transportation (five countries) and water and sanitation (five countries), there are budgetary categorizations for risk reduction measures. Most of these, however, do not have sufficient budget allocation in practice.

Disaster Preparedness (DP). The DP score of the Infrastructure iGOPP varied from a high of 59.3 points in Peru to a low of 0 points in Haiti and Uruguay, with an average of 17.9 points, positioning the region at the *incipient* level of governance conditions for disaster preparedness. In eight countries (53%) there are regulations in place that mandate the formulation of emergency or contingency plans at the national level. However, sectoral contingency plans are extremely scarce in practice, particularly in the environment, water and sanitation, energy and transportation sectors. There are no identified sectorial contingency plans in any of the 15 study countries.

3.2 Status of Incorporation of DRM in National Public Investment Systems (NPIS study)[8]

Methodology

Similar to iGOPP, this study assesses the condition of legal and institutional framework specifically in terms of the incorporation of DRM in National Public Investment Systems (NPIS). This study includes a total of 23 parameters that are grouped in to five (5) criteria including (i) institutional framework for NPIS; (ii) development of conceptual models, methodologies and tools to incorporate DRM in PIPs; (iii) dissemination, training and technical support on the incorporation of DRM in NPIS to the relevant actors; (iv) policy consensus and follow up on the gradual adoption of technical tools for the incorporation of DRM in NPIS; and (v) mechanisms of

[8] NPIS refers in this study to the definition made by Ortegón and Dorado (2006), a set of standards, instruments and procedures common to the public and private sector entities that execute public investment in preparation, execution, and follow-up projects within the national framework of development policies, plans and programs. The methodology of this study was developed as a technical input for the Bank's Regional Policy Dialogue in 2012.

control[9]. Each of the 23 parameters are assessed by interviews with senior or high-level officials to evaluate, with a certain justification, its progress and then categorize the results on three levels of development: green (complete progress), yellow (in progress), and red (no progress).

The study has been applied to 10 member countries of the Bank, which have also participated in the IDB's Regional Policy Dialogue meetings during 2012 – 2015 viz. Costa Rica, Panama (applied twice in 2012 and 2014), Barbados and Trinidad & Tobago (in 2013), Colombia, Peru and Guatemala (in 2014) and The Bahamas, Guyana and Jamaica (in 2015)[10].

Results

Figure 3.1 shows the study results for all 10 countries. The results of the study indicate:

- According to the result of category 1, the institutional framework for NPIS (regulation, organizational structure, approval process and manual) is well established (either completed or about to complete); 91% of the parameters (a total of 70 items evaluated – seven parameters across 10 countries) are either "complete progress" or "in progress". The 10 study countries already have legal frameworks for NPIS with legislation, organizational structure and approval mechanisms of public investment projects (PIP). However, the absence of a communication instrument (manual for the NPIS and Guidelines of the PIP) is still a pending issue for some countries.

- The conceptual models, methodologies and technical tools for incorporating DRM in PIP (topic of category 2) need to accelerate progress. 58% of the parameters (total 60 items: six parameters across 10 countries) resulted with either "no progress" or "in progress". A technical methodology for DRM incorporation in PIP and the tool to guide the incorporation of DRM in NPIS has progressed well (all of the countries were assessed as "complete progress" or "in progress"). However, five or 50% of the study countries lack the mechanism of technical approval of the PIP including risk analysis.

- Dissemination, training and technical support for DRM incorporation in PIP (category 3) showed unfavorable progress. 80% of the parameters (total of 50 items: five parameters across 10 countries) had "no progress" or "in progress". None of the 10 study countries had personnel responsible for the project design trained in the application of risk analysis.

- Policy consensus and follow-up mechanism (category 4) also resulted with an unfavorable progress. None of the countries except Colombia and Peru had completed all three parameters of this category including the periodical upgrade of the regulations, the timely management of the project variability, and the mechanism to share successful experience.

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[9] (i) institutional framework for NPIS; (ii) development of conceptual models, methodologies and tools to incorporate DRM in PIPs; (iii) dissemination, training and technical support on the incorporation of DRM in NPIS to the relevant actors; (iv) policy consensus and follow up on the gradual adoption of technical tools for the incorporation of DRM in NPIS; and (v) mechanisms of control. See IDB (2012) for details of all 23 parameters and a detailed methodology of this study.

10 The results of this study were disseminated in three Regional Policy Dialogue meetings in Guatemala (in 2012), Panama (in 2014) and Barbados (in 2015). For example, the aspect DM includes the subject of "emergency preparedness plan" as one of the six "sub-indicators".

- Quality control mechanism (category 5) resulted with the worst progress among the five categories. None of the countries in this category, except Colombia, had any progress for both parameters related to audit and sanctions.

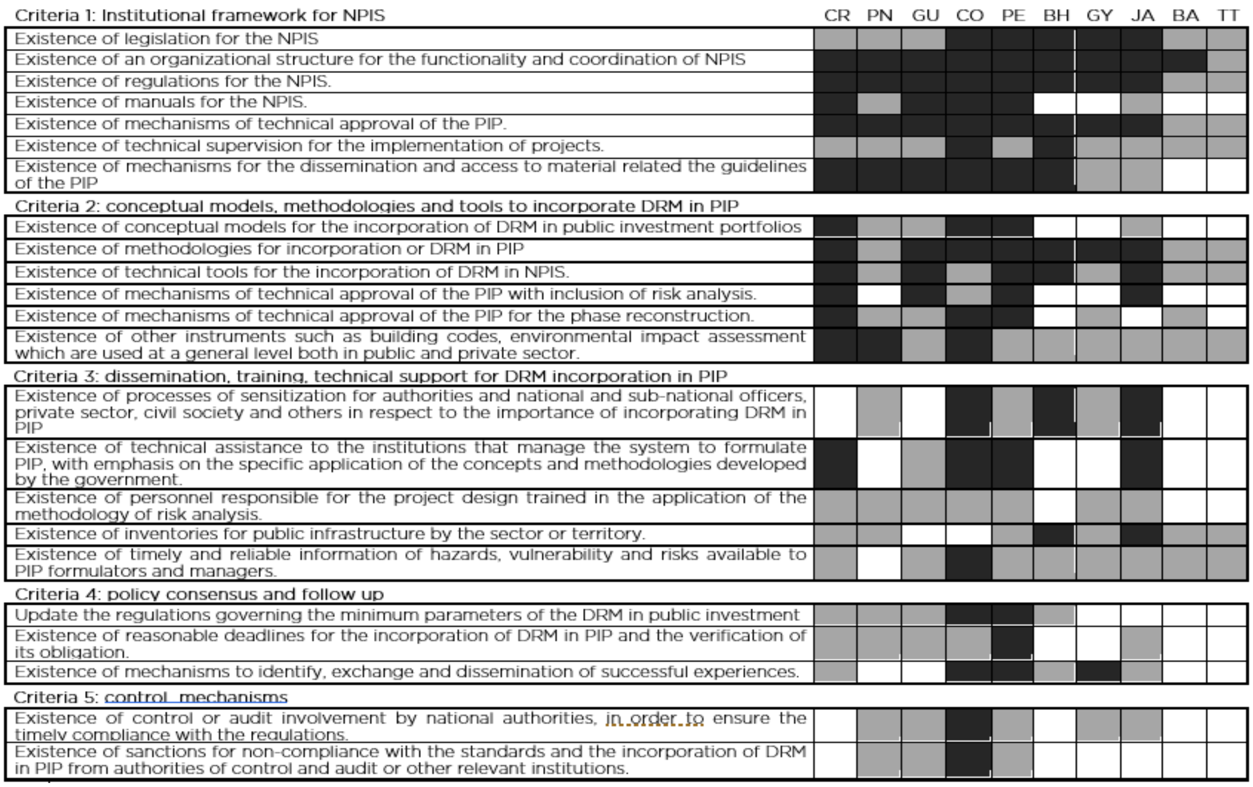

Figure 3.1. Results of the NPIS study on DRM in 10 countries. CR=Costa Rica, PN=Panama, GU=Guatemala, CO=Colombia, PE=Peru, BH=The Bahamas, GY=Guyana, JA=Jamaica, BA=Bahama and TT=Trinidad and Tobago. Black mark means the complete progress, gray means in progress, and white means no progress.

