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Longevity of Civil Engineering Structures under Uncertainties

Longevity of civil engineering structures is crucial to the sustainable development of society. In their lifespan, these structures are likely to suffer from structural deterioration due to aggressive environments and long