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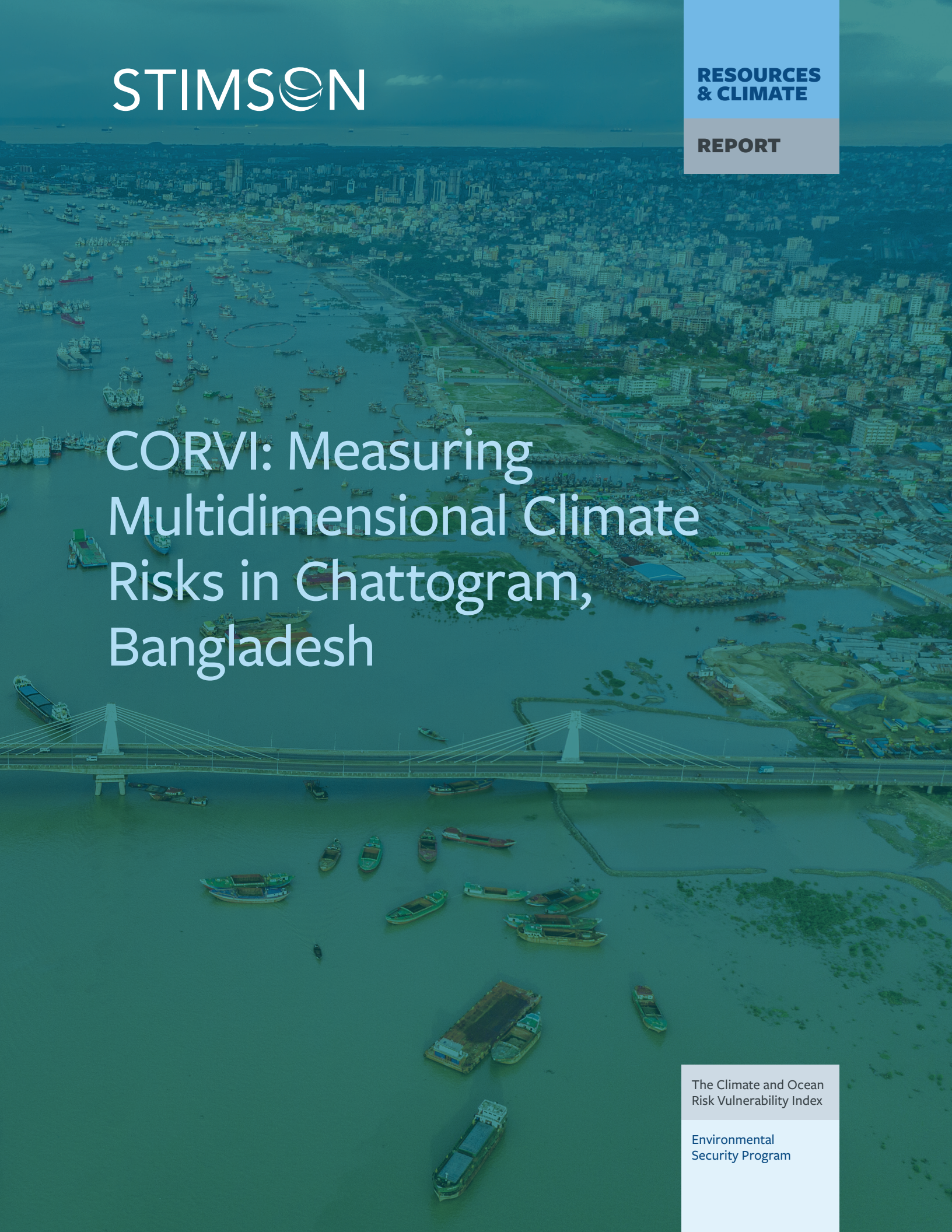

# CORVI: Measuring Multidimensional Climate Risks in Chattogram, Bangladesh

The Climate and Ocean Risk Vulnerability Index

Environmental Security Program

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# Introduction

## CORVI

As risks from climate change to coastal cities continue to increase, governments, public and private investors, and the insurance industry need targeted risk information to prioritize action and build resilience where it matters most.

In response, the Stimson Center developed the Climate and Ocean Risk Vulnerability Index (CORVI). CORVI is a decision support tool that compares a diverse range of ecological, financial, and political risks across 10 categories and nearly 100 indicators to produce a holistic coastal city risk profile. Each indicator and category is scored using a 1-10 risk scale relative to other cities in the region, providing a simple reference point for decision makers looking to prioritize climate action and resilience investment.

This CORVI Risk Profile presents a comprehensive profile of climate and ocean risk for the city of Chattogram, Bangladesh. The assessment combines empirical data from surveys and from global, national, and local datasets with local information from expert interviews to analyze how climate and ocean risks are impacting the city. The information is used to develop detailed priority recommendations for Chattogram to reduce its climate vulnerabilities, build resilience, and work to develop a more secure and sustainable future.

This risk profile was produced in collaboration with the Ocean Policy Research Institute of the Sasakawa Peace Foundation and the Centre for Bay of Bengal Studies at Independent University Bangladesh.

## Chattogram

Chattogram is the second-largest city in Bangladesh and the busiest seaport on the Bay of Bengal. The city accounts for 40 percent of the country's industrial output, 80 percent of its international trade, and 50 percent of government revenue. The city is home to over 3.2 million people, with approximately 5.3 million living in the broader urban area. This represents an increase of around 25 percent over the last 10 years, and the population is expected to grow to over 7 million people in the broader urban area by 2035. Such dramatic growth poses challenges that are being exacerbated by climate change. The geographic area of this risk profile includes the 41 wards under the jurisdiction of the Chattogram City Corporation (CCC).

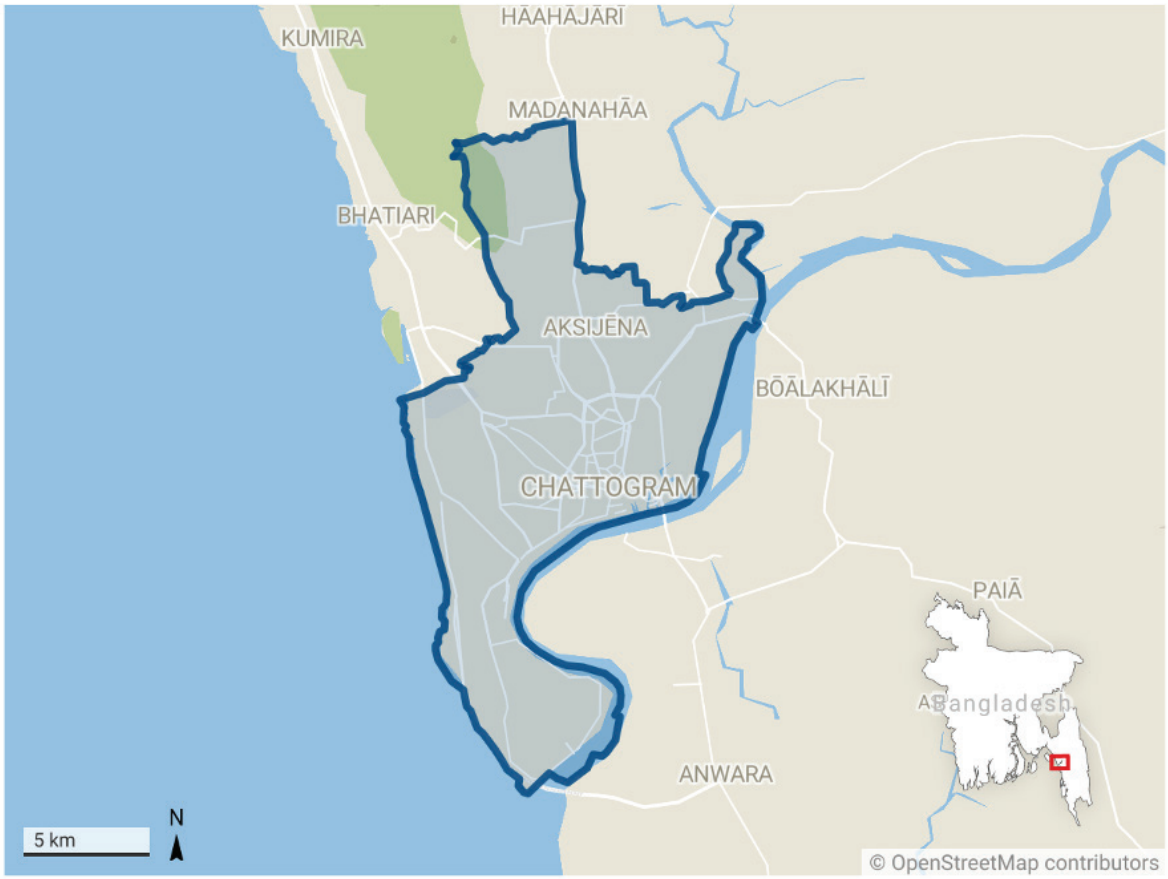
Pre-existing data was collected, and 83 expert surveys were conducted across 10 categories and 95 indicators. This information was displayed and incorporated into the Chattogram CORVI risk profile. These scores were supplemented with information about resilience planning already underway, including from 14 in-depth interviews from local experts, and seminars in Dhaka and Chattogram.

# Summary Findings

The CORVI analysis highlights significant environmental, economic, and social risks reflecting the diverse climate vulnerabilities faced by Chattogram. The medium-high risk scores for Geology and Water (6.74) and Social and Demographics (6.50) show risks associated with rapid unplanned urbanization in a city that already faces severe challenges from flooding and waterlogging. Additional medium-high risk scores for Infrastructure (6.32), Ecosystems (6.26), and Climate Change (5.98) reflect how challenges associated with informal settlements, untreated wastewater, vulnerable infrastructure, degraded coastal and marine ecosystems, and rising sea levels compound these challenges. These impacts are closely associated with corresponding financial risks captured in the Economics (5.80) and Major Industries (5.41) categories.

Tropical cyclones and heavy rainfall are key hazards, related to risks across multiple categories. Rapid urbanization drives the expansion of informal settlements and uncollected solid waste, with both resulting in blocked drainage channels that exacerbate waterlogging. Untreated wastewater from residential sources and from the city's major industries such as shipbreaking and garment making enter the city's key waterways, including the Karnaphuli and Halda rivers and the Bay of Bengal. This wastewater harms human health and the health of key coastal and marine ecosystems — ecosystems are already under threat from development to accommodate the city's growth — and their degradation reduces coastal protection and endangers the blue economy.

### Study Area: Chattogram City




Map: Stimson Center • Created with Datawrapper

## Chattogram Risk Profile

CORVI Category Scores: **Low Risk** 1 - 2.5 | **Medium Risk** 2.51 - 5 | **Medium-High Risk** 5.01 - 7.5 | **High Risk** 7.51 - 10

| Ecological Risk | | Financial Risk | | Political Risk | |
|---|---|---|---|---|---|
| Geology and Water | 6.74 | Infrastructure | 6.32 | Social and Demographics | 6.50 |
| Ecosystems | 6.26 | Economics | 5.80 | Stability | 5.12 |
| Climate Change | 5.98 | Major Industries | 5.41 | Governance | 4.44 |
| Fisheries | 5.33 | | | | |

Table: Stimson Center • Created with Datawrapper

Critical infrastructure — including Chattogram port, the Shah Amananat International Airport, the national Eastern Refinery Limited, and the Karnaphuli tunnel — is located in Chattogram near the coast and the Karnaphuli River. The location makes the infrastructure and the industries that rely on them susceptible to storm surge and prolonged flooding. The Karnaphuli tunnel, expected to open in January 2023, will connect the Chattogram seaport and the airport to southern commercial and tourist districts, while areas on the south bank of the Karnaphuli river are rapidly industrializing in anticipation of the tunnel's opening.[1] The city is also home to Patenga Sea Beach, which is a main tourist attraction in Bangladesh. Chattogram is Bangladesh's commercial capital and generates 40 percent of Bangladesh's industrial output, 80 percent of its international trade, and 50 percent of government revenue.

The government of Bangladesh is a global leader in climate change adaptation planning. The country's development plan includes the Delta Plan 2100 and the Mujib Climate Prosperity Plan 2041. Both plans are aligned with the Bangladesh Climate Change Strategy and Action Plan and National Adaptation Plan. The Chittagong Development Authority is currently drafting a new city master plan, scheduled to be completed in 2024, that will include action plans for stormwater drainage and flood control, communications and transportation, and environmental management.[2] However, shortcomings in implementing prior regulation and plans due in part to a fragmented governance landscape have hindered efforts to strengthen climate resilience. The CORVI risk profile identifies three priority areas in need of action in order to build resilience and plan for systemic risks.

## Summary Recommendations

- **Improve and expand flood adaptation and waste management:** The CCC and Water and Sanitation Authority should adopt a multilayered plan to reduce solid waste, including public collection, performance-based contracts for private providers, and support for informal waste pickers. They can also explore solutions such as waste-to-energy projects. This should be accompanied by clearing drainage channels, expanding green spaces, and restoring waterbodies. Finally, the CCC and the national government should expand financial access to facilitate resilience building and disaster recovery at the individual, household, and business levels.
- **Improve urban climate resilience implementation and invest in climate-smart infrastructure:** The national government, local government, civil society, and international partners should work together to reduce fragmented governance and improve project implementation. This work should draw on international best practices such as Urban Performance Grants, in which fiscal transfers are conditioned on meeting specific performance benchmarks, and broad stakeholder consultation and buy-in. The upcoming city master plan provides a focal point for this effort. The national government can explore emerging sources of finance to help resource climate resilience implementation, including climate-

resilient debt clauses, debt-for-nature swaps, resilience bonds, and new insurance initiatives.

