Using Quantitative Risk Analysis to Address Vulnerabilities to Climate Change

Being better prepared through risk-informed hardening of infrastructure

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According to the August 2021 Intergovernmental Panel on Climate Change report, climate change is increasing both the frequency and intensity of extreme weather events. Weather hazards including extreme heat, wildfires, floods, droughts, winter freezes, and storms—all of which make headlines every year—can damage infrastructure, which in turn affects our health, businesses, and the environment.

Proactively protecting assets from extreme weather is crucial. In a changing climate, technical rigor is no longer optional; it is fundamental. Broad qualitative statements about the increased risk and effects of climate change come easy, but attaching numbers (i.e., economic costs or life-safety risks) to those statements is much more challenging. Asset managers can quantify the impact associated with such risks in terms of expected costs to inform future investments in risk mitigation.

Risk Mitigation

Asset owners planning for climate change face a daunting challenge. Prioritizing mitigation options requires a site-specific understanding of the expected frequency and intensity of future weather events and the identification of specific asset vulnerabilities. Such assessments must be multi-faceted, location-based, facility-specific, and technically rigorous. While publicly available tools (assessment methods, models, etc.) are useful for understanding climate-related risk at a national or regional level, this information must be downscaled and refined to site-specific and asset-specific detail for facility-level management of climate risks.

Quantitative risk analysis (QRA) is becoming increasingly common for identifying and quantifying climate risks. For a QRA, subject matter experts provide their best climate projections and asset capacities that allow engineering estimates of annual consequence rates (such as the annual cost of climate-change-related damage). Despite the scale, complexity, and importance of the problem being addressed, the basic framework is surprising in its simplicity. Projected future weather intensities (e.g., annual peak temperature or wind speed) and the capacities of assets to resist them (e.g., roof strength against uplift) are treated as random variables characterized by probability distributions. The typically used distributions are fully defined by only a few parameters: the expected intensity of the weather (or the expected strength of the asset to resist) and the associated uncertainty.

Climate Parameters: Quantitative risk assessments that include climate hazards use a common, if often misunderstood, measure—the *return period*. Intense storms are often characterized as 100-year or 1,000-year events. This means that a storm of this intensity will occur on average once every 100 or 1,000 years. In a changing climate, scientists can project how return periods of damaging weather events will themselves change over time. For instance, a wind speed that historically had a 100-year return period may be expected to occur once every 50 years by 2050—i.e., this damaging wind may occur roughly twice as frequently in the future as it did in the past. Engineers can use projected return periods of various site environmental hazards (e.g., wind speed, flood depth, peak temperature) to predict increased repair frequency and associated costs.

Engineering Parameters: The vulnerability of an asset to a given weather intensity is known as its *fragility*. Fragility is the conditional probability of some level of damage given the intensity of the hazard—for instance, the likelihood that a roof eave will fail when wind speeds reach 80 miles per hour. When combined with climate projections, fragility functions allow estimation of the future frequency of various damage states with and without mitigation, which informs decisions regarding which assets to harden and by how much. A key advantage of the QRA process is that one can go beyond simply looking at scenarios (e.g., what happens if the wind gets up to 80 mph?) and consider the entire range of plausible events, say from 1 mph peak gust speed (very frequent event with no consequences) to 200 mph (very rare tornadic event with serious consequences). Like climate, fragilities will evolve over time as the assets degrade (through mechanisms such as wood decay, steel corrosion, etc.) or are hardened through regular maintenance. Evolving hazards and fragilities allow comparison of annual costs with or without the effects of climate change on an asset-specific level.

Bringing It All Together

Climate and engineering parameters are integrated to determine the expected rate that a given level of damage will be exceeded, i.e., mean time between failures or, equivalently, annual failure probability. Importantly, modern procedures allow for consideration and weighting of the full range of possible hazard intensities, rather than a single intensity such as the 100-year flood. Because calculations are performed dynamically, the risk of exceeding some damage state is evaluated not just as a fixed value representing today’s snapshot but as a value that grows as hazard intensities and fragilities evolve.

Given the predicted frequency of damage, the evolving present and future, direct and indirect annualized costs of asset repair or replacement can be calculated. Costs take on several dimensions, often in the context of the so-called “three D’s”—death, dollars, and downtime—annualized to compare the effectiveness of candidate mitigation measures. Annualized mitigation expense versus cost of damage avoided, considering quantified life-safety risk reduction, are used to make intelligent, risk-informed decisions about asset strategy.

For example, an asset manager facing sea level rise could decide that raising the elevation of chemical storage tanks provides adequate protection because it reduces the expected losses and environmental consequences below a tolerable threshold. Alternatively, the asset manager could decide that it is more efficient to construct a berm to protect the tank. Both options could be compared to the annualized cost of doing nothing. Armed with these numbers, asset managers can develop technically defensible, risk-informed mitigation strategies.

How Exponent Can Help

Exponent’s asset integrity management team works with industrial clients to safeguard their operations and minimize liabilities through proactive, data-driven strategies. Our quantitative, risk-based operability assessments accurately evaluate asset performance to enable real-time decisions that protect customers and communities. Our multidisciplinary asset integrity management experts safeguard our clients’ infrastructure through proactive programs and tools that assess each asset’s vulnerability to climate extremes to inform inspections and proactive hardening.

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