DEVELOPING DISASTER IMPACT ASSESSMENT (DIA) TOOL
FOR PUBLIC INVESTMENT
(DIA FRAMEWORK)

ToT Manual

SUBMITTED BY

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FOR THE ASSIGNMENT OF
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UNDER NATIONAL RESILIENCE PROGRAMME (NRP)

TO

UNDP, DHAKA, BANGLADESH

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List of Abbreviations

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
BNBC	Bangladesh National Building Code
BWDB	Bangladesh Water Development Board
CDA	Chattogram Development Authority
DDM	Department of Disaster Management
DIA	Disaster Impact Assessment
DM	Disaster Management
DPP	Development Project Proforma
DRR	Disaster Risk Reduction
ECNEC	Executive Committee of the National Economic Council
GED	General Economics Division
HDI	Human Development Index
JICA	Japan International Cooperation Agency
KDA	Khulna Development Authority
LGED	Local Government Engineering Department
MoDMR	Ministry of Disaster Management and Relief
MoWR	Ministry of Water Resources
NEC	National Economic Council
NHA	National Housing Authority
NPDM	National Plan of Disaster Management
PWD	Public Works Department
RDA	Rajshahi Development Authority
RAJUK	Rajdhani Unnayan Katripakha
SOD	Standing Orders on Disasters
ToT	Training of the Trainers
UNDP	United Nations Development Programme

1.0 Introduction

1.1 Role of infrastructure in development

In modern society, infrastructure is the main pillar of development. Important infrastructures include transportation infrastructure, energy infrastructure, water infrastructure, waste infrastructure (for liquid and solid waste), building for public facilities (schools, hospitals, offices, shopping mall, etc.), and communication infrastructures. Railways, highways, ports, airports, metros and toll roads are the examples of transportation infrastructure. Water infrastructure includes dams, irrigation networks, drainage networks, sewerage and municipal water supply network. Power plants (gas fired, coal fired, nuclear, renewable etc.) and the distribution system are part of the energy infrastructure.

Sufficient provision of infrastructure and administration are necessary conditions to promote economic growth and competitiveness. Figure 1.1 shows the strong correlation between infrastructure and growth. Infrastructure is also principal to improve the quality of life of the modern society.

Figure 1.1: Correlation between infrastructure and growth (Source: Pudyastuti and Nugraha, 2018)

1.2 Impact of disasters

Disasters can be natural or man-made, predictable or totally unexpected and can be of any size. However, they cause considerable damage to the built environment. Economic losses due to disaster are on the rise both from an increase in the number of disaster events and from an increase in the average loss associated with each disaster event coupled with a greater concentration of exposed assets (World Bank, 2012). In Bangladesh, the disproportionate increase in flood damage during major floods (Figure 1.2) can be attributed to increase in infrastructural assets.

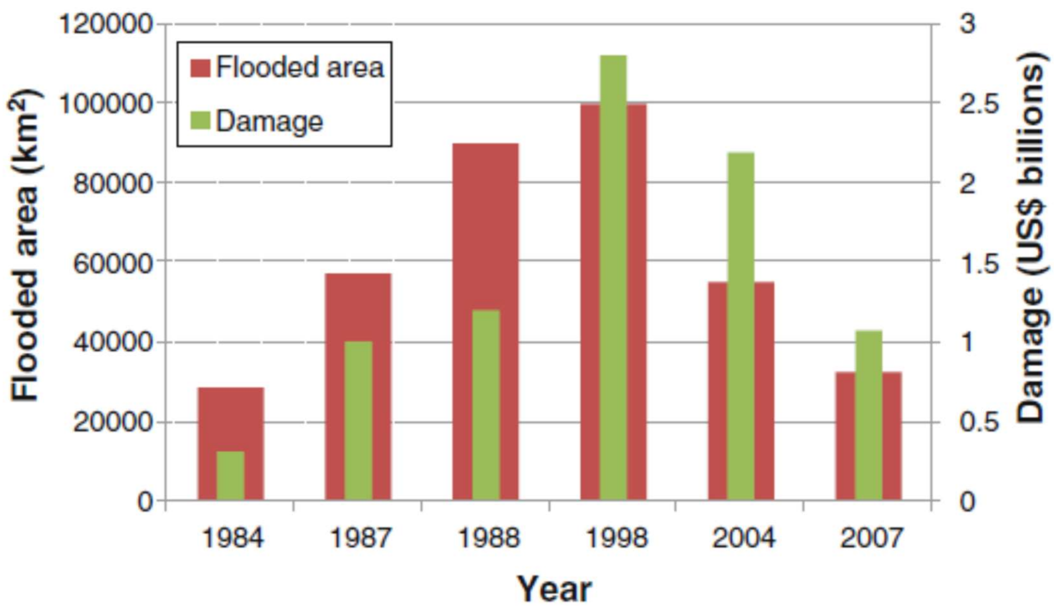


Figure 1.2: Flood damage during major floods (Source: Rahman and Salehin, 2013)

Not only have direct losses resulting from the physical destruction of assets increased, indirect losses due to natural disasters have also multiplied (World Bank, 2012). Indirect losses include the broader consequences of disasters, including the interruption of business operations, a decrease in private and public revenues, widespread unemployment, and market destabilization.

Evidence is emerging that disaster preparedness can be highly cost-effective in minimizing losses. Every dollar spent in reducing people's vulnerability to disasters saves around seven dollars in economic losses. Investing in prevention not only increases the resilience of countries to future disaster but protects economic growth and other development achievements from being lost in a single catastrophic event (UNDP, 2015). Analysis by Hugenbusch & Neumann (2016) suggests that DRR is, on average, more successful in countries with a lower HDI. This is a powerful argument for the expansion of DRR measures in developing countries like Bangladesh.

1.3 Disaster Impact Assessment

Bangladesh is making investment in various types of infrastructures in order to make rapid progress towards becoming an upper middle-income country. As a result, more infrastructural stocks are becoming vulnerable to disasters. In order to reduce the vulnerability so as to make the development sustainable, proper Disaster Impact Assessment (DIA) at the project feasibility stage is very much needed.

DIA is a mainstreaming tool to integrate knowledge and information about disaster and climate related events, trends, forecasts and projections into the development planning process to minimize loss and damage caused by disasters. DIA will be used to screen DPPs prepared by different Ministries or government agencies, whether the proposed development initiatives can increase the intensity, frequency and extent of existing disaster risks or generate new risks. There are a wide range of tool and decision support system for analyzing or assessing disaster and climate related risks, however practice of using such tools for national level disaster and climate risk assessment of public and private investment in Bangladesh needs to be scaled up and mainstreamed in the project planning system.

1.4 Outline of the manual

This manual has been prepared to train the trainers on the disaster impact assessment framework which has been formulated under this project and is demonstrated in Chapter 6. The preceding chapters have been prepared as additional training materials to familiarize the trainers and the participants with many pertinent issues related to disaster management in order to better understand and appreciate the need of DIA in sustainable development.

Chapter 1 highlights the central role that infrastructure plays in development and then stakes out the need for DIA in making that development sustainable. Chapter 2 discusses the current disaster risk management situation in Bangladesh. Chapter 3 describes the major hazards that the country faces regularly and the kind of damages that they cause to various infrastructures. Chapter 4 discusses the vulnerabilities of common infrastructures such as roads, bridges. embankments etc. with respect to typical hazards.

Chapter 5 describes various tools that can be used for scrutinizing disaster impact assessment reports. It also introduces various important considerations such as gender and climate change that need to be made in DIAs. It explains the concept of resiliency which is gaining more and more importance in disaster risk management. A case study is provided to illustrate the lack of resiliency of coastal polders which has become evident in the face of recent cyclone 'Amphan'.

These background chapters/lecture materials are not exhaustive and need to be used only as example by the trainers. They can give examples of hazards and vulnerabilities of their own choice in order to make them more relevant to the attending participants. Training materials are provided at the end of respective chapters which can be used to tailor trainings according to background of attending group of trainees. The trainers are also encouraged to use case studies more as lecture materials. This will keep the participants more engaged. This manual provides few case studies.

1.5 Lesson Plan

The overall goal of the training program is to familiarize the trainers with the need for DIA and then the application of DIA framework. A day-long training of the trainers (ToT) program is proposed in this regard with the following lesson plan.

Time	Intended Learning Outcome	Materials
10 – 11:30 am	Participants become familiar with the major hazards faced by different infrastructures and their vulnerability to such hazards.	Chapter 1: Introduction Chapter 2: Disaster management in Bangladesh Chapter 3: Major hazards Chapter 4: Vulnerability of common infrastructures
11:30 am – 1 pm	Participants become familiar with various tools/techniques and important issues of DRR including resilience	Chapter 5: Disaster Risk Reduction

1 – 2 pm	Break	
2-3:30 pm	Participants become familiar with different steps and aspects of DIA	Chapter 6: DIA Framework
3:30 – 5 pm	Participants are confident in application of DIA	Hands on practice/training

Training materials

Hugenbusch, D. & Neumann, T. (2016). Cost-Benefit analysis of disaster risk reduction - A synthesis for informed decision making. Germany's Relief Coalition (2016).

Pudyastuti,P.S. and Nugraha, N.A. (2018). Climate change risks to infrastructures: A general perspective. AIP Conference Proceedings 1977, 040030 (2018); https://doi.org/10.1063/1.5043000. Published Online: 26 June 2018

Rahman, R. and Salehin, M. (2013). Flood Risks and Reduction Approaches in Bangladesh. R. Shaw et al. (eds.), Disaster Risk Reduction Approaches in Bangladesh, Disaster Risk Reduction. Springer Japan 2013.

UNDP (2015). Putting Resilience at the Heart of Development. https://www.undp.org/content/undp/en/home/librarypage/crisis-prevention-and-recovery/putting-resilience-at-the-heart-of-development.html. Site accessed on July 25, 2020.

World Bank (2012). Disaster Risk Management in South Asia: A Regional Overview.

2.0 Disaster Management in Bangladesh

2.1 Disaster Risk

Bangladesh is among the countries that are most vulnerable to extreme weather disasters (Figure 2.1). The main disasters affecting Bangladesh are floods, cyclones, thunderstorms and droughts among others. Figure 2.2 depicts vulnerability to multiple hazards across the country. It shows that the entire country is vulnerable to one or more hazards. Figure 2.3 shows the distribution of disaster affected households by disaster categories. Flood and cyclone are the most common disasters affecting 24.44% and 15.10% of disaster affected households respectively.

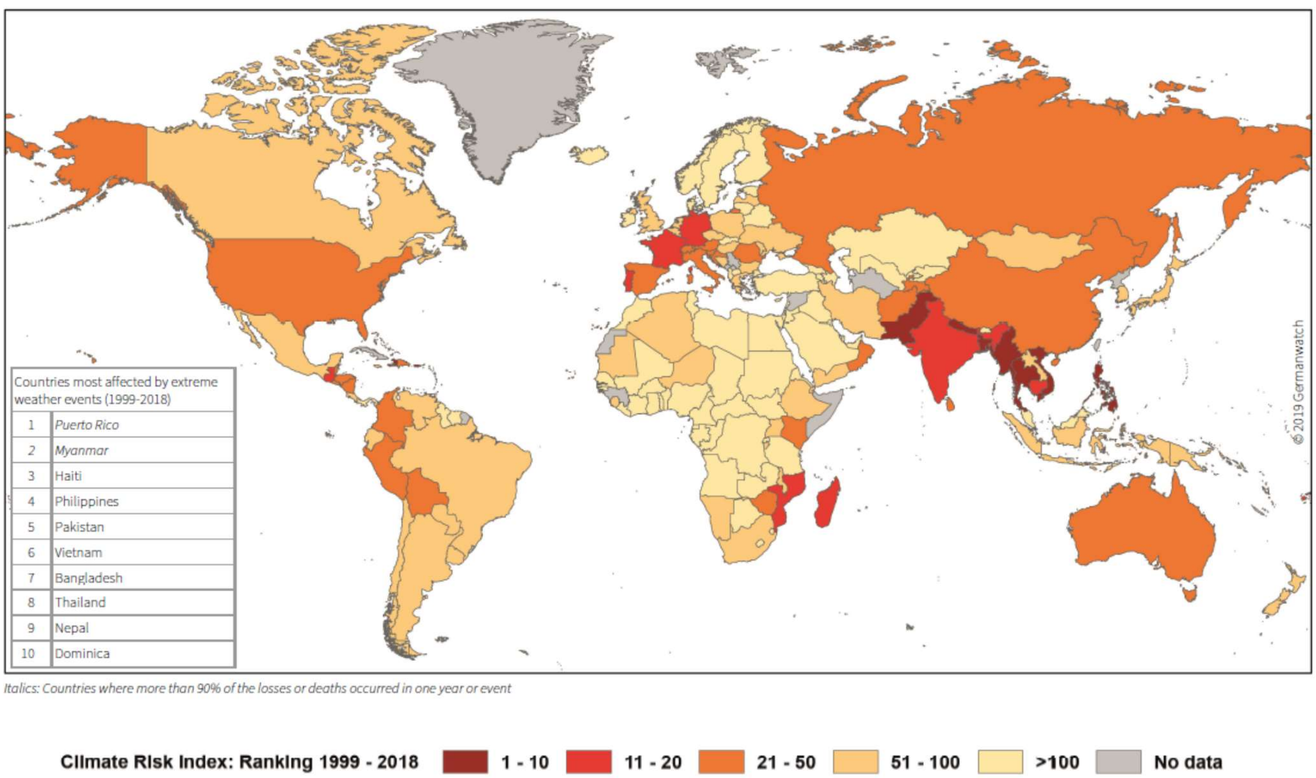


Figure 2.1: Global Climate Risk Index 2020 (Germanwatch, 2020)

