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“Tools and Methods to Assess Coastal Infrastructure Resilience

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Lessons Learned and Best Practices: Resilience of Coastal Infrastructure, March 8-9 2017
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OUTLINE

I. Coastal resilience in practice

II. Infrastructure performance:
   Project → System → Community

III. Discuss tools – simple to detailed

IV. Examples – simple to detailed

V. Next steps
I. RESILIENCE IN PRACTICE – BARRIER ISLAND

- Stockpile of sand in case of breach
- Vegetated shorelines
- Reef to break waves
- Raised infrastructure
- Buried seawall
- Consider extreme variability and non-stationarity in forcing

Bay

Ocean

- Anticipate weak links and be ready to recover.
- Provide diverse and redundant protection.
- Ensure availability of alternate networks – components are independent of, and complement each other.
- Provide accessible information for rapid decision-making.
I. RESILIENCE IN PRACTICE

- **Build partnerships**
- **Assess existing and future vulnerabilities in system**
- **Develop strategies & contingency plans**

- **Utilize features with adaptive capacities that can be modified and will absorb impacts and resist damage**
- **Provide diverse and redundant protection**
  - Ensure availability of alternate networks – components are independent of, and complement each other
- **Implement operations for rapid recovery**
  - Foster natural and human actions for natural, nature-based, and hybrid features to facilitate adaptation
- **Consider non-structural measures (e.g., relocation, zoning, education and advanced alerts, etc.)**
II. PROJECT VS. SYSTEM VS. COMMUNITY

For example…suppose:

- **PROJECT** = seawall
- **SYSTEM** = barrier island, cross-shore and longshore transport
- **COMMUNITY** = economic driver is tourism

Seawall is resilient! But system performance affects community goals

Must consider resiliency of **PROJECT** within the **SYSTEM** context, and how both perform to support **COMMUNITY** priorities.
III. TYPES OF ASSESSMENT METHODS

• Tools can assimilate many factors and help to evaluate relative costs and benefits (e.g., existing & future infrastructure conditions; range in environmental forcing; implications of human actions)

• Simple tools → expert elicitation; general system performance

• Complex tools → system customization; time-dependent performance

Modified from: PIANC TG 193, in preparation (Fox-Lent, Ch 5)
III. PARAMETERS OF ASSESSMENT METHODS

- Essential parameters of resilience assessments
  (Connolly et al. 2017)

  Define **Critical Function**: purpose of infrastructure for system functioning

  Specify the **Threshold**: conditions under which infrastructure can no longer meet critical functioning

  Estimate **Recovery**: time to recover critical functioning

  Assess **Memory & Adaptive Capacity**: capacity to learn & modify based on experience

_Type of tool utilized depends on data availability, resources (time, funds), and purpose; simple tools can inform detailed methods_

## IV. EXAMPLES: SCORECARD

### CRITICAL INFRASTRUCTURE AND FACILITIES

The following are key indicators that will give a preliminary assessment of your community’s disaster resilience. A more detailed assessment process is available in the FEMA 386-2 publication (fema.gov).

1. Place a check mark in the column where your community’s critical infrastructure and facilities are located. You may need to use flood maps to determine where the boundaries would be. If the facility is located in multiple areas, put a check in all that are applicable. Then put a check mark in the last column if the infrastructure or facility is functional after a disaster (assuming Scenario 1). Use the total check marks in the last column for Section A and Section B to complete page 9, “Determining Your Resilience Index.”

<table>
<thead>
<tr>
<th>Example: Power grid</th>
<th>Special Flood Hazard Area (SFHA)</th>
<th>Bad Storm Scenario 1</th>
<th>Future Storm Scenario 2</th>
<th>Infrastructure or facility functions after disaster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

### Section A: Critical Infrastructure

- Wastewater treatment system
- Power grid
- Water purification system
- Transportation/evacuation routes

Total check marks for Section A: [ ]

### Section B: Critical Facilities

- City Hall or other local government building(s)

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[http://masgc.org/coastal-storms-program/resilience-index](http://masgc.org/coastal-storms-program/resilience-index)
## IV. EXAMPLES: MATRIX