- **Implement a sustainable shoreline development strategy:** Integrating economic development with sustainable environmental management, envisioned by the Delta Plan 2100, requires an integrated strategy to protect Chattogram's coastal and marine ecosystems while promoting growth. This strategy could include expanded marine zoning coupled with stronger enforcement of existing protected areas, improving treatment of residential and industrial wastewater by passing and enforcing pollution standards, embracing creative solutions such as using decommissioned vessels for artificial reefs, facilitating housing development in low-risk areas of the city, and supporting integrating rice agriculture with other crops, including the use of salt-tolerant rice varieties.

# Ecological Risk

Chattogram is known for its natural beauty. Its marine and land ecosystems play a big part in protecting coastal areas from flooding, supplying important fish sanctuaries, and making Chattogram stand out as the country's main tourist destination. However, Geology/Water risk and Ecosystems category scores are among the highest ecological risk categories in the Chattogram risk profile, reflecting risks driven by coastal erosion and the poor health of key marine ecosystems. Ecological risk scores also highlight significant vulnerability to worsening climate effects, including acute events like tropical cyclones as well as more long-term changes such as warming sea surface temperatures and more frequent incidents of heavy rain.

- In the **GEOLOGY/WATER** category (expert weighted average of 6.74), there are high and medium-high risk scores for the rate of coastal erosion (7.58), projected change in sea level rise (7.47), level of geophysical risk of landslides (7.38), percent of the metropolitan area at risk of flooding (7.33), and degree of saltwater intrusion in coastal aquifers (7.28). These scores demonstrate the vulnerabilities to the urban center posed by geological and water-related risks.
- In the **ECOSYSTEMS** category (expert weighted average 6.26), there are high risk scores for the health of existing seagrass beds (7.98) and health of existing coral reefs (7.74), along with medium-high risk scores for level of mangrove coverage (7.47), level of coral reef coverage (7.42), and level of seagrass bed coverage (6.07). These scores underline the dangers posed by climate change and habitat destruction to these key coastal and marine ecosystems, negatively impacting marine habitats and nature-based city defenses.
- The **CLIMATE CHANGE** category (expert weighted average 5.98) includes four indicators scored as high risk, the most of any single category in this assessment. These scores reflect the vulnerability related to the number of tropical cyclones (8.38), the number of people affected by extreme weather events (8.30), change in sea surface temperatures (7.93), and the number of wet days (7.93).
- The **FISHERIES** category (expert weighted average 5.33) is the only category under Ecological Risk to have no indicators scored as high risk. Nonetheless, medium-high risk scores for fish consumption per capita (7.23), number of incidents of foreign vessels fishing in the exclusive economic zone (EEZ) (6.81), and fisheries certified by the Marine Stewardship Council (MSC) (6.04) reflect risks to the food security of city residents.

Bangladesh's long coastline has a coastal zone that covers 32 percent of the country,[3] leaving the country vulnerable to **tropical cyclones**, which are the highest risk score in Ecological Risk (8.38). These cyclones hit Bangladesh on average every three years,[4] frequently forming in the Bay of Bengal during the early summer and late rainy season.[5] Tropical cyclones have killed almost 900,000 people over the last 35 years.[6] In 1991, Cyclone Marian, one of the deadliest tropical cyclones ever recorded, hit the Chattogram area,[7] killing almost 140,000 people, including 25,000 from Chattogram.[8] Losses reached nearly $1.8 billion, as the cyclone destroyed 780,000 homes, damaged or destroyed 9,300 schools and 655 health centers, and left Chattogram's port in shambles.[9] In the agricultural sector, the cyclone destroyed over 280,000 tons of crops, killed 442,000 livestock and 2.4 million chickens, and severely damaged 31,000 hectares of shrimp farms.[10] Cyclone Marian was classified as a super cyclonic storm on the Indian Meteorological Department scale and a Category 5 tropical cyclone on the Saffir-Simpson scale, and while Chattogram has been fortunate to avoid storms of that magnitude since 1991, it has been hit by Cyclones Viyaru/Mahasen in 2013, Komen in 2015, Roanu in 2016, Mora in 2017,[11] and, most recently, Sitrang in late October 2022. The strong winds brought by a tropical cyclone can cause more damage than storm surge flooding, as suggested by a study of the destruction caused by Cyclone Sidr in 2007.[12]

Climate change will increase the risks posed by tropical cyclones, excelling in frequency and intensity,[13] driven by warmer sea surface temperatures and rising sea levels. In addition to being vulnerable to stronger winds, the population in coastal Bangladesh will face a sharp growth in storm surge inundation. By 2050, more than twice as many people will be vulnerable to inundation

of more than 1 meter compared to the present, and almost three times as many people will be vulnerable to inundation of more than 3 meters compared to the present.[14] This increase is not solely due to climate change, as population growth, coastal erosion, subsidence, and other factors will also play a role.

**Sea surface temperature** in the Bay of Bengal has risen by 0.2-0.3°C over the last 45 years and is projected to rise by another 2.0-3.5°C by 2100,[15] reflected in the high risk score (7.93). This rise in temperature will have several detrimental effects, including increased intensity of tropical cyclones, faster rise in sea levels, more frequent occurrence of harmful algal blooms (5.82), and reduced productivity of many marine species.[16]

**Sea level rise (SLR)**, scored as medium-high risk (7.47), will increase the impacts of tropical cyclones and flooding. SLR around Chattogram is accelerating, based on readings from gauges at Char Changa and Cox's Bazar, which are located to the west and south of the city, respectively. Annual SLR between 1977 and 1998 was 6 and 7.8 millimeters, respectively,[17] but more recent measurements showed annual SLR of 7.6 millimeters per year at Char Changa (between 1993 and 2019) and 14.5 millimeters per year at Cox's Bazar (between 1993 and 2011).[18] More broadly, the rate of SLR in the Northern Bay of Bengal from 1983 to 2000 was significantly higher than the worldwide average, at 4 millimeters per year in the Bay of Bengal vs. 3.32 millimeters per year on average globally.[19]

In Chattogram, SLR is accelerated by land subsidence. The city is one of the fastest-sinking cities in the world, with a peak rate of over 25 millimeters per year.[20] Groundwater extraction and the weight of dense construction are major causes of this subsidence, both driven by the city's rapidly growing population.[21] **Coastal erosion** was also scored as high risk (7.58), as more than 60 percent of Chattogram's coast is experiencing erosion, with a maximum rate of 36 meters per year.[22]

Climate change is also driving increasingly erratic rainfall patterns, reflected in a high risk score for **number of wet days** (7.93). This was demonstrated clearly during the 2022 monsoon season. In June, record levels of rainfall left much of the city — together with much of the rest of the country — submerged.[23] The following month, Chattogram division recorded total rainfall was 68 percent below the July average, mirroring the situation for the rest of the country, which saw the lowest levels of rainfall in July since consistent record-keeping began in 1980.[24]

Flooding in Chattogram, 2018

Chattogram often experiences prolonged flooding and waterlogging during periods of heavy rainfall, reflected in a medium-high risk (7.33) for **percent of the metro area at risk of flooding**. This issue has worsened in recent years, exacerbated by uncollected waste and the disappearance of many of the city's waterbodies, over 75 percent of which disappeared between 1991 and 2007.[25] Low-lying areas of the city are particularly vulnerable, such as East Baklia, South Baklia, Halishohor, Sholokbahar, Muradpur and Bahaduraghat zone, Chandgaon, Mohra, Chaktai, Khatunganj, Asadganj, Chawkbazar and Patenga areas. Interviewees noted that in some flood-prone areas of the city, the ground floor of many buildings has been abandoned because of frequent inundation, and roads have already required raising.[26] Interviewees also observed that waterborne diseases are increasing in areas of the city that see consistent flooding during the rainy season.[27]

In the areas surrounding Chattogram, excessive rainfall creates additional risk beyond those commonly associated with low-lying urban environments. The **risk of landslides** is growing in the urbanized hilly areas of Chattogram, reflected in the medium-high risk score (7.38). On June 11, 2007, a catastrophic landslide disaster killed 128 people after 610 millimeters of rain fell over eight consecutive days.[28] The main causes of this increased landslide hazard are indiscriminate deforestation, hill cutting, and heavy rainfall.[29] Interviewees also noted that landslides contribute to waterlogging in Chattogram.[30] Yet the city authorities have not produced a landslide hazard zonation map, nor an effective landslide alert system.

Marine and coastal ecosystems play a key role in shaping Bangladesh's vulnerability to extreme weather events. The country's southeast coast used to have significant mangrove coverage in the form of the Chakaria Sundarbans. Located south of Chattogram in Cox's Bazar district, shrimp and salt farms have almost entirely replaced the mangroves.[31] During the 1991 Super Cyclone, the absence of mangroves as a natural buffer resulted in significant loss of life and property destruction to Chakaria and surrounding areas.[32] By contrast, during Cyclone Sidr in 2007, the limited and unplanned growth of mangroves on coastal embankments substantially reduced storm surge velocity.[33] Mangrove forests once covered the whole coast of Chattogram. Today, deforestation of mangroves continues as a result of coastal development, heavy metal poisoning,[34] expansion of shrimp farming,[35] and untreated wastewater,[36] reflected in the medium-high risk score for **mangrove coverage** (7.47).

Less research exists on threats to coral reefs and seagrass beds, though preliminary findings suggest that untreated wastewater and pollution from Chattogram's port and shipbreaking industry may be damaging both types of ecosystems.[37] The results of the expert surveys, which scored **health of seagrass beds** (7.98) and **health of coral reefs** (7.74) as high risk, also suggest that both ecosystems face ongoing threats. Medium-high risk scores for **coral reef coverage** (7.42) and **seagrass bed coverage** (6.07) suggest that both ecosystems are shrinking. The national government has taken steps to protect its coral reefs, most notably the declaration of a marine protected area around St. Martin's Island, where the local coral reefs are found. Bangladesh's adaptation planning has not prioritized the protection of seagrass beds.[38]

For a nation with such an extensive coastline, marine capture fisheries in Bangladesh are a small part of the overall fisheries sector, comprising less than 20 percent of the total industry.[39] An estimated 1.35 million individuals work in marine capture fisheries out of a workforce of about 20 million in the aggregate fisheries industry (full- and part-time, including inland output).[40] Inland fisheries and aquaculture comprise the majority of the industry, with production of 1,248,401 megatons and 2,583,866 megatons, respectively, compared to 671,104 megatons for marine capture in 2020.[41] Bangladesh is the fifth-largest aquaculture producer in the world, according to the Food and Agriculture Organization,[42] and accounts for over half of the total fisheries output of Bangladesh.[43] Shrimp (prawn) production is a key facet of aquaculture, and Chittagong-Cox's Bazar and Khulna-Shatkira-Bagerat regions dominate shrimp production. These two regions account for approximately 95 percent of the total area dedicated to shrimp culture.[44] Aquaculture farmers are exposed to significant risks including shrimp diseases, fluctuation in price and demand, and availability of quality product.[45] Inland shrimp production also increases coastal vulnerability, contributing to the **salinization of arable land**,[46] reflected in the medium-high risk score for salinization of arable land (7.03), the decline in aquatic biodiversity,[47] and the destruction of mangroves.[48]

The medium-high indicator scores related to levels of **fish consumption per capita** (7.23) and the percentage of **certified sustainable fisheries** (6.04) may reflect the reliance on inland capture and farmed fish to a greater extent than marine capture fisheries. Fish play an important role in the Bangladeshi diet. They provide more than 60 percent of animal source food, which represents a crucial source of micro-nutrients, and are also culturally important.[49] From 2005 to 2016, the country's per capita fish consumption increased by 49 percent, reaching 22.85 kg in 2016, higher than the average global consumption of 20.5 kg per capita.[50]

Nonetheless, medium-high risk scores for **nearshore fish stock status** (5.81) and **offshore fish stock status** (5.31) indicate concerns related to marine fish stocks and their management. Similarly, the medium-high risk score for the **number of incidents of foreign vessels fishing in the EEZ** (6.81), which was the second-highest scoring indicator in the Fisheries category, indicates the need for stronger cooperation among countries fishing in the Bay of Bengal. Authorities have seized vessels from Sri Lanka and arrested fishers off the shores of Bangladesh. Other conflicts are dealt with directly at sea. For example, trawler skippers from Chittagong spoke of the sinking of smaller vessels by other fishers, which sometimes goes unreported.[51]

Processes and mechanisms for data sharing and a functional platform to cooperate in marine fisheries management are needed, according to Mohammed Latifur Rahman, director of Bangladesh's marine fisheries office.[52]

In the past, government initiatives attempted to mitigate coastal risks, including massive plantation and embankment construction. Unfortunately, these conventional initiatives ultimately turned out to be impractical and ineffective.[53] For example, coastal polders — low-lying tracts of land surrounded by embankments, constructed in the 1960s and 1970s to protect farmers from floods and saltwater intrusion — have caused waterlogging in coastal zones and often were turned into shrimp farms, further exacerbating coastal risk.[54] A modern adaptation approach is required for better management of the coastal zones of Bangladesh, in particular environmental hazards. This approach should be integrated with "appropriate measures based on knowledge on the physical geography of potentially affected areas."[55] The government of Bangladesh declared 1,743 square kilometers of the Bay of Bengal adjacent to Saint Martin's Island as Saint Martin Marine Protected Area to conserve marine biodiversity, and constructed the 15.2-kilometer-long Chattogram Marine Drive Expressway for protecting coastal erosion.