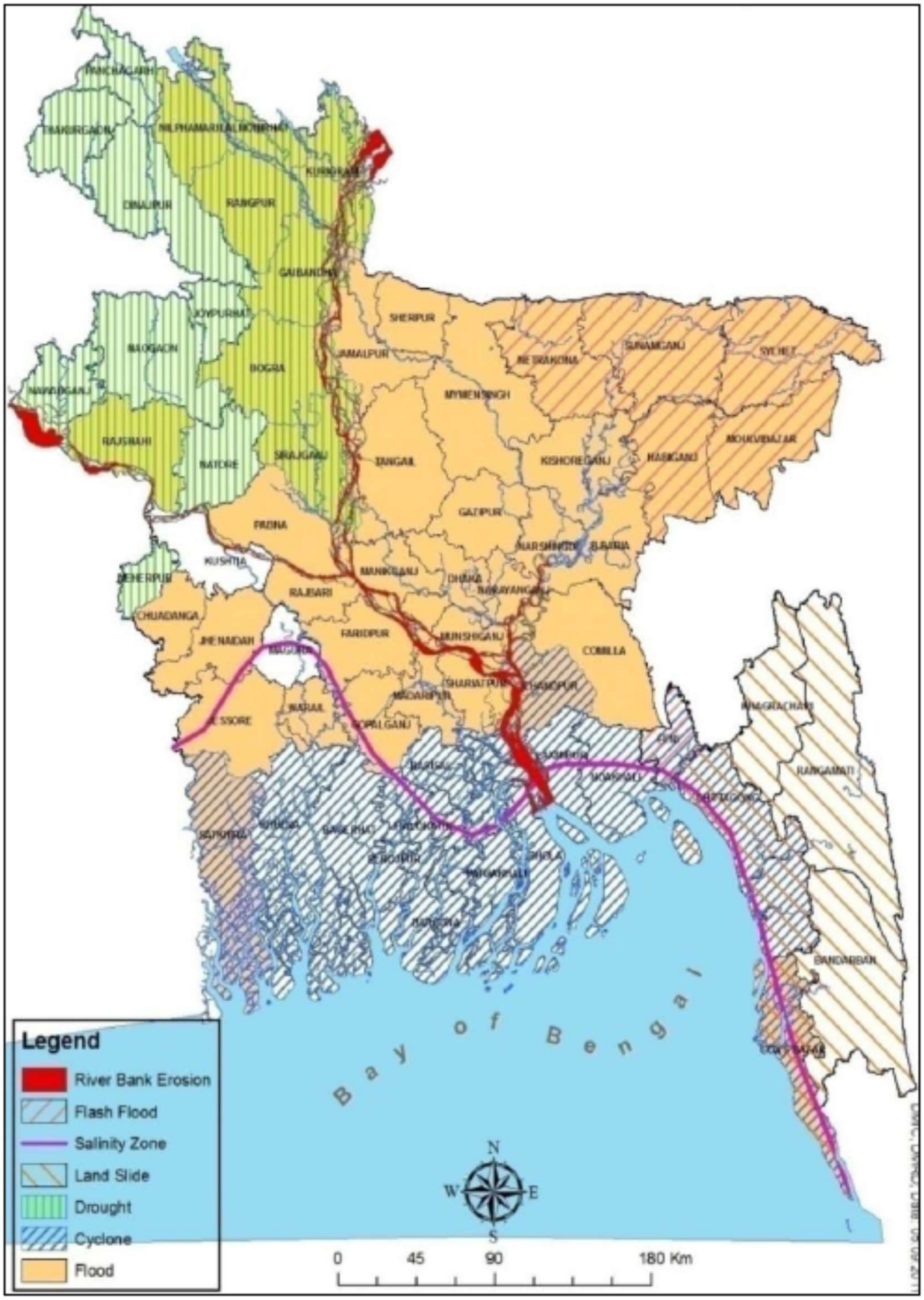


Figure 2.2: Multi-Hazard map of Bangladesh (Source: GED, 2015)

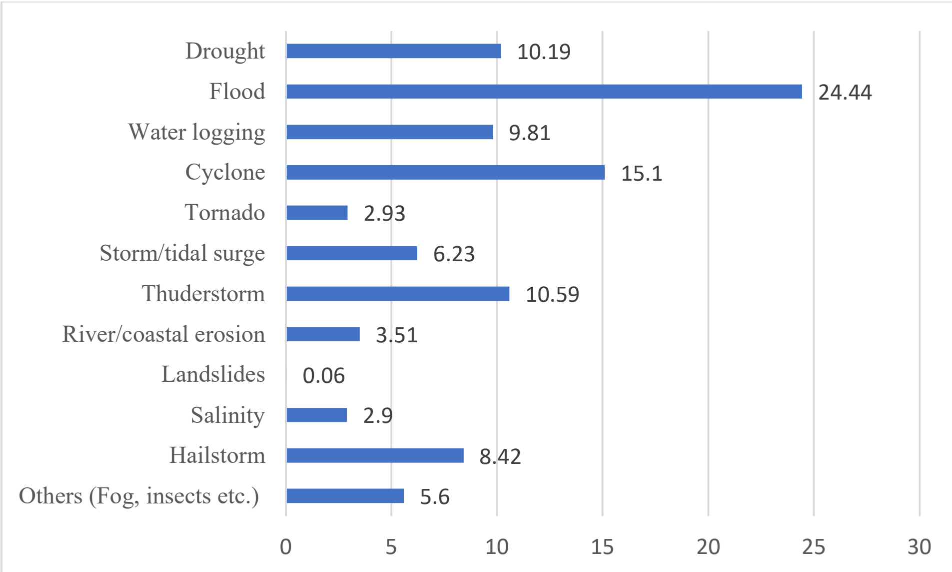


Figure 2.3: Percentage of disaster affected households by disaster categories 2009-’14 (Source: BBS, 2015)

2.2 Risk Management

Bangladesh is now considered to be a role model in disaster management. Over the years, the country has made significant progress in disaster risk management as evident by significant fall in casualties in cyclonic events (Figure 2.4) and quick recovery in crop production after flood events. As a result, the effect of disaster and cyclones on economic growth has become insignificant proving improved resiliency of the country to disasters.

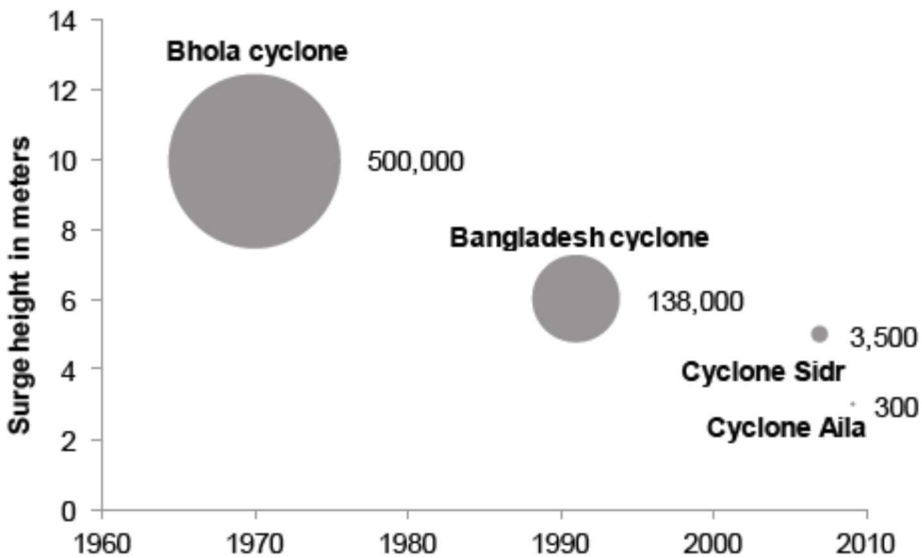


Figure 2.4: Death tolls during cyclone events (Source: ICAI, 2011)

On the other hand, disasters arising from lacking in planning and design of built infrastructures are on the rise. There are now more and more high-rise buildings, many of which are vulnerable to fire due to lack of fire equipment and/or not following building codes. Recent COVID19 pandemic has shown the enormous stress on health infrastructure due to lack of ICU beds and oxygen supply system.

2.3 Policy environment

Disaster Management (DM) in Bangladesh is guided by a number of national and international drivers which among others includes: a) Disaster Management Act 2012; b) Standing Orders on Disasters (SOD) first introduced in 1997 and then revised in 2010 and 2019; c) National Plan for Disaster Management 2016-2020; d) Disaster Policy Act 2015; e) SAARC Framework for Action (SFA) 2006-2015; f) Sendai Framework for Disaster Risk Reduction (SFDRR) 2016-2030; g) Asian Regional Plan for Disaster Risk Reduction (ARPDRR); and the Sustainable Development Goals (SDGs). GoB's Seventh (7th) Five Year Plan reflects the essence of international disaster related frameworks in its long-term sectoral plans that allow translating disaster risk reduction measures into the different sectors.

National Plan for Disaster Management

National Plan for Disaster Management (NPDM) 2016-2020 focuses on the following SFDRR priorities and action plans which were derived following an 'all-hazards' approach with hazard-specific activities linked to broader priority level action plans.

- Priority 1: Understanding disaster risk – Action plans under this priority focus on raising awareness, research and development activities, networking, and information/knowledge management.

- Priority 2: Strengthening disaster risk governance to manage disaster risk – This priority area is concerned with inclusion of Disaster Impact Assessment (DIA) into policy, inter-ministerial coordination, institutional capacity strengthening, public-private engagement, and international and regional cooperation.

- Priority 3: Investing in disaster risk reduction for resilience – Under this priority, actions plans include nationwide capacity building, physical works for resilience, DM financing, institution building, addressing the key hazards of floods and cyclones, but also following an 'all-hazards' approach.

- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction – Concerned action plans include strengthening forecasting and early warning systems, emergency response capacity building, sector-wise preparedness, inclusive recovery and rehabilitation, business continuity, and multi-hazard response and recovery measures.

Disaster Management policy

The Disaster Management (DM) Policy has been approved by GoB in 2015, with a strong emphasis on Disaster Risk Reduction (DRR). The policy places importance on the DM fund as a dedicated financial resource for DM activities at all levels. It is expected that the policy will be an effective instrument to advance DM in Bangladesh.

Disaster Management Act 2012

The objectives of this Act are substantial reduction of disaster risk to an acceptable level with appropriate interventions. The Disaster Management Act 2012 of GoB endorses the Standing Orders on Disaster (SOD) and provides the legal basis for DM in the country.

Disaster Management Institutions

Key national level DM institutions include:

- National Disaster Management Council (NDMC) headed by the Honourable Prime Minister to formulate and review DM policies and issue relevant directives;

- Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) headed by the Honourable Minister in charge of the Disaster Management and Relief Division (DM&RD) to implement disaster management policies and decisions of NDMC/ GoB;

- National Disaster Management Advisory Committee (NDMAC) headed by an experienced person;

- National Platform for Disaster Risk Reduction (NPDRR) headed by Secretary;

- Earthquake Preparedness and Awareness Committee (EPAC) headed by Honourable minister for Ministry of Disaster Management and Relief (MoDMR);

- Focal Point Operation Coordination Group of Disaster Management (FPOCG) headed by the Director General of DDM.

- Department of Disaster Management (DDM) is a department of the MODMR and responsible for government management of natural disasters.

Training materials

BBS (2015). Bangladesh Disaster-related Statistics 2015. Impact of Climate Change on Human Life (ICCHL) Programme. Bangladesh Bureau of Statistics, May 2016.

GED (2015); Seventh Five Year Plan 2016-2020. General Economics Division, Planning Commission, Government of the Peoples' Republic of Bangladesh. December 2015.

Germanwatch (2020). GLOBAL CLIMATE RISK INDEX 2020. This publication can be downloaded at: www.germanwatch.org/en/cri

ICAI (2011); The Department for International Development's Climate Change Programme in Bangladesh, Report 3. Independent Commission for Aid Impact. November 2011.

NPDM (2017). National Plan for Disaster Management (2016-2020): Building Resilience for Sustainable Human Development. Ministry of Disaster Management and Relief.