<table>
<thead>
<tr>
<th>Alt</th>
<th>Prepare</th>
<th>Withstand</th>
<th>Recover</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt 1</td>
<td>Rating 4</td>
<td>Rating 4</td>
<td>Rating 3</td>
<td>Rating 4</td>
</tr>
<tr>
<td>Alt 2</td>
<td>Rating 5</td>
<td>Rating 5</td>
<td>Rating 4</td>
<td>Rating 5</td>
</tr>
<tr>
<td>No Action</td>
<td>Rating 2</td>
<td>Rating 1</td>
<td>Rating 2</td>
<td>Rating 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alt</th>
<th>1: Critically Low R/Extremely High Risk – Vulnerable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2: Low R/High Risk – Likely for Damage/Loss</td>
</tr>
<tr>
<td></td>
<td>3: Moderate R/Moderate Risk – Damage/Loss possible</td>
</tr>
<tr>
<td></td>
<td>4: Good R/Lower Risk – Measures reduce risk &amp; keep habitat</td>
</tr>
<tr>
<td></td>
<td>5: High R/Low Risk – Extremely well-prepared; low vulnerability</td>
</tr>
</tbody>
</table>

Assessments must be in context of **system framework** with understanding of **community priorities and needs**

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IV. EXAMPLES: INPUT-OUTPUT

Intended for operational systems

Steps:
1. Identify key functions in a given process - input, output, time, control, precondition, & executing condition
2. Identify variability of functions and thresholds
3. Test: how performance variability can propagate through system
4. Test: how variability can be monitored, managed, or eliminated

Example for port operations: relates vessel traffic, environmental conditions, communications, channel condition, availability of berth, tugs, etc. to functionality.

IV. EXAMPLES: NETWORK

Goal: Evaluate community functionality with respect to life-safety, housing, utilities, transportation (evacuation/return)

Approach: Evaluate effects of storms (via numerical modeling) on functional performance of infrastructure (housing, utilities, transportation) and life-safety

<table>
<thead>
<tr>
<th>System Function</th>
<th>Performance Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-safety</td>
<td>Minimize the number of residents exposed to flooding</td>
</tr>
<tr>
<td>Housing</td>
<td>Maximize residents who can reoccupy homes post-storm</td>
</tr>
<tr>
<td>Utilities</td>
<td>Maximize residents with services -- potable water, wastewater, and electric</td>
</tr>
<tr>
<td>Transportation</td>
<td>Minimize travel time to/from homes to boundaries (evacuate/return)</td>
</tr>
</tbody>
</table>

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IV. EXAMPLES: NETWORK

Nodes:
- Housing
- Transportation routes, bridges
- Electrical substations
- Wastewater plants
- Pumping stations
- Tide, storm surge, waves
- Policies: beach & dunes, wetlands, mandatory evacuation

Nodes populated using conditional probability tables:

Models: Advanced Circulation Model (ADCIRC), Steady State Spectral Wave (STWAVE), Storm-induced Beach Change Model (SBEACH)

Databases: Primary Land Use Tax Output (PLUTO), US Census, DHS Critical Infrastructure, HAZUS and local city and utility databases.

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Simple Scorecard
Index Matrix
Input-Output
Complex Network
IV. EXAMPLES: NETWORK

**Overall Resilience in Jamaica Bay**

- Status quo
- Alternatives

**Resilience of Four System Functions**

- Transportation
- Utilities
- Housing
- Life Safety

Utilities most vulnerable

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V. NEXT STEPS FOR COASTAL INFRASTRUCTURE RESILIENCE TOOLS – COLLABORATION OPPORTUNITIES

- Documentation of tool applications in case studies
- Validation of case study results
  - e.g., did results of the application accurately predict post-hazard experience?
- Integrated decision-support toolbox linking data, performance indices, processes, and coastal infrastructure & regional information into system framework
- Data & best practices for recovery and adaptation
- Guidance for
  - Types of tools applicable to level of study
  - Representative performance indices/metrics