ADB Bangladesh Capacity Building for Disaster Risk Finance Project
Risk Modeling

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Dhaka – December 8, 2014
Natural Hazard Risk Profile of Bangladesh
## Major Hazards in Bangladesh

<table>
<thead>
<tr>
<th>Peril</th>
<th>Most Impacted Locations</th>
<th>Type</th>
<th>Potential Economic Severity</th>
<th>Relative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>Southern Coast, Along Major Rivers</td>
<td>Catastrophic</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Tropical Cyclone</td>
<td>Southern Coast</td>
<td>Catastrophic</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Earthquake</td>
<td>North, East</td>
<td>Catastrophic</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Severe Storm</td>
<td>Central</td>
<td>Catastrophic</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Drought</td>
<td>Northwest, Southeast</td>
<td>Catastrophic</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Extreme Temperature</td>
<td>West, Northwest</td>
<td>Catastrophic</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Landslide</td>
<td>Southeast</td>
<td>Catastrophic</td>
<td>Local</td>
<td>Low</td>
</tr>
<tr>
<td>Fire</td>
<td>Major Cities</td>
<td>Catastrophic</td>
<td>Local</td>
<td>Moderate</td>
</tr>
<tr>
<td>Building Collapse</td>
<td>Major Cities</td>
<td>Catastrophic</td>
<td>Local</td>
<td>Low</td>
</tr>
<tr>
<td>River Bank Erosion</td>
<td>Along Major Rivers</td>
<td>Slowly On-Setting</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Arsenic Contamination</td>
<td>Southwest, Southeast</td>
<td>Slowly On-Setting</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Saltwater Intrusion</td>
<td>Southern Coast</td>
<td>Slowly On-Setting</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Climate Change</td>
<td>Southern Coast</td>
<td>Slowly On-Setting</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Maps

- **Tropical Cyclone**
- **Flood**
- **Earthquake**
- **Severe Storm**
General Natural Hazard Risk Profile of Bangladesh

- Overall, flood and cyclones have been shown to most adversely affect Bangladesh
  - high population density
  - low-lying deltaic geography
  - location within an active monsoon and tropical cyclone basin

- Full Disaster Profile from EMDAT:

<table>
<thead>
<tr>
<th>Peril</th>
<th>People Killed (Percent Total)</th>
<th>People Affected (Percent Total)</th>
<th>Estimated Damage (Percent Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>7%</td>
<td>75%</td>
<td>68%</td>
</tr>
<tr>
<td>Tropical Cyclone</td>
<td>89%</td>
<td>18%</td>
<td>27%</td>
</tr>
<tr>
<td>Severe Storm</td>
<td>1%</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Earthquake</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
<td>6%</td>
<td>-</td>
</tr>
</tbody>
</table>

- Does not include damage reported for the 2004 Indian Ocean Earthquake and Tsunami.
- Other peril includes collapse, drought, extreme temperature, significant fire disasters, landslides, complex disasters, and significant transport/industrial/miscellaneous accidents. Does not include the 1943 Bengal Famine or epidemics.
Tropical Cyclone Risk

- Bangladesh is situated within the active North Indian Ocean tropical cyclone (TC) basin
  - The historical record indicates, on average, about one TC makes direct landfall in Bangladesh per year
- Tropical cyclone activity in Bangladesh is typically higher during the months of May, June, October, and November
- In addition to high winds, TCs are associated with flooding and severe storm surge

<table>
<thead>
<tr>
<th>Area</th>
<th>Surge Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk Area</td>
<td>Above 1 m</td>
</tr>
<tr>
<td>Risk Area</td>
<td>Less than 1 m</td>
</tr>
<tr>
<td>High Wind Area</td>
<td>None</td>
</tr>
</tbody>
</table>

Source: SPARRSO
Historical Cyclones in Bay of Bengal

- Historical database derived from IBTrACS (2013)
- Typically data from one or more reporting agency is available per storm
  - IMD, JTWC, others
- 1,455 events from 1877 to 2013
- Existing consequence databases are limited
- Information was collected and assemble from dozens of data sources, including:
  - BMD, DDM, DMIC, EMDAT, GOB, MDMR, MunichRE, SAARC, World Bank, Banglapedia, other reports/papers
- The database contains 88 events from 1582 to 2013
- Most significant events include:
  - 1970 Cyclone
  - 1991 Cyclone
  - 2007 Sidr
- In general, there are several gaps in the data