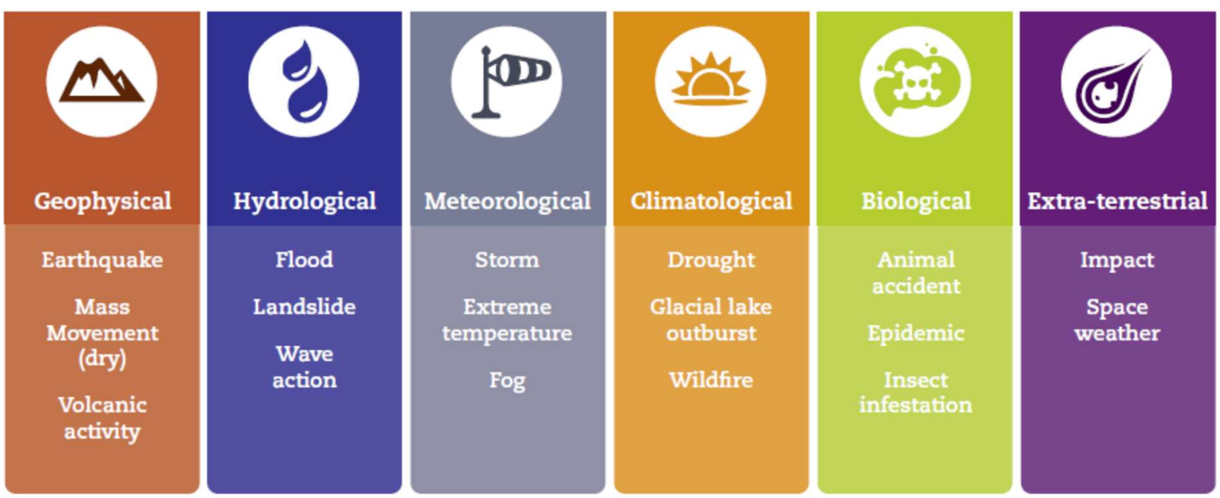
3.0 Major Hazards

Hazard may be defined as "a dangerous condition or event, that threatens or have the potential for causing injury to life or damage to property or the environment." Hazards can be grouped into two broad categories namely natural and manmade.

1. **Natural hazards** are hazards, which are caused because of natural phenomena (hazards with meteorological, geological or even biological origin). Examples of natural hazards are cyclones, tsunamis, earthquake and volcanic eruption, which are exclusively of natural origin. Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and man-made. For example flooding may be caused because of heavy rains, landslide or blocking of drains with solid waste.

2. **Manmade (anthropogenic) hazards** are hazards, which are due to human negligence. Manmade hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife etc.

Various types of hazards (UNISDR, 2015)



In the following sub-sections, some major hazards faced by the country are briefly described.

3.1 Cyclone

Cyclone occurs during pre-monsoon and post-monsoon seasons. Bay-of Bengal is one of the most cyclone-prone area in the world. Cyclonic wind speed can be as high as 250 km/hour with accompanying surge height reaching 10-15 meters. The cyclone hazard map of the country is shown in Figure 3.1. Entire coast of Bangladesh is exposed to cyclonic hazard. However, western coast is relatively more protected from hazard due to presence of Sundarbans mangrove forest. Polders in the coastal region also provides certain level of protection. Polder with foreshore afforestation is more effective as a shield against cyclone.

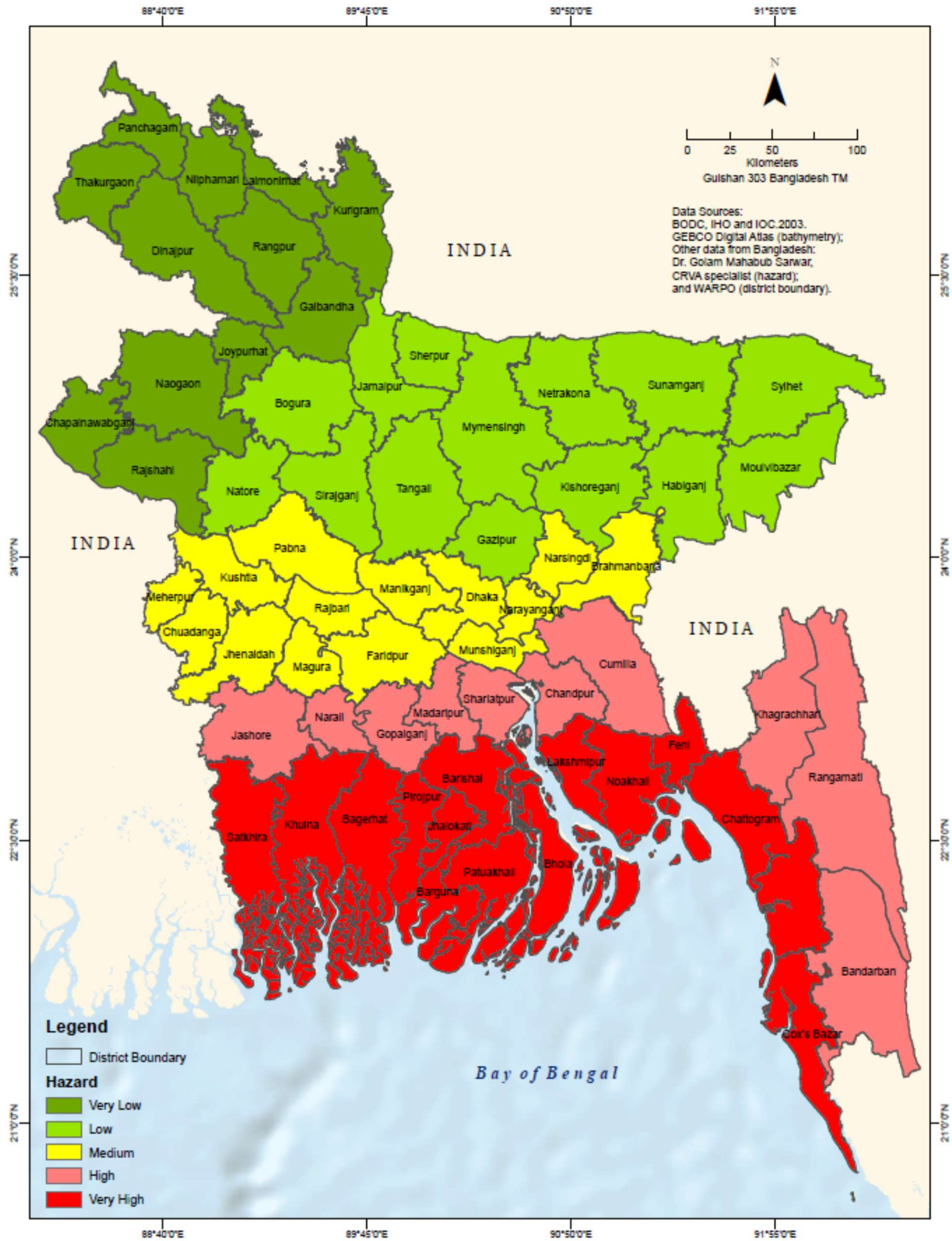


Figure 3.1: Cyclone hazard index map of the country (source: PC, 2018)

During a cyclonic event, major infrastructures that are subject to heavy damage from storm surge are embankments, roads and bridges, and from wind are power grids and cell towers.

3.2 Earthquake

Earthquakes are not uncommon in Bangladesh as number of faults run through the country e.g. the plate boundary faults, Madhupur Fault, and the Dauki Fault (Figure 3.2) illustrating their characteristics like magnitude, detailed location, faulting history, recurrence period, lengths, types etc. All theses faults have the potential to generate large earthquakes with magnitude more than 7.5 or 8.5.

In the last 250 years history, Bangladesh has suffered from severe large earthquakes, such as the 1762 Arakan earthquake, the 1869 Cacher earthquake, the 1885 Bengal earthquake, the 1897 Great Assam earthquake, and the 1918 Srimangal earthquake (Source: Banglapedia). The 1885 Bengal earthquake and 1918 Srimangal earthquake had their epicenter in Bangladesh.

The 1897 Great Assam earthquake had a magnitude of 8.7 and epicentre at Shillong Plateau. The great earthquake caused serious damage to masonry buildings in Sylhet town where the death toll rose to 545. This was due to the collapse of the masonry buildings. The tremor was felt throughout Bengal, from the south Lushai Hills on the east to Shahbad on the west. In Mymensingh, many public buildings of the district town, including the Justice House, were wrecked and very few of the two-storied brick-built houses belonging to zamindars survived. Heavy damage was done to the bridges on the Dhaka-Mymensingh railway and traffic was suspended for about a fortnight. The river communication of the district was seriously affected (Brahmaputra). Loss of life was not great, but loss of property was estimated at five million Rupees. Rajshahi suffered severe shocks, especially on the eastern side, and 15 persons died. In Dhaka damage to property was heavy. In Tippera masonry buildings and old temples suffered a lot and the total damage was estimated at Rs 9,000.

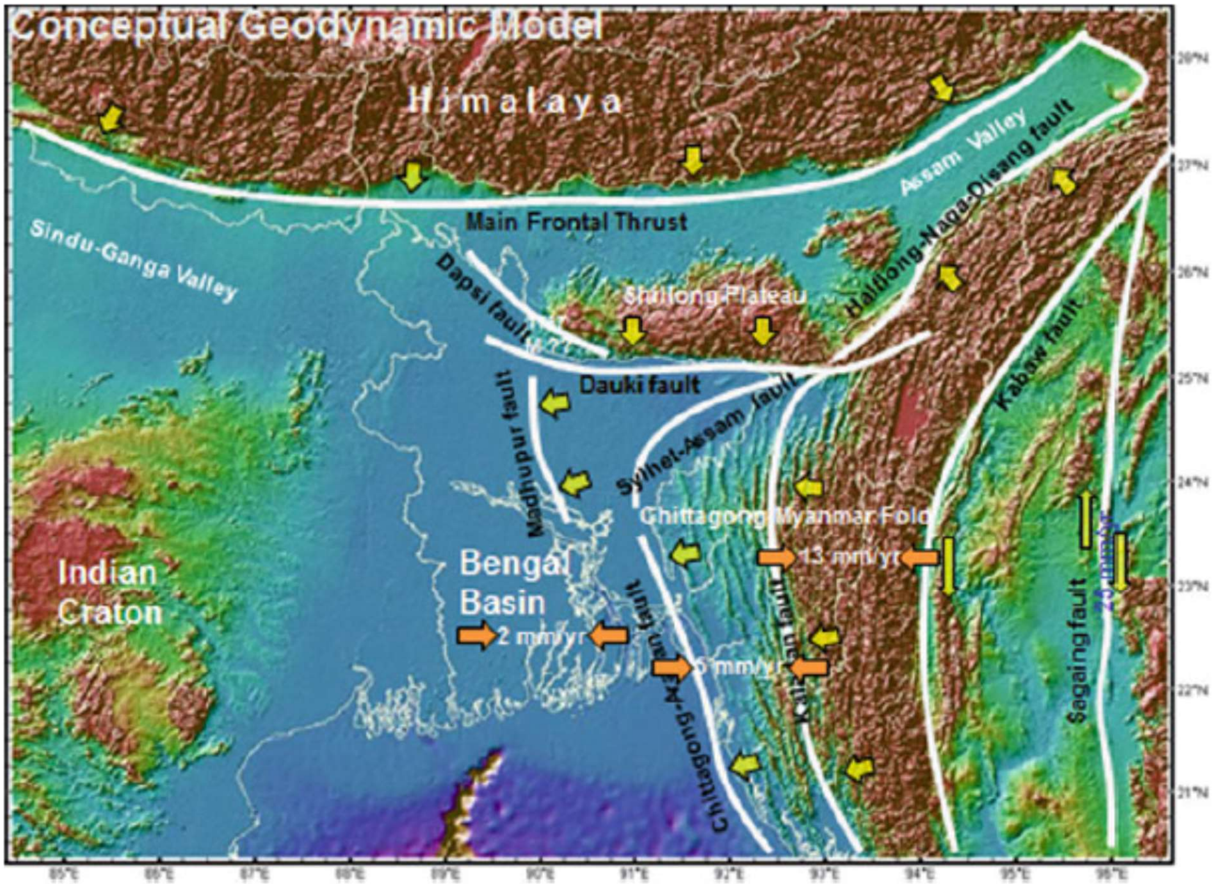


Figure 3.2: Major seismic faults in Bangladesh (source: Kamal, 2013)

An earthquake can cause significant damage to all types of infrastructures, especially to elevated roads, buildings etc. (Photo 3.1)

Photo 3.1: Tilting of expressway and buildings during Kobe earthquake in 1995

3.3 Flood

Almost the entire country (80%) is flood prone as can be seen in Figure 3.3. Flash floods occurs in the foothills in the north-east region. The accompanying high velocity in the range of more than 5 m/s cause significant erosion around the piers and abutments of the bridges. The monsoon flood which occurs throughout the country submerges land for longer period of time as long as 2-3 months which can cause significant damage to the top grades of the roads (Photo 3.2). The tidal flood in the coast damages various structures such as cyclone shelter due to corrosive effect of the salinity.

