Research Brief
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Quantifying hazard life-cycle cost

PROBLEM

Life-cycle cost assessment (LCCA) provides the analytical basis to quantify the economic implications of different construction systems. It supports homeowners', builders' and architects' decisions regarding the selection of a cost-effective design over a prescribed time period. One of the major challenges in developing a comprehensive LCCA framework for building is how to quantify and incorporate different performance metrics into the process of comparative cost assessment. One performance metric that needs to be considered is the resilience of the built system, and specifically the structural resistance to hazards. Decision making on multiple-hazard mitigation is a complex process. There is significant uncertainty in both the frequency and intensity of hazards, as well as structural performance and the gravity of resulting damage. Hence it is necessary to incorporate uncertainty and risk into the process of comparative cost assessment.

APPROACH

In this research we present a probabilistic risk-based approach for quantifying lifetime hazard damage cost in residential buildings. The presented framework combines probabilistic hazard modeling, fragility modeling, and damage cost estimation. The annual probabilities of different damage states are calculated by convolving the probability of building failure conditioned on hazard intensity with the annual hazard frequency. These annual probabilities are in turn used to compute the probability of exceeding a damage state over the entire lifetime of buildings. The lifetime damage probabilities are then used to calculate the expected life-cycle cost of maintenance due to hazard as a fraction of initial construction cost.

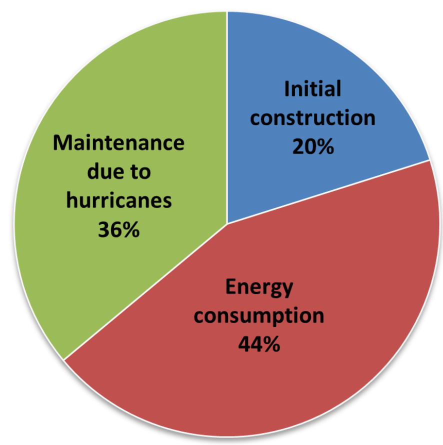

Fig. 1: Relative expected life-cycle costs for a wood-frame single-family home in New Orleans over 50-yr period. The initial construction includes materials, insulations and labor for the building envelope. The structural fragility for hurricane damage is obtained from Hazus database. The energy consumption is calculated using BEOpt.

FINDINGS

The probabilistic risk-based framework is used to calculate the life-cycle cost of maintenance due to hurricane and earthquake hazards for generic wood-frame single-family homes from the Hazus database. The analysis shows that for this type of building, the lifetime damage probabilities are much higher for areas with high hurricane risk as compared to earthquake high-risk areas. For instance, the 50-year probabilities for different levels of damage due to earthquakes can vary between 4%-20% for San Francisco, whereas for New Orleans the probabilities of hurricane wind damage over 50 years can be as high as 70%-99% depending on the damage level. Based on these 50-year damage probabilities, the analysis shows that the highest expected cost of maintenance due to hazard is approximately 2% of total life-cycle cost for San Francisco, whereas for New Orleans this percentage can be as high as 36%, which is similar in magnitude to both initial construction cost and lifetime energy costs.

IMPACT

This development links together probabilistic hazard modeling and damage cost estimation to quantify the life-time cost of repair due to earthquake and hurricane hazard. It provides a way to incorporate quantitative hazard resistance into LCCA and thus supports decisions on the cost-effectiveness of alternative building systems, in particular those that exceed minimum performance codes.

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