3.3 Risk Management Indicator (RMI)[11]

Methodology

Different from the Infrastructure iGOPP and the NPIS analysis, which measure the existence of policy, legal and financial instruments, the Risk Management Index (RMI) measures an institutional and community performance on DRM, or whether actions are meaningfully taken for disaster risk reduction. RMI consists of 24 indicators grouped by four components (six indicators in each component)[12], and each of the 24 indicators (See IDB (2007) for details of the criteria of

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[11] RMI is one of the IDB's five Indicators. See previous footnote 5 for its background.

[12] The four components are: Risk Identification (RI: Activities related to technical, scientific and academic studies and researches); Risk Reduction (RR: Disaster risk mitigation or civil protection measures that public and private entities plan, implement and maintain); Disaster Management (DM: Emergency preparedness in general; planned, coordinated, organized and maintained by local/national civil protection agencies and community organizations); and Governance and Financial Protection (FP: financial arrangement, preparation and disbursement for immediate response, rehabilitation and reconstruction in case of disasters. The

these 24 indicators) assess performance from level one (*low* performance) to level five (*outstanding* performance). This assessment is made through interviews with 10 to 20 national and international experts using a standard evaluation criteria[13]. With specific weight settings in each of the four components and a unique calculation including fuzzy-sets and centroid evaluation methodology to adjust subjectivity of the interviewer raised by the linguistic interview[14], the RMI measures its value (or each country's DRM performance) from 0 (minimum) to 100 (maximum).

The latest application of RMI was made during 2014-2015 in the following 15 countries: Argentina, Belize, Bolivia, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Jamaica, Mexico, Nicaragua, Peru, and Venezuela[15].

Results

Table 3.2 shows the results of the RMI for 15 study countries in 1995, 2000, 2005, 2010 and 2013. Figure 3.2 shows the average RMI value of the 15 countries.

The RMI result of 15 counties indicate the following three general implications related to the progress of the institutional and community performance on DRM.

- The average RMI value of the 15 countries has been constantly increasing from 1995 to 2013. This means the institutions' and communities' performance on DRM is consistently improving. Despite that, the recent RMI average value (in 2013) is 37.32 out of 100, meaning the study countries still have a significant opportunity to improve the institutional and community performance for reducing disaster risk.

- The Risk Identification (RI) component, which measures the existence of hazard, vulnerability and risk evaluation and its dissemination to incorporate in development planning, made progress, increasing from 4.6 (of full RMI RI score 25) in 1995 to 10.88 in 2013 (240% increase, based on the 1995 value), resulting in the greatest increase among the four components of RMI. The increase was reflected particularly in the following sub-indicators: historical disaster loss inventory, hazard monitoring and hazard mapping were favorably progressed in the study countries. Vulnerability/risk analysis were observed as its favorable progress but only in some countries. Public dissemination and training in risk analysis have made less progress.

- RR, which measures the existence of actions necessary for reducing the risk, improved from 4.82 (1995) to 8.52 (2013) - a 170% increase, the worst progress and the one of the lowest value among all four RMI components (IR, RR, RM and PF). Especially the sub-

Ministry of Finance and Economy is in general the main actor for this). See http://www.preventionweb.net/publications/view/47999 for details.

[13] See Main Technical Report of the Indicators (p80-83): http://www.preventionweb.net/publications/view/47999

[14] See Main Technical Report of the Indicators (p84-87): http://www.preventionweb.net/publications/view/47999

[15] The results of the RMI are published in the Bank's publication portal site as Technical Notes, together with the result of other three indicators. See IDB Portal Site: http://www.iadb.org/en/research-and-data/regional-policy-dialogue/meetings-disaster-risk-management,17736.html

components related to land use and urban planning, civil protection infrastructure and retrofitting practices were observed to have less progress in the study countries.

- RM, which measures the effectiveness of the organization capacity and planning operativity in case of disasters, made progress increasing from 4.84 (1995) to 11.27 (2013) – a 230% increase and one of the highest improvements from 1995. Especially the sub-component related to the emergency response planning development, the simulation practice, and the community preparedness exercise showed great enhancements. On the other hand, the subject related to planning for rehabilitation and reconstruction observed unfavorable progress.

- PF, which measures the establishment and availability of financial resources for DRM, improved favorably by 220%, from 3.24 (1995) to 7.05 (2013), however, its value is the worst among the other four sub-components. Especially the performance on the reserve funds for institutional strengthening, budget allocation and mobilization, and insurance coverage did not make favorable progress.

3.4 Summary and implications

Drawing from the findings of the results of the three studies, a number of conclusions can be drawn about the status related to the DRM national framework for disaster resilient infrastructure in LAC countries.

First, the incorporation of DRM in project design/implementation is not always a national policy mandate for the LAC countries. This is especially observed from the result of iGOPP; no responsibility is assigned for risk assessment and risk reduction in many countries in many sector ministries. NPIS study identified five countries (50% of the study) that lack the mechanism of technical approval of the PIP with inclusion of risk analysis. This unfavorable situation may be due to the lack of information necessary for risk analysis; the result of RMI indicated that the disaster risk or vulnerability study is only made in some limited countries; even though many countries have made progress in hazard monitoring and analysis risk and vulnerability analysis is still insufficiently developed in LAC countries. Only a few sectors in limited countries assigned responsibility for sectorial risk analysis to incorporate in the project design, according to the result of iGOPP.

The LAC countries have made some specific progress related to the DRM policy. The result of the Infrastructure iGOPP indicate that 11 out of 15 study countries already have building standards that incorporate seismic hazard risk consideration in development projects. In nine out of 15 study countries, there are regulations on development planning and land use to specify hazard risk area. The SNIP study indicates that the technical methodology for DRM incorporation in PIP and tool to guide it have made favorable progress. On the contrary, the results of the RMI indicate that land use, urban planning, civil protection infrastructure, and retrofitting practices were observed to have less progress. This means that while the LAC countries have made some progress made in policy framework, its implementation in practice still needs further progress. In none of the SNIP study countries do exist personnel responsible for the project design trained in the application of the risk analysis.

Table 3.2: result of the four sub-indicators of RMI for 15 countries.