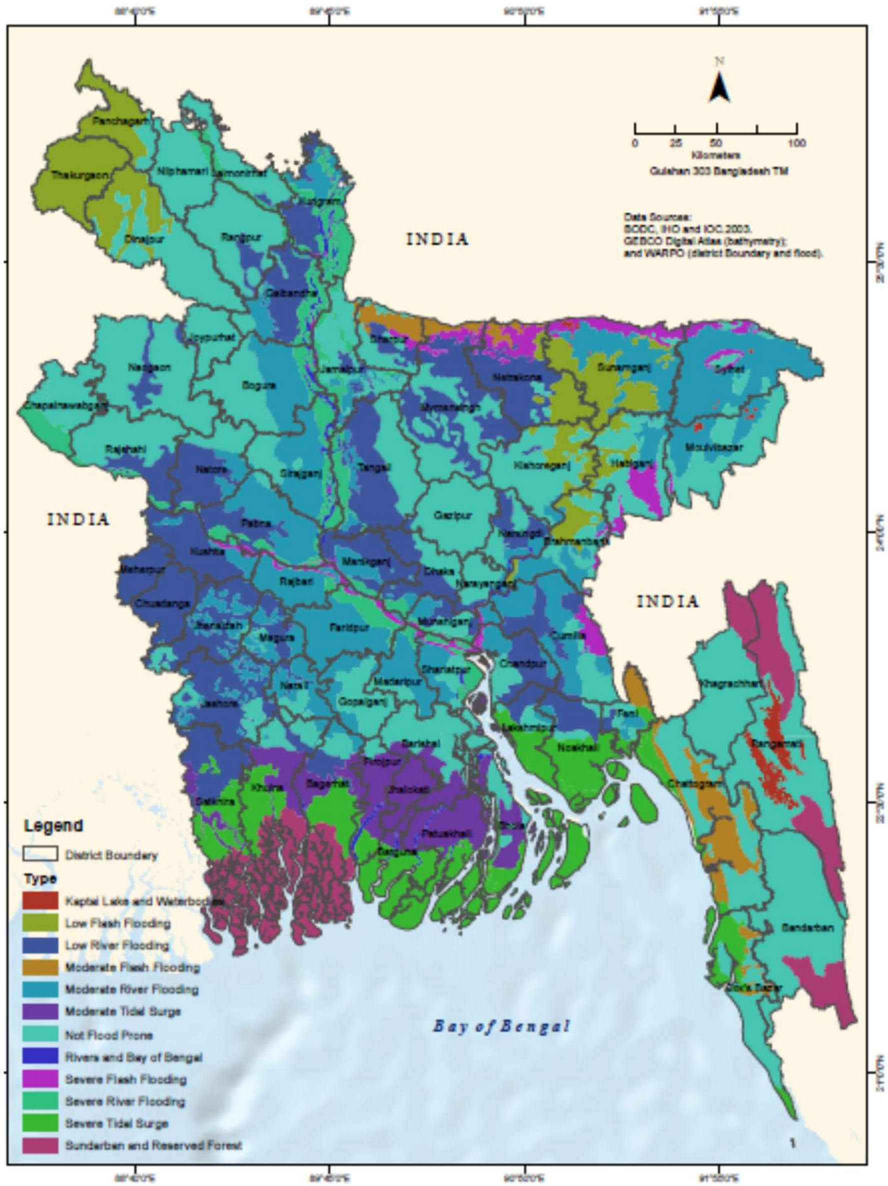


Figure 3.3: Flood prone area in Bangladesh (Source: PC, 2018)

Photo 3.2: Typical damage to top grades due to submergence of roads during flood affecting communication

3.4 Erosion

The rivers of Bangladesh flowing through newly formed delta are highly unstable and dynamic. Erosion and accretion are common features of the riverine system, especially along the major rivers (Figure 3.4).

Figure 3.4: Erosion hazards along the major rivers in the country (Source: PC, 2018)

Each year Padma and Jamuna erodes 3000 ha of land devouring besides croplands, established facilities like schools, offices, hospitals, roads etc. disrupting the services provided by these facilities.

Photo 3.3: Typical scene of bank erosion of Padma river

Photo 3.4: Upazila Health Complex at Naria, Shariatpur plunges into Padma in 2018

Training materials

Kamal, A.S.M.M. (2013). Earthquake Risk and Reduction Approaches in Bangladesh. R. Shaw et al. (eds.), Disaster Risk Reduction Approaches in Bangladesh, Disaster Risk Reduction. Springer Japan 2013.

PC (2018). Draft Final Report on Establishing a Climate Risk Screening System for Mainstreaming Climate Change Adaptation into National Development Budgeting Activities. Programming Division, Planning Commission, GOB and ADB.

UNISDR (2015). The human cost of weather related disasters 1995-2015. The United Nations Office for Disaster Risk Reduction.

4.0 Vulnerability of common infrastructures

Physical and socio-economic settings that may further aggravate or damp out the impact of a hazard is defined as vulnerability.

Physical Vulnerability: It includes notions of who and what may be damaged or destroyed by natural hazard such as earthquakes or floods. It is based on the physical condition of people and elements at risk, such as buildings, infrastructure etc; and their proximity, location and nature of the hazard. It also relates to the technical capability of building and structures to resist the forces acting upon them during a hazard event.

Socio-economic Vulnerability: The degree to which a population is affected by a hazard will not merely lie in the physical components of vulnerability but also on the socioeconomic conditions. The socio-economic condition of the people also determines the intensity of the impact. For example, people who are poor and living in the sea coast don't have the money to construct strong concrete houses. They are generally at risk and loose their shelters whenever there is strong wind or cyclone. Because of their poverty they too are not able to rebuild their houses.

Vulnerability of few common infrastructures against some hazards are illustrated below.

4.1 Cyclone shelter

Multi-purpose Cyclone shelter (Photo 4.1) is the preferred method of sheltering the people during cyclonic events. When not used as shelter, it is typically used as school or community center or health clinic. The shelters are highly vulnerable to storm surge and wind. The shelter is built on stilt so that storm surge can safely pass through. Three typical heights are recommended by Multipurpose Cyclone Shelter Programme (MCSP, 1993) – 7 meters in off-shore islands within the high risk area, 5.25 meters in other high risk areas and 3.5 meters in risk zone. A maximum wind speed of 260 km/hr is used for designing the shelters. The shelters are also subject to salt corrosion during construction due to salinity in water and after construction due to fine salt particles in the air. Making the shelters salt resistant is a major challenge.

After the cyclone passes, resuming the normal services provided by the shelter is another challenge. The planning and design of the shelters need to consider these concerns beforehand so that disruption to services after an event are kept to a minimum.

Photo 4.1: A typical school-cum-cyclone shelter in the coast

4.2 Embankments

The embankments are vulnerable to overtopping by floods and storm surge. The water may overtop the embankment, if the design flood is under-estimated. Usually embankments for major projects are designed against 100 year flood and for other condition the return period is between 5 to 50 years. In case of floods having higher return periods, the provision of freeboard help in safe-guarding the embankment up to certain extent .

Amanullah (1989) reviewed the mechanisms of failures of embankments. Seepage of water through the foundation subsequently resulting into piping action has been responsible for more than one third of embankment failures. Seepage is inevitable in all earth embankments.

Piping is a major cause of earthen embankment failure and many of the modern techniques of embankment design and construction have been developed to prevent it. For example, the present stringent requirements for uniformly compacted embankments with emphasis on control of construction water content and density have been developed to provide dense and homogenous cores which reduce the incidence of concentrated leaks and resist piping when leaks do develop.

The above-mentioned study found that in almost all the FCDI/FCD projects selected, breach and erosion are the major causes of failure of embankment prior to 1987 flood. In 1987 and 1988 floods overtopping and public cut constitutes the other two major causes of embankment failure. To a lesser extent also unsuitable construction materials, delayed normal annual maintenance, incomplete repair of flood damages, deviation from the design were found to be causes of failure.

Hossain et al. (2008) found that the cause of failure of all the flood control embankments in the year 2007 could be attributed to erosion and sliding of embankment materials due to river encroachment and migration. Planting of trees were found to cause damage to the embankment during the Cyclone Sidr in 2007 (Islam et. al. 2011)

4.3 Roads

Deterioration of road structural integrity because of flooding may cause huge expenditure for rehabilitation and maintenance of roadway. In principle, the design of pavement structure is based on the strength of compacted soil known as the subgrade or road foundation. Therefore, subgrade is a significant part of the road structural system. When roads are inundated for a long time or repeatedly, the materials in each layer of road structure become saturated, and the original condition of subgrade soils will be compromised.

4.4 Buildings

During earthquake, permanent ground deformations can tear a structure apart. Some foundation types are better able to resist these permanent ground deformations than others. For example, the use of pile foundations, with the piles extending beneath the anticipated zone of soil liquefaction, can be effective in mitigating the hazard’s effects. The use of heavily reinforced mats can also be effective in resisting moderate ground deformation due to fault rupture or lateral spreading.

Most earthquake-induced building damage, however, is a result of ground shaking. When the ground shakes at a building site, the building's foundations vibrate in a manner that's similar to the surrounding ground.

Brittle elements tend to break and lose strength. (Examples of brittle elements include unreinforced masonry walls that crack when overstressed in shear, and unconfined concrete elements that crush under compressive overloads.) Ductile elements are able to deform beyond their elastic strength limit and continue to carry load. (Examples of ductile elements include tension braces and adequately braced beams in moment frames)

For economic reasons, building codes permit buildings to be damaged by the infrequent severe earthquakes that may affect them, but prevent collapse and endangerment of life safety. For buildings that house important functions essential to post-earthquake recovery, including hospitals, fire stations, emergency communications centers, etc., codes adopt more conservative criteria that's intended to minimize the risk that the buildings would be so severely damaged they could not be used for their intended function.

4.5 Bridges

There are many ways that a bridge could be damaged in an extreme flood event. If the structure is completely inundated during the flood, the damage to the property depends on the length of time it was submerged as well as the elements collected around or passing the structure. Even after the flood water recedes, extra care should be taken to inspect the supports of the bridges. Approaches of a bridge could be damaged due to debris impact, settlement or depressions. Debris against substructure and superstructure, bank erosion and damage to scour protection will damage the waterways. Movement of abutments, wing walls, piers, rotation of piers and missing, damaged dislodged or poorly seating of the bearings are the major reasons for substructure failure. Superstructure could be damaged due to the debris on deck, rotation of deck, dipping of deck over piers or damage of girders. Due to any of these reasons, the members of a bridge could be damaged and bridge may not be completely functional.

Training materials

Amanullah (1989). A Study on Failure of Embankments in Bangladesh. M.Engr. (WRE), BUET, 1989.

Hossain, Z., Islam, Z., and Sakai, T., (2008) An Investigation on Failure of Embankments in Bangladesh. International Conference on Case Histories in Geotechnical Engineering. 4. Missouri University of Science and Technology, USA.

Islam, A.K.M.S., Bala, S.K., Hussain, M.A., Hossain, M.A., & Rahman, M.M. (2011). Performance of Coastal Structures during Cyclone Sidr. Natural Hazards Review, Vol. 12, No. 3, 2011.

MCSP (1993). Multipurpose Cyclone Shelter Programme – Final Report. BUET and BIDS, 1993.

5.0 Disaster Risk Reduction

5.1 Tools

There are various tools that need to be consulted in carrying out a DIA. Some are legally binding such as BNBC and some are advisory such as various departmental guidelines. Some features of few tools are described briefly here.

5.1.1 Building code

The National Building Code (BNBC, 1993) provides directives to safeguard buildings and building occupants from various manmade and natural hazards. For the purpose of these provisions, buildings, structures and related equipment shall be classified into five structure importance categories as listed in Table 5.1, based on the level of necessity of remaining safe and functional during any post disaster period e.g. after a cyclone, or an earthquake. Each building or structure shall be placed in one of the structure importance categories and provided with a structure importance coefficient for design against wind and earthquake induced forces.

Loads Due to Flood and Surge

For the determination of flood and surge loads on a structural member, consideration shall be given to both hydrostatic and hydrodynamic effects. Required loading shall be determined in accordance with the established principles of mechanics based on site specific criteria and in compliance with the following provisions of this section. For essential facilities like cyclone and flood shelters and for hazardous facilities specified in Table 5.1, values of maximum flood elevation, surge height, wind velocities etc., required for the determination of flood and surge load, shall be taken corresponding to 100-year return period. For structures other than essential and hazardous facilities, these values, shall be based on 50-year return period.

