Towards a Comparative Index of Seaport Climate-Risk: Development of Indicators from Open Data

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Abstract

In order to better understand the distribution of risk across ports and to inform transportation resilience policy, we are developing a comparative assessment method to measure the relative climate-risk faced by a sample of ports. Our mixed-methods approach combines a quantitative, data-driven, indicator-based assessment with qualitative data collected via expert-elicitation. In this presentation, we identify and synthesize over 120 potential risk indicators from open data sources. Indicators represent exposure, sensitivity, and adaptive capacity for a pilot sample of 30 ports. Our exploratory data analysis, uncovered sources of variance between individual ports and between indicators. Next steps include convening an expert panel representing the perspectives of multiple transportation system agencies to find consensus on a suite of robust indicators and metrics for maritime freight node climate-risk assessment. The index will be refined based on expert feedback, the sample size expanded, and additional indicators sought from closed data sources. Developing standardized indicators from available data is an essential step in risk assessment, as robust indicators can help policy-makers monitor resilience strategy implementation, target and justify resource expenditure for adaptation schemes, communicate adaptation to stakeholders, and benchmark progress.

Background

Seaports are:

- **Critical**: > 90% of global trade carried by sea [*IMO*, 2012]
- **Constrained**: functionally restricted to water's edge
- **Exposed**: Ports face impacts from today's weather extremes & tomorrow's climatic changes in:
  - Storm frequency & intensity
  - Sea level
  - Temperature
  - Tidal regime
  - Sedimentation rates
  - Salinity
  - pH

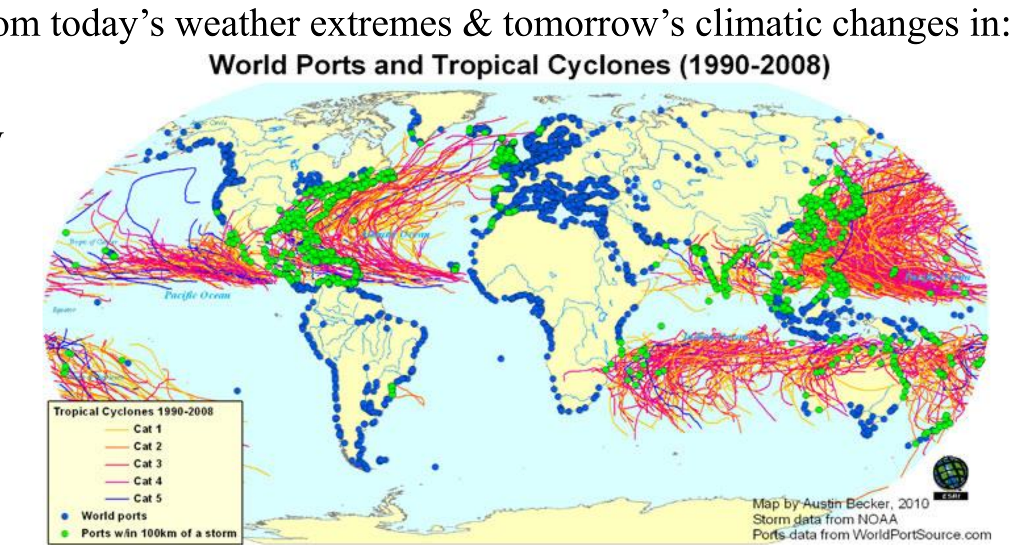


Fig. 1 Map of Tropical Cyclone tracks 1990 - 2008

- [*Becker et al.*, 2011] surveyed 93 global port administrators and found that while most respondents agree that the ports community needs to address climate change adaption, most felt relatively uninformed about potential climate impacts

Definitions

- **Adaptive Capacity:** attributes and resources available that can be used to prepare for and undertake actions to reduce adverse impacts
- **Climate impact, adaptation, and vulnerability (CIAV) decisions:** choices, the results of which are expected to affect or be affected by the interactions of the changing climate with ecological, economic, and social systems
- **Decision support:** a set of processes intended to create the conditions for the production of decision-relevant information and for its appropriate use [*National Research Council*, 2009]
- **Decision-relevant information:** yields deeper understanding of, or is incorporated into making a choice that improves outcomes for decision makers and stakeholders or precipitates action to manage known risks
- **Exposure:** the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
- **Indicator:** a measureable, observable variable that serves as a proxy for an aspect of a system that cannot be directly, adequately measured
- **Open data:** publicly available data structured in a way that enables the data to be fully discoverable and usable by end users
- **Risk:** the potential for consequences where something of value is at stake and where the outcome is uncertain, risk results from the interaction of vulnerability, exposure, and hazard

Open Data

Adopting open data for indicator development increases transparency, facilitates reproducibility, and can enhance reliability when using standardized data sources [*Janssen et al.*, 2012]