		1995	2000	2005	2010	2013			1995	2000	2005	2010	2013
Argentina*	**RMI total (0-100)**	**19.13**	**20.13**	**21.5**	**26.53**	**36.87**	**El Salvador**	**RMI total (0-100)**	**22.64**	**33.02**	**13.52**	**28.2**	**34.1**
	RI (0-25)	3.6	4.14	4.3	8.86	9.99		RI (0-25)	7.36	7.53	7.53	10.68	13.08
	RR (0-25)	5.4	5.68	6.34	6.95	10.91		RR (0-25)	3.44	6.55	1.31	5.84	6.26
	DM (0-25)	8.69	8.87	9.42	9.28	13.52		DM (0-25)	2.85	9.58	2.77	8.46	10.76
	PF (0-25)	1.44	1.44	1.44	1.44	2.45		PF (0-25)	9	9.36	1.91	3.23	4.01
Belize	**RMI total (0-100)**	**21.35**	**23.29**	**23.29**	**23.08**	**34.73**	**Guatemala**	**RMI total (0-100)**	**24.26**	**38.49**	**17.92**	**23.11**	**38.02**
	RI (0-25)	3.92	5.86	5.86	6.87	8.91		RI (0-25)	3.24	9.31	4.3	4.3	11.06
	RR (0-25)	5.69	5.69	5.69	11.41	7.62		RR (0-25)	3.29	4.3	3.06	4.3	9.78
	DM (0-25)	11.75	11.75	11.75	11.74	13.03		DM (0-25)	10.74	17.44	8.54	9.09	11.02
	PF (0-25)	0	0	0	6.1	5.17		PF (0-25)	7	7.45	2.01	5.41	6.17
Bolivia	**RMI total (0-100)**	**5.57**	**11.25**	**9.45**	**15**	**25.51**	**Jamaica**	**RMI total (0-100)**	**40.69**	**45.06**	**31.01**	**33.13**	**35.59**
	RI (0-25)	1.31	4.03	3.42	4.3	9.82		RI (0-25)	10.34	14.34	10.34	9.76	10.83
	RR (0-25)	1.64	2.99	1.31	4.3	7.93		RR (0-25)	8.61	8.61	4.3	6.11	6.3
	DM (0-25)	1.31	1.88	3.17	4.3	4.3		DM (0-25)	12.59	12.95	12.81	11.99	12.81
	PF (0-25)	1.31	2.35	1.55	2.09	3.45		PF (0-25)	9.15	9.15	3.55	5.27	5.65
Chile	**RMI total (0-100)**	**19.66**	**25.8**	**28.37**	**36.12**	**41.67**	**Mexico**	**RMI total (0-100)**	**27.13**	**41.98**	**34.77**	**34.69**	**38.83**
	RI (0-25)	4.3	4.3	6.87	6.87	7.95		RI (0-25)	9.82	12.64	9.92	8.96	13.08
	RR (0-25)	7.88	10.78	10.78	11.41	11.41		RR (0-25)	9.86	9.86	9.04	5.67	4.3
	DM (0-25)	4.3	7.56	7.56	11.74	16.2		DM (0-25)	4.12	10.98	8.85	10.41	11.18
	PF (0-25)	3.17	3.17	3.17	6.1	6.1		PF (0-25)	3.33	8.51	6.96	9.66	10.27
Colombia	**RMI total (0-100)**	**30.27**	**37.57**	**40.05**	**35.52**	**45.7**	**Nicaragua**	**RMI total (0-100)**	**-**	**-**	**42.25**	**33.99**	**44.56**
	RI (0-25)	10.07	11.98	11.25	11.25	11.95		RI (0-25)	-	-	11.67	11.25	12.6
	RR (0-25)	9.64	10.46	12.28	11.25	11.25		RR (0-25)	-	-	9.85	9.44	10.85
	DM (0-25)	3.4	5.8	7.27	7.27	11.25		DM (0-25)	-	-	12.83	10.6	13.1
	PF (0-25)	7.16	9.33	9.25	5.75	11.25		PF (0-25)	-	-	7.89	2.71	8.02
Costa Rica	**RMI total (0-100)**	**43.31**	**48.28**	**31.23**	**34.79**	**47.74**	**Peru***	**RMI total (0-100)**	**7.67**	**15.69**	**18**	**27.94**	**40.9**
	RI (0-25)	10.02	11.74	9.07	5.56	12.17		RI (0-25)	2.47	3.43	4.3	4.3	11.25
	RR (0-25)	11.96	12.3	6.22	9.91	11.22		RR (0-25)	2.58	7.18	7.44	7.7	9.94
	DM (0-25)	14.38	13.16	8.25	10.51	12.46		DM (0-25)	1.31	3.77	4.23	9.92	11.04
	PF (0-25)	6.95	11.08	7.69	8.8	11.89		PF (0-25)	1.31	1.31	2.02	6.02	8.67
Dominican Republic	**RMI total (0-100)**	**6.55**	**15.9**	**23.5**	**21.53**	**34.01**	**Venezuela**	**RMI total (0-100)**	**11.03**	**17.22**	**22.67**	**27.9**	**29.11**
	RI (0-25)	1.89	3.44	6.66	6.66	11.1		RI (0-25)	2.53	3.92	7.96	9.13	9.13
	RR (0-25)	2.05	6.16	4.2	3.04	6.77		RR (0-25)	3.3	8.1	8.1	7.99	7.77
	DM (0-25)	1.31	3.86	8.79	8.25	8.25		DM (0-25)	3.13	3.13	3.72	6.75	8.19
	PF (0-25)	1.31	2.45	3.86	3.59	7.9		PF (0-25)	2.07	2.07	2.89	4.02	4.02
Ecuador	**RMI total (0-100)**	**17.95**	**24.53**	**18.68**	**22.11**	**37.34**							
	RI (0-25)	8.53	10.62	4.48	6.14	10.92							
	RR (0-25)	3.92	4.14	4.3	3.28	4.3							
	DM (0-25)	4.19	8.46	6.14	8.71	11.55							
	PF (0-25)	1.31	1.31	3.76	3.99	10.57							

Many specific topics show unfavorable progress in both policy framework consolidation and its implementation in practice. Most of the study countries have no budget allocation for disaster risk reduction in practice except some few sector ministries, according to the result of iGOPP. Additionally, the RMI study indicated that slow progress has been made in establishing the reserve funds for institutional strengthening, budget allocation, mobilization, and insurance coverage. The contingency plan and rehabilitation and reconstruction plan is another challenge for both policy enactment and implementation in practice, according to the result of iGOPP and RMI. Especially the contingency plan is important to normalize socioeconomic activities as quick as possible in case of disaster, e.g., to normalize the function of public roads and other transportation facilities, electricity, water, communication and other critical services in case of disaster.

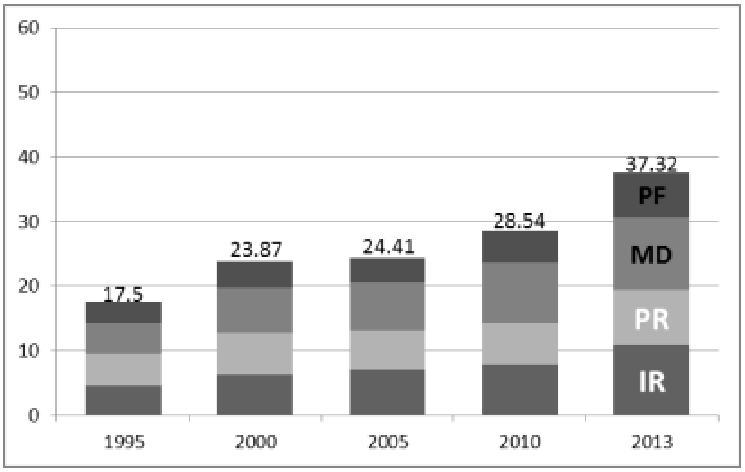

Figure 3.2. Average of the four sub-indicators of RMI of 15 countries.

4. Recent Infrastructure Damages in LAC region due to Disasters and Lessons

Based on the challenges identified, this section reviews recent infrastructure damages due to disasters in LAC region and identifies lessons. The section reviews the following four recent case studies that damaged infrastructure. These four case studies are related to the projects financed by IDB in its planning and implementation, as well as IDB financed in recuperation phase after disaster: (i) Ecuador earthquake in April, 2016; (ii) Floods in Argentina due to "El Niño - Southern Oscillation" (ENSO) during 2015-2016; (iii) Honduras earthquake in May 2009; and (iv) Flush foods in Santa Ana, El Salvador in 2014.