Table 5.1: Structural Importance Categories (BNBC, 1993)

Structure Importance Category	Occupancy Type or Functions of Structure	
	General	Particular
I	Essential Facilities	1. Hospital and other medical facilities having surgery and emergency treatment area. 2. Fire and police stations. 3. Tanks or other structures containing, housing or supporting water or other fire-suppression materials or equipment required for the protection of essential or hazardous facilities, or special occupancy structures. 4. Emergency vehicle shelters and garages. 5. Structures and equipment in emergency-preparedness centres, including cyclone and flood shelters. 6. Standby power-generating equipment for essential facilities. 7. Structures and equipment in government communication centres and other facilities required for emergency response.
II	Hazardous Facilities	Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released.
III	Special Occupancy Structures	1. Covered structures whose primary occupancy is public assembly with capacity > 300 persons. 2. Buildings for schools through secondary or day-care centres with capacity > 250 students. 3. Buildings for colleges or adult education schools with capacity > 500 students. 4. Medical facilities with 50 or more resident incapacitated patients, not included above. 5. Jails and detention facilities. 6. All structures with occupancy > 5,000 persons. 7. Structures and equipment in power-generating stations and other public utility facilities not included above, and required for continued operation.
IV	Standard Occupancy Structures	All structures having occupancies or functions not listed above.
V	Low Risk Structures	Buildings and Structures that exhibit a low risk to human life and property in the event of failure, such as agricultural buildings, minor storage facilities, temporary facilities, construction facilities, and boundary walls.

Seismic loads

Based on the severity of the probable intensity of seismic ground motion and damages, Bangladesh has been divided into three seismic zones, i.e. Zone 1, Zone 2 and Zone 3 as shown in Figure 5.1 with Zone 3 being the most severe. Seismic zone for a building site shall be determined based on the location of the site on the Seismic Zoning Map. Each building or structure shall be assigned a Seismic Zone Coefficient, Z corresponding to the seismic zone of the site

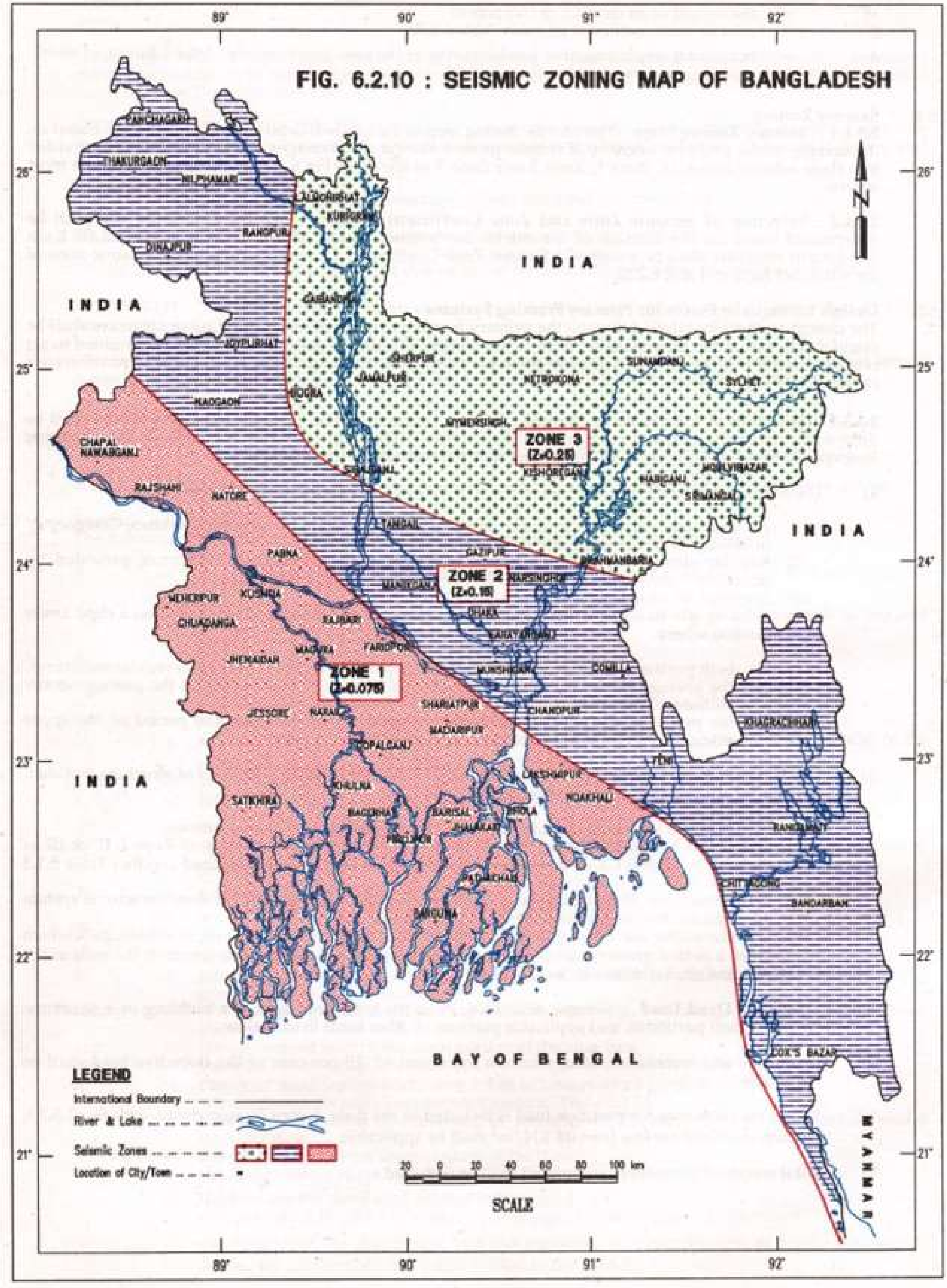


Figure 5.1: Seismic zones of Bangladesh (BNBC, 1993)

5.1.2 Standing orders

The SOD or Standing Order on Disasters (MODMR, 2019) provides directives to all relevant ministries and agencies for all phases of disaster management including risk reduction. Few of the directives for some agencies for risk reduction are as follows.

Roads and Highways Department

(a) Consider current and future disaster risks in the design of any infrastructure.

(b) Strengthen the roads and embankments, light bridges and culverts, so that they can withstand the tidal bore/high floods whipped up by cyclones.

(c) Prepare agency contingency plan.

(d) Keep operationalized the agency contingency plan.

Local Government Engineering Department (LGED)

(a) Consider all hazard risks in preparing the Action Plan of the LGED.

(b) Draw up plans of feeder roads, bridges and culverts and complete their construction keeping provision for easy flow of waters and easy discharge of tidewaters.

(c) Encourage and inspire people through Union Parishads for construction of two storied buildings if possible. Suggest that at least one room on the roof of cyclone/flood resisting brick built residential house for the purpose of using them as shelter place during cyclone/flood.

(d) Prepare maps identifying population centres, water holes (wells), protected ponds/water reservoir/tube-wells for drinking water and other water sources.

(e) Prepare and periodically update the agency contingency plan.

(f) Follow Building Code and take necessary measure to ensure its proper execution where necessary.

(g) To mitigate earthquake risks in the construction and urban planning arrange training programmes for government engineers, planners and the architects on infrastructure and urban planning.

Public Works Department (PWD)

(a) Ensure proper execution of the BNBC.

(b) Include current and future disaster risks in the policies, programmes and guidelines of all the development works of the Department.

(c) Prepare manual explaining seismic capacity evaluation and earth proofing design.

(d) Prepare and periodically update the list of the vulnerable structure and disseminate the information to concerned.

(e) Disseminate the Technical information related to earthquake and Tsunami to engineers.

(f) Support the retrofitting works.

Urban Development Authority (RAJUK, CDA, KDA, RDA & NHA)

(a) To identify vulnerable areas contact with the GSB to ensure receipt of the earthquake risk maps. Integrate earthquake micro-zonation mapping in detail areas planning of the city.

(b) Create measures and provide technical support for the constructing of high rise buildings in the affected areas following BNBC.

(c) Include the specific measures (provisions for wide roads for smooth running of the transports involved in rescue work, arrange for building of emergency shelters in the open/free space in every Para) in the urban development planning for mitigation of earthquake disaster.

(d) Collect earthquake risk maps and conduct survey to progressively cover all the buildings and other structure in the working area on. If necessary, plan for emergency measure.

5.1.3 Prime Minister’s directives

In various NEC meetings over the years, Hon’ble Prime Minister has given different directives to make various infrastructures disaster resilient. Example directives are as follows:

(ECNEC meeting on 11/04/2017)

The following three issues must be considered when constructing cyclone shelters in coastal areas:

(1) In-house water reservoir should be set up on the floor underneath the roof, to harvest rainwater from the roof

(2) Shelters should have solar panels installed

(3) Store rooms will need to be established for protecting valuable possessions/documents during a disaster

(ECNEC meeting on 17/02/2009)

To prevent road accidents in hilly areas, safety measures should be undertaken wherever necessary for all the roads under the project, and steps have to be taken to ensure different road signs, milestones etc. are clearly visible and easily readable. This needs to be considered for all future projects of similar nature.

5.2 International best practices

Practice of DIA as a separate exercise independent of EIA is rather exception than the norm. Sri Lanka has formulated a comprehensive manual for DIA targeted towards road sector (DMC & JICA DiMCEP, 2012) which can be cited as a good example of DIA.

Objectives of this DIA application are

i. It helps to assess the influences of disasters to the development actions itself

ii. It helps to assess the influences of disasters in the surrounded area. These disasters are caused by the development actions which had been damaged by disasters and;

iii. It helps to assess the influences of possible of disasters caused by development actions to the surrounded area and also, it is confirmed countermeasures.

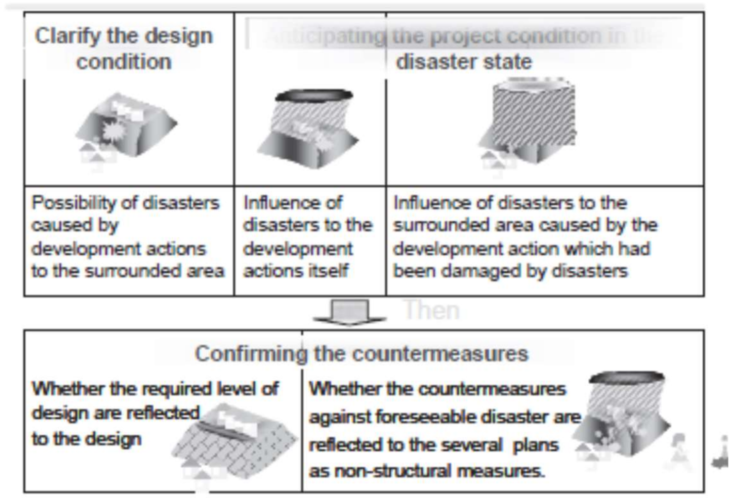


Figure 5.2: Objectives of DIA

- Natural disasters and technological disasters should be considered separately. Based on these classifications and survey results relevant to road sector, three key points for use of the checklists on road projects are focused on such as (1) which countermeasures are considered at design stage? (2) What should be prepared against the natural disasters and (3) How to identify the hazards after in-service? Based on these three points, three types of checklists have been prepared for checkups relevant to design, disaster management and inspection at maintenance. With the purpose of keeping records of the disaster events to review the relation to damage and countermeasures, checklist forms related to disaster record have been introduced.

- Checklist Form A will be utilized to confirm whether the design conditions are checked against the hazardous considerations. Checklist Form B will be confirmed whether non-structural measures cover the deficit of insufficient structural measures, in the above normal conditions. Checklist Form C will be supported in maintenance system to identify the hazardous conditions during an in-service period of the road.

- Once a disaster event occurred, that particular event will be recorded by Checklist Form D. Based on this record, relevant organizations can arrange restoration & mitigation for the identified problematic locations. Therefore, it has high potential to contribute mitigation of disaster damages using any methods (both structural and non-structural measures).

- These checklists are one part of DIA system. It needs to add the other parts and continue improvement stepwise with improvements. It is expected to realize capacity development for disaster management through DIA Application.

