Addressing the Transport and Trade Logistics Challenges of the Small Island Developing States (SIDS): Samoa Conference and Beyond

11 July 2014

Climate Change and Climate Variability: Critical Risk Factors for Air and Seaport Operations in Small Islands

Presentation by

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Climate Change and Climate Variability: Critical Risk Factors for Air and Seaport Operations in Small Islands

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Importance of Air and Seaports in SIDS

• Social and economic development of most SIDS - Caribbean, Pacific, AIMS regions - is closely tied to the functionality and efficiency of their air and seaports → imports and exports
  ◦ Between 50% and 95% of all food and beverages consumed in SIDS come from external sources
  ◦ >90% of all energy products used in SIDS, primarily hydrocarbon fuels, handled through seaports
  ◦ >75% of consumables in other sectors imported
• SIDS earn significant foreign and local revenues from port-related activities, including:
  ◦ Berthing, bunkering & airport landing fees
  ◦ Air and cruise passenger imposts
  ◦ Containerized and other storage charges; waste reception fees, etc.
**Key Climate Risk Factors for Seaports and Airports in SIDS**

- Rising air and ocean temperatures → (i) thermal expansion of ocean surface (ii) greater *convection potential* over ocean
- Rising sea level and surge → (a) raise H₂O levels (b) *high amplitude waves* and increased potential for damage
- Higher wind speeds → increased storminess (IPCC AR5)
  - No clear trend in projections of total number of storms BUT *tropical cyclone intensity projected to increase*
  - *Frequency of the most intense storms* likely to increase substantially in some basins
  - Likely increase in both *global mean tropical cyclone maximum wind speed* and *rain rates*

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<table>
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<th>Rank</th>
<th>Absolute Exposure (Millions)</th>
<th>Relative Exposure (% of pop. Exposed)</th>
<th>Absolute GDP loss</th>
<th>Loss as % of GDP</th>
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<td>New Caledonia 0.7</td>
<td>Bangladesh 5.9</td>
</tr>
</tbody>
</table>
Sample of Assets and operations At Risk: Air- and Seaports

- Climate-induced changes can cause serious damage to port infrastructure and cause major business interruption:
- Tarmacs/runways & aircraft, fuel storage tanks
- Terminal facilities & associated throughput of passengers, goods and related services
- Utilities $\rightarrow \text{H}_2\text{O}$, power supply, telecommunications
- Berths, bulkheads, seawalls, breakwaters
- Emergency response $\rightarrow$ e.g. fire and ambulance services
- Projected impacts could overwhelm existing capacities, e.g. storm and wastewater management systems
- SIDS, like other nations, will be faced with increased exposure and related cumulative risks at air – and seaports

◊ Implications for insurance, legal liability & operating costs?

How Would Climate Change Affect Wave Energy?

- *Wave Energy* ($E$) is proportional to the amplitude ($\alpha$) of wave
- $\alpha$ is also partly controlled by wind speed ($V$)

Climate change signals?

$\uparrow \Theta$ (air & sea) $\rightarrow$

(a) Thermal expansion
(b) Melting of land ice

$\downarrow \text{H}_2\text{O}$ Depth ($d$)
(c) Increasing wind speed
(d) Pressure gradient change

$\downarrow$ Higher wave energy

- $E$ increases *exponentially* with increasing $V$
- $E$ also increases as $d$ ($\text{H}_2\text{O}$ depth)
Key Components of Water level Change:
Implications for Coastal Infrastructure

i. Astronomical Tide
ii. Wave set up → increase in mean water level landward of breaker zone due to flux of $H_2O$ at coast
iii. Sea Level Anomaly → measure of the difference between short- and long-term MSL → negative and positive anomalies
iv. Sea level Rise
v. Storm Surge

Note:
ii., iii. iv. and v. are climate-sensitive phenomena

In coastal areas, quantitatively small changes have disproportionately large effects, e.g. storm surge

- Storm surge is associated with a rapid fall in barometric pressure, accompanied by strong onshore winds, as hurricane passes → ‘Inverse barometer’ triggers a rapid elevation of $H_2O$ level.
- Surge generates large surface waves, leading to the ‘piling up’ of $H_2O$ at the coast.
- Relationship between reduction in pressure and $H_2O$ level is not linear:
  - Small drop in pressure can induce a significant rise in $H_2O$ level. For example, a 25.4 mm (1.0 in.) fall in the barometric pressure could produce a sea surface rise of approx. 33 cm (13.0 in.).
Sea Level Rise Projections – Caribbean SIDS

Sea Level Rise Projections – Indian Ocean SIDS
Sea Level Rise Projections: Pacific SIDS

Port of Bridgetown, Barbados

- Handles >90% of all goods used in retail, manufacturing and tourism.
- Contributed > USD 2.0 Billion in direct revenues in 2011

Area (shaded green) that would be inundated by a category 3 hurricane, whose passage coincides with astronomical high tide, under a likely sea level rise scenario of 0.5 m (50 cm) relative to 1992 MSL.

Source: Cruiseshipcaptain.wikidot.com
Scenario for Coastal Vulnerability to Sea Level Rise/Storm Surge

Elevation ≈ 4.0 m a.m.s.l.; Projected SLR 18 cm by 2025, 30-34 cm by 2050, 58-84 by 2100. Storm surge modeling - category 4/5 hurricanes → H₂O levels 3-4 m.

Key Risk Factors for Port of Kingston and Norman Manley International Airport

Norman Manley Airport is located on a barrier beach 3 m a.m.s.l. Connected to the mainland via the Norman Manley highway → located parallel to Palisadoes sand spit = 3.0 m a.m.s.l.