## Chattogram: Ecological Risk

Each category score comprises multiple indicators.
**Low** 1 - 2.5 **Medium** 2.51 - 5 **Medium-High** 5.01 - 7.5 **High** 7.51 - 10

| Category | | Indicator | |
|---|---|---|---|
| Geology and Water | 6.74 | Rate of Coastal Erosion | 7.58 |
| | | Projected Change in Sea Level Rise | 7.47 |
| | | Level of Geophysical Risk of Landslides | 7.38 |
| | | Percent of Metro Area at Risk of Flooding | 7.33 |
| | | Degree of Saltwater Intrusion in Coastal Aquifers | 7.28 |
| | | Degree of Soil Salinity in Arable Lands | 7.03 |
| | | Percent of Landscape That Is Arable Land | 5.73 |
| | | Percent of Bodies of Water with High Water Quality | 5.64 |
| | | Piped Water Supply Continuity | 4.68 |
| Ecosystems | 6.26 | Health of Existing Seagrass Beds | 7.98 |
| | | Health of Existing Coral Reefs | 7.74 |
| | | Level of Mangrove Coverage | 7.47 |
| | | Level of Coral Reef Coverage | 7.42 |
| | | Percent of GDP Protected by Mangroves | 6.23 |
| | | Percent of GDP Protected by Seagrass Beds | 6.12 |
| | | Level of Seagrass Bed Coverage | 6.07 |
| | | Rate of Occurrence of Harmful Algal Blooms | 5.82 |
| | | Incidences of Invasive Species | 5.40 |
| | | Percent of GDP Protected by Coral Reefs | 4.47 |
| | | Health of Existing Mangroves | 3.26 |
| Climate Change | 5.98 | Total Number of Tropical Cyclones | 8.38 |
| | | Number of People Affected by Extreme Weather Events | 8.30 |
| | | Number of Wet Days | 7.93 |
| | | Change in Sea Surface Temperature | 7.93 |
| | | Number of Droughts | 4.48 |
| | | Cases of Vector-Borne Disease Infections | 4.37 |
| | | Number of Flood Events | 4.04 |
| | | Number of Extreme Heat Events | 3.31 |
| Fisheries | 5.33 | Fish Consumption per Capita | 7.23 |
| | | Number of Incidents of Foreign Vessels Fishing in EEZ | 6.81 |
| | | Percent of Fisheries Certified by MSC | 6.04 |
| | | Nearshore Fish Stock Status | 5.81 |
| | | Offshore Fish Stock Status | 5.31 |
| | | Capacity of Fisheries Enforcement Institutions | 5.30 |
| | | Number of Fisheries Access Agreements with Foreign Nations | 4.23 |
| | | Level of Unreported Catch Estimate | 2.63 |

Table: Stimson Center • Created with Datawrapper

# Financial Risk

Chattogram is the commercial hub of Bangladesh and the busiest seaport on the Bay of Bengal. The city generates 40 percent of the country's industrial output, 80 percent of its international trade, and 50 percent of government revenue.[56] However, as a crowded, low-lying, commercial hub, it faces attendant climate risks, particularly a large informal economy, numerous informal settlements, inadequate treatment of wastewater and solid waste, and losses from extreme weather events.

- The **INFRASTRUCTURE** category (expert weighted average 6.32) highlights the risks associated with the level of informal or unplanned settlement (8.66), the proportion of wastewater safely treated (7.51), and the degree of compliance for solid waste management procedures (7.33). Medium-high risk scores reflect risks to the resilience of critical infrastructure, including ports and shipping (6.96), roads (6.57), water distribution infrastructure (6.37), airports (5.95), and the power grid (5.17). Finally, medium-high risk scores also reflect the risk associated with the percent of low-income housing in relation to flood zones (6.67) and the level of housing damage from extreme weather events (6.64).
- In the **ECONOMICS** category (expert weighted average 5.80), high risk scores highlight the economic importance of coastal cities (8.19) and the size of Chattogram's informal economy (7.95). Medium-high risk scores reflect risks due to market losses from extreme weather events (7.35), income inequality (7.26), national GDP per capita (6.78), and urban unemployment (6.10).
- The **MAJOR INDUSTRIES** category (expert weighted average 5.41) is the only category under Financial Risk to have no indicators scored as high risk. Nonetheless, it includes medium-high risk scores for the percent of national economy based in port and shipping industries (7.02), in the nearshore fishing industry (6.78), and in the offshore fishing industry (6.75).

Chattogram is Bangladesh's commercial capital because of its diversified industrial base and seaport. It is a regional transshipment hub, with proximity to northeast India, Nepal, Myanmar, Bhutan, and southwest China. The city is home to many of the country's oldest and largest corporations, such as A K Khan & Company, Abul Khair Group, Bangladesh Shipping Corporation, and Habib Group. The importance of Chattogram to the national economy of Bangladesh is reflected in a high risk score for percent of **GDP generated in coastal cities** (8.19), of which Chattogram is the largest.

Bangladesh's economically critical coastal cities, however, are highly vulnerable to extreme weather events, reflected in a medium-high risk score for **market losses from extreme weather events** (7.35). Five of the 10 deadliest tropical cyclones in the world since 1900 have occurred in Bangladesh, including the 1970 Bhola cyclone, considered the deadliest ever recorded.[57] Tropical cyclones alone are expected to cause an average of approximately $1 billion in losses every year to Bangladesh.[58] Individual years and even individual events, however, will result in greater losses. The economic impact of the 1991 cyclone was between $1.8 and $3.0 billion and that of Cyclone Sidr in 2007 was between $1.7 and $3.8 billion, despite the lower death toll.[59] Rainfall-driven flooding due to non-cyclonic storms has also caused high economic losses.[60]

Chattogram's port is a key part of the city's economy, reflected in the medium-high risk score for the size of **the port and shipping industry** (7.02). In 2011, it handled $60 billion in annual trade, the third most in South Asia after Mumbai and Colombo.[61] Ninety percent of Bangladesh's imports and exports are handled through the port of Chattogram,[62] which is part of China's Maritime Silk Road that runs from China via the Suez Canal to the Mediterranean.[63] The Chattogram Export Processing Zone (CEPZ) is one of the leading special economic zones in the world. The UK-based Foreign Direct

Investment magazine ranked CEPZ fourth in the "Best Economic Potential" category and third in the "Best Cost Competitive" category in 2010.[64]

Besides being a major port of entry for shipping, Bangladesh is the world's leading country for shipbreaking. The industry's yards are located just outside Chattogram. In 2021, approximately one-third of the ships broken down were dismantled in Bangladesh.[65] The industry directly employs 50,000 people and another 100,000 indirectly,[66] and provides around 80 percent of the country's steel.[67] Laws to protect workers and the environment, however, are weakly enforced.[68] Despite some increase in the use of personal protective equipment,[69] the first half of 2022 saw a "surge of accidents."[70] Similarly, a bill passed in 2018 to reduce the environmental impact of the shipbreaking industry has had limited effect,[71] and an estimated 79,000 tons of asbestos, 240,000 tons of PCBs, and 69,200 tons of toxic paints will be imported into the country between 2010 and 2030 through the industry, according to a World Bank estimate.[72] Since appropriate storage and treatment facilities remain limited, these pollutants are typically either dumped into the marine environment or resold, causing further health impacts.[73]

Shipbreaking in Chattogram, July 2009

Chattogram is also home to a growing shipbuilding industry. The industry employed an estimated 30,000 people in 2018, with projections to employ 20,000 in the subsequent five years and reach 100,000 in 15 years.[74] The country's leading shipbuilder is the Chattogram-based Western Marine Shipyard Ltd., which in 2018 accounted for 89 percent of the country's shipbuilding exports,[75] though the company has faced financial challenges in recent years.[76]

Many of the workers employed in shipping-related industries in Chattogram are informally employed,[77] and the informal economy as a whole accounts for 86 percent of total employment in the city.[78] These workers are often excluded from social protection measures such as sick leave and paid vacation leave,[79] and also from accessing formal financial institutions.[80] This makes informal workers more vulnerable to economic shocks, as demonstrated by the COVID-19 pandemic. Of those urban workers in Dhaka and Chattogram who were required to stop working because of business shutdowns, 68 percent lost their jobs. Informal workers suffered a 50 percent fall in their income.[81] This uncertainty in the work environment leaves informal workers more vulnerable to the impacts of extreme weather events and limits the ability of informal businesses to make the upfront investments often required to strengthen climate resilience. Businesses and workers operating in the informal economy also generally pay fewer taxes than those in the formal economy. This contributes to Bangladesh's limited tax collection; the country collects the fewest taxes as a share of its economy of any country in South Asia.[82] These vulnerabilities are reflected in the high risk score for the **size of the informal economy** (7.95).

Chattogram is also characterized by widespread informal settlements — home to approximately one-quarter of the city's population[83] — as reflected in the high risk score for the **level of informal or unplanned settlement** (8.66). Residents of these informal settlements have less access to public services, such as healthcare, and face higher levels of air and water pollution.[84] The housing found in informal settlements usually consists of temporary, fragile structures, made of tin or mud.[85] As a result of rapid urbanization and increasing land prices, some informal settlements are constructed on government land,[86] including drainage canals.[87] Such housing both leaves residents at risk of eviction and worsens the city's challenges with flooding and waterlogging. The disposal of household waste into local waterbodies and on the ground — the practices followed by 58 percent and 39 percent of informal settlement residents in Chattogram, respectively — further exacerbates flooding and waterlogging.[88]

Shortcomings in waste management are an enduring challenge in Chattogram even beyond its informal settlements, reflected in the medium-high risk score for **solid waste management** (7.33). The city generates 3,000 tons of solid waste every day, according to the CCC's 2019-2020 Waste Report.[89] One estimate found that waste generation per capita in Chattogram doubled in the decade between 1999 and 2009 as a result of a rising standard of living.[90] Plastic consumption per person in Bangladesh's urban areas tripled between 2005 and 2020, driven in part by increased use of single-use plastics during the COVID-19 pandemic (specifically, reliance on single-use personal protective equipment).[91] Chattogram's waste management systems have been unable to handle this level of waste generation, with as much as 33 percent of it going uncollected.[92] This waste, especially discarded plastic, often sits in the city's rivers, waterbodies, and drainage channels, most of which are uncovered. It then has three principal impacts. First, over time the plastic degrades into microplastics that pose a significant risk to human and marine ecosystem health.[93] Second, city residents fall into the open drainage channels, an occurrence that killed five people and injured dozens in 2021.[94] Third, the solid waste clogs drainage channels, exacerbating the city's challenges with flooding and waterlogging, which has caused over Tk 250 crore ($24 million) in damages annually on average over the last decade.[95] Previous efforts to reduce solid waste generation and improve waste management, including the 2002 national plastic shopping bag ban and a pilot waste management project in Nabinagar beginning in 2021, have seen limited results.[96]

Drainage channel in Chattogram clogged with solid waste, 2022

Besides the city's solid waste challenges, Chattogram faces high risk in the area of **wastewater treatment** (7.51). The city generates 400 million liters of sewage per day, which is expected to grow to 515 million liters by 2030.[97] That untreated sewage currently enters the Karnaphuli and Halda rivers before ending up in the Bay of Bengal, where it damages key coastal and marine ecosystems and human health.[98] The city also generates 539 cubic meters of fecal sludge per day, projected to grow to 715 cubic meters by 2030.[99] Of the 539 cubic meters, 15 is currently managed by the CCC, 20 by the nongovernment organization DSK, and the remaining 504 cubic meters of untreated fecal sludge enters the city's rivers and the Bay of Bengal, further damaging human and ecosystem health.[100] The Chattogram Water and Sewerage Authority drafted a master plan in 2017 that envisions treating the city's wastewater through a combination of six sewage treatment plants, which would cover 75 percent of households, and two fecal sludge treatment plants.[101] Work has begun on the first sewage treatment plant, and tentative approval by the national government for a second came in October 2022.[102]

## Chattogram: Financial Risk

Each category score comprises multiple indicators.
**Low** 1 - 2.5 **Medium** 2.51 - 5 **Medium-High** 5.01 - 7.5 **High** 7.51 - 10

| Category | | Indicator | |
|---|---|---|---|
| Infrastructure | 6.32 | Level of Informal or Unplanned Settlement | 8.66 |
| | | Proportion of Wastewater Safely Treated | 7.51 |
| | | Degree of Compliance for Solid Waste Management Procedures | 7.33 |
| | | Level of Resilience for Ports and Shipping | 6.96 |
| | | Percent of Low-Income Housing in Relation to Flood Zones | 6.67 |
| | | Level of Housing Damage from Extreme Weather Events | 6.64 |
| | | Level of Resilience for Roads | 6.57 |
| | | Level of Water Distribution Infrastructure Resilience | 6.37 |
| | | Renewable Energy Share in Total Energy Consumption | 6.33 |
| | | Percent of People Living Below 5 Meters Above Sea Level | 6.29 |
| | | Level of Shoreline Development | 6.22 |
| | | Level of Resilience for Airports | 5.95 |
| | | Level of Grid Resilience | 5.17 |
| | | Level of Solid Waste Treated | 4.49 |
| | | Percent of Population with Adequate Access to Electricity | 3.90 |
| Economics | 5.80 | Percent of GDP Generated in Coastal Cities | 8.19 |
| | | Level of Informal Economy | 7.95 |
| | | Market Losses from Extreme Weather Events | 7.35 |
| | | Income Inequality | 7.26 |
| | | National GDP per Capita (Purchasing Power Parity) | 6.78 |
| | | Urban Unemployment Rate | 6.10 |
| | | National Youth Unemployment Rate | 4.00 |
| | | National Unemployment Rate | 3.49 |
| | | Debt Ratio (% of GDP) | 2.71 |
| Major Industries | 5.41 | Percent of National Economy Based in Port and Shipping Industries | 7.02 |
| | | Percent of National Economy Based in Near Shore Fishing Industry | 6.78 |
| | | Percent of National Economy Based in Off Shore Fisheries | 6.75 |
| | | Percent of National Economy Based in Agriculture | 4.91 |
| | | Diversity of Lodging Types | 4.73 |
| | | Percent of National Economy Based in Tourism Industry | 2.99 |

Table: Stimson Center • Created with Datawrapper

# Political Risk

Many of Chattogram's highest political risks are associated with the city's rapid population growth. The city also faces high risk from limited investment in climate resiliency projects and medium-high risks from climate risks to key industries, poverty, civil society engagement, and adaptation implementation.