Classifications		Checklist types	Focus Points	Contents
Natural Disaster		Form B Disaster Management	What should we prepare against the natural disaster?	Understanding in which condition the construction is designed. And also the non-structural measures, cooperation with local government and related organizations etc. are confirmed.
Technological Disaster	Design Construction	Form A Design	Which countermeasures are considered at design stage?	Confirmation of design standard and design condition. And also hazard locations and road structure locations including structural measures are confirmed.
Technological Disaster	Management Maintenance	Form C Inspection	How to identify the hazards after in-service?	Inspection of the condition of hazardous locations and road structures including structural measures by periodical checkup
After Disaster		Form D Disaster Record	How was the affected situation by the disaster?	Record of the disaster situation by site visits and interviewing people in the affected area

Figure 5.3: Composition of checklist

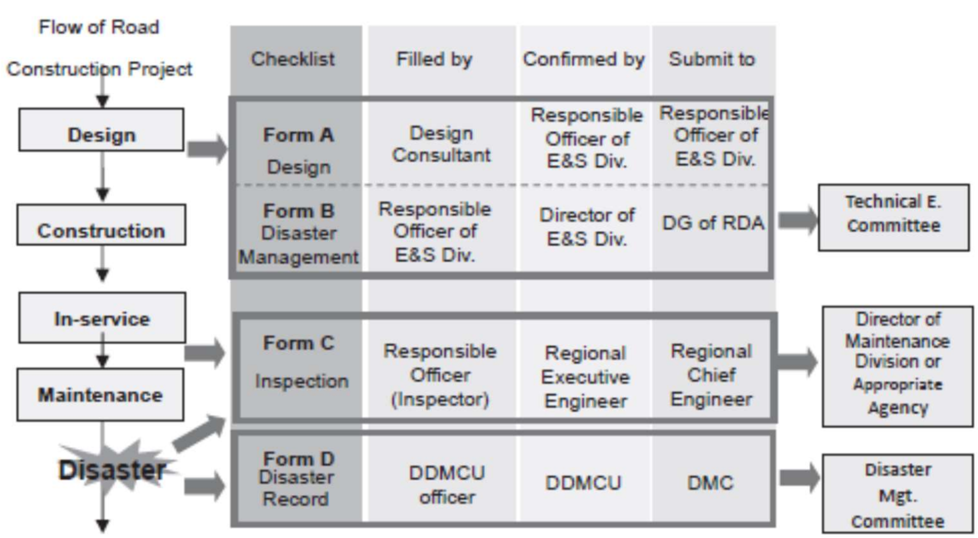


Figure 5.4: Proposed system of DIA for road sector in Sri Lanka

5.3 Gender considerations

Gender concerns are recognized in policies and strategies in infrastructural development. It has been recognized that understanding the different living conditions and needs of women and men at project planning stage and taking them into account in the design and implementation of projects is important (JICA, 2010). Gender policies include the followings.

1) Women and men must equally participate in climate change, disaster risk reduction, decision-making processes and other government programs at community, regional and nationwide levels;

2) Integration of gender-sensitive criteria into planning, design implementation, monitoring and evaluation of programs, projects and initiative; and

3) Allocation of adequate resources to address the needs of women, for example funding appropriate and environmentally sound technologies and supporting women's grassroots initiative in sustainable use of natural resources.

In implementation of such policies, proper DIA shall include the activities but not be limited to the following;

1) Undertake environmental planning through public consultation or multi-stakeholders forum and identify gender issues and concerns in the involvement of women, youth, senior citizens and disabled persons in infrastructure development. Women should constitute at least 30%of the total participants.

2) Develop gender-based information within the influence area of the proposed project.

3) Conduct social gender analysis such as trend of employment of women at all levels (actual construction, technical and management) in infrastructure projects or services, capacity of women to influence decisions about the planning design, operation and maintenance of infrastructure facilities; resettlement of women and their families as a result of the construction of infrastructure; access of women to water, health and transport services, etc. It is noted that the involvement of women in infrastructure development is very limited.

4) Prepare standard gender-sensitive design of infrastructure and facilities that caters the needs of women, aged people and children,

such as wider space on restrooms for women, provision of ladders in the abutments of bridges and dikes, etc.

5) Incorporate in the plan of such gender-sensitive structure/facilities in the study and the cost in the economic evaluation.

5.4 Climate change considerations

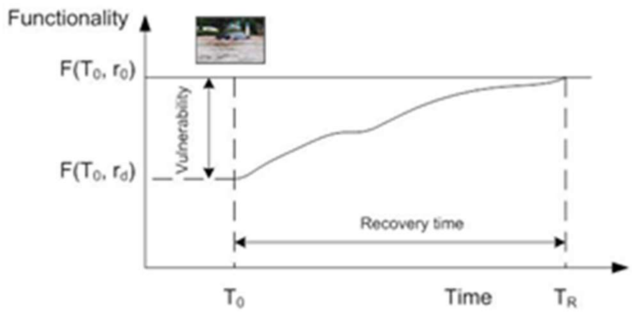
Uncertainties in the weather pattern and rise in temperature are attributed to climate change. Trends in temperature and rainfall frequency and intensity are changing. Precipitation extremes will result in increased flooding, both because of the increase in monsoon rains, and due to the increased incidences of flash floods induced by erratic precipitation regimes. Coastal flooding is a major impact of sea level rise. This is higher in Bangladesh because of the effects of tectonic subsidence. Sea level rise is also associated with increased riverside flooding, because it causes more backwater effect of the Ganges-Brahmaputra-Meghna Rivers along the delta. This will result in increased drainage congestion due to higher water levels, which will be exacerbated by other factors associated with climate change such as siltation of estuary branches in line with increased surface runoff, and higher riverbed levels. Higher temperatures will result in increased glacier melt, increasing runoff from the neighboring Himalayas into the Ganges and Brahmaputra rivers.

These changes affect the planning of different infrastructure including flood control projects. Design safety level of flood control structures are lowered as a result of climate change scenario. For instance, a 10-year design scale would decline to 6-year return period in 2050 (JICA, 2010). Sea level rise requires configuration of river walls and other flood control structures influenced by tidal fluctuations and storm surge.

5.5 Resilience

There are many definitions reported in the literature for resilience as provided by Lokuge and Sutenge (2013). It can be defined as the ability to maintain functionality and return to normality following an extreme event making sure that the damage is tolerable and affordable. It was defined as the ability of a system to reduce the chances of a shock, to absorb a shock if it occurs and to recover quickly after a shock. A resilient system should have low probability of failure, even if it fails, very low impact on the society in terms of loss of lives, damage and negative economic and social consequences and most importantly low recovery time.

Figure 5.5 (a) shows the functionality of an infrastructure with time. At time T_0, the system was fully functioning [$F(T_0, r_0)$] when the extreme event occurred. Functionality was reduced to $F(T_0, r_d)$ due to the damage to the infrastructure system. At time T_R, the system completely recovered and started functioning as it was at time T_0. By considering the above qualities for a resilient system, it can be concluded that if the functionality due to damage is not much and/ or if the recovery time is less than the system is more resilient. Therefore, if the area shown in Figure 5.5 (b) is less the system is more resilient.



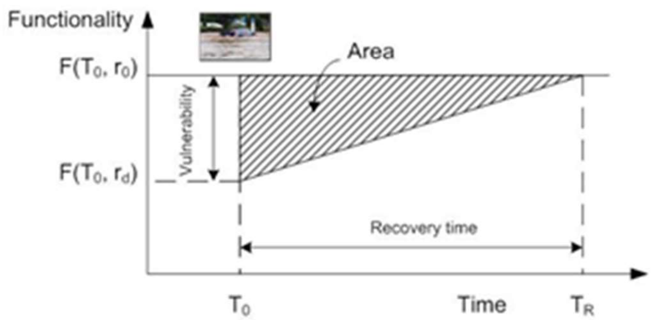


Figure 5.5: Representation of resilience and vulnerability (Lokuge and Sutenge, 2013)

Case Study – Coastal polder system

We have seen and experienced the difficulty in rebuilding the polders after Aila (2007) and Sidr (2009). The polders still remain in broken state and caused immense suffering to the inhabitants during Amphan (2020). This long delay in repairing the polders can be taken as a classic case of lack of resiliency of the coastal polders and thereby its inability to recover from shocks in a timely manner. There are many reasons both physical and socio-economic behind such lack of resiliency which are illustrated in the following article. During DIA, it is important to consider such issues in order to reduce the suffering of inhabitants when failure of infrastructure occurs. Below is a case study to understand the issues.

Helping the helpers by Dr. M. A. Quassem; The Daily Star March 30, 2010

I have just returned from Aila-affected polder 32 in Dakope Upazilla and polder 15 (Gabura) -- an island on the fringe of the Sundarbans. I have seen people dying, houses demolished, crops destroyed, but never such a horrible destruction of the landscape. In this respect, Aila is unprecedented. As a hydraulic engineer, I can comprehend the breaches on the embankments, but the damage it caused to the terrain -opening up new canals and widening small channels to rivers -- is beyond comprehension. There has been a lot of criticism against the officers in the field -- particularly the Bangladesh Water Development Board (BWDB) -- regarding the failure to repair the embankments and reluctance of the people to return to their habitat. I want to highlight (a) the arduous tasks which confront the BWDB field officials; (b) the multidimensional problems being faced in rehabilitation work; and (c) the lessons for the future; and in no way to make excuses for any real failure.

Aila affected, according to BWDB sources, 47 polders (areas confined by embankment for protection against saline water intrusion due to tidal rise and to facilitate drainage). BWDB identified the destruction of and damage to embankments and water resources infrastructures and estimated the cost of emergency repair work. The government allotted wheat and money for the emergency repair work. By July-August 2009, with the GOB's own resources, BWDB closed 303 breaches totaling 85.9 km, 122 closures out of 152, repaired 32 sluice gates and other water structures, and made 41 out of 47 polders flood-free. The rest of the work was taken up in December 2009. In my opinion, sometime might have been gained between August and December.

Post-disaster rehabilitation is not easy. The rehabilitation work in polder-32, which was constructed in 1966, may be illuminating. The embankments weathered the fury of the coastal waves without the necessary maintenance and were worn out. Added to this is the uncountable number of unlawful pipes -- put in the embankments by shrimp cultivators -- are destructive and make the embankment extremely vulnerable. BWDB's cry for action against these irresponsible shrimp cultivators goes unheard. BWDB never gets the required money for repair and maintenance.

By July-August 2009, BWDB had closed 6 breaches on the embankment, constructed 6 closures out of 13 planned, and made one-third of the polder flood-free. Seven closures remained, which were tendered in November 2009. The work sites were difficult, earth for embankment was scarce, labour was not available, and financial support was uncertain. Works for only 2 closures started but, unfortunately, one was washed out after construction by the high tidal flow on February 24, which was only one foot less than the Aila height. Five closures could not be started at the right time.

Pushed by circumstances, BWDB modified the plan and design of the works and took a lot of risk on their shoulders to persuade the contractors to participate in the bidding. Finally, the work of the 5 tenders started around the first week of February, which was quite late. Anyway, now works are going on all the crucial places and all but one are expected to be closed.

The one which may not be completed is the construction of the Nalian river closure (140 m wide) with 2.70 km of connecting approach embankment, estimated at Tk.303.46 lakh. This closure was tendered five times. Those who know about construction of closures will consider the bid price as normal (even less) for a closure, because of the risks and hazards involved. However, the Public

Procurement Rules (PPR) of the Government prohibits award at rate higher than 5 percent.

The situation was further complicated by conflicting vested interests. Firstly, the poor residents of the polder feel safe on the embankment and are happy with the relief they have been receiving. Their problem is lack of drinking water. Secondly, there is a quarter that thinks that if the polder is not closed, land price inside the polder will come down to the advantage of the rich ones, particularly the shrimp farmers. Thirdly, there is conflict between the outside and the local labourers. Fourthly, there is strong demand to sub-divide the polder in two.

So the quarter did not want the Nalian river closure as proposed in the tender and considered this an opportunity to have the polder divided, which finally boiled down to what they call the 2nd strategy – a closure 10.5 km inside with embankments (ring bunds) on both sides of the Nalian river. Ironically, this alignment traverses over 4 km of marshy land with bad sub-soil condition, where normal construction methods cannot be used.

The departure from the original concept of the Nalian closure may prove costly both in terms of money and success. A group of design engineers and BWDB high-ups are working to devise a strategy and design for closing it. The executive engineer hopes to succeed provided army is deployed within 2-3 days (I visited the polder on March 12). The Bangladesh Navy was deployed on March 16 to assist BWDB.

In many places, the repair work could not yet be completed, and need immediate strengthening before a severe high tide or similar event occurs.

BWDB has to work under extreme constraints. Not to speak of an emergency, even the staff under normal set-up is also not there. None of the 6 work assistants and surveyors were posted there. One sub-divisional engineer (SDE) and one section officer (SO) are not enough for emergency jobs. The logistic support is even worse -- no office, no water transport, no accommodation is available. A hired engine trawler, which takes more than 4 hours to go to the furthest work site, is used; the SO lives in a hired country boat where he cooks, eats and operates the office. There is no contingency plan(s) to face an emergency.

The BWDB field office has to work in spite of these constraints. They are thankful to the ADG and chief engineer of BWDB, who stay in the Aila area almost full-time, and also to the DG BWDB and the Secretary, MoWR, who have visited the places several times to give them support. They have expressed gratitude to their colleagues of other departments also.

Cropping up of vested quarters of profiteers, who trade on the sufferings of the distressed people after a disaster, is a usual phenomenon which needs to be handled severely.

Post-disaster management, particularly the rehabilitation of infrastructures destroyed/damaged by any disaster, should be handled on an emergency basis under special emergency rules and procedures. Special emergency rules and procedures should include special powers for relevant executing agencies on technical and financial sanctions, and procurement rules to facilitate emergency execution of works.