4.1 Ecuador Earthquake in April 2016.

Background

Ecuador is one of the most vulnerable countries in the LAC region in terms of its exposure to multiple natural hazard events; 24.4% of its national territory, 73.6% of the total population and 72.2% of the GDP are exposed to two or more natural hazards (World Bank, 2005). Between 1900-2015, the country was affected by 96 major disasters, including earthquakes, floods, landslides and volcanic eruptions, among others (EM-DAT, 2016). These disasters include 13 severe earthquakes with the Mercalli intensity scale seven or greater.

On Saturday April 16th, 2016, a 7.8 magnitude earthquake struck the coastal region of Ecuador. The epicenter of the earthquake was 27 km away from the coastal town of Muisne (west of the Esmeraldas Province), with a 20 km depth. Immediately following the earthquake, the Government of Ecuador (GoE) declared a state of emergency, activating its emergency operations center and deploying military and national police forces to assist with rescue and first-aid response in six provinces: Esmeraldas, Guayas, Los Ríos, Manabí, Santa Elena and Santo Domingo.

The total number of deaths caused by this earthquake amounted to 668 (La Hora, 2016); the Ministry of Public Health reported 16,600 injured people that received medical attention; 25,640 people were in emergency shelters; 51 public health facilities and 875 schools were damaged or affected; and 35,000 housings were unsafe to use. 83 km of roads and US$67 million of water facilities were damaged. Total amount of damage and loss is estimated to total US$3,300 million, of which 67% is public infrastructure damage (ECLAC, 2016a). This earthquake was one of the most severe catastrophes in Latin American history.

Some of the infrastructure damages include the projects that IDB have financed to the GoE. These include schools damaged in Pedernales and La Siberia that were financed by the recent IDB operation: National Infrastructure Program for the Universalization of Education with Quality and Equity (Project #: EC-L1075).

Project Description

The objective of the Program EC-L1075 is to incorporate 40,000 new students in 45 selected parishes into Ecuador's educational system where many children have limited educational opportunities. The project components/sub-components include the construction of school facilities, the provision of equipment necessary for educational program implementation, and the capacity development for teachers, among others. The output includes 660 early childhood education classrooms, 102 first grade classrooms, and 886 high school classrooms in the selected 45 parishes. The Bank approved this project in 2010 with a total amount of US$75 million. By the end of 2015, 77% of the approved budget had been disbursed.

Damages

Some school facilities constructed with the financial resources of EC-L1075 were damaged due to the April 2016 earthquake (Figure 4.1) including the following two located in Pedernales and La Siberia:

Pedernales. This school was located close to the April 2016 earthquake epicenter thus the impact was greater than the other facilities. When the earthquake hit, this school was under 90% of its construction progress. Most of the damage was to non-structural components - walls, ceilings and windows (Figure 4.1(a)). Structural components (e.g., columns and beams) were generally not seriously damaged, aside from one joint that experienced some damage (Figure 4.1(b)). Fortunately, there were no children directly affected by these damages because the earthquake hit on late Saturday. However, if the earthquake had occurred during school operation time, a large number of children would have likely been affected due to the serious non-structural damages. Cost to be necessary for the repairs is estimated to be approximately US$1.6 million.

La Siberia. This school was still at 60% of its construction progress when the earthquake hit in April 2016. The structure remains, but a joint of the columns and beams was seriously damaged (Figure 4.2). It is supposed that this damage was not only made at the single main shock in April 16 but during the multiple aftershocks after April 16. Applicability of concrete materials was observed as an issue. Cost necessary for repairs was estimated approximately US$300,000.

Fortunately, the damages in both cases were covered by earthquake insurance.

Figure 4.1. Schools damaged by the earthquake: top (two photos): in Pedernales – left (a) shows the most of the damages are the non-structural parts, and right (b) shows a joint damage of this school. Photos: IDB.

Figure 4.2 Joint damage in the school in La Siberia. This school was under construction when hit the earthquake. Photo: IDB.

Points to be discussed

The damages occurred in the two school facilities in Ecuador were observed due to:

- Severe damage of the non-structural building parts (e.g., walls and ceilings).
- Structural part damaged (the joint between column and beams) due to the repeated aftershock.
- Building material may not have been used appropriately.

4.2 Floods in Argentina, 2015-2016.

Background

From 1970 to 2015, the country was affected with 97 disasters of high intensity (EM-DAT, 2016): 93% were hydro-meteorological events (floods and landslides caused by heavy rains) that affected 14 million people and caused US$10,000 million in economic losses; the remaining 7% were geological events including earthquakes and volcanic activity that affected 110,000 people and caused US$180 million economic losses. In recent years, hydro-meteorological events have become more frequent; in the last decade (2005-2015), 27 disasters were registered in the EM-DAT database, while the 1970s only experienced 10 disasters.

One of the most severe hydro-meteorological hazards affecting Argentina is El Niño - Southern Oscillation (ENSO), a cyclical weather phenomenon characterized by rising sea temperatures in the equatorial Pacific Ocean. In Argentina, ENSO usually begins in September and continues until June or July of the following year. The recent intensive ENSOs occurred during 1982-83, 1991-92 and 1997-98. Severe floods in many river basins of the La Plata River occurred during these periods and affected the Provinces of Formosa, Chaco, Santa Fe, Buenos Aires, Misiones, Corrientes and Entre Ríos; these provinces comprise 90% of the country's population and 70% of the Gross Domestic Product (GDP).

The latest ENSO started in August 2015 and heavy rains were observed in the provinces of Buenos Aires, Cordoba and Santa Fe. Several continuous floods occurred in the watersheds of the Luján, Arrecifes, Areco and Salado rivers. By the end of December 2015, intense rain was observed on the Uruguay River basin which generated floods and affected villages located downstream of Salto Grande Concordia, Colón and Concepción del Uruguay. The coastal towns of the Parana and Paraguay rivers were affected repeatedly on January 2016. Other severe floods occurred in the same river basins in March 2016. Until May 2016, a total of 40,000 people were affected and 10,000 people were evacuated (The Government of Argentina, 2016). The Oceanic Niño Index (ONI) indicated that 2015-2016 ENSO's peak intensity was 2.3; this peak value is greater than 1982-83 (2.1) and 1991-92 (1.6) (NOAA, 2016).

Project Description

After the devastating floods from January to May 2016, the IDB approved a loan known as the Emergency Program for an Immediate Response to the Flooding in Argentina (AR-L1245) in June 2016 with a total amount of US$20 million. The objective of this loan was to collaborate with the government's efforts to restore infrastructure and basic services affected by the heavy rains and floods induced by ENSO. The Activities of this loan include (i) the rehabilitation of 40 km of roads and highways; (ii) the rehabilitation of 18 km of flood protection infrastructures; (iii) the cleanup and rehabilitation of basic services for 14 communities including electricity, water, and sanitation, and (iv) the rehabilitation of 103 public buildings including schools and evacuation centers. The beneficiary includes seven Provinces: Formosa, Chaco, Santa Fe, Buenos Aires, Misiones, Corrientes and Entre Ríos.

Damages

Some of the infrastructures that were damaged and restored by the financial support from the Bank include:

Rural path in the Nuevo Puerto Bermejo City, Chaco Province. A road between New Puerto Bermejo City and Old City (and its port) (4.5km) had severe erosions due to heavy rains and floods during December 2015 and February 2016 (Figure 4.3). Nearly 2,500 people, including local citizens and the citizens living in neighbor cities, use this rural path on a daily basis. This path is important for local socioeconomic activities for Paraguay as well. For example, some Paraguay citizens use this path to take advantage of a health facility in Nuevo Puerto Bermejo City. The total cost for the rehabilitation of this path was estimated at US$1.4 million. In fact, this rural path had been repaired twice before; after the ENSO related floods in 1983 and in 1992. This third repair was realized with the financial resources of the AR-L1045 loan, however, the focus of these financial resources is just for repairs, additional investment would be necessary to protect from future floods under the concept of "build back better" (Salvatierra, 2016).