Major storms flood highway, severing airport from mainland, e.g. Hurricane Ivan 2004.
Many SIDS airports vulnerable to SLR and storm surge

Male Airport, Maldives
<1.5 m a.m.s.l.
http://www.themaldives.net/icms/assets/image/capital/male-maldives-capital-aerial-view.jp

Runway

Rangiroa Airport, French Polynesia,
2.0 m a.m.s.l.
www.google.com/maps

Seychelles Int’l Airport, Mahé Island,
<3.0m a.m.s.l.
http://flyawaysimulation.com/media/images12/images/FSIA-Seychelles-International-Airport-fsx1.jpg

Papeete Airport, French Polynesia
(Source:http://www.regenboogadvies.nl)

Airport at current elevation relative to mean sea level
Simulation showing airport completely inundated with sea level rise of 88 cm

Runway
Coastal road

Runway
Coastal road
Examples of Vulnerable Pacific Island Airports
(Source: Digital Globe Map Data, 2014 Google)

Bonriki Airport, Kiribati, <3.0 m a.m.s.l.
SLR 3.1 mm yr⁻¹ since 1993

Vulnerability amplified by regional
SLR, storm surge and "king tide" phenomenon

Funafuti Airport, Tuvalu, 2.0 m a.m.s.l.

Majuro Airport, Marshall Islands, 2.0 m a.m.s.l.

Honolulu Airport, Hawaii, built on offshore reef, <2.0 m a.m.s.l.
SLR 1.5 mm yr⁻¹ (0.6 in/decade)

June 25, 2013 airport closed due to flooding from waves; runway seawall badly damaged. United Airlines flight redirected.

Port of Apia, Upolu Island, Samoa

- Only commercial port, handles >98 of foreign cargoes
- Berthing, warehousing, container storage, stevedoring, health & quarantine services
- December 13, 2012 cyclone Evan → Storm surge 4.5 m → major dislocation to services, coastal infrastructure, port functions. Damage USD 200 M.
Island of Rarotonga, Cook Islands

SLR – 1.51 mm yr⁻¹: high vulnerability to tropical cyclones:
• Minor impact every 2 yrs
• Moderate impact every 4 yrs
• Major impact every 9 yrs (de Scally, 2008)

Port of Avatiu is main sea port, handling >90% of all sea cargoes. Tourism accounts for >50% of GDP in Cook Islands; >75% of goods supporting the industry are cleared through the Port of Avatiu.

Transport & Infrastructure Damage - Hurricane Lenny, Nov. 1999

Northwestern & southern tip of the island most affected - landslides, severe beach erosion, airport flooded; 65% of Barbuda flooded, sanitary & water storage facilities overflowing; USD 51.3 M damages.

Damage & interruption at both airports
• Pottersville to Rockway highway closed;
• flooding at air & seaports; Roseau severed from petroleum storage facilities; west coast sea defenses breached; USD 21.5 M damages.

Most damage at Soufriere, waterfront, Gros Islet, Anse La Raye, Choiseul; severe erosion on NW coast, housing & tourism damage; damage to seaport, flooding at airports; hospital cut off from town; USD 6.6 M.

Seawall & other coastal defenses at Airport facilities damaged; structural failure and boat damage at St. George’s Port; much damage to roads linking main settlements to air- & seaport; heavy damage to tourism plant; USD 94.3 M damages.
Building Resilience at Ports – The Necessity for Adaptation in SIDS

- Almost all air- and seaport operations face heightened risks as a consequence of climate change & climate variability. For SIDS, implementation of a suite of adaptation options will be the only choice, given their high dependency on these facilities, juxtaposed against following realities:
  - Past global GHG emissions & current trajectory guarantee that warming of atmosphere & oceans, and SLR will continue for decades (‘climate inertia’ → volume of GHGs already emitted).
  - No evidence that an enforceable post-Kyoto agreement will eventuate anytime soon → BAU scenarios likely.
  - Air- and seaport infrastructure represent major investment → amortized over medium-to-long periods, e.g. minimum of 25-30 years, in some cases as many as 50 years → fall within the timeframe of current climate change projections.

Potential Adaptation Strategies for Air- & Seaports in SIDS

| Engineering | Enhance the structural integrity and efficiency of critical facilities including sea defenses, berths, mooring facilities, runways, parking aprons etc, based on design criteria that reflect changing wind, sea level and wave conditions; recalculation of return periods for major events such as hurricanes and floods, so that more resilient structures can be engineered. |
| Technological | Invest in more climate-resilient technologies and equipment in planned expansion and upgrade programmes, e.g. gantry cranes that can operate at higher wind thresholds; solar photovoltaics to generate electricity more efficiently for both operations and administration. |
| Planning & Development | Internal capacity building and re-training that recognizes the magnitude and implications of the threat; building of redundancy into critical operations, wherever feasible; off-site warehousing and storage in less vulnerable areas, etc. |
| Management Systems | Various operational systems need to ‘mainstream’ climate change considerations into their procedures, e.g. ‘shut down’ and ‘start up’ operations; emergency protocols and evacuation; environmental management systems; occupational safety and health protocols, etc. |
| Insurance | Some risks cannot be avoided, therefore must be insured by third parties; ongoing collaboration with port management, climate scientists and insurers will yield a better understanding of risks and strategies. |
Thank You
leonard.nurse @cavehill.uwi.edu

8 MW photovoltaic energy system – Athens International Airport