Identifying optimal adaptation of buildings threatened by hurricanes, climate change

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The need for adaptation strategies to reduce the threat of hurricanes to society is of critical importance, as evidenced by the recent damage to coastal regions in the U.S. and the Caribbean this past year. The fact that the number of residential buildings in coastal areas has increased significantly combined with the impacts of climate change means that the increase in hurricane intensity and frequency is likely to continue.

According to Dan M. Frangopol, the Fazlur R. Khan Endowed Chair of Structural Engineering and Architecture at Lehigh University and You Dong, Assistant Professor of Structural Engineering at The Hong Kong Polytechnic University, the majority of previous studies have focused on structural performance and loss assessment under hurricanes

In a paper, recently published in the *ASCE Journal of Performance of Constructed Facilities*, Frangopol and Dong propose a framework to aid the optimal adaptation of residential buildings considering climate change effects in a life-cycle context. Life-cycle engineering, of which Frangopol is a recognized pioneer, is an approach to assess the environmental impacts in conjunction with economic impacts that includes a structure's life c-ycle from its production to its use and its end.

In their paper, called "Adaptation Optimization of Residential Buildings under Hurricane Threat Considering Climate Change in a Lifecycle Context," Frangopol and Dong present a systematic framework for the optimal adaptation of residential buildings at a large scale under various scenarios of impending climate change during a long-term interval.

Different adaptation strategies are investigated to ensure adequate structural performance and to mitigate the damage loss and adverse consequences to society. A genetic algorithm-based optimization process is adopted to determine the optimal adaptation types associated with buildings within an investigated region. The framework considers the probabilistic occurrence models of hurricanes, structural vulnerability of typical residential buildings, possible climate change scenarios, and optimization of various climate adaptation strategies in a lifecycle context.

They apply their approach to a real-life case study: a group of single-family residential buildings located in Miami-Dade County, Florida.

The article concludes:

"This paper proposed a general computational procedure associated with optimal adaptation strategies of residential buildings subjected to hurricanes and climate change effects. The loss of buildings under probabilistic wind hazard is computed and the effects of adaptation on structural performance are considered in a lifecycle context. The optimal structural adaptation strategies are identified considering expected lifecycle loss/benefit and total structural adaptation cost during the investigated time interval. The presented approach was illustrated on residential buildings located in Miami- Dade County, Florida.

The following conclusions are drawn:

1. The expected lifecycle loss of buildings under hurricane effects is significantly affected by the investigated time interval and monetary annual discount rate. These parameters should be carefully evaluated within the lifecycle performance assessment process.

2. For the case study analyzed in this paper, the buildings within 1-10 km

of the shore revealed the largest loss compared with the buildings located in other regions. Furthermore, buildings built before 1970 contribute substantially to the total annual loss for the buildings located in this region.

3. The changes in the probability of occurrence and intensity of hurricanes due to climate change have significant effects on the expected lifecycle loss of the buildings within the investigated region. The change associated with hazard intensity has a larger effect on the loss than that due to the increase of the hazard occurrence rate.

4. Optimum adaptation strategies of residential buildings can be obtained by using a biobjective approach, resulting in a Pareto optimal front. This allows decision makers to make informed decisions based on their particular preference.

5. The cost-benefit evaluation and optimization of adaptation actions can produce the best structural adaptation strategies considering both the expected lifecycle loss and total structural adaptation cost. The cost and benefit can be considered together to determine the effectiveness of an alternative.

6. Within the context of climate change engineering, lifecycle loss, cost-benefit analysis, and optimization can provide the decision maker important information necessary for assessment and adaptation of structural systems at a large scale. This information can be used in design, maintenance, and management processes of civil infrastructure considering extreme events and climate change."

Prof. Dan M. Frangopol is the inaugural holder of the Fazlur R. Khan Endowed Chair of Structural Engineering and Architecture at Lehigh University. He is "widely recognized as a leading educator and creator in the field of life-cycle engineering." (ASCE). His main research interests

are in the development and application of probabilistic concepts and methods to civil and marine engineering, including: structural reliability; life-cycle cost analysis; probability-based assessment, design, and multi-criteria life-cycle optimization of structures and infrastructure systems; structural health monitoring; life-cycle performance maintenance and management of structures and distributed infrastructure under extreme events (earthquakes, tsunamis, hurricanes, and floods); risk-based assessment and decision making; multi-hazard risk mitigation; infrastructure sustainability and resilience to disasters; climate change adaptation; and probabilistic mechanics. His research, teaching and service have garnered numerous awards from ASCE, IASSAR, IABSE, SAE and other professional organizations.

According to ASCE "Dan M. Frangopol is a preeminent authority in bridge safety and maintenance management, structural systems reliability, and life-cycle civil engineering. His contributions have defined much of the practice around design specifications, management methods, and optimization approaches. From the maintenance of deteriorated structures and the development of system redundancy factors to assessing the performance of long-span structures, Dr. Frangopol's research has not only saved time and money, but very likely also saved lives."

More information: You Dong et al, Adaptation Optimization of Residential Buildings under Hurricane Threat Considering Climate Change in a Lifecycle Context, *Journal of Performance of Constructed Facilities* (2017). DOI: 10.1061/(ASCE)CF.1943-5509.0001088

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