Each service-oriented government agency should have a general contingency plan to handle natural disasters, including formation of special task forces to assist the normal institutional arrangement and mechanism, to take immediate decision and be equipped with minimum logistic support.

Placement of pipes on the embankments and violation of rules on use of embankments and sluices must be severely dealt with by punitive actions.

Post-disaster rehabilitation is like fighting a war. Let us all appreciate the difficulties and complications which are faced by the people-on-the-job, and let us all help and inspire them, not demoralize them when they are at war.

5.6 Build Back Better

Many infrastructures in the country are aged or have been severely damaged or completely destroyed by natural forces such as floods, cyclones or erosions. For example, the earthen polders in the south-western coast which were built in the 1960's were easily breached during this year's cyclone Amphan (Photo 5.1). Brahmaputra Right Embankment has been damaged at number of places during this year's (2020) flood. New school building in Chandpur was washed away by flood and erosion during the same flood (Photo 5.2).

Photo 5.1: Polder breached at Koyra, Khulna during Cyclone Amphan

Photo 5.2: A newly constructed school building being washed away by flood and erosion of Padma River in July, 2020

These infrastructures could not provide the intended level of service and themselves became subject to various hazards. It is expected that they will be rehabilitated soon. During this rebuilding process, a thorough DIA exercise need to be carried out so that these infrastructures become disaster resilient in future. NPDM 2016-2020 in line with the Sendai Framework also promotes build-back-better in recovery, rehabilitation and reconstruction.

Training materials

BNBC (1993). Bangladesh National Building Code. Ministry of Housing and Public Works.

DMC & JICA DiMCEP (2012). Disaster Impact Assessment – Checklist System for Road Sector. Sri Lanka

JICA (2010). Technical Standards and Guidelines for Planning of Flood Control Structures. Project for the Strengthening of Flood Management Function of the DPWH, the Philippines. June, 2010.

Lokuge, W.P. and Setunge, S. (2013). Evaluating disaster resilience of bridge infrastructure when exposed to extreme natural events. 3rd International Conference on Building Resilience 2013: Individual, Institutional and Societal Coping Strategies to Address the Challenges Associated with Disaster Risk. Sri Lanka. September 2013

MODMR (2019). Standing Orders on Disaster 2019. Ministry of Disaster Management and Relief.

6.0 DIA Framework

6.1 Purpose

A practical framework has been prepared which will be used to address Section 24.3 of Development Project Proforma (DPP). This is a simple tool to help both proponent and appraiser to assess whether disaster issues have been adequately considered in DPP in order to make the project sustainable.

6.2 Principles

The principles behind this framework are as follows:

Simple yet comprehensive: i.e. the format should be easily understandable and workable yet it needs to cover major issues related to DIA.

It is a living document: i.e. it is not static rather dynamic. It is expected that the manual will be updated with time.

No new analysis: The format will use information already available from Feasibility Report. Such information will be presented in a DIA format.

6.3 Scope

The scope of this manual is as follows:

Applicable for DIA at project level only: DIA can be carried out at policy and programme level which are equally needed. However, this format is applicable for preparation of DPP for projects only.

Applicable for infrastructure projects: At this stage, the DIA format has been prepared considering infrastructure projects. This is because, these types of projects are more vulnerable to hazards, may create more hazards and need to be resilient most.

Consideration of service: This format encourages to consider not only the physical damage to the infrastructure itself but the services that these infrastructures provide.

Consideration of chain of hazards: One hazard may lead to other hazards such as from damage to a building during earthquake may generate fire hazard.

Gender consideration: The countermeasures need to duly consider gender aspects.

The infrastructures and the hazards that they might face which have been considered in formulation of the framework are as follows:

Infrastructures	Hazards
• Road • Bridge • Shelter • Embankment • Buildings (including schools, hospitals etc.) • WASH facilities • Town protection • Dredging • Power plant • etc	Natural • Flood • Drought • Cyclone • Earthquake • Erosion • Tornado • Landslide • Lightning • Salinity • etc. Manmade • Fire • Water logging • etc.

6.4 Steps of DIA

The proposed DIA format has six steps as below:

1. Locating project site on hazard map
2. Identification of impact of hazards
3. Proposing counter measures
4. Assessment of resilience
5. Estimating cost of DRR
6. Reporting residual risk

The steps are described as follows.

1. Locating project site

The site of the project should be located on maps of hazards that the project is facing. Districts facing different types of hazards have been prepared by Planning Commission and ADB (PC, 2018) as given below.

Table 6.1: List of districts and respective exposure to types of hazards.

Division	**District**	**Potential Hazards**	**Note**
Barisal	1. Barisal	C, Er, F, SS	*C = Cyclone* *D = Drought* *Eq = Earthquake* *Er = Erosion* *F = Flood* *FF = Flash flood* *S = Salinity* *SLR = Sea-level Rise* *L= landslides* *SS= Storm Surge*
	2. Bhola	C, Er, F, S, SLR, SS	
	3. Barguna	C, Er, F, FF,S, SLR, SS	
	4. Jhalokati	S, Er, F, S	
	5. Patuakhali	C, Er, F, S, SS	
	6. Pirojpur	C, Er, FF,S, SLR	
Chattogram	7. Bandarban	Er, Eq, FF, L	
	8. Brahmanbaria	Er, F, FF,S, SLR	
	9. Chandpur	Er, F	
	10. Chattogram	C, FF, SLR, Eq, L	
	11. Cumilla	Er, F	
	12. Cox'z Bazar	C, Er, FF, S, SLR, L	
	13. Feni	C, Er, F, S, SLR	
	14. Khagrachhori	C, Er, F, FF, Eq, L	
	15. Lakshmipur	C, Er, F,S, SLR	
	16. Noakhali	C, Er, F, FF,S, SLR	
	17. Rangamati	C, FF,S, SLR, Eq, L	
Dhaka	18. Dhaka	F	
	19. Faridpur	Er, F	
	20. Gazipur	F	
	21. Gopalganj	Er, F, S	
	22. Kishoreganj	Er, F, FF	
	23. Madaripur	Er, F	
	24. Manikganj	Er, F, Eq	
	25. Munshiganj	Er, F	
	26. Narayonganj	Er, F,	
	27. Narsingdi	F	
	28. Rajbari	Er, F	
	29. Shariatpur	Er, F	
	30. Tangail	Er, F	
Khulna	31. Bagerhat	C, Er, F, FF,S, SLR	
	32. Chuadanga	Er, F	
	33. Jashore	Er, F	
	34. Jhenaidah	F, S,	
	35. Khulna	C, Er, F, S, SLR, SS	
	36. Kustia	F, Er, S	
	37. Magura	Er, F, S, D	
	38. Meherpur	Er, F, D, S	
	39. Narail	Er, S, F	

	40. Satkhira	Er, S, SLR, F	
Rajshahi	41. Bogura	C, Er, F, D	
	42. Joypurhat	Er, F, D	
	43. Naogaon	Er, F, D, S	
	44. Natore	Dr, F	
	45. Nawabganj	C, Er, F, D	
	46. Pabna	Er, F, D	
	47. Rajshahi	Er, F, D	
	48. Sirajganj	Er, F, D	
Rangpur	49. Dinajpur	Dr, Er, F	
	50. Gaibandha	Er, F	
	51. Kurigram	C, Er, F, D	
	52. Lalmonirhat	Er, F, D	
	53. Nilphamari	Er, F, D	
	54. Panchagarh	Er, F, D	
	55. Rangpur	Er, F, D, Eq	
	56. Thakurgaon	Er, F, D	
Sylhet	57. Habiganj	Er, FF, F, FF	
	58. Moulvibazar	Er, F, FF	
	59. Sunamganj	Er, F, FF	
	60. Sylhet	Er, F, FF	
Mymensingh	61. Jamalpur	Er, F	
	62. Mymensingh	Er, Eq, F	
	63. Netrokona	Eq, Er, F, FF	
	64. Sherpur	Er, F, Eq	

The hazard maps have also been prepared by the Planning Commission and ADB. One map, as an example, is reproduced here (Figure 6.1). Once the site is located on map, the expected impact of the hazard on the project becomes apparent. The projects can be categorized as red, yellow or green based on their location on the map. It is recommended that Red category projects be required DIA. Yellow category be required preliminary DIA and green category be required of no DIA.

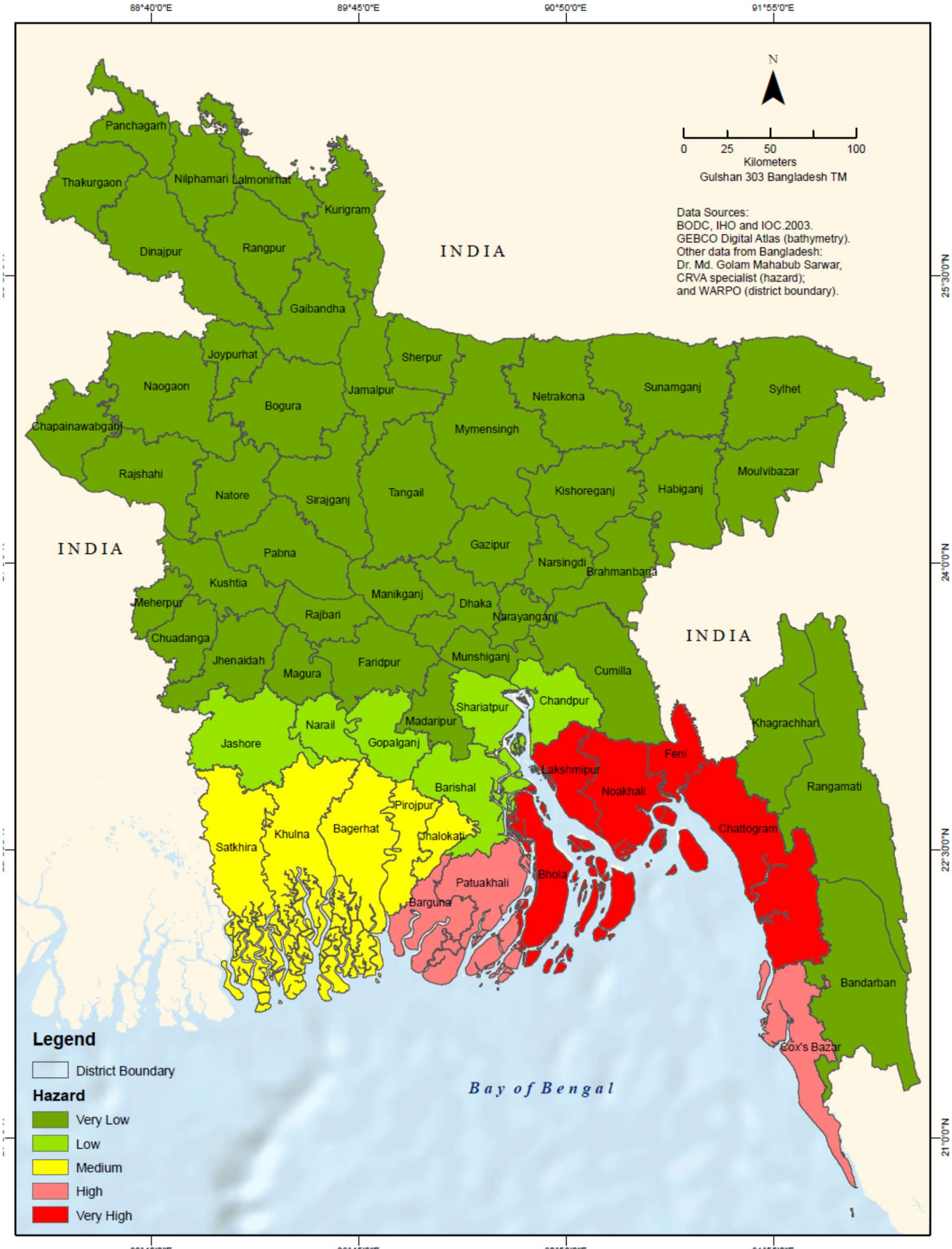


Figure 6.1: Storm surge hazard index map (source: PC, 2018)

2. Impact of hazards

Then the impact of hazards on the structure (including the services they provide) will be reported. Example of impacts for major infrastructures are as follows:

- Cyclone shelter will be exposed to wind hazard, storm surge and salinity.
- Embankments may be breached or overtopped by storm surges leading to water logging.
- Roads through a floodplain may be submerged by flood disrupting communication.
- Bridges may be subject to river erosion.
- Buildings may be damaged by earthquake and then creating fire hazard.
- Collapsed or damaged infrastructure might cause injury and bring challenges for women, adolescent girls, person with disability and aged people for equal access and safety.
- Increase of salinity, water logging has negative impact on women's reproductive health and hygiene practice.
- Damage of infrastructure specifically to road communication can cut off supply of goods and services that make negative impact on economic life of people.