Figure 4.3. The rural path with erosions due to floods. Source: Salvatierra (2016)

Water control and pumping facility in Las Palmas – La Leonesa, Chaco Province (in Argentina). This flood control infrastructure was constructed just after the 1997-98 ENSO flood (Figure 4.4). The components of this infrastructure include water pumping stations, river defense walls along with the Paraguay River, and drainage networks for inland water control. The water pumping stations (Figure 4.5) did not work correctly during the 2015-2016 ENSO. River defense walls and drainage networks were also damaged. As a result, Las Palmas and La Leonesa, with a total 2,500 population located in the river basin, were affected by floods. In fact, after the installation of this infrastructure (after the 1997-98 ENSO floods), this area was affected by droughts for a long time. At that time, the local government gave high priority to protect the citizens from drought impact, which meant that flood control was temporary a low priority and minimal maintenance was made for many years. As a result, the infrastructure was not effective during the ENSO rainy season of 2015-2016, causing severe floods in the area.

Figure 4.4. Flood control facility (water pump station) constructed just after the 1997-97 ENSO floods. Source: Salvatierra (2016)

Figure 4.5. Flood control facility damaged during 2015-2016 ENSO. Source: Salvatierra (2016)

Points to be discussed

The damages occurred during 2015-16 ENSO in Argentina may indicate:

- Given that the "build back better" concept was not applied, immediate repair works were needed three times in the same place.
- Drought and floods occur alternately. No maintenance for drainage (or flood control) infrastructure was performed during the lengthy droughts.

4.3 Honduras Earthquake, May 2009

Background

Honduras is one of the most vulnerable countries in the world in terms of its hazard susceptibility; historically the country has suffered significant impacts due to disasters (Birkmann et al., 2011; UNDP, 2012). Over the last decade, 15,548 people in the country have lost their lives and additionally, US$4.41 billion of economic assets and activities were lost due to disasters (The World Bank, 2010). These damages are mostly due to climate-related hazard events, especially floods and hurricanes. For example, Hurricane Mitch in 1998 caused an economic loss equivalent to 52% of its GDP (IDB, 2009). Conversely, the country has recorded only a few earthquake events and therefore has made fewer efforts to prepare against earthquake hazards.

However, on May 28th 2009, an earthquake of 7.3 magnitude hit the Atlantic coast of the country. This event caused at least 20 casualties, 136 injuries, and nearly 13,000 houses were damaged or destroyed (COPECO, 2009). Additionally, the earthquake damaged 37 bridges, 248 schools, 51 roads/highways, 56 churches, 27 hospitals, 17 water infrastructures and 69 public administration buildings. Most of the damages occurred in the northern area of the country including Atlántida, Cortés, Intibuca, and Santa Bárbara (COPECO, 2009). The liquefaction effect was observed to cause additional damage to infrastructure including terminals, ports, wharfs, and small buildings located in and near Puerto Cortes (Luna, 2010).

Project Description

The IDB approved a loan program titled "Judicial System Modernization (HO0109)" in 1996. The aim of this program was to modernize the national justice system. The total amount of the investment was US$7.7 million. The program included three components: 1) the modernization of legislation; 2) the institutional strengthening; and 3) the access to justice. Before starting the Program, it was difficult for citizens to access the justice system because of its insufficient access points; on average, there was a judge for every 12,416 citizens. Additionally, most judges and courts were concentrated in the metropolitan area and the west central region of the country (IDB, 2000).

The program, through its component 3, financed the construction of 86 additional court house buildings for justice of peace[16] in municipalities including Atlántida, Colón, Comayagua, Choluteca, El Paraíso, Morazán, Olancho, Yoro, Cortés, Intibucá, La Paz, Santa Bárbara, Ocotepeque, Copan, and Valle (Palao William & Co., 2003). The total investment of the construction work was US$4.6 million. Additionally, a grant Technical Cooperation project (ATN/SF-5170-HO) supported the installation of additional equipment[17]. The program was completed in 2002 with the construction of all 86 court houses in the beneficiary municipalities. However, some of these facilities were damaged due to the 2009 earthquake.

Damages and Losses

The Municipality of Omoa (in the Department of Cortés) was seriously damaged due to the 2009 earthquake (La Prensa, 2009). Copeco (Comisión Permanente de Contingencias) reported severe damage observed in basic infrastructure of this region including housing, schools, catholic churches, clinics (Figure 4.6), and court house buildings (La Prensa, 2009). Within these damaged infrastructure, a clinic and the court house were financed through the Program HO0109. These facilities' perimeter and building walls were seriously damaged. Additionally, outside of Omoa there were additional 11 court house buildings for justice of peace across the country that suffered similar damages to the perimeter and building walls, roofs, aqueducts and metallic doors (CJPJH, 2015). These damages were repaired during 2014 – 2015. The total repair cost was more than US$12 million (CJPJH, 2015).

[16] The judicial branch of government consists of a Supreme Court of Justice, Courts of Appeals, Courts of First Instance (*Juzgados de Letras*), and Justices of the Peace. The lowest level of the court system consists of justices of the peace distributed throughout the country. (Center for Administration of Justice)

[17] Under this subcomponent, for municipalities in which the population is less than 10,000, the buildings with an area of about 140 m^2 were built, while for the municipalities in which the population is more than 10,000, the buildings with an area of about 220 m^2 were built.

Figure 4.6. A clinic located in Municipality of Omoa. Photo: La Prensa.

One of the infrastructures that was severely damaged was the Supreme Court building of San Pedro Sula (Figure 4.7)[18]. The damages in this specific case were caused by soft soil and reclaimed land (Luna, 2010). Soft soils amplify ground shaking so that buildings on soft soils tend to be damaged or destroyed easily (USGS, 2016). The Court building, a reinforced three-story concrete frame, was constructed on 3m depth of soft soil without ground-strengthening or building foundation strengthening measures. In contrast, a multi-story reinforced concrete stadium located less than a half mile away constructed on strengthened ground experienced only minor damages (Luna, 2010). This experience illustrates the importance of soil analysis and the implementation of strengthening measures to reduce earthquake risk.

An additional cause of the Court building damages was due to its insufficient structural design; damages were observed in walls made by concrete frames in-filled with brick masonry (Luna, 2010). This in-filled wall design had a small separation between the column and the in-fill, which caused weakness of the building and evolved in small gaps which led to the structure's failure (referred to as "short-column effect"). This is a well-known problem, but is often ignored in practice (Luna, 2010). The Court building in San Pedro Sula was finally reconstructed with anti-seismic technology and re-opened in 2015 with a total cost of US$6 million.

Figure 4.7. Damaged Building of Supreme Court in San Pedro Sula. Photo: HRN La Voz de Honduras

[18] However, this facility was not build with the finance of the Program HO0109.

Points to be discussed

- No soil condition survey. Building damage due to the soft soil and increased shaking intensity.
- Structural damage due to the appropriate use of materials (e.g., in-filled walls).