- In the **SOCIAL/DEMOGRAPHICS** category (expert weighted average 6.50), high risk scores for urban population (8.78), urbanization rate (8.75), and percent of the urban population below 30 years of age (8.25) highlight the risks associated with a rapidly growing population in a city with already strained infrastructure.
- The **STABILITY** category (expert weighted average 5.12) shows medium-high risk scores for the percents of people employed in agriculture (6.55), the commercial fishing industry (5.92), and the port and shipping industries (5.49).
- Although the **GOVERNANCE** category (expert weighted average 4.44) has the lowest average score in the assessment, a high risk score for investment in climate resiliency development projects (8.15) highlights concerns around insufficient resources mobilized to strengthen climate resilience in the city. Medium-high risk scores for civil society participation (6.52) and national climate adaptation plan (5.10) highlight additional challenges.

Chattogram is the second most populous city in Bangladesh and is continuing to grow rapidly, reflected in high risk scores for **urban population** (8.78) and **urbanization rate** (8.75). The city's population is over 3.2 million (defined by the 41 wards under the jurisdiction of the CCC), and the population of the metropolitan area is 5.3 million. The city has added almost 650,000 people — a 25 percent increase — in a decade.[103] The metropolitan area has added over a million during the same time period and is expected to reach over 7 million people by 2035.[104] This growth will continue to strain municipal public services, most notably solid waste management and wastewater treatment. Continued growth will also likely result in further encroachment of housing on hazard-prone areas without effective regulation. It will also contribute to the further reduction in available green spaces in Chattogram, which has already fallen by nearly half from 68 percent of the city's area in 1990 to 37 percent in 2020.[105]

Low-lying settlement in Chattogram

Migration from rural areas to Chattogram is a major source of the city's rapid population growth rate.[106] In addition to the draw of Chattogram's flourishing economy, there are several important push factors driving people to leave their homes and move to Chattogram, particularly the transition from rice agriculture to shrimp farming that has occurred along much of the Bangladeshi coast. Shrimp farming has significantly lower labor requirements than rice agriculture, especially in rural areas, thus reducing local job opportunities.[107] It also contributes to increased soil salinity, reducing the productivity of local rice farms even where they are not converted to shrimp farms.[108] The risks to **agricultural employment** from both climate factors, such as rising sea levels, and non-climate factors is reflected in the medium-high risk score (6.55). Interviewees also cited displacement by extreme weather events and the undermining of rural livelihoods through deforestation as key migration drivers.[109]

Much of the city's population is young, reflected in the high risk score for percent of **urban population below 30 years of age** (8.25). Just under 69 percent of the city's population was literate as of the 2011 census, the lowest of any city corporation except for Sylhet,[110] reflected in a medium-high risk score (5.08). The COVID-19 pandemic increased Chattogram's poverty rate, reversing previous reductions. Marginal gains to combat poverty in 2021 remain precarious, reflected in a medium-high risk score for the **percent of the population in poverty** (6.84). Major drivers of the increase in poverty during the pandemic include the sharp reduction in demand for exported manufactured goods, especially garments, and the exclusion of a large share of the city's workers from social safety nets.[111]

Chattogram also faces high risk around **investment in climate resiliency development projects** (8.15). Chattogram has several climate adaptation plans (discussed in greater detail in the section on "The Status of Resilience Planning" below), and **national climate adaptation planning** scored as a medium-high risk (5.10). The Chattogram Development Authority (CDA) is updating its master plan for the first time since 1995.[112] Interviewees noted that despite some outreach from the CDA during the drafting process, there is still insufficient substantive consultation with youth and civil society,[113] and **participation of civil society** was scored as a medium-high risk (6.52). Additionally, interviewees observed that in the past these plans have often fallen short in implementation. For example, they noted that Chattogram's city-level disaster management committee is not active, and that climate change is not integrated into the CCC's annual planning and budget.[114]

The shortcomings in implementation likely stem in part from challenges around mobilizing financial resources. This is in turn due partially to Chattogram's dependence on the national government for funding. Bangladesh is one of the least financially decentralized countries in the world,[115] and 35-45 percent of the CCC's revenue comes from the central government.[116] This reliance would be especially problematic when the CCC, which has a locally elected leadership, is governed by a different party than the national government. In other cities, this kind of vertically divided authority has negatively impacted the delivery of urban services.[117] However, mobilizing financial resources is a challenge that affects all of Bangladesh, as the country raises the fewest taxes as a share of its economy of any country in South Asia,[118] in part because its large informal economy provides limited tax revenue.[119]

In Chattogram, fragmented governance further hinders the effective implementation of climate resilience projects and delivery of public services. The principal division is between the CCC and CDA. Leadership of the former is elected locally, while the national government appoints leaders to the CDA. However, there are numerous other agencies operating in the city with overlapping and intersecting mandates and management plans. Waste management, one of the most pressing issues facing the city, provides a salient example of the challenges associated with this fragmentation. The CCC is ostensibly responsible for proper disposal of solid waste and drainage management.[120] However, in practice, the CDA, Chattogram WASA, Bangladesh Water Development Board (WDB), and Chattogram Port Authority all play some role in drainage management in the city.[121] Bureaucratic confusion and divisions of authority are often unclear or conflicting, paralyzing the necessary work.

For example, a project to mitigate Chattogram's waterlogging challenge was approved in August 2017 with a budget of almost Tk 8,000 crore ($770 million) and a project deadline of 2020. The CCC, CDA, and WDB were all given responsibilities under the project, but work did not begin until

mid-2019 because of delays in finalizing plans and hiring consultants. The COVID-19 pandemic and delays in releasing funds by the National Ministry of Housing and Public Works held up the CDA's work. Opposition from the Chattogram Port Authority delayed the WDB's work. Insufficient allocation of funds for land acquisition delayed the CCC's work. By mid-2021, little of the work had been completed, and as of late 2022 the city's drainage channels remain uncovered and clogged with solid waste.[122]

## Chattogram: Political Risk

Each category score comprises multiple indicators.
Low 1 - 2.5 | Medium 2.51 - 5 | Medium-High 5.01 - 7.5 | High 7.51 - 10

| Category | | Indicator | |
|---|---|---|---|
| Social and Demographics | 6.50 | Urban Population | 8.78 |
| | | Urbanization Rate | 8.75 |
| | | Percent of Urban Population Below 30 Years of Age | 8.25 |
| | | National Population Density | 7.36 |
| | | Percent of Population Below Poverty Line | 6.84 |
| | | Percent of International Migrants Living in Country | 6.73 |
| | | Urban Population Density | 5.55 |
| | | Dependency Ratio | 5.54 |
| | | Percent of Adult Citizens Living Outside of the Country | 5.43 |
| | | Percent of Population Achieving Proficiency in Literacy and Numeracy | 5.08 |
| | | National Population | 4.32 |
| Stability | 5.12 | Percent of People Employed in Agriculture | 6.55 |
| | | Percent of People Employed in the Commercial Fishing Industry Nationwide | 5.92 |
| | | Number of Years that the Current Government Structure has been in place | 5.78 |
| | | Percent of People Employed in Port and Shipping Industries | 5.49 |
| | | Level of Social Tension | 4.95 |
| | | Percent of People Employed in Artisanal and Subsistence Fishing | 4.66 |
| | | Number of Incidences of Civil Unrest or Instability | 4.60 |
| | | Percent of People Employed in Tourism | 3.29 |
| Governance | 4.44 | Investment in Climate Resiliency Development Projects | 8.15 |
| | | Civil Society Participation | 6.52 |
| | | Capacity of Ethics Enforcement Bodies | 5.57 |
| | | National Climate Adaptation Plan | 5.10 |
| | | Voter Turnout | 3.24 |
| | | Capacity of Current Disaster Response | 3.17 |
| | | Rule of Law | 2.93 |
| | | Access to Healthcare | 2.89 |
| | | Level of Perceived Transparency Within Government | 2.89 |

Table: Stimson Center • Created with Datawrapper

# The Status of Resilience Planning

The government of Bangladesh has taken significant steps to integrate climate change adaptation and mitigation strategies into its national policy and development framework. The country was the first in South Asia to adopt a coordinated action plan to address climate change, the Bangladesh Climate Change Strategy and Action Plan in 2009,[123] and in 2011 the country enshrined the preservation of natural resources and biodiversity, including wetlands and forests, in its constitution.[124] Prime Minister Sheikh Hasina received the United Nations Champions of the Earth award in 2015.

Bangladesh has continued its leadership in climate planning, including the country's National Adaptation Plan, the Mujib Climate Prosperity Plan, and the Delta Plan 2100. The Delta Plan 2100 aims to balance economic development and environmental sustainability and includes specific goals around protection from floods and other climate disasters, conserving and preserving wetlands and other ecosystems, and ensuring the sustainable management of river systems and estuaries.

The government of Bangladesh established the Climate Change Trust Fund in 2009, allocating $450 million between fiscal year 2009-10 and fiscal year 2018-19. It has been a valuable tool for piloting climate change adaptation programs, as well as some important mitigation actions, including community-based disaster management programs, ecosystem-based approaches, and nature-based solutions. However, a lack of access to expertise, technology, and technological assistance has resulted in a wide gap between the high demand for projects and the capacity of experts and technology to conduct efficient and effective adaptation activities.[125]

Although the Disaster Management Bureau was established in 1993 and the Ministry of Disaster Management and Relief in 2002, the Disaster Management Act was not adopted until 2012. The Act aims to coordinate and enhance disaster risk reduction, humanitarian assistance, and emergency response. This was followed by the National Disaster Management Policy in 2015 and Standing Orders on Disaster in 2019.[126]

In Chattogram, the new Marine Drive Expressway stretches 170 kilometers in length, including roughly 100 bridges and 80 kilometers of coastal protection infrastructure.[127] It will join economic zones from Chittagong to the tourism hub of Cox's Bazar and improve access to seaports and airports. In addition, it provides economic benefits to more than 10 special economic zones in the Chattogram region. The highway also provides protection from coastal storms and frequent flooding that have plagued the area historically, and interviewees mentioned that it provided protection during Cyclone Sitrang in 2022.[128]

# Priority Recommendations to Build Resilience

Despite capacity constraints, both national and local actors have made considerable progress in building climate resilience in Chattogram. The 15.2-kilometer-long Marine Drive Expressway is already providing protection from extreme weather events and coastal erosion. The national government of Bangladesh designated 1,743 square kilometers of the Bay of Bengal next to Saint Martin's Island as the Saint Martin Marine Protected Area in early 2022. Although this is located south of Chattogram, the protections afforded to coastal and marine ecosystems may strengthen the city's coastal protection and offshore industries. Chattogram intends to conduct a risk assessment and hazard mapping as part of Delta Plan 2100. The evidence gathered through this assessment can help inform that work, but also suggests that more work is required to fully integrate the multidimensional climate risks that Chattogram faces and ensure successful implementation of climate resilience strategies.

The highest risks highlighted in the CORVI assessment are categorized under **Geology/ Water** (6.74), **Social/Demographics** (6.50), **Infrastructure** (6.32), and **Ecosystems** (6.26). The analysis identified unplanned urbanization, flooding from tropical cyclones and heavy rainfall, vulnerable coastal ecosystems, a large informal economy, and fragmented governance as key risks faced by the city. Shortcomings in solid waste management and wastewater treatment, rising and warming seas, a limited investment in climate resilience, and a lack of adaptation planning implementation all compound the impacts of these vulnerabilities. These risks can begin to be addressed through the following actions.

## Improve and expand flood adaptation and waste management

Bangladesh has made significant progress in reducing the country's vulnerability to tropical cyclones. Its Cyclone Preparedness Program, launched in the 1960s, was a pioneer in establishing a coastal early warning system.[129] Despite this progress, Chattogram continues to face serious challenges with flooding and waterlogging that are due to storms and heavy rainfall compounded by solid waste, which clogs drainage channels, and untreated wastewater, which harms human and ecosystem health. The city and national government have made efforts to reduce solid waste, clear drainage channels, and improve wastewater treatment, but ongoing challenges point to the need for a more multilayered approach to flood adaptation and waste management.

The Chattogram City Corporation decided to turn residential waste collection over to the private sector. However, residents remain concerned that this decision will result in higher charges without improved service.[130] The use of performance-based contracts could be one option that has shown promise in other countries.[131] Private waste management may also have limited effectiveness in informal settlements and other poorer communities. To fill this gap, the government could provide training to the informal waste pickers already operating in informal settlements, either directly or by supporting NGO-led efforts.[132] Such support could include financial support and training to improve the efficiency of their collection methods. The government could also explore the idea of linking informal waste pickers to private waste management companies, providing support for the former and extending the collection capacity of the latter.

Waste-to-energy and waste to worth projects could be another option to explore. Such an approach could simultaneously reduce the quantity of uncollected solid waste and improve access to electricity in a country that relies heavily on increasingly expensive natural gas.[133] Previous analysis, however, found several hurdles to such a project, including absence of waste separation, lack of financial support, and limited intergovernmental coordination, that would need to be addressed.[134]

In addition to improving solid waste management to reduce waterlogging, Chattogram could take other steps to mitigate the impacts of flooding. Ensuring that drainage channels are free from unplanned housing is critical. The CDA and CCC could augment their current approach of destroying illegal

structures with a strategy to improve alternative housing options, including formalizing land tenure in non-hazard-prone areas of the city. Another way to reduce the impacts of flooding and alleviate waterlogging would be to reduce impermeable surfaces such as streets and parking,[135] expand green spaces, and restore some of the waterbodies that have been lost.