Risk Assessment as Decision Support

- Because all decisions on CIAV are affected by uncertainty and focus on valued objectives, all can be considered as decisions involving risk [*IPCC*, 2014]
- As part of an iterative approach to risk management, climate-risk assessments serve as support for CIAV decisions [*ibid.*]
- Risk is measurable as $R = p(L)$, but potential loss (L) and probability of occurrence (p) – can be speculative & difficult to measure in the climate-risk context. Yet, there is increasing call from policymakers for methods to 'measure' these types of concepts [*Cutter et al.*, 2010; *Hinkel*, 2011]
- In the climate-risk/vulnerability/resilience assessment literature, we find that assessment methods tend to fall into one of two categories with the following characteristics:

1. **Self-assessment** (qualitative): participatory, inductive, relies on stakeholder perceptions of the response – site specific
   - e.g., [*Semppier et al.*, 2010]
2. **Indicator-based** (quantitative): normative, deductive, commonly based on 'indicators' – can be comparative
   - e.g., [*Cutter et al.*, 2010]

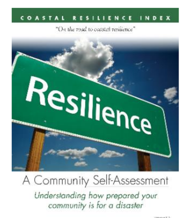


Fig. 2 [*Semppier et al.*, 2010] Coastal Community Resilience Index: A Community Self-Assessment

- [*IPCC*, 2012] recommends quantitative approaches be complemented with qualitative approaches to capture the full complexity and various tangible and intangible aspects of vulnerability

Indicator-based Risk Assessment

- For CIAV decision support requiring comparative information products (e.g. for decisions at the scale of multiple ports, or the marine transportation system [MTS]), indicator-based assessment can allow difficult to measure concepts (risk/vulnerability/resilience) to be operationalized
- Desirable indicators are variables that summarize relevant information, make visible phenomena of interest, and quantify relevant information [*Gallopin*, 1997]
- The utility of indicators will depend upon the questions being asked [*U.S. CMTS*, 2015]
- Best practice suggests over-aggregation be avoided, lest the concept being measured (e.g. climate-risk) evolve into a generic condition that has little relevance or meaning [*Barnett et al.*, 2008].
  - Accordingly, any aggregation and/or weighting of these variables will be done via iterative expert elicitation (e.g. Delphi method), and any aggregation will retain a disaggregated substructure

Methods

- Identified 126 potential climate-risk *exposure*, *sensitivity*, and *adaptive capacity* indicators from open sources (e.g., EPA, FEMA, NOAA, NWS, MARAD, USFWS, USACE)
  - narrowed to 61 viable indicators based on data availability
- Compiled a dataset with 61 viable indicators (15 *exposure*, 27 *sensitivity*, 19 *adaptive capacity*) for a pilot sample of 30 ports:
  - 27 N.E. Medium & High Use Ports (throughput > 1 M tons) plus LA, Long Beach, and Honolulu for contrast
- Exploratory data analysis:
  - Examined correlations and clustering patterns of ports and of indicators
  - Outputs will inform iterative rounds of expert elicitation to:
    - Reduce dimensionality and seek consensus around the following concepts:
      - How does risk relate to "resilience" as for the MTS?
      - What measurable indicators of risk are common across ports?
      - How can indicator data be synthesized to be decision-relevant for port decision makers?

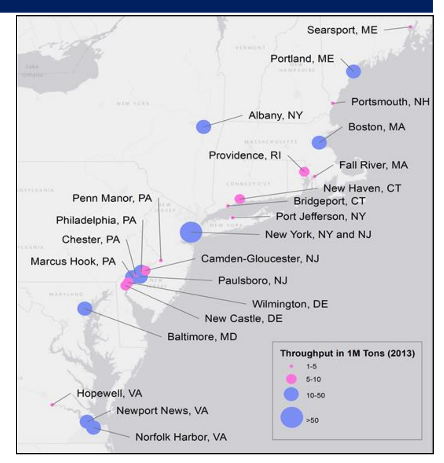


Fig. 3 Pilot Sample: U.S. North Atlantic Ports

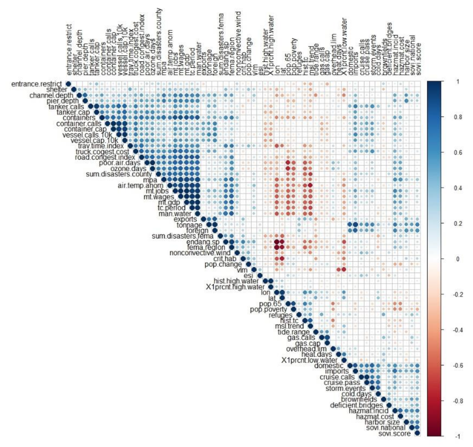


Fig. 4 Correlation matrix of potential indicators

Preliminary Results

The tables below show selected examples of indicators of port climate-risk, grouped by their potential to affect the port's *exposure*, *sensitivity*, and *adaptive capacity*.