4.4 Flash floods in Santa Ana, El Salvador, September 2014

Background

El Salvador, located in the northern area of Central America, is exposed to multiple hazard events including hurricanes, earthquakes, floods, droughts, landslides and volcanic eruptions. From 1980 to 2015, the country has experienced 46 "large scale" or intensive disasters that affected a total of 3.7 million citizens (EM-DAT, 2016). Recent severe disasters in the country include two earthquakes in 2001 (amounting a total of US$1,604 million economic loss (ECLAC, 2001)); Hurricane Stan and the Santa Ana Volcano eruption, both in 2005 (in total US$355.6 million of economic loss (ECLAC, 2005)); and the tropical storm 12E in 2011 (US$ 902.3 million of economic loss and 500,000 people affected (ECLAC, 2011)).

In addition to the intensive disasters, the country is suffering from non-intensive, or "daily" small scale disasters across the country. For example, Santa Ana city, with its 290,000 population and located 60 km northwest of the nation's capital, San Salvador, has experienced 43 floods from 1980 to 2011; nearly 1.5 floods/year, and these floods affected 62,000 local citizens in total (DesInventar, 2016). The impact of small scale disasters in developing countries should not be overlooked (Passerini, 2000; Hardoy et al., 2001; Zimmerman and Carter, 2003; Sperling and Szekely, 2005; Hellmuth et al., 2007; Ahmed et al., 2009; McSweeney and Coomes, 2011). Instead, cumulative effects of small scale disasters are a sign of a potential large scale disaster (Quarantelli, 1998; Birkmann, 2006; Lavell et al., 2012).

Project Description

The IDB, in coordination with the municipality and the national government, elaborated the Santa Ana Action Plan in 2012. This Action was developed under the IDB's Emerging and Sustainable Cities Initiative (ESCI). The aim of the Plan was to provide greater development opportunities and sustainable welfare to the citizens (IDB, 2012a). The Plan intended to address the emergent needs and challenges of the city, including the 2.6% annual population growth in the last decade (the highest growth rate of the country - four times more rapid than other cities of the country). Based on this, the Plan defined three priority pillars including the appropriate preparation for hazard events.

Prior to the Plan, the IDB developed a technical study to identify probable local flood areas and its eventual socioeconomic impact (IDB, 2012b). According to the study, more than 20,000 citizens will be affected even due to a high frequent flood (once every 10 years' probability, Figure 4.8). On these bases, the Action Plan recommended the two lines of actions for flood risk reduction including (i) reforestation and land use management in the upper watershed, and (ii) additional drainage infrastructure to reduce impact from floods in the lower watershed.

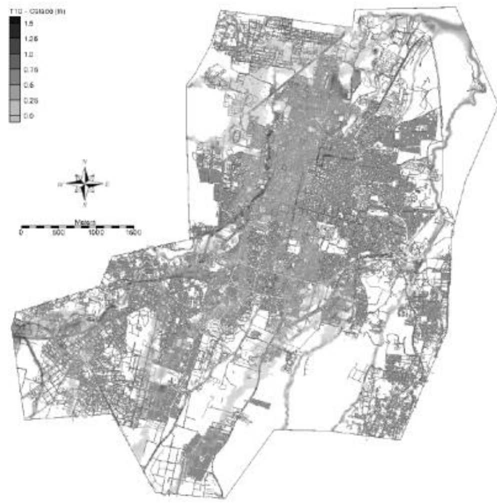

Figure 4.8. Flood hazard map (probability of once 10 years). Source: BID (2012b).

Damage and losses

Two floods occurred in Santa Ana during 2014, or after two years of the Action Plan. The first flood occurred in May 2014 in several areas of the city - not only in the lower watersheds (or urban area) but also in the middle-upper watershed where the water-flow runs directly from the Santa Ana volcano[19]. Additionally, the water flow was intensified due to significant garbage thrown, which blocked the drainage[20]. The Local Red Cross reported some people that severely affected that needed to be rescued (ElSalvador.com, 2014). Local authority estimated a US$15 million fund was needed to resolve the problem (ElSalvador.com, 2014).

Another flood occurred in September 2014, four months after the flood in May (Figure 4.9). The Ministry of Environment and Natural Resources (MARN) recorded a precipitation of 46 millimeters/hour in the urban area (La Página, 2014). The flood was caused not by the volume of the precipitation, but the malfunctioning the drainage system, which experienced reduced performance due to the illegal dumpling (La Prensa, 2014). 14 vehicles were damaged and several citizens had to be evacuated (Redhum, 2014).

[19] There was 14.36% of the forest coverage in the city for 2002; however, it was reduced to 11.32% in 2010 (Dominiguez and Lopez, 2012); this may increase the running water precipitation and thus increase flood risk.

[20] Although there is a change in climate events that should be considered, bear in mind that not everything is due to this. Many of the causes are linked to inappropriate territorial management (garbage blocking the drains, an inadequate drainage system, increasing urbanization, land-use conflicts, and institutions with responsibility gaps).

Figure 4.9. Floods in September 2014 in Santa Ana. Source: Elsalvador.com (2014)
Points to be discussed

The experience of the damages from the floods of 2014 in Santa Ana may imply:

- Increased rainfall runoff from the upper river basin, mainly due to deforestation.
- Two floods in the same year due to the same reason: obsolete drainage system of the city and garbage disposal blocking the drains.
- Institutional gaps in defining clear responsibilities for the maintenance of the drainage system
- No actions in practice even though the high flood risk was identified.

4.5 Summary: lessons learned from recent disasters.

This section reviews the four case studies related to the recent infrastructure damages and extracts key lessons. Table 4.1 shows all the lessons extracted.

1. Discussion - for achieving hazard resilient infrastructure

The lessons from the recent disasters in the LAC region presented in the previous section, in combination with the good practice on DRM in Japan, implies the following challenges for hazard resilient infrastructure in the LAC region:

Lack of disaster risk assessment prior to project design

The previous section identified an inappropriate infrastructure design as a result of a lack of risk assessment prior to the project design. The Supreme Court building of San Pedro Sula suffered serious damages due to the earthquake in 2009 because the project design didn't include a soil survey and an earthquake risk assessment. If the risk assessment was conducted and the needs of retrofitting measures in the structural design had been identified and implemented, damage to the Supreme Court building could have been reduced - as seen in the reinforced concrete stadium

Table 4.1: Summary of the lessons from four case studies**.**

Case Study	Lessons
Ecuador Earthquake in April 2016	• Severe damage of the non-structural building parts (e.g., walls and ceilings). • Structural part damaged (the joint between column and beams) due to the repeated aftershock. • Building material was not used appropriately.
Floods in Argentina, 2015-2016	• Immediate repair works were repeated three times in the same place - no "build back better" concept was taken into consideration. • Droughts and floods occur alternately. No maintenance of drainage (or flood control) infrastructure during lengthy droughts and vice versa.
Honduras Earthquake, May 2009	• No soil condition survey. Building damage due to the soft soil and increased shaking intensity. • Structural damage due to the inappropriate use of materials (e.g., in-filled walls).
Flash floods in Santa Ana, El Salvador, September 2014	• Increased rainfall runoff from the upper river basin, mainly due to deforestation. • Two floods in the same year due to the same reason: obsolete drainage system of the city and garbage disposal blocking the drains. • Institutional gaps in defining clear responsibilities for the maintenance of the drainage system • No actions in practice even though the high flood risk was identified.

located less than a half mile away from the building. The reconstruction cost of the Court building was US$6 million, however the costs for a soil survey and design for structural retrofitting measures would be much lower than this.

Fundamentally, disaster risk or vulnerability assessments are conducted only in some countries in the LAC region, according to RMI results. Disaster risk assessment at the project design level is not always a high policy mandate for the LAC countries. A responsible person is not yet assigned for risk assessment in many sector ministries according to the results of IGOPP. In fact, 50% of the NPIS study countries lack of a formal establishment of PIP approval mechanisms with the inclusion of risk analysis.