Finally, improving access to financial resources, especially for residents of informal settlements and workers in the informal economy, will help both recovery from flooding and making important small-scale resilience investments at the individual, household, and business levels. There are three principal avenues for accomplish this. First, the local or national government could provide financial access directly, with India's recent embrace of widespread digital financial inclusion providing a model.[136] The government or international partners could also provide an enabling environment that reduces the risk for private sector entities lending to high-risk individuals and households, such as through loan guarantees.[137] The government or international partners could also provide support to existing alternative financial institutions, such as microfinance, which was an important tool to support garment workers who lost their jobs during the COVID-19 pandemic.[138]

## Improve urban climate resilience implementation and invest in climate-smart infrastructure

Bangladesh has been a global leader in planning for the impacts of climate change. From the 2009 Climate Change Strategy and Action Plan, the first of its kind in South Asia, to the Mujib Climate Prosperity Plan and Delta Plan 2100, the country has embraced long-range planning that incorporates climate adaptation as a foundational principle. At the local level, however, interviewees observed that planning and operations in Chattogram do not always integrate climate change.[139] The implementation of climate resilience plans at both the national and local levels is constrained by fragmented governance and limited access to financial resources. Technical committees have been established to improve coordination between the governmental entities operating in Chattogram,[140] but unclear and conflicting divisions of authority and responsibility remain an enduring issue.[141]

Improving climate resilience implementation will require the participation of diverse stakeholders, including the national government, local government entities, civil society, and international partners, and can draw on international best practices. Performance-based fiscal transfers to cities, known as Urban Performance Grants, have shown success in other contexts. Under these agreements, the fiscal transfers from the central government are conditioned on meeting specific performance benchmarks in predetermined areas. The World Bank's Global Practice for Urban, Disaster Risk Management, Resilience, and Land, the UN Capital Development Fund, the European Union, and the UN Development Programme, among others, have supported these types of programs.[142] Another practice that has been successful in cities with vertically divided authority is the use of "medium- to long-term municipal contracts that involve ex-ante commitments by both central and municipal governments," which have shown success even when power at the local and national levels is held by opposing political parties.[143]

Clarifying and simplifying lines of authority and responsibility for Chattogram among and between national- and local-level governing entities could also improve urban service delivery and resilience implementation. Ensuring that clear lines of authority and responsibility are accompanied by clear lines of accountability along with sufficient resourcing would enhance the likelihood of success. The updated master plan that is currently being drafted by the CDA provides an opportunity around which to undertake this effort. Obtaining broad and substantive stakeholder input and buy-in for the master plan and for the divisions of authority, responsibility, and accountability is critical. This input and buy-in is vital not just from currently governing entities, but also from civil society and the public to ensure that implementation is successful and sustainable across political cycles and shifts in public opinion.

Alongside these efforts, the government of Bangladesh should engage in innovative and emerging sources of both public and private adaptation financing. Recent efforts by small island developing states have shown that consistent and creative engagement with large international financial institutions can give rise to new financing frameworks that free up capital for disaster recovery.[144] Bangladesh's consistent track record of climate leadership, its success at reducing vulnerability to tropical cyclones, and the findings from this assessment can help convince potential lenders that adaptation funding will have real impacts

in strengthening coastal climate resilience in Chattogram. Examples of the types of innovative financing mechanisms that the government of Bangladesh could consider include climate-resilient debt clauses,[145] debt-for-nature swaps,[146] green, social impact, and resilience bonds,[147] and insurance initiatives like the recently launched "Global Shield," which aims to strengthen climate risk insurance and social protection schemes.[148]

## Develop a sustainable shoreline development strategy

The government of Bangladesh has recognized the need to integrate economic development with sustainable environmental management, developing the Delta Plan 2100 for this express purpose based on a long-term vision of the Bangladesh Delta through the end of the century. To ensure that it responds to the specific needs and vulnerabilities of Chattogram, the Delta Plan 2100 will include a risk assessment and hazard mapping for the city. This assessment can inform that work and support the prioritization of investments needed for sustainable shoreline development. The government of Bangladesh is also working with international partners through initiatives such as the Delta Coalition to protect the health of the Bay of Bengal.

Employing nature-based solutions by protecting and restoring Chattogram's marine and coastal ecosystems — including seagrasses, coral reefs, and mangroves — is key to sustainable shoreline development. These coastal ecosystems can offer many benefits: protecting Chattogram's shoreline from storm surge and reducing damage from tropical cyclones; improving water quality; providing habitat for marine species; supporting the growth of the blue economy, which is a key priority for the government of Bangladesh;[149] and sequestering carbon to help Bangladesh meet its nationally determined contribution under the Paris Agreement.

The recently designated Marine Protected Area around St. Martin's Island, home to Bangladesh's only coral reef,[150] is an important step in this process. This could be complemented with additional marine zoning around Chattogram, developed using the kind of participatory process that small island developing states have used to great effect.[151] The protection of the 13 designated Ecologically Critical Areas that were declared since 1999 has fallen short of expectations, limiting the benefits derived from such designation, pointing to the need for improved implementation of these regulations.[152]

The government, international partners, and local NGOs could also build on this conservation work by restoring and expanding Chattogram's coastal and marine ecosystems. This could include extending mangrove planting efforts currently ongoing in the Sundarbans to the country's southeastern coastline. It could also include planting seagrasses by adapting best practices from previously successful efforts in the Western Indian Ocean[153] and Australia.[154]

Sustainable shoreline development should also address the land-based pollution harming the coastal and marine environment. This pollution includes industrial waste, residential waste, and the toxins and waste that run off the land from agriculture, aquaculture, and city streets into canals into rivers that lead to the sea and coastal areas. In Chattogram, control and treatment of residential and industrial wastewater, which currently enters the Karnaphuli and Halda rivers and the Bay of Bengal, could be improved. Treating residential wastewater could take the form of supporting the Chattogram Water and Sewerage Authority's plan to develop a comprehensive sewage treatment system for the city and ensuring that the plan retains sufficient foresight and resourcing to accommodate Chattogram's growing population.

Treating industrial wastewater could involve engaging with the city's key industries to control pollutants that are released into the Bay of Bengal. For the shipbreaking industry, these pollutants include asbestos, PCBs, toxic paints, oxyacetylene gas, and residual oil.[155] The government of Bangladesh could strengthen existing efforts to regulate the environmental impacts of the industry, such as the Bangladesh Ship Recycling Act of 2018 and the International Labor Organization's "Safe and Environmentally Sound Ship Recycling in Bangladesh." Bangladesh could also consider creative uses for some decommissioned vessels, such as using them for artificial reefs, as has been done in the United States, especially in Florida.[156]

The garment industry generates as much as 300 metric tons of water pollution per ton of fabric. Research has shown that more efficient factories are both more profitable and less polluting,[157] suggesting that the government of Bangladesh could pass and implement regulations requiring or incentivizing a shift to efficient production standards for the industry. Other growing industries,

such as shipbuilding, could also be proactively engaged to address potential pollution challenges before they become a crisis.

Promoting sustainable shoreline development could also include regulating or limiting development in flood-prone areas of Chattogram and combining green infrastructure approaches with gray or hybrid infrastructure. Combining such restrictions with the facilitation of development in lower-risk areas could improve the effectiveness of such a strategy, as nature-based approaches provide additional benefits beyond flood control. Reducing the push factors driving migration into Chattogram from rural areas could also lessen the pressure for housing on flood-prone areas of the city. This could include supporting rice agriculture, including through the use of salt-tolerant rice varieties,[158] which could also help address soil degradation and fertilize overuse.[159] It could also include providing support for intercropping and agroecology in rice farming, which has been shown to improve yields and sustainability while reducing water use and weed infestation.[160]

# Appendix

## ORGANIZATIONS SURVEYED

Arannayk Foundation
Bandarban University
Bangladesh Forest Research Institute
Bangladesh Meteorological Department (BMD)
Bangladesh Sangbad Sangstha
Blue Economy Cell, Energy and Mineral Resources Division
BRAC
BRAC University
Industrialist
Center for Participatory Research and Development
Centre for Environment and Sustainability
Chattogram City Corporation
Chattogram Development Authority
Chemonics International Inc; Retired Bangladesh Navy
Chittagong University of Engineering & Technology
Civil Servant (Former State Minister)
East Delta University
Feed the Future Bangladesh Trade Activity
Former secretary, GoB
Civil Servant (Diplomats)
ICCCAD
Independent University, Bangladesh
Journalist
Marine Fisheries Academy
Ministry of Environment, Forest and Climate Change
Ministry of Finance, Bangladesh
Ministry of Public Administration Bangladesh
The Prime Minister's Office of Bangladesh
The World Bank
University of Chittagong
University of Dhaka
University of Rajshahi
Western Illinois State University
WorldFish
Young Power in Social Action (YPSA)

## ORGANIZATIONS INTERVIEWED

Bangladesh Institute of Maritime Research and Development (BIMRAD)
Bangladesh Sangbad Sangstha
Chattogram City Corporation
Chattogram Development Authority
Chittagong University of Engineering and Technology
Feed the Future Bangladesh Trade Activity, USAID
Independent University, Bangladesh
Ministry of Disaster Management and Relief
University of Chittagong
University of Dhaka
University of Rajshahi
Western Illinois State University
Young Power in Social Action

# Introducing the Climate and Ocean Risk Vulnerability Index

Urban coastal areas and island states are likely to experience the earliest onset and potentially most severe impacts from climate change. However, the risks associated with climate change for specific coastal cities are much more difficult to untangle. In order for coastal cities to efficiently allocate resources and enact effective adaptation strategies, they must understand their multidimensional climate risks. These efforts are impeded by incomplete data.[161] In small island developing states and least developed coastal countries data on climate risks is rarely available at the city or island level and, when it does exist, it is often poorly managed and stored in silos that make access and use difficult, even for city government officials.[162] This issue is compounded by technical, financial, and capacity gaps, trapping coastal cities and island states in a vicious cycle where they cannot develop holistic strategies to prioritize investment and access the funds needed to implement resilience actions.

> In multiple meetings with stakeholders, experts noted that data gaps impeded their ability to assess multidimensional climate risks and provide evidence-based policy recommendations to key decision makers.[163]

Without data at the appropriate geographic scale, decision makers are often left with the choice of either waiting for greater data availability or attempting to downscale national-level data. Neither of these is an ideal solution for effective climate change adaptation.

Despite these challenges, decision makers need to act now in the face of uncertainty to build resilience to the climate crisis. To do this, they need tools that will enable them to consider multidimensional climate risks, develop cohesive strategies, and utilize this information to unlock additional climate finance and implement resilience actions.

In response, the Stimson Center developed the Climate and Ocean Risk Vulnerability Index (CORVI). CORVI is a decision support tool that compares a diverse range of climate-related risks across the land and seascape to produce a coastal city or island state risk profile.[164] These risks are displayed across 10 categories, grouped under three risk areas: ecological, financial, and political (see figure 2). The 10 categories are in turn made up of close to 100 indicators, covering a range of issues including the vulnerability of vital infrastructure, the health of marine ecosystems, and urbanization dynamics in the chosen coastal city. Each indicator and category is scored using a 1-10 risk scale relative to other cities in the region, offering a simple reference point for decision makers looking to pinpoint and categorize climate risks. The CORVI risk scores that form the basis of a coastal city risk profile are augmented with existing academic and gray literature, government documents, and key informant interviews to develop a comprehensive narrative and understanding of the coastal city's climate risks and to identify priority policy recommendations.