Table 1. System **Exposure** (*stress faced by system*)

Sub-Category	Sub-Sub-Category	Indicator	Data Source
Storm Hazard	Storm Frequency	# of storm events w/ $1M damage	NOAA Storm Events Database
Storm Hazard	Wind Hazard	Non-convective high winds	NOAA Storm Events Database
Storm Hazard	Storm Surge Hazard	Highest historical water level	NOAA
Storm Hazard	Storm Surge Hazard	1% annual exceedance probability high water	NOAA Extreme Water Levels
Storm Hazard	Proximity to Historical Tropical/Extra-tropical Cyclone Tracks	# cyclones within 100 nm	NOAA Historical Hurricane Tracks
Storm Hazard	Hurricane Frequency	Return period for Hurricane	NHC
Sea Level Rise Hazard	Empirical SLR	Local Mean Sea Level Trend	NOAA Tides and Currents- Sea Level Trends
Temperature Hazard	Heat hazard	Days with excessive heat events	NOAA Storm Events Database
Temperature Hazard	temperature anomaly	Annual Average Air Temperature Anomaly (°F 1945-2000 Base Period)	NOAA National Centers For Environmental Information NCDC
Disasters	by FEMA Region	Sum of Presidential Disaster Declarations in FEMA Region	FEMA, Historical Disaster Declarations

Table 2. System **Sensitivity** (*extent sector will be affected*)

Sub-Category	Sub-Sub-Category	Indicator	Data Source
Environmental	Surrounding Environment	Nearby Critical Habitat Areas	U.S. Fish & Wildlife Service, Critical Habitat Portal
Environmental	Air Quality	Days with Poor Air Quality based on Ozone	EPA
Environmental	Hazmat	Cost of Hazmat Incidents	U.S. DOT Safety Administration, Incident Statistics
Built Asset	Land-Side Built Asset	Structurally Deficient Bridges	Structurally Deficient Bridges on the National Highway System
Built Asset	Water-Side Built Asset	Cargo Pier / Wharf Depth	World Port Index
Economic	Regional Economic	Marine Transportation Jobs	NOAA Office for Coastal Management Economics: National Ocean Watch
Economic	Regional Economic	Marine Transportation Gross Domestic Product	NOAA Office for Coastal Management Economics: National Ocean Watch
Social	Surrounding Population's	% Population Over 65 (2010)	NOAA NOS Special Projects Office, Spatial Trends in Coastal Socioeconomics County Demographic Trends
Social	Surrounding Population's	% Population in Poverty (2010)	NOAA, Spatial Trends in Coastal Socioeconomics
Social	Surrounding Population's	Port County Social Vulnerability (SoVI) Score	Social Vulnerability Index

Table 3. **Adaptive Capacity** (*degree to which system can cope*)

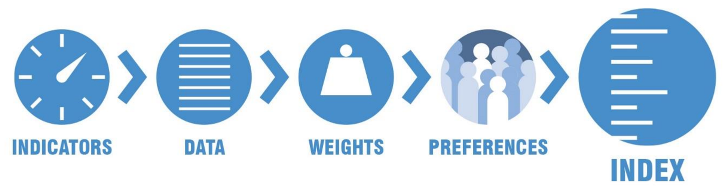
Sub-Category	Sub-Sub-Category	Indicator	Data Source
Operational Efficiency	Efficiency of Transport Connections	Annual Truck Congestion Cost	Texas Transportation Institute Urban Mobility Information
Operational Efficiency	Efficiency of Transport Connections	Roadway Congestion Index	Texas Transportation Institute Urban Mobility Information
Operational Efficiency	Planning	State/local adaptation plans in place	State Planning Office
Water-Side Capacity	Vessels	Vessel Calls	MARAD
Water-Side Capacity	Vessels	Vessel Capacity	MARAD
Water-Side Capacity	Vessels	Tanker Calls	MARAD
Water-Side Capacity	Vessels	Container Vessel Calls	MARAD
Water-Side Capacity	Cargo	Total Throughput	USACE Navigation Data Center
Water-Side Capacity	Cargo	Domestic Throughput	USACE Navigation Data Center

Many challenges of standardizing the reporting of port data remain; some statistics (e.g., *vessel calls*, *throughput*) are reported at different scales:

- *Vessel calls* are reported by MARAD for each port individually (e.g. LA and Long Beach) yet in the USACE Principal Port files, *throughput* is reported for LA and Long Beach combined
- Additionally, because the USACE Principal Port files list the *throughput* of the top 150 U.S. ports, the same ports are not necessarily reported every year

Next Steps

Next steps include iterative expert elicitation (Delphi method) to seek consensus on final indicators, weighting, and aggregation to produce CIAV decision-relevant information products for the marine transportation system.



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