In contrast to this, Japan promotes disaster risk assessment prior to the project design phase. In the case of the JICA's investment project in Istanbul, Japan supported, using computer simulation and engineering design, the bridge construction design specifically to protect it from the wake of earthquakes with a probability of 50% in 50 years, and additionally, not to be seriously damaged even during the earthquake at a probability of 2% in 50 years. Prior to the Tietê River Basin flood mitigation project, JICA made a probabilistic risk analysis and identified a once-in-100-year flood exposed area. Additionally, probabilistic risk assessment was made for the Nepal's power plant project. In project designs in Japan, a responsible person is assigned for disaster risk assessment and its inclusion in the project design. When electric companies or authorities construct new dams or hydropower facilities in Japan, they need to obtain an approval from river offices. The national government prepared the technical guidelines for constructing structures, such as dam, weirs, bridges, intakes, and parks, in the whole river basin areas to reduce flood risk.

IDB encourages developing probabilistic disaster risk assessments for the member countries. These include a Disaster Risk Profile at national scale[21] and a Hazard and Risk study at city scale[22]. However, these studies are not always directly referred to in IDB investment projects design. In fact, prior to the project formulation or project profile, IDB screens in its Safeguard toolkit, under the IDB's Environment and Safeguards Compliance Policy, climate/disaster risks that may need further risk analysis for project design (See Annex 1 for more information on the Bank's climate and risk screening efforts). The Bank is currently developing technical guidelines for project teams and clients to successfully implement a disaster risk assessment (DRA) after the screening process so that the Toolkit can fully integrate both the Environment and Safeguards Compliance Policy and the Disaster Risk Management Policy. The approach experienced in Japan, which consists of assigning responsibility and conducting a disaster risk assessment prior to loan implementation and incorporating its result directly into the project design, should be an important reference for the IDB new guidelines.

Needs to review and upgrade building codes of each country

Another lesson observed in this study is related to the seismic risk analysis especially for non-structural construction. Ecuador suffered severe damages of non-structural building parts of schools (ceilings and walls) on Saturday 16th of April 2016. While this specific event resulted in few casualties, had the earthquake occurred during school hours, the school children would likely have been seriously affected due to the damage of the non-structural components. Compromised non-structural building parts is a similar problem that was additionally identified by COSIPLAN (2016), especially at airports and port facilities in the region.

Japan has repeatedly suffered from intensive earthquakes. The government formulated the first building code in 1924 following the Great Kanto Earthquake and has subsequently revised the code several times - including after the Great Hanshin Awaji Earthquake in 1995. Each update of building codes required a significant effort for strengthening national capacity, including policy

[21] See https://publications.iadb.org/ and find with the words "disaster risk profile" or "Perfil de Riesgo"
[22] See http://www.iadb.org/en/topics/emerging-and-sustainable-cities/

reforms, budget assignments, institutional strengthening and repeated laboratory engineering tests. As a result of a combination of this capacity strengthening and practice of retrofitting activities, only minimal damage occurred during the strong main shock of the Great East Japan Earthquake (GEJE) in 2011, even though its magnitude was historically intensive (Mw 9.0).

Efforts for reviewing and upgrading the building codes should include both policy and institutional strengthening and engineering laboratory works. These are the areas in which the IDB could support member countries for increasing hazard resilience infrastructure. Additionally, IDB should have a special role to facilitate sharing lessons among countries, including the Ecuador lessons related to the vulnerability of non-structural construction parts.

Lack of spatial or areal disaster risk management plan

The case study identified two experiences of similar disasters repeated in locations within Argentina and El Salvador. The Argentina case study revealed the experience of repeated repair works required in and around the same rural path after recurring flooding in 1983, 1992 and 2015-2016. Repeated flooding in Santa Ana of the same year (2014) also occurred due to, among other causes, the increased rainfall runoff from the upper river basin due to deforestation, the garbage disposal issue blocking the drains and limited capacity of the drainage system in the urban area. Both recurring disasters are related to climate events - events that have higher frequencies than earthquakes.

Japan is also often affected by repeated floods; the Kobe City located at the foot of the Rokko Mountain Range has suffered from urban floods several times. From the end of the 18th century to date, the national and local government implemented continuous measures to control debris and floods at the river-basin scale which has proven effective. In general, Japan's approach to reduce flood risk is based on the urban flood management regulation of 1977 – at a river-basin scale and not at a city and project level one. This comprehensive and effective approach at the river-basin scale, with a spatial/areal disaster risk management plan, includes a flood risk estimation of the whole river basin, design and implementation of structural measures and nonstructural measures. Because of this areal disaster risk management approach at a whole river-basin scale, Japan has recently reduced repeated flooding events. On these bases, JICA supported the Philippines to mitigate flood risk in the Manila river-basin and the whole metropolitan area. The supports include the flood risk estimation incorporating climate change scenarios, land use planning, design and implementation of measures and non-structural measures.

This comprehensive approach for flood risk reduction at the river-basin scale is hardly seen in LAC countries and within IDB projects. Instead, there are some projects on flood risk reduction limited to an urban area or city scale. Although, the IDB's Emerging and Sustainable City Initiative[23] seems to be an important initiative to do so, this initiative doesn't implement at the

[23] http://www.iadb.org/en/topics/emerging-and-sustainable-cities/emerging-and-sustainable-cities-initiative,6656.html

whole river-basin scale and is limited to urban areas only. This point is important, and a good example is the whole river-basin of Rio Yaque Del Norte, which has been severely affected in 2016 due to repeated and intense rains (the area was also affected by Hurricane Noel in 2007). The Emerging and Sustainable City Initiative developed an Action Plan for Santiago de los Caballeros which focused on the upper river basin of Rio Yaque Del Norte, rather than the whole sustainable river-basin – the latter choice which would have been more effective.

In order to minimize losses and realize resilient infrastructure that covers a whole river-basin, a more holistic approach is recommended to fully addresses all the development elements including climate disaster risk reduction measures within that region. In fact, this idea is better referred to as "a sustainable (whole) river-basin" initiative. Based on the experiences in Japan, this idea of sustainable river-basin initiative should include flood risk estimations that incorporate climate change scenarios, land use planning and structural and non-structural measures at whole river-basins.

Needs for appropriate infrastructure maintenance is another key issue.
This issue was revealed especially from two cases: Argentina and Santa Ana. The Argentina case study observed that one of the reasons behind repeated floods was due to the insufficient maintenance of the drainage system during long-term droughts. After the installation of the drainage system after the 1997-98 floods, the area was affected by droughts for a long time and the local government prioritized measures for reducing drought impact. Consequently, the drainage system was not sufficiently maintained and did not work correctly during 2015-2016, thereby causing floods. The Santa Ana lesson implies that the insufficient capacity of the drainage infrastructure is due to, among other things, the garbage blockage of the drains as well as overall reduced drainage system maintenance. These two challenges might contribute to the lack of infrastructure maintenance related to the LAC region's insufficient control or audit mechanism after project implementation; for instance, nine out of the 10 NPIS study countries had no control or audit by authorities to ensure the function of infrastructures financed from NPIS.

Japan has the guidelines that clarify the responsibility of river offices to inspect the function of flood mitigation infrastructure. The offices conduct routine inspections on the measures once every few years. JICA supported capacity development in Nepal that continued for two decades and included the training on flood risk management infrastructure maintenance. As a result, the Department of Water Induced Disaster Management in Nepal which leads with not only implementing disaster risk management projects but also its leads its inspection and maintenance.