Sometimes the projects itself create new hazards. Such will also need to be reported here. Examples of such transfer of risks are as follows:

- Embankment can raise flood level in the unprotected area
- Roads may lead to water congestion

<u>Disaster Impact Mechanism</u>

The flow of impact by a natural disaster can be divided into two stages: the primary impact and the secondary impact. Primary impact means direct impact from a natural disaster itself on infrastructure with physical damages and losses. For example, a hurricane brings few destructive powers such as winds, rain, flood, hail, tornado, etc. Infrastructure in the influenced territory would get damaged or collapse directly due to the impact of the hurricane. The results could be outage of electricity, break in communications, collapse of buildings, roads and bridges, etc. After these direct impacts or during the disaster impact on infrastructure, secondary impact will be on the services of associated industries. These service failures occur due to damaged infrastructure.

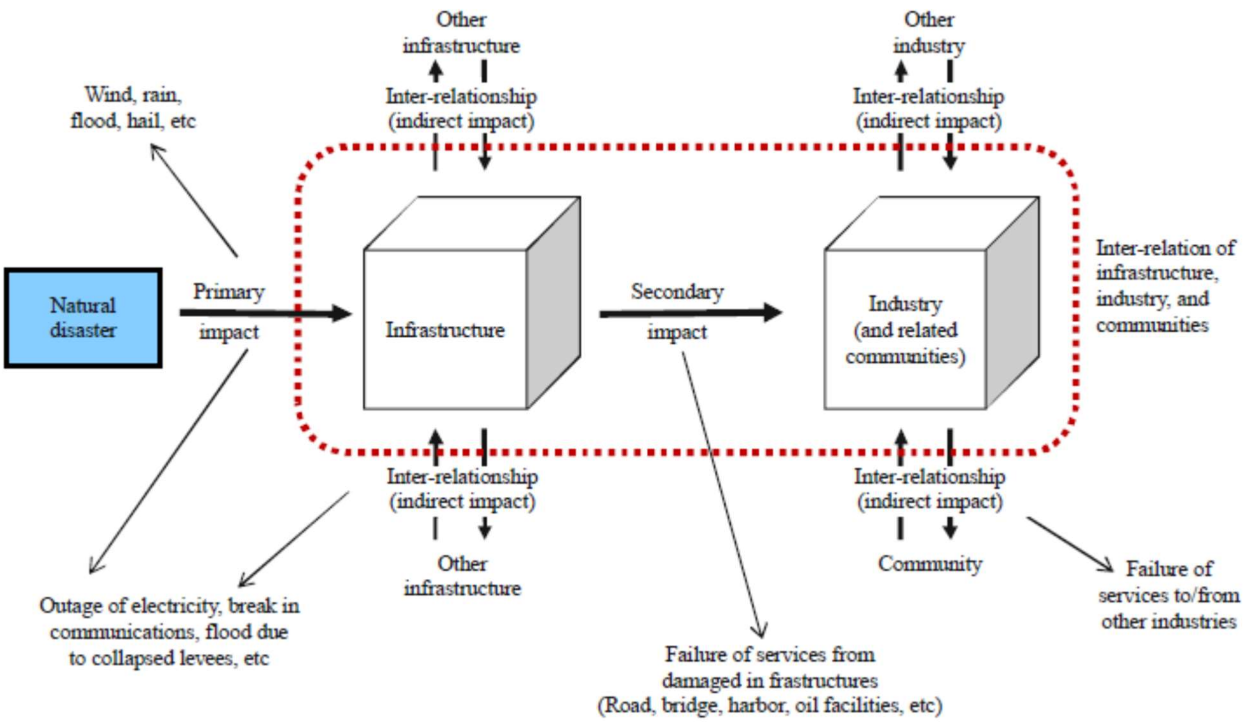


Figure 6.2. Disaster Impact Mechanism (Source: Oh et.al., 2010)

Inter-relations of infrastructure and associated industries are the key component to establish a disaster impact mechanism. A natural disaster primary impacts the infrastructure with physical power and some vulnerable infrastructure may get damaged. Then the damaged infrastructure secondarily transfers its impact to associated industries according to their inter-relation. Figure 6.3 shows the flow of the impact from a natural disaster to associated industries through damaged infrastructure for the representative case, Hurricane Katrina. Few critical infrastructure and associated industries are chosen as examples to show the impact flow and how they are inter-related.

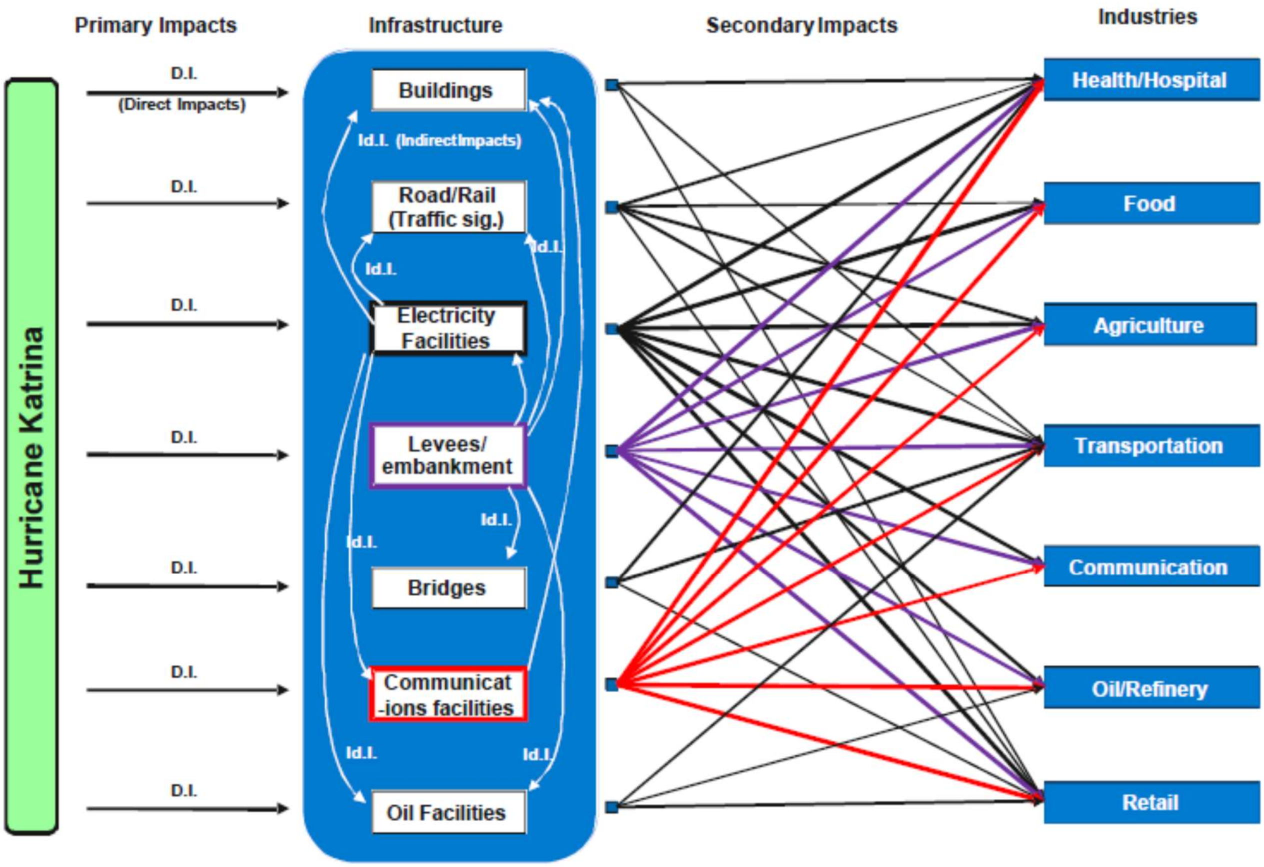


Figure 6.3. Impacts on Infrastructure and Industries from Hurricane Katrina (Source: Oh et.al., 2010)

Case study:

According to Volker (Volker, 1983) the effects of embanking can be divided into three groups:

- the hydraulic effects;
- the morphological effects;
- other environmental impacts;

Hydraulic Effects: These effects are caused by the elimination, by embanking, of the overland flow and overland storage of water on the land areas. The result is a rise of the flood levels, the downstream areas are exposed to higher floods and the rise propagates also in upstream direction. The strip between the channel and the embankment will be exposed to deeper flooding than before which led to public cut of embankments.

Morphological Effects: Embanking tends to increase the velocity of the flood flow and as such, enable the river to carry more silt load. Thus, after embanking, while some river show aggrading tendency (braided form) on account of progressive silt deposit, some remain stable (Srivastave, 1985). The bank erosion may introduce a failure of the embankments. In many cases, after embanking, a rise of the river bed has been observed leading to still higher flood levels. Embanking halts the natural process of building up of the land areas. Embanking also stops the deposition of fertilizing silt.

Other Environmental Impacts: After embanking excess water from local rainfall will not flow to the receding river. Not only drainage outfalls (sluices) in the embankments are necessary but also a system of drainage canals to convey the water to the outfalls. This leads to disappearance of water conservation and to storage of water in the beginning of the dry season. Also, the beneficial effects of flooding in the early stages of the growing season has been eliminated. In a number of cases, like in Polder 22, the farmers have made cuts in the embankments to admit the water. Embankments also eliminate the beneficial effects of the floods in removing dirt, wastes and salinity accumulated during the dry season, rinsing of the canals will be necessary.

3. Counter-measures

This section will report the countermeasures that have been taken against the impacts noted in the previous section. Countermeasures should address both hazard and vulnerability. An example is provided below.

Project	Risk reduction	Measures
Cyclone shelter	Hazard	
	Wind	Max wind speed considered as per BNBC
	Storm surge	Plinth level above historically highest surge level
	Salinity	Thicker covering; modular construction
	Vulnerability	
	River erosion	Sufficient set back distance has been maintained

	Access to shelter	Roads and culverts have been provided Roads and other communication are accessible, safe and secured for women, adolescent girls, and person with disability.
	Safety at shelter	Separate areas for men and women with separate WASH facilities with sufficient light; Emergency lighting facilities in place.
	Services afterwards	Plan for resuming normal operation is in place

Main causes of damage/breaching of dike and its countermeasures are as follows:

Causes of damage	Countermeasures
Erosion (Scouring)	The surface of the dike on both sides shall be covered with vegetation for protection against erosion. The riverside should be protected with revetment, if necessary.
Overflow	Sand bagging for emergency measure. For long term measure, provide concrete and asphalt covering for the crest and the landside slope.
Seepage	To prevent the collapse of dike caused by seepage, embankment materials for the dike should consist of impervious materials (e.g. clay) in the riverside, and pervious materials in the inland side. Drainage structures and related facilities works should be provided at the inland side to drain accumulated water.
Earthquake	Immediately repair/restoration after the earthquake.

4. Assessment of resilience

The resilience can be assessed by the following indicators:

1) Whether the project has an Emergency disaster management plan – All projects are subject to fail and therefore need to have emergency/contingency plan. For example, if a building collapses during earthquake, then there needs to be an evacuation plan and arrangement

for automatic shutdown of utilities such as electricity, gas etc. to prevent fire.

2) Service continuity plan – Important installations such as hospitals, schools, power plants etc need to have service continuity plan for immediate aftermath of a disaster. For example, a school need to resume schooling as soon as possible after a flood when large number of people took shelter in that school building; community health services including provision of reproductive health services to women need to continue even after a hospital is lost to river erosion; mobile network needs to resume operation quickly after a cyclone even if there is loss of few transmission towers.

3) Time of recovery – If a project fails, then it may require considerable period of time for rehabilitation if this issue is not considered during project planning and design. For example, many polders damaged after cyclone Aila and Sidr in later part of 2000s still await full rehabilitation prolonging the sufferings of the inhabitants.

5. Cost of DRR

Cost of DRR will be reported in this section. The percentage of DRR cost compared to the total project cost will also be reported.

Some projects are entirely DRR projects such as cyclone shelter, embankments etc. Here entire project cost is the DRR cost. On the other hand, in some projects cost of DRR is incremental cost. For example, a sea-side road may need protection from sea erosion. In this case, cost of DRR is only the cost of erosion protection.

Costs should also be reported unit-wise. For example, in case of cyclone shelter, in addition to total cost, cost for sheltering each person would be reported.

6. Residual Risk

Risk cannot be absolutely eliminated. In this regard, it is important for the appraiser to judge the residual risk with respect to cost incurred for DRR and the total cost of project.

In this section, the remaining risk after the intervention will be reported. This is to facilitate comparison of residual risk with the cost of DRR. If a road is designed above 1 in 100-year flood it should be reported that there is likelihood that the road will be flooded once in 100 year. If a building is designed to withstand earthquake with a magnitude of 7 in Richter scale then the probability of earthquake above 7 need to be reported.

Training materials

Oh, E.H., Deshmukh, A., and Hastak, M. (2010). Disaster impact analysis based on inter-relationship of critical infrastructure and associated industries. International Journal of Disaster Resilience in the Built Environment, Vol. 1 No. 1, 2010, pp. 25-49

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