Flooding around the Karnaphuli River from the 1991 Cyclone
(Source: DVIC)
## Tropical Cyclone Consequence Database

- **Example of the Tropical Cyclone Consequence Database**

<table>
<thead>
<tr>
<th>Year</th>
<th>Dwellings Damaged</th>
<th>Dwellings Destroyed</th>
<th>Source</th>
<th>People Affected</th>
<th>Source</th>
<th>Life Loss Max</th>
<th>Source</th>
<th>Econ Loss Min (M USD)</th>
<th>Source</th>
<th>Econ Loss Max (M USD)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>400,000</td>
<td>-</td>
<td>BANGLAPEDIA</td>
<td>4,700,000</td>
<td>SAARC</td>
<td>500,000</td>
<td>SAARC</td>
<td>63.0</td>
<td>MUNICHRE</td>
<td>86.4</td>
<td>EMDAT</td>
</tr>
<tr>
<td>1991</td>
<td>882,705</td>
<td>819,608</td>
<td>SAARC</td>
<td>15,438,849</td>
<td>EMDAT</td>
<td>150,000</td>
<td>BANGLAPEDIA</td>
<td>1,780.0</td>
<td>EMDAT</td>
<td>3,000.0</td>
<td>MUNICHRE</td>
</tr>
<tr>
<td>1994</td>
<td>62,677</td>
<td>45,000</td>
<td>SAARC</td>
<td>500,000</td>
<td>SAARC</td>
<td>400</td>
<td>BANGLAPEDIA</td>
<td>130.5</td>
<td>SAARC</td>
<td>200.0</td>
<td>PRAMANIK</td>
</tr>
<tr>
<td>May 1997</td>
<td>452,886</td>
<td>290,320</td>
<td>GOB</td>
<td>3,784,916</td>
<td>GOB</td>
<td>155</td>
<td>SAARC</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2007 (SIDR)</td>
<td>957,110</td>
<td>564,967</td>
<td>GOB</td>
<td>8,923,259</td>
<td>GOB</td>
<td>4,407</td>
<td>GOB</td>
<td>1,675</td>
<td>GOB</td>
<td>3,775</td>
<td>MUNICHRE</td>
</tr>
<tr>
<td>2009 (AILA)</td>
<td>369,702</td>
<td>242,882</td>
<td>DMIC</td>
<td>4,826,630</td>
<td>DMIC</td>
<td>500</td>
<td>MUNICHRE</td>
<td>270</td>
<td>MUNICHRE</td>
<td>1,149</td>
<td>GOB</td>
</tr>
<tr>
<td>2013 (MAHASEN)</td>
<td>114,396</td>
<td>21,736</td>
<td>DMIC</td>
<td>1,328,237</td>
<td>DMIC</td>
<td>17</td>
<td>DMIC</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Flood Risk

- Floods in Bangladesh are annual phenomena
  - most severe flooding occurs during July and August
- Flooding in Bangladesh is the result of several factors:
  - heavy rainfall (from monsoons, cyclones, depressions, etc.)
  - convergence of major rivers inside Bangladesh
  - low-lying topography
Flood Consequence Database

- Existing consequence databases are limited
- Information was collected and assemble from dozens of data sources, including:
  - DDM, DFO, DMIC, EMDAT, GOB, MDMR, NWMP, World Bank, other reports/papers
- The database contains consequence information for major floods spanning from 1954 to 2013
- The floods of 1988 and 1998 were particularly catastrophic, each affecting over 60% of Bangladesh and causing more than 8% GDP in losses
- In general, there are several gaps in the data
- Example from database:

