Increase Social Justice by Quantifying Resilience with Broad Community Participation

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Idea in a Nutshell

The world's coastal cities are facing an uncertain future of accelerating sea level rise. The frequency and magnitude of flooding of coastal cities will increase. The global challenge is how to wisely invest limited resources to reduce the impact of coastal flooding while also reducing social injustice. Social benefits are not presently quantifiable in monetary units for inclusion as risk reduction. However, social benefits are quantifiable as an increase in resilience. Community, infrastructure and ecological benefits can be combined to demonstrate an increase in total resilience.

The primary aim of this recommendation is to increase social justice by inviting underrepresented communities to participate and be properly evaluated for flooding vulnerabilities. By engaging citizen scientists and citizen engineers in quantifying increased resilience to coastal flooding, the process of responding to disasters and disruptions will impact a broader population.

Specific Recommendations

The specific implementation of this recommendation requires two actions. The first action is to develop a method that includes resilience quantification because current practice only evaluates risk in terms of monetary savings of flood damage reduction benefits of the studied alternatives. The second action is to include broader number of citizens in the development of the method to represent the maximum number of people.

Quantifying the increased resilience to coastal flooding is a new metric to evaluate mitigation and adaptation alternatives for rising seas. Resilience measures functional performance of housing, utilities, transportation and communication needs of people impacted by flooding. Our current practice only evaluates risk as the metric in terms of monetary savings of flood damage reduction "benefits" of the studied alternatives. Social functional performance benefits are never included because they are difficult to measure in monetary terms. Risk reduction involves maintaining the **form** of residential and commercial buildings, utility structures (water, waste water, gas, power), roads, bridges, airports, and communication lines and structures. Increased resilience involves maintaining the **function** of these same items. Risk measures the form and resilience measures the function.

Value

The value of a resilience calculation that focuses on functionality is more effective than a risk calculation that focuses on form. Improvement of social justice is a result of an inclusive method designed by a greater percentage of the population at risk.

A probabilistic measure of resilience can be assessed for a coastal community using a Bayesian network. The Bayesian network provides the correct mathematical and probabilistic way to quantify the ***increase*** in system functional resilience for various mitigation and adaptation alternatives. The functional performance robustness and rapidity improvements can be quantified for the people regarding their housing, the utilities serving their homes and the access and egress to reach their homes. Their homes may be damaged structurally. Form damages evaluated in monetary terms for the risk reduction in terms of the benefit/cost (B/C) ratio may dictate a certain alternative for flood damage reduction. Functional performance damage evaluated in probability terms for the resilience increase may dictate a different alternative(s) for mitigation or adaptation.

Resilience quantification requires a priori establishment of limit-state values for both functional performance levels (robustness) and recovery times (rapidity) at specified recurrence intervals (probability of exceedance) for flooding events. This process brings the scientific, engineering, planning, investor/developer and community (people) together to establish creditable levels for the limit-state values. For example, at the 100-yr recurrence interval level (1% exceedance probability each year) of water elevation for flooding, the limit-state for robustness could be set at 0.90 and the limit-state for rapidity of recovery set at 7 days for the Housing Function of the system. This means that only 10% of the residences will not be able to return home immediately but will need to wait at least 7 days before doing so. The limit-states for the Utilities Function and Transportation Function of the system are also connected so that the joint probability dictates the total functional resilience to flooding of the system.

Reasoning

The current risk reduction metric as determined by the B/C ratio analysis method commonly used for study and selection of flood hazard mitigation and adaptation alternatives does not support social equality. Using both existing (risk) and new (resilience) methods to evaluate mitigation and adaptation alternatives gives a better method for decision-making. A method that allows for quantification of resilience provides the missing link between engineering/economic analysis of risk and social/environmental analysis and resilience.

Figure 1 illustrates how both the risk metric (red) as determined by the Benefit/Cost (B/C) ratio and plotted on the x-axis and resilience metric (green) as quantified by the Bayesian network and plotted on the y-axis are both needed to evaluate alternatives for flood damage mitigation (both form and function). The “best” alternative may not be the one with the greatest B/C ratio for **risk** reduction but the one with the greatest increase in **resilience** and shown in **yellow**. The “best” alternative may be a compromise and balance between risk reduction and increased resilience.

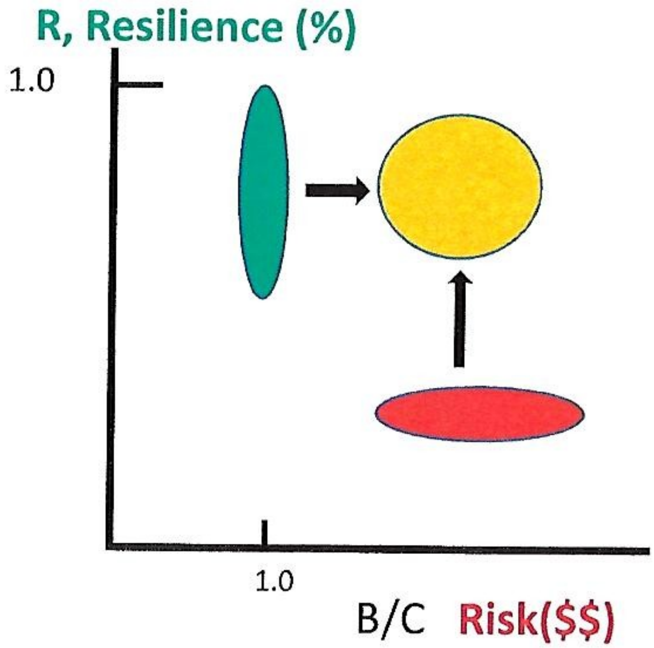

Figure 1. Schematic illustration of risk and resilience metrics
for evaluation of flood mitigation and adaption alternatives.

Bayesian networks have found many applications in medicine, business, marketing, investing and other fields where conditional probability theory is needed because of the complexity of cause-effect decisions in many directions. Bayesian network numerical software models using graphical methods to define nodes and conditional probability tables (CPT) are the key elements in the model. An example of this applicaton is Jamaica Bay, New York City as described by Schultz and Smith (2016) *Assessing the Resilience of Coastal Systems: A Probabilistic Approach*, Journal of Coastal Research, vol 32, no 5, pp 1032-1060. This was a pilot study conducted by the Corps of Engineers.