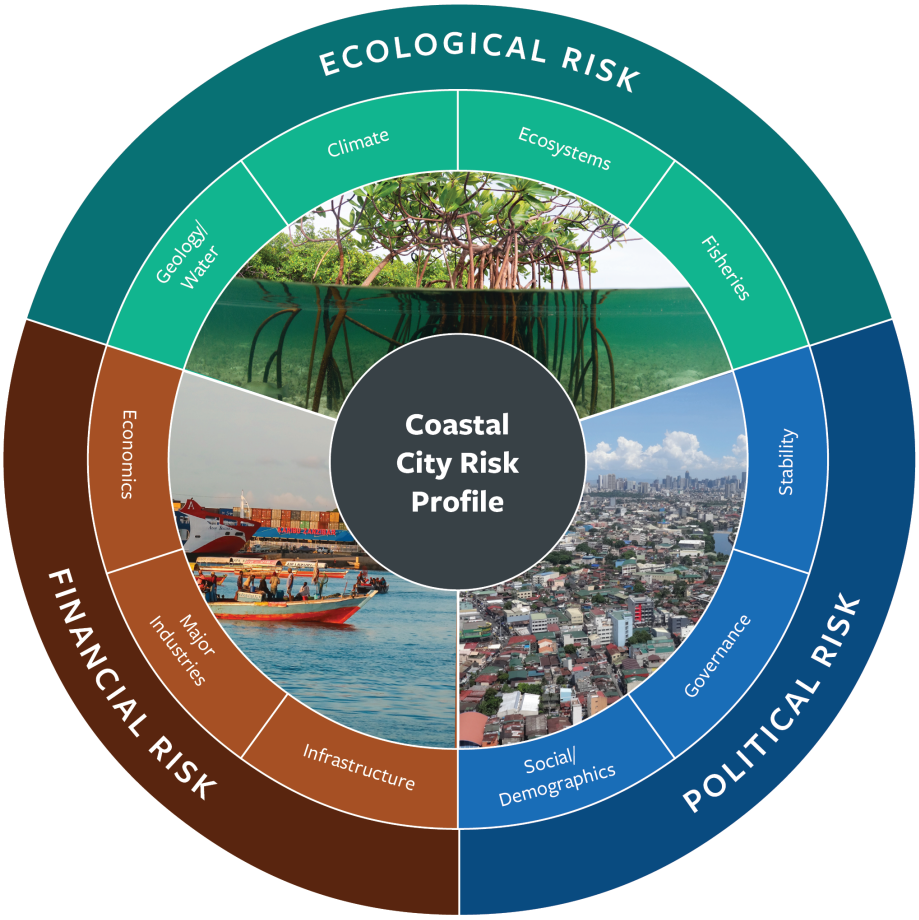
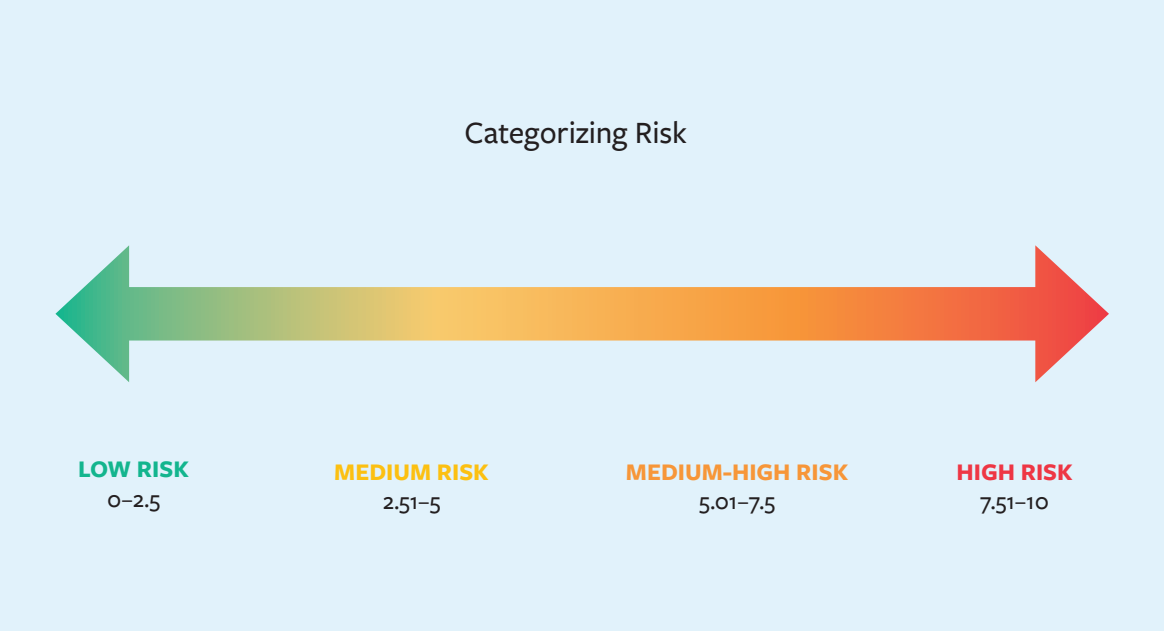



Figure 2: CORVI Risk Types and Categories

## How CORVI is Different

CORVI builds on the work of previous indices but is distinct in three ways.

1. **City-Based:** Unlike many other indices that tend to focus on the national level, CORVI is city-based, providing subnational-level detail on the nature and impact of climate and ocean risks. This focus is based on extensive interviews with potential issuers of the CORVI tool, who noted the difficulty of downscaling national-level risk and vulnerability data to inform policy action to build climate resilience in specific communities.
2. **Holistic:** CORVI looks across a broad set of ecological, financial, and political risk factors that are connected to climate change impacts and that influence vulnerability of coastal cities and their residents. As part of the category and indicator selection process, indicator inclusion was primarily based on its ability to capture and explain climate change risks in coastal cities, and not on whether data was available. This approach promotes a holistic understanding of climate change impacts on coastal cities.
3. **Data-Driven:** Through its utilization of SEJ, CORVI is suited to producing actionable insights in data-sparse environments. By combining empirical and survey data across a wide range of indicators, CORVI fills data gaps to provide a holistic assessment, while reducing data availability bias. This approach provides a contextual and data-driven evaluation of climate and ocean vulnerability.




### INTERPRETING RISK SCORES

**Low risk** scores mean that either the coastal city has successfully built resilience in the issue area or the indicator is not as relevant for understanding risk in that city.

**Medium risk** scores indicate that while resilience has been built to address the specific risk, future changes could destabilize resilience gains.

**Medium-High risk** scores mean that current measures are insufficient and more attention is required to build resilience against future climate security impacts.

**High risk** scores indicate that the issue area represents a key threat to the coastal city with the potential to undermine the security of its residents.

CORVI was successfully piloted in the coastal cities of Castries, Saint Lucia and Kingston, Jamaica. These first two CORVI city assessments demonstrated the value of CORVI's holistic approach in helping leaders and decision makers prioritize actions and smart investments for risk reduction in coastal cities. Despite the challenges posed by COVID-19, data and recommendations from both risk profiles are beginning to be incorporated into urban resilience planning.[165]

In collaboration with a wide range of on-the-ground research institutions, and the support of local and national governments, CORVI is now active in 15 coastal cities and island states around the world. In addition to providing decision makers in the specific city with a complete risk picture, each risk profile is added to a global database to improve decision makers' understanding of regional risk dynamics.

### ADVANCING THE SUSTAINABLE DEVELOPMENT GOALS

CORVI aims to contribute to the delivery of the SDGs—an essential framework to guide lasting, positive change. Twenty-seven CORVI indicators are directly related to SDGs, with a further 13 indicators indirectly supporting the implementation of an SDG indicator or target. By providing data and information to measure climate risks in coastal cities, CORVI supports the delivery of the following SDGs:


## Indicators

To ensure that the CORVI indicator scores provide a holistic risk rating, each comprises five factors: current, past, and expected trends, the rate of change of the risk, and the impact of this risk on the coastal city.

1. The **BASELINE** measures the current level of risk for each indicator relative to other coastal cities in the region. Baseline data for economic and social indicators are derived from the most recent year of complete data. Climate indicators use an extended time period of 15 years.[166]
2. **PAST TREND** assesses the trend of risk for the past 10 years, measured from the baseline year. The only exception to the 10-year trend measure is the climate indicators, which use a 15-year trend horizon to account for slow-onset changes.
3. **EXPECTED TREND** assesses the anticipated trend of risk in the next 10 years, measured from the baseline year. The only exception to the 10-year trend measure is the climate indicators, which use a 15-year trend horizon to account for slow-onset changes.
4. **MAGNITUDE** assesses the degree of expected future trend change relative to other cities in the region. Change that happens more quickly than expected are assumed to increase risk when compared to changes that take place over a longer time scale. This assumes that longer periods of change contribute to less risk, as decision makers have more time to adapt and build resilience.
5. Finally, **IMPACT** assesses the importance of change for each indicator in describing future risk in the coastal city.

### CORVI ASSESSMENTS COMPLETED

- Basseterre, St. Kitts and Nevis
- Castries, St. Lucia
- Chattogram, Bangladesh
- Dagupan, Philippines
- Dar es Salaam, Tanzania
- Kingston, Jamaica
- Mombasa, Kenya
- Suva, Fiji

### PILOT RAPID ASSESSMENTS

- Bridgetown, Barbados
- Colombo, Sri Lanka
- Tarawa, Kiribati

### ASSESSMENTS UNDERWAY

- Belize City, Belize
- Roseau, Dominica
- Port Louis, Mauritius
- Toamasina, Madagascar

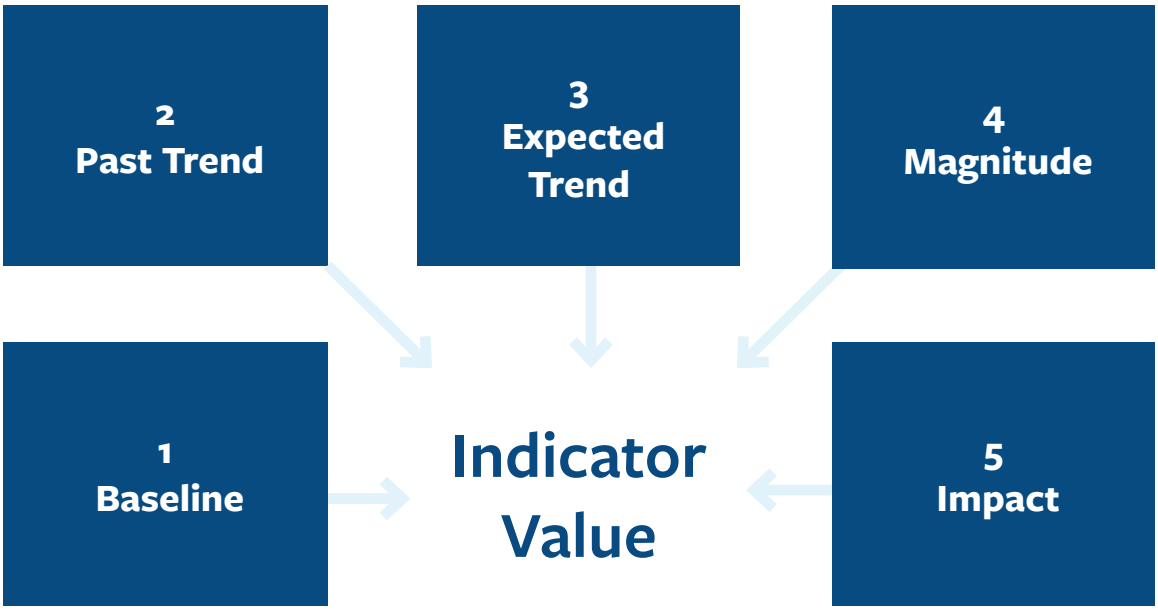



Figure 3: Indicator Factors

## Data Collection and Structured Expert Judgement

To overcome data gaps, CORVI employs structured expert surveys to collect data that is otherwise unavailable. This primary data is combined with secondary data using structured expert judgment (SEJ) to produce a comparative score for each indicator in the assessment.[167] SEJ is a well-established social science technique that seeks to quantify risk when preexisting secondary data is inadequate. Through interviews and surveys, as well as a series of weighting procedures to ensure that data is representative, SEJ allows researchers to quantify topics that might otherwise be challenging to study in such a systematic fashion.

To apply SEJ to CORVI, subject matter experts across academia, government, civil society, and the private sector are identified through research and extensive outreach to stakeholders in the target coastal cities. These experts then refer the project team to other experts and stakeholders with appropriate expertise using "snowball sampling."[168] To guard against confirmation bias, survey answers are compared to a regional secondary empirical dataset to weigh the expert responses by utilizing a coherence check.[169] The coherence check ensures that experts whose answers do not match secondary data are not weighed as highly as those who do.

This approach has several strengths. First, CORVI incorporates the views of subject matter experts and local stakeholders at each stage of its implementation. This allows the final product to better reflect the specific context it is seeking to measure and provide more focused information for end users. Second, pairing primary survey data with secondary data through SEJ allows CORVI to provide insight into risks relating to urban coastal environments that existing secondary datasets do not cover. While the use of SEJ allows CORVI to assess a diverse range of risks, however, it should not be regarded as a substitute for empirical data collection. Rather, SEJ is best viewed as an alternative research technique specialized to analyzing topics with significant data gaps.[170]

# Endnotes


1 Azad, Abu. "Karnaphuli Tunnel: A potential harbinger of growth." The Business Standard. July 2, 2022. https://www.tbsnews.net/bangladesh/infrastructure/karnaphuli-tunnel-potential-harbinger-growth-451374 Accessed November 11.

2 Ullah, Sifayet. "Ctg getting new master plan after 27 years." The Daily Star. June 22, 2022. https://www.thedailystar.net/chattogram/news/ctg-getting-new-master-plan-after-27-years-3053441.

3 Ahmad H (2019) Bangladesh Coastal Zone Management Status and Future. J Coast Zone Manag 22:1.

4 Moran, A., Raleigh, C., Busby, J., Wight, C., & Krishnan, N. "Fragility and Climate Risks in Bangladesh". USAID. September 2018.

5 Hoque, M., Pradhan, B., Ahmed, N., Ahmed, B., & Alamri, A. (2021). "Cyclone vulnerability assessment of the western coast of Bangladesh". *Geomatics, Natural Hazards and Risk*, 12(1), 198-221. https://doi.org/10.1080/19475705.2020.1867652

6 Mallick, B., Rahaman, K. R., & Vogt, J. (2011). "Social vulnerability analysis for sustainable disaster mitigation planning in coastal Bangladesh". *Disaster Prevention and Management*, 20(3), 220-237. https://doi.org/10.1108/09653561111141682

7 "The Bangladesh Cyclone of 1991". USAID. https://pdf.usaid.gov/pdf_docs/PNADG744.pdf

8 Subah, Z. "Cyclone and Preparedness: Chittagong, Bangladesh". APDC. https://www.adpc.net/igo/contents/iPrepare/iprepare-news_id.asp?ipid=240

9 "The Bangladesh Cyclone of 1991".

10 Ibid.

11 Rahman, Sajibur. "11 cyclones claimed nearly 4,000 lives since 2007". The Financial Express. May 5, 2019. https://thefinancialexpress.com.bd/national/11-cyclones-claimed-nearly-4000-lives-since-2007-1556971146

12 Kasia Paprocki. *Threatening Dystopias: The Global Politics of Climate Change Adaptation in Bangladesh* (Ithaca and London: Cornell University Press, 2021), 92.

13 Rezaie, A. M. and Haque, A. "Development of Storm Surge Inundation Model and Database for Enhanced Climate Services in Bangladesh". *Frontiers in Water*. July 4, 2022. https://doi.org/10.3389/frwa.2022.887631

14 Dasgupta, S., et. al. "Vulnerability of Bangladesh to Cyclones in a Changing Climate". World Bank Policy Research Working Paper. April 2010.