<table>
<thead>
<tr>
<th>Year</th>
<th>Flood Affected Area</th>
<th>Dwellings Destroyed</th>
<th>Dwellings Damaged</th>
<th>Source</th>
<th>People Affected Max</th>
<th>Source</th>
<th>Lives Lost Max</th>
<th>Source</th>
<th>Damage Min (M USD)</th>
<th>Source</th>
<th>Damage Max (M USD)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>61%</td>
<td>1,151,189</td>
<td>2,536,408</td>
<td>MDMR</td>
<td>47,000,000</td>
<td>AHMED</td>
<td>2,440</td>
<td>EMDAT</td>
<td>1,137</td>
<td>UNDP/GOB</td>
<td>3,205</td>
<td>AHMED</td>
</tr>
<tr>
<td>1998</td>
<td>68%</td>
<td>984,002</td>
<td>2,456,795</td>
<td>MDMR</td>
<td>55,000,000</td>
<td>AHMED</td>
<td>2,709</td>
<td>DFO</td>
<td>2,128</td>
<td>WB</td>
<td>4,300</td>
<td>EMDAT</td>
</tr>
<tr>
<td>2004</td>
<td>38%</td>
<td>969,161</td>
<td>3,602,009</td>
<td>MDMR</td>
<td>40,955,375</td>
<td>MDMR</td>
<td>910</td>
<td>DFO</td>
<td>1,860</td>
<td>DMIC</td>
<td>2,280</td>
<td>WB</td>
</tr>
<tr>
<td>2007</td>
<td>42%</td>
<td>65,522</td>
<td>919,575</td>
<td>MDMR</td>
<td>13,851,380</td>
<td>EMDAT</td>
<td>1,230</td>
<td>EMDAT</td>
<td>1,067</td>
<td>GOB</td>
<td>1,100</td>
<td>WB</td>
</tr>
</tbody>
</table>
Analysis of Flood Consequence Database

- Reported economic flood loss (from consequence DB) and flood affected area (from BWDB) can be used to generate a loss trend
- Flood affected area by return period is available from the NWMP
- Information can be joined to infer the flood loss by return period

\[ y = 0.194x - 0.032 \]
\[ R^2 = 0.931 \]

<table>
<thead>
<tr>
<th>Return Period (years)</th>
<th>Area Affected by Flood (Source: NWMP, 2000)</th>
<th>Loss Normalized by GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20%</td>
<td>0.7%</td>
</tr>
<tr>
<td>5</td>
<td>30%</td>
<td>2.6%</td>
</tr>
<tr>
<td>10</td>
<td>37%</td>
<td>4.0%</td>
</tr>
<tr>
<td>20</td>
<td>43%</td>
<td>5.1%</td>
</tr>
<tr>
<td>50</td>
<td>52%</td>
<td>6.9%</td>
</tr>
<tr>
<td>100</td>
<td>60%</td>
<td>8.4%</td>
</tr>
<tr>
<td>500</td>
<td>70%</td>
<td>10.4%</td>
</tr>
<tr>
<td>Annual Average</td>
<td>-</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

2014 GDP = 147,349 million USD
11,335 billion BTD
Summary of Natural Hazard Impact in Bangladesh from 2000 to 2013

- Major Events:
  - 2004 Floods
  - 2007 TC Sidr
  - 2007 Floods
  - 2009 TC Aila
Catastrophe Risk Modeling
- To the best of our knowledge, industry catastrophe risk models for Bangladesh that provide probabilistic modeling for natural hazards do not exist at this time
- One objective of this project is to develop new resources to quantify a selected hazard for Bangladesh in support of the overall TA objectives
- Given the state of resources, project timeline, stakeholder feedback, peril severity, and feasibility of disaster risk financing (DRF) solutions, the peril of tropical cyclone was selected as the pilot example for quantitative catastrophe risk analysis in Bangladesh
- Generally all successful country cat DRF solutions have been developed using risk models (for example, PCRAFI, FONDEN, CCRIF, etc.)
AIR Catastrophe Modeling Framework

HAZARD
- Event Generation
- Local Intensity Calculation

ENGINEERING
- Exposure Data
- Policy Conditions
- Damage Estimation

FINANCIAL
- Insured Loss Calculation
Hazard: Event Generation

Tropical Cyclone Frequency

Annual Frequency

LandFall Strength

- CAT0
- CAT1
- CAT2
- CAT3
- CAT4
- CAT5

Tropical Cyclone Frequency

Annual Frequency

LandFall Segment

- 4
- 5
- 6
- 7

CAT0
CAT1
CAT2
CAT3
CAT4
CAT5

Simulation
Historical

Historical Tropical Cyclones
1877 - 2013
Risk Sustained Wind Speed (vmax)
> 80 kph
50 - 80 kph
40 - 50 kph
30 - 40 kph
20 - 30 kph

Capacity Building for Disaster Risk Finance in Bangladesh

November, 2014
Refer to subject reports for methodology, assumptions, and inferences.
Hazard: Local Intensity Calculation

Probabilistic Tropical Cyclone Wind Hazard

<table>
<thead>
<tr>
<th>Mean Return Period (Years)</th>
<th>Dhaka</th>
<th>Chittagong</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>250</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Maximum One-Minute Sustained Wind Speed (mph)
Exposure Data

- The exposure database is a country-specific database containing:
  - risk counts and their respective replacement values
  - information about physical and non-physical characteristics of the modeled assets

- Exposure database has been validated based on available information
Exposure Database Summary

Exposure Database Summary Statistics

<table>
<thead>
<tr>
<th>Exposure Vintage</th>
<th>End 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Native Resolution</td>
<td>Approximate 1km grid</td>
</tr>
<tr>
<td>Population</td>
<td>157,702,419</td>
</tr>
<tr>
<td>Residential Dwellings</td>
<td>35,500,080</td>
</tr>
<tr>
<td>Total Replacement Value</td>
<td>11,526 Billion BDT</td>
</tr>
</tbody>
</table>

Share of Number of Dwellings by Construction per Division
Damage Estimation

- Damage functions relate the intensity of the hazard (e.g., wind speed, flood depth) into monetary loss
- The model offers separate wind and flood damage functions for various combinations of occupancy, construction, and height classes
Tropical Cyclone Risk Modeled Loss Profile

Absolute Modeled Loss by District

Note: Losses to Modeled Exposure (Residential and Non-Residential Buildings)

Does not include storm surge losses

Relative Modeled Loss by District

Note: Modeled Average Annual Loss

Million USD

November, 2014

Refer to project reports for methodology, assumptions, and limitations.
Analysis of Storm Surge Risk

- Storm surge impact is significant in Bangladesh for coastal regions.
- The effect of storm surge is determined using the modeled exposure, storm surge risk maps (SPARROS and IWM), historical data, and the modeled loss results.
- Factors are applied to at-risk coastal districts.

IWM Surge Hazard Map

Exposure Database

Inferred Surge Risk Map
Loss Profile Considering Storm Surge

- In general, country-wide losses increase by a factor of $\approx 1.5$
Model Validation

Reported Impact by District
(People Affected Normalized by Population)

Modeled Impact by District
(Modeled Loss Normalized by Exposure Value)
Preliminary Loss Results

Inferred EP Curve

- Tropical Cyclone
- Flood

Loss (Million USD) vs. Mean Return Period (Years)

Note: TC EP curve derived from modeled loss EP curve, with a factor of 1.5 to account for storm surge and a 2.0 factor to account for losses to other non-modeled sectors.

Flood EP curve derived from historical record.

Annual Average Loss | Cyclone | Flood
--- | --- | ---
M USD | 994 | 2,505
M BDT | 76,480 | 192,687
% GDP | 0.7% | 1.7%

2014 GDP = 147,349 million USD 11,335 billion BTD

Estimated Economic Loss (% GDP)

<table>
<thead>
<tr>
<th></th>
<th>Estimated Economic Loss (% GDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bangladesh</td>
</tr>
<tr>
<td>Cyclone</td>
<td></td>
</tr>
<tr>
<td>Flood</td>
<td></td>
</tr>
</tbody>
</table>

Annual Average

<table>
<thead>
<tr>
<th></th>
<th>Annual Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Cyclone</td>
</tr>
<tr>
<td>0.7%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

2009 AILA
2007 SIDR
1998 FLOOD

2009 AILA
2007 SIDR
1998 FLOOD
Thank You