In general, IDB investment projects include a maintenance cost for the infrastructure to ensure its operational function, but the cost is limited only during the project implementation period (around five years). After that, the countries themselves are expected to implement maintenance works with their own resources. The LAC countries already have had a huge amount of infrastructure shocks. Economic incentives that encourage its maintenance are important not only to ensure the infrastructure's original function but also for sustainable hazard resilience. This may be an additional demand for the region. A study Policy Evaluation Framework on the Governance of Resilient Critical Infrastructure in Latin America (IDB, 2016) seems to be an appropriate initiative to start complementing this gap. Additionally, in practice, it should be required to identify the critical infrastructures that are needed for intensive maintenance works in the member countries (or may be called "infrastructure maintenance ratings"), prior to the development of technical designs for the maintenance works and support for policy reform or budgetary resource enhancement of the countries to implement the works.

Multipurpose infrastructure observed in Japan may be an effective approach to increment the efficiency of infrastructure maintenance works. These include the school grounds that are designed for, in addition to its original usage as children's learning facility, retarding ponds to mitigate flood risk in case of heavy rains and elevated expressways which functioned well in Sendai City as a tsunami embankment, protected tsunami waves and reduced housing damages from tsunamis in 2011. Additionally, the Kobe "Green belt" that increased the forestation areas to retain rainwater and reduced flood risk, aggregated recreational and social value of the city. Disaster risk reduction measures can be implemented under this multipurpose infrastructure approach or integrated approach. This may increase the investment effectiveness and may reduce the total maintenance cost. Additionally, this approach can be relatively easy to convince stakeholders and citizens to having more hazard resilience infrastructure rather than to plan specific disaster risk reduction measures.

2. Conclusion

The overall aim of this study was to discuss the LAC countries' further hazard-resilient infrastructure. This paper first reviewed the good experience in Japan for achieving the high-quality infrastructure. The paper then reviewed the overall progress in LAC countries' national framework on DRM and its performance. Lessons from the four recent disaster case studies were also analyzed. Finally, the study discussed and identified the four approaches for realizing hazard-resilient infrastructure in the LAC region. These include:

- **Need for disaster risk assessment prior to project design.** JICA's approach of conducting disaster risk assessments prior to loan design (or infrastructure design) is critical for the building of hazard-resilient infrastructure in the LAC region. IDB screens climate/disaster risk in its Safeguard toolkit to identify the needs of further risk analysis for project design. IDB is currently developing technical guidelines to implement disaster risk assessment (DRA) at the project level after the screening process so that the Safeguard can fully integrate both the Environment and Safeguards Compliance Policy and the Disaster Risk Management Policy. The approach experienced in Japan may be an important reference for the IDB new guidelines.

- **Continuous review and upgrade building codes of each country.** Efforts for upgrading building codes repeatedly in Japan includes both continuous policy/institutional strengthening and engineering laboratory works. IDB could support the member countries based on these experiences in Japan. Additionally, IDB should have a special role to facilitate sharing the lessons learnt among countries, including the recent Ecuador lessons related to the vulnerability of non-structural construction parts.

- **Lack of spatial disaster risk management plans.** All actions necessary for flood risk reduction should be realized in the view of the whole river-basin. The IDB and LAC countries could encourage the comprehensive approaches for flood risk reduction at river-basin scale with longer periods of interventions – this may title a "sustainable (whole) river-basin initiative".

- **Appropriate infrastructure maintenance is critical.** The LAC countries already have had a huge amount of infrastructure shocks but seems to have insufficient resources for maintenance works. Identifying emergent infrastructures of all the IDB member countries should be an entry point to complement this gap – an initiative may be called a "infrastructure maintenance rating."

These four approaches should be realized in practice, such as incorporating these aspects in eventual technical guidelines for JQI. Pilot projects to concretely implement these approaches can also be effective.

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ANNEX 1: Efforts to Mainstream Climate Change, Disaster Risk Management and Sustainability at the IDB

The Bank has also been looking at ways to mainstream climate change, disaster risk management, and sustainability issues within the Bank processes, and to prepare the Bank to respond to the needs and demands of countries for resilient and low carbon infrastructure. The DRM Policy, Upstream planning and NDC[24] initiatives, and the Sustainable Infrastructure Initiative are some examples of where the Bank has been taking action on these issues.

Climate and Risk Screening

Following the 2015 Paris Agreement, Governors of the Inter-American Development Bank and Inter-American Investment Corporation welcomed Management's objective to improve screening and evaluation of climate risks by 2018 as a way to better identify opportunities for resilience and adaptation measures. To this aim, IDB Group will make use of existing internal policies that could guide the process towards this goal and at the same time evaluate the need for additional guidelines or modifications.

The Bank approved in 2007 the Disaster Risk Management (DRM) Policy (OP-704), which incorporated disaster risk within the project cycle using a set of guidelines to facilitate this process. The DRM guidelines (GN-2354-11) define a procedure to assess project disaster risk in two steps: (i) a first project risk screening and classification step, integrated in the safeguards system; and (ii) a further analysis step if the project is classified as medium or high risk. This step ends up with a Disaster Risk Assessment (DRA). The Bank is currently enhancing this methodology in order to be able to assess climate risk and identify resilience opportunities for projects.

Upstream Planning and NDCs

The IDB Group is an important actor when it comes to identifying, preparing, financing, and implementing infrastructure projects in LAC. However, challenges in local planning capacity, as well as, low creditworthiness and cash flow constraints of many borrowing entities often present challenges for effective project preparation and lending in both sovereign and non-sovereign operations. Under these circumstances, when climate change considerations are not dealt with in the infrastructure planning phase, adding additional layers of requirements late in the project cycle, even if as critical as climate resilience and sustainability, can be perceived as complex, time consuming, risky, and expensive. In other words, at project execution, incentives aren't aligned to give climate change and sustainability the relevance they justifiably deserve; if such elements and concerns are not identified and assessed in the upstream activities of infrastructure planning and project preparation. The Bank is currently working on a platform and facility to support national and subnational entities to plan, design and set guidelines for investments that support their sustainable infrastructure agenda, by channeling funds to mainstream climate and sustainability issues into relevant guidelines and institutional arrangements, as well as by providing resources to cover additional costs associated with the design and preparation of sustainable and climate resilient infrastructure. The facility will also seek to increase the bankability of low carbon and climate resilient sustainable infrastructure projects whilst creating greater visibility and transparency necessary to attract other investors, particularly from the domestic capital markets.

[24] Nationally Determined Contributions. For more information, see http://unfccc.int/focus/ndc_registry/items/9433.php

To complement this work, the IDB though the division of Climate Change and Sustainability (CCS) is carrying out a set of upstream activities at the planning level to ensure investments are consistent with low carbon paths and resiliency, as well as with the private sector to identify the potential for institutional investors to increase investment on sustainable and resilient infrastructure. This is particularly relevant as countries embark on implementing their NDC commitments post Paris.

Sustainable Infrastructure

LAC countries need to invest 5% of GDP (US$ 250 billion) to close the infrastructure gap (current investment rates are only between 2-3%) (IDB, 2014a). In addition, estimates point to a US$ 30 billion annual gap in financing for climate change. The need to increase investments is further growing as demand for energy, tranport, water is rising. In addition, as demand for new and rehabilitated infrastructure is growing fast, there is an **urgent need for infrastructure projects that are able to reconcile economic, social, and environmental sustainability** through improved design and address climate change adaptation and mitigation.

The objective of the Bank's Sustainable infrastructure for competitiveness and inclusive growth (Bank, 2014a) is to guide future Bank support for the countries of the Region toward their adoption of a new vision of the sector. According to this vision, infrastructure is planned, built, and maintained in order to support the provision of adequate quality services that promote sustainable and inclusive growth.