15 Achyuthan, H. "Climate Change as Observed in the Bay of Bengal". *Journal of Climate Change*, vol. 7, no. 3. September 2, 2021. http://dx.doi.org/10.3233/JCC210020

16 Ibid.

17 SMRC, 2003. The Vulnerability Assessment of the SAARC Coastal Region due to Sea Level Rise: Bangladesh Case. SAARC Meteorological Research Center, Dhaka, SMRC-No. 3.

18 Ashrafuzzaman, M., Santos, F., Dias, J., & Cerdà, A. (2022). "Dynamics and Causes of Sea Level Rise in the Coastal Region of Southwest Bangladesh at Global, Regional, and Local Levels". *Journal of Marine Science and Engineering*, 10(6). https://doi.org/10.3390/jmse10060779

19 Shaila Akhter, Fangli Qiao, Kejian Wu, Xunqiang Yin, K M Azam Chowdhury, Nur Uddin Md Khaled Chowdhury. (2021). "Seasonal and long-term sea-level variations and their forcing factors in the northern Bay of Bengal: A statistical analysis of temperature, salinity, wind stress curl, and regional climate index data." *Dynamics of Atmospheres and Oceans*, 95, 101239. https://doi.org/10.1016/j.dynatmoce.2021.101239

20 Tay, C., Lindsey, E.O., Chin, S.T. et al. Sea-level rise from land subsidence in major coastal cities. *Nat Sustain* 5, 1049–1057 (2022). https://doi.org/10.1038/s41893-022-00947-z

21 "Chittagong: Industries versus individuals in limited water supply". Global Voices. November 4, 2022. https://globalvoices.org/2022/11/04/chittagong-industries-versus-individuals-in-limited-water-supply/

22 Ahmed, N., Howlader, N., Hoque, M. A., Pradhan, B. "Coastal erosion vulnerability assessment along the eastern coast of Bangladesh using geospatial techniques". *Ocean and Coastal Management* Volume 199 (2021). https://doi.org/10.1016/j.ocecoaman.2020.105408

23 Barua, Pimple. "'No fear of Chittagong flooding like Sylhet'". Dhaka Tribune. June 22, 2022.

24 Hossain, Emran. "42-yr-low July rain follows extreme June downpour". New Age Bangladesh. August 3, 2022.

25 Ahmed, Nawshad. "Develop Chattogram's drainage system before more lives are lost". The Daily Star. December 5, 2021. https://www.thedailystar.net/views/opinion/news/develop-chattograms-drainage-system-more-lives-are-lost-2909656

26 Interview with representative from Chattogram City Corporation.

27 Interview with representative from Young Power in Social Action.

28 Ahmed, B., Rahman, M. S., Islam, R., Sammonds, P., Zhou, C., Uddin, K., & Al-Hussaini, T. M. (2018). "Developing a dynamic Web-GIS based landslide early warning system for the Chittagong Metropolitan Area, Bangladesh". *ISPRS International*

*Journal of Geo-Information*, 7(12), 485. https://doi.org/10.3390/ijgi7120485

29 Mia, M. T., Sultana, N., & Paul, A. (2015). "Studies on the causes, impacts and mitigation strategies of landslide in Chittagong city, Bangladesh". *Journal of Environmental Science and Natural Resources*, 8(2), 1-5. https://doi.org/10.3329/jesnr.v8i2.26854

30 Interview with representative from Chattogram Development Authority.

31 Rahman, M. M. and Mahmud, M. A. "Economic feasibility of mangrove restoration in the Southeastern Coast of Bangladesh" *Ocean and Coastal Management* Volume 161 (2018). https://doi.org/10.1016/j.ocecoaman.2018.05.009

32 Dasgupta, S., et. al. "Vulnerability of Bangladesh to Cyclones in a Changing Climate".

33 Ibid.

34 Rahman, Mohammed Mahabubur; Chongling, Yan; Islam, Kazi Shakila; Haoliang, Lu (2009). *A brief review on pollution and ecotoxicologic effects on Sundarbans mangrove ecosystem in Bangladesh. International Journal of Environmental Engineering, 1(4), 369–*. doi:10.1504/ijee.2009.027982

35 Islam, Shafi Noor (2014). *An analysis of the damages of Chakoria Sundarban mangrove wetlands and consequences on community livelihoods in south east coast of Bangladesh. International Journal of Environment and Sustainable Development, 13(2), 153–*. doi:10.1504/ijesd.2014.060196

36 Ibid.

37 Murshed, S., Griffin, A. L., Islam, M. A., Wang, X. H., Paull, D. "Assessing multi-climate-hazard threat in the coastal region of Bangladesh by combining influential environmental and anthropogenic factors". *Progress in Disaster Science*. Volume 16. December 2022. https://doi.org/10.1016/j.pdisas.2022.100261

38 "National Adaptation Plan of Bangladesh (2023-2050)". Ministry of Environment, Forest and Climate Change, Government of Bangladesh. 2022.

39 Chakraborty, Binay Kumar. "Status of Fish Diversity and Production in Bangladesh". National Conference on Integrating Biological Resources for Prosperity. June 2021; Baul, Sanjoy. "Status of Marine Fisheries in Bangladesh: Resource Utilization, Production Pattern, Performance and Prediction". *International Journal of Scientific & Engineering Research*, 13 (1), pp. 428-435.

40 Baul. "Status of Marine Fisheries in Bangladesh: Resource Utilization, Production Pattern, Performance and Prediction".

41 "Yearbook of Fisheries Statistics of Bangladesh, 2019-20". Department of Fisheries, Ministry of Fisheries and Livestock. March 2021.

42 FAO. 2021. FAO Yearbook. Fishery and Aquaculture Statistics 2019.

43 Baul. "Status of Marine Fisheries in Bangladesh: Resource Utilization, Production Pattern, Performance and Prediction".

44 "A Pro-Poor Analysis of the Shrimp Sector in Bangladesh". USAID. February 2006.

45 Ahsan, D.A. (2011), "Farmers' motivations, risk perceptions and risk management strategies in a developing economy: Bangladesh experience". *Journal of Risk Research*, 14 (3), pp. 325-349 https://doi.org/10.1080/13669877.2010.541558

46 Paprocki, *Threatening Dystopias: The Global Politics of Climate Change Adaptation in Bangladesh*, 83.

47 Ibid., 148.

48 Interview with representative from Young Power in Social Action.

49 Belton, B., et. al. "Review of Aquaculture and Fish Consumption in Bangladesh". The WorldFish Center. November 2011.

50 Hoque, M. Z. and Myrland, Ø. "Consumer preference for fish safety inspection in Bangladesh". *Aquaculture*. Volume 551. March 30, 2022. https://doi.org/10.1016/j.aquaculture.2022.737911

51 Arju, Mohammed. "Jailing fishers won't save the fish of the Bay of Bengal". China Dialogue Ocean. June 3, 2020. https://chinadialogueocean.net/en/fisheries/13955-jailing-fishers-wont-save-bay-of-bengal-fish/

52 Ibid.

53 Rahman, A. and Rahman, S. (2015), "Natural and traditional defense Mechanisms to reduce climate Risks in coastal zones of Bangladesh", *Weather and Climate Extremes*, 7, pp. 84-95. https://doi.org/10.1016/j.wace.2014.12.004

54 Ibid.

55 Brammer, H. "Bangladesh's dynamic coastal regions and sea-level rise", *Climate Risk Management*, 1, pp. 51–62. https://doi.org/10.1016/j.crm.2013.10.001

56 Sen, S., Antara, N., Sen, S., & Chowdhury, S. "The Unprecedented Pandemic 'COVID-19' Effect on the Bangladesh Apparel Workers by Shivering the Apparel Supply Chain. *Journal of Textile and Apparel, Technology and Management*, 11(3), 1-20. http://dx.doi.org/10.2139/ssrn.3598542

57 Ozaki, Mayumi. "Disaster risk Financing in Bangladesh". Asian Development Bank. September 2016. https://www.adb.org/sites/default/files/publication/198561/sawp-046.pdf

58 "Country Climate and Development Report: Bangladesh". World Bank Group. October 2022.

59 Ozaki. "Disaster risk Financing in Bangladesh".

60 "Country Climate and Development Report: Bangladesh".

61 Ethirajan, A. "Bangladesh pins hope on Chittagong port". September 4, 2012. BBC News. https://www.bbc.com/news/business-19462142

62 Interview with representative from Chattogram City Corporation.

63 Islam, M.S, (2014). "Maritime Silk Road and Economic Belt: Emerging opportunities for Bangladesh". Daily Star. October 1, 2014. https://www.thedailystar.net/maritime-silk-road-and-economic-belt-emerging-opportunities-for-bangladesh-44025

64 Hussain, Z. Z. "Economic Zones in Bangladesh: Unbound Opportunities for Foreign Investment". Institute of South Asian Studies, National University of Singapore. November 2013.

65 "Ship breaking and recycling industry of Bangladesh". Business Inspection BD. February 18, 2022. https://businessinspection.com.bd/ship-breaking-industry-of-bangladesh/

66 Ibid.

67 Vidal, John. "'Mollah's life was typical': the deadly ship graveyards of Bangladesh". The Guardian. January 31, 2020. https://www.theguardian.com/global-development/2020/jan/31/khalid-mollah-life-was-typical-the-deadly-ship-graveyards-of-bangladesh

68 "Bangladesh". Ship Breaking Platform. https://shipbreakingplatform.org/our-work/the-problem/bangladesh/

69 Karim, Naimul. "Bangladesh's Infamous Shipbreaking Yards Launch Race for Cleaner, Safer Future". gCaptain. November 2, 2021. https://gcaptain.com/bangladeshs-infamous-shipbreaking-yards-launch-race-for-cleaner-safer-future/

70 Schuler, Mike. "Shipbreaking Watchdog Calls Out Bangladeshi Shipbreaker Over Accidents". gCaptain. June 6, 2022. https://gcaptain.com/shipbreaking-watchdog-calls-out-bangladeshi-shipbreaker-over-accidents/

71 Interview with representative from Young Power in Social Action.

72 "Bangladesh". Ship Breaking Platform.

73 Ibid.

74 Shariful Islam and Rafikul Islam. "Bangladesh's shipbuilding industry: How breakers turned into builders". Dhaka Tribune. May 23, 2018. https://archive.dhakatribune.com/business/2018/05/23/bangladesh-s-shipbuilding-industry-how-breakers-turned-into-builders

75 "Western Marine wins int'l award". The Financial Express. February 4, 2018. https://today.thefinancialexpress.com.bd/print/western-marine-wins-intl-award-1517671939

76 Anik, Anis Mahmud. "What Happened To Western Marine Shipyard?". Business Inspection. July 26, 2021. https://businessinspection.com.bd/what-happened-to-western-marine-shipyard/

77 Interview with representative from Young Power in Social Action.

78 "The Informal Sector and Informal Employment in Bangladesh". Asian Development Bank. 2010.

79 Ibid.

80 Interview with representative from Young Power in Social Action.

81 "Employment in Bangladesh: How to Tackle the Informal Sector Conundrum". LightCastle Partners. October 29, 2020. https://www.lightcastlebd.com/insights/2020/10/employment-in-bangladesh-how-to-tackle-the-informal-sector-conundrum/

82 Mavis, Meraj. "Bangladesh has the lowest tax GDP ratio in South Asia". Dhaka Tribune. March 20, 2022. https://www.dhakatribune.com/business/2022/03/20/nbr-bangladesh-has-the-lowest-tax-gdp-ratio

83 Nasir Uddin. "Assessing urban sustainability of slum settlements in Bangladesh: Evidence from Chittagong city". *Journal of Urban Management*. Volume 7, Issue 1. (2018). https://doi.org/10.1016/j.jum.2018.03.002

84 Ibid.

85 Ibid.

86 Ibid.

87 Interview with representative from Chattogram Development Authority.

88 Uddin. "Assessing urban sustainability of slum settlements in Bangladesh: Evidence from Chittagong city".

89 "Waste Report 2019-2020". Chattogram City Corporation. https://ccc.portal.gov.bd/sites/default/files/files/ccc.portal.gov.bd/npfblock/59b6fde6_1f8f_4696_8ef3_c7a1f9ad8ba9/2021-07-01-05-45-27e5c3b91fddeef7aff9e665477a786d.pdf

90 Biswas, Sarmistha, Nandy, Ananya, Islam, Nafisa and Rafa, Nazifa. "Environmental citizenship and solid waste management in Chattogram, Bangladesh" *Open Economics*, vol. 3, no. 1, 2020, pp. 135-150. https://doi.org/10.1515/openec-2020-0109

91 World Bank. 2021. "Towards a Multisectoral Action Plan for Sustainable Plastic Management in Bangladesh." Washington, DC. The World Bank Group.

92 "Waste Report 2019-2020". Chattogram City Corporation.

93 World Bank. 2021. "Towards a Multisectoral Action Plan for Sustainable Plastic Management in Bangladesh."

94 "Yet another woman falls in Ctg canal". New Age Bangladesh. April 16, 2022. https://www.newagebd.

net/article/168196/yet-another-woman-falls-in-ctg-canal

95 Ahmed, Nawshad. "Develop Chattogram's drainage system before more lives are lost".

96 World Bank. 2021. "Towards a Multisectoral Action Plan for Sustainable Plastic Management in Bangladesh."; Azad, Abu. "Chattogram: A case of waste mismanagement". The Business Standard. March 27, 2022. https://www.tbsnews.net/bangladesh/chattogram-case-waste-mismanagement-391930

97 Chowdhury, Jobaer. "Ctg to have centralised sewerage system by 2030". The Business Standard. February 15, 2022. https://www.tbsnews.net/bangladesh/ctg-have-centralised-sewerage-system-2030-370828

98 Ibid.

99 Ibid.

100 Ibid.

101 Ibid.

102 Amin, Nurul. "Ctg WASA to have Sewage Treatment Plant by 2024". The Daily Observer. October 22, 2022. https://www.observerbd.com/news.php?id=389356

103 "Population & Housing Census 2022: Preliminary Report". Bangladesh Bureau of Statistics, Ministry of Planning. August 2022.

104 Metropolitan area population estimates from World Population Review. https://worldpopulationreview.com/world-cities/chittagong-population

105 Sumaiya Siddique and Md. Mahin Uddin. "Green space dynamics in response to rapid urbanization: Patterns, transformations and topographic influence in Chattogram city, Bangladesh". Land Use Policy. March 2022. https://doi.org/10.1016/j.landusepol.2022.105974

106 M Shahidul Islam. "Cities of Hope, Cities of Despair". The Daily Star. April 28, 2015. https://www.thedailystar.net/op-ed/cities-hope-cities-despair-79440

107 Paprocki, *Threatening Dystopias: The Global Politics of Climate Change Adaptation in Bangladesh*, 141.

108 Ibid., 83.

109 Interview with representative from Young Power in Social Action.

110 "Population & Housing Census 2011: Urban Area Report". Bangladesh Bureau of Statistics, Ministry of Planning. August 2014.

111 "Poverty & Equity Brief: Bangladesh". World Bank. April 2022.

112 Ullah. "Ctg getting new master plan after 27 years".

113 Interview with representative from Young Power in Social Action.

114 Ibid.

115 Goufrane Mansour, Waliul Islam & Md. Akhtaruzzaman. "Situation analysis of the urban sanitation sector in Bangladesh". *Water and Sanitation for the Urban Poor*. July 2017.

116 Ahammad, R. (2011). Constraints of pro-poor climate change adaptation in Chittagong city. *Environment and Urbanization*, 23(2), 503–515. https://doi.org/10.1177/0956247811414633

117 Resnick, D. (2014). Urban Governance and Service Delivery in African Cities: The Role of Politics and Policies. Development Policy Review, 32(1), s3-s17. https://doi.org/10.1111/dpr.12066

118 Mavis. "Bangladesh has the lowest tax GDP ratio in South Asia".

119 Deléchat, C. and Medina, L. "What Is the Informal Economy". International Monetary Fund. December 2020. https://www.imf.org/external/pubs/ft/fandd/2020/12/pdf/what-is-the-informal-economy-basics.pdf

120 "State of Cities: Governance for a Livable Chittagong". BRAC Institute of Governance and Development, BRAC University". September 2014.

121 Ibid.

122 Yousuf, Mostafa. "Mitigating Waterlogging in Chattogram City: Over Tk 3,000cr spent, yet no remedy in sight". The Daily Star. August 3, 2021. https://www.thedailystar.net/mycity/chittagong-city-corporation/news/over-tk-3000cr-spent-yet-no-remedy-sight-2143666

123 "Bangladeshi Prime Minister wins UN environment prize for leadership on climate change". UN News. September 14, 2015. https://news.un.org/en/story/2015/09/508702

124 The Constitution of the People's Republic of Bangladesh. Article 18A.

125 Klein, R. J. T., Midgley, G. F., Preston, B. L., Alam, M., Berkhout, F. G. H., Dow, K., Shaw, M. R., Gitay, H., Thurlow, J., Buob, S., & Thomas, A. (2015). Adaptation opportunities, constraints, and limits. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*, 899–944. https://doi.org/10.1017/CBO9781107415379.021

126 "Information on Disaster Risk Reduction of the Member Countries: Bangladesh". Asian Disaster Reduction Center. https://www.adrc.asia/nationinformation.php?NationCode=50&Lang=en

127 Mir Mostafizur Rahaman. "Marine drive expressway project likely from 2022". The Financial Express. December 11, 2021. https://thefinancialexpress.com.bd/trade/marine-drive-expressway-project-likely-from-2022-1639190195

128 Interview with representative from Chattogram Development Authority.

129 Islam, E (2022). Bangladesh's efforts at adaptation and what more needs to be done for sustainable disaster recovery. *CBOBS Journal*, Volume-1, Centre for Bay of Bengal Studies, Independent University Bangladesh

130 Azad, "Chattogram: A case of waste mismanagement".

131 Srinivasan, Sujatha. "Performance-based Contracting in Sanitation Delivery". Institute for Financial Management and Research. 2015. https://ifmrlead.org/performance-based-contracting-in-sanitation-delivery/

132 Interview with representative from Young Power in Social Action.

133 Ruma Paul and Sudarshan Varadhan. "Bangladesh plunged into darkness by national grid failure". Reuters. October 4, 2022. https://www.reuters.com/world/asia-pacific/large-parts-bangladesh-without-power-after-national-grid-failure-daily-star-2022-10-04/

134 Khan I, Chowdhury S, Techato K. Waste to Energy in Developing Countries — A Rapid Review: Opportunities, Challenges, and Policies in Selected Countries of Sub-Saharan Africa and South Asia towards Sustainability. *Sustainability*. 2022; 14(7):3740. https://doi.org/10.3390/su14073740

135 "Flooding: How to increase your city's permeability". C40 Knowledge Hub. September 2022. https://www.c40knowledgehub.org/s/article/Flooding-How-to-increase-your-city-s-permeability

136 Yan Carrière-Swallow, Vikram Haksar, and Manasa Patnam. "Stacking Up Financial Inclusion Gains in India". International Monetary Fund. July 2021. https://www.imf.org/external/pubs/ft/fandd/2021/07/india-stack-financial-access-and-digital-inclusion.htm

137 Shannon K. O'Neil. "Loan Guarantees and Financial Inclusion in the Developing World". Council on Foreign Relations. June 10, 2015. https://www.cfr.org/blog/loan-guarantees-and-financial-inclusion-developing-world

138 Interview with representative from Young Power in Social Action.

139 Ibid.

140 Palash, Rahul Sarker. "Technical committee formed to resolve CDA-WASA conflict". Bangladesh Post. April 1, 2021. https://bangladeshpost.net/posts/technical-committee-formed-to-resolve-cda-wasa-conflict-57140

141 Interview with representative from Young Power in Social Action.

142 "Strengthening Urban Management and Service Delivery through Performance-Based Fiscal Transfers". World Bank Group. December 8, 2022. https://www.worldbank.org/en/topic/urbandevelopment/brief/strengthening-urban-management-and-service-delivery-through-performance-based-fiscal-transfers

143 Resnick. "Urban Governance and Service Delivery in African Cities: The Role of Politics and Policies".

144 Lustgarten, Abraham. "The Barbados Rebellion". The New York Times. July 27, 2022. https://www.nytimes.com/interactive/2022/07/27/magazine/barbados-climate-debt-mia-mottley.html

145 "ICMA publishes new climate resilient debt clauses to facilitate sovereign debt relief and financial stability". International Capital Market Association. November 9, 2022. https://www.icmagroup.org/News/news-in-brief/icma-publishes-new-climate-resilient-debt-clauses-to-facilitate-sovereign-debt-relief-and-financial-stability/

146 Kristalina Georgieva, Marcos Chamon, and Vimal Thakoor. "Swapping Debt for Climate or Nature Pledges Can Help Fund Resilience". International Monetary Fund. December 14, 2022. https://www.imf.org/en/Blogs/Articles/2022/12/14/swapping-debt-for-climate-or-nature-pledges-can-help-fund-resilience

147 Prasad, Ananthakrishnan, Elena Loukoianova, Alan Xiaochen Feng, and William Oman, 2022. "Mobilizing Private Climate Financing in Emerging Market and Developing Economies." IMF Staff Climate Note 2022/007, International Monetary Fund, Washington, DC.

148 Collins, Jennifer. "Germany, G7 launch 'Global Shield' climate finance at COP27". DW. November 14, 2022. https://www.dw.com/en/germany-g7-launch-global-shield-climate-finance-at-cop27/a-63728889

149 Interview with representative of Ministry of Disaster Management and Relief.

150 "A New Marine Protected Area to Protect Biodiversity and Coral Habitat Around Saint Martin's Island in Bangladesh". WCS Newsroom. https://newsroom.wcs.org/News-Releases/articleType/ArticleView/articleId/17095/A-New-Marine-Protected-Area-to-Protect-Biodiversity-and-Coral-Habitat-Around-Saint-Martins-Island-in-Bangladesh.aspx

151 Agostini, V. N., et. al. "Marine zoning in St. Kitts and Nevis: A design for sustainable management in the Caribbean". *Ocean & Coastal Management*. February 2015. https://doi.org/10.1016/j.ocecoaman.2014.11.003

152 Siddique, Abu. "In Bangladesh, Ecologically Critical Areas exist only on paper". Mongabay. December 16, 2022. https://news.mongabay.com/2022/12/in-bangladesh-ecologically-critical-areas-exist-only-on-paper/

153 Erftemeijer, P. L. A. "Seagrass Ecosystem Restoration Guidelines for the Western Indian Ocean Region". UN Environment Programme, Nairobi Convention, Western Indian Ocean Marine Science Association, and Global Environment Facility. https://www.nairobiconvention.org/CHM%20Documents/

WIOSAP/WIOSAP%20docs%20for%20website/Third%20WIOSAP%20PSC/Seagrass%20Restoration%20Guideline_v06_REVISION.pdf

154 Tan, Yi Mei, et. al. "Seagrass Restoration Is Possible: Insights and Lessons From Australia and New Zealand". Frontiers in Marine Science. August 14, 2020. https://doi.org/10.3389/fmars.2020.00617

155 Chapman, Kit. "The toxic tide of ship breaking". Chemistry World. February 21, 2022. https://www.chemistryworld.com/features/the-toxic-tide-of-ship-breaking/4015158.article

156 "National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs". US Environmental Protection Agency & US Maritime Administration. May 2006. https://www.epa.gov/sites/default/files/2015-09/documents/artificialreefguidance.pdf

157 "Standout Practices at High-Performing Bangladeshi Textile Mills". Natural Resources Defense Council. September 2012. https://www.nrdc.org/sites/default/files/cbd-textile-mills-standout-practices-bangladesh.pdf

158 George, Rebecca. "Resurrecting Climate-Resilient Rice in India". Yes! Magazine. December 14, 2022. https://www.yesmagazine.org/environment/2022/12/14/rice-india-climate

159 Siddique, Abu. "Degraded soil threatens to exacerbate Bangladesh food crisis". Mongabay. December 30, 2022. https://news.mongabay.com/2022/12/degraded-soil-threatens-to-exacerbate-bangladesh-food-crisis/

160 Shah, T.M.; Tasawwar, S.; Bhat, M.A.; Otterpohl, R. Intercropping in Rice Farming under the System of Rice Intensification — An Agroecological Strategy for Weed Control, Better Yield, Increased Returns, and Social–Ecological Sustainability. *Agronomy* 2021, 11, 1010. https://doi.org/10.3390/agronomy11051010

161 Alistair Hunt and Paul Watkiss, "Climate Change Impacts and Adaptation in Cities: A Review of the Literature," *Climatic Change* 104, no. 1 (December 2011): 13–49.

162 Jorgelina Hardoy and Gustavo Pandiella, "Urban Poverty and Vulnerability to Climate Change in Latin America," *Environment and Urbanization* 21, no. 1 (April 2009): 203–224.

163 Separate interviews with representatives from Mombasa Country Executive (July 2021), UN Capital Development Fund (December 2020), and The Nature Conservancy (April 2021).

164 Jack Stuart and Sally Yozell, "CORVI: Understanding and Measuring Climate Risk: A Guide to the Climate and Ocean Risk Vulnerability Index," The Stimson Center, Environmental Security Program, 2020, accessed August 16, 2021, https://www.stimson.org/2020/corvi-understanding-and-measuring-climate-risk/.

165 Stuart and Yozell, "CORVI: Understanding and Measuring Climate Risk."

166 Thirty-year time horizons are traditionally used to calculate the seasonal cycle and other long-term averages of climate variables. However, as the climate changes, current conditions are more dissimilar to those from 30 years ago than to those from 10 years ago. In this environment, the Optimum Climate Normals (OCN) method can be used to calculate the minimum number of years required to accurately produce the climatological average for climate variables. The National Oceanic and Atmospheric Administration suggests that a 10-year time series for temperature and a 15-year time series for precipitation are acceptable minimum limits to produce an accurate climatology within a non-stationary period. CORVI follows the same limits that NOAA uses in their experimental seasonal forecast product by using a similar 15-year time horizon to measure climate indicators. For more information on OCN, see Daniel S. Wilks and Robert E. Livezey, "Performance of Alternative 'Normals' for Tracking Climate Changes, Using Homogenized and Nonhomogenized Seasonal U.S. Surface Temperatures," *Journal of Applied Meteorology and Climatology* 52, no. 8 (August 2013): 1677–1687, https://doi.org/10.1175/JAMC-D-13-026.1.

167 For an introduction to structured expert judgment, see Cherie Maestas, "Expert Surveys as a Measurement Tool: Challenges and New Frontiers," in *The Oxford Handbook of Polling and Survey Methods*, eds. Lonna Rae Atkeson and R. Michael Alvarez (Oxford: Oxford University Press, 2018).

168 Snowball sampling or chain-referral sampling is a non-probability sampling technique used when samples have traits that are difficult to find. In this sampling technique, existing subjects provide referrals to recruit additional subjects required for a research study.

169 Abigail Colson and Roger Cooke, "Expert Elicitation: Using the Classical Model to Validate Experts' Judgements," *Review of Environmental Economics* and Policy 12, no. 1 (2018): 113–132.

170 H. Kunreuther, S. Gupta, V. Bosetti, R. Cooke, V. Dutt, M. Ha-Duong, H. Held, J. Llanes-Regueiro, A. Patt, E. Shittu, and E. Weber, "Integrated Risk and Uncertainty Assessment of Climate Change Response Policies," *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J. C. Minx (Cambridge: Cambridge University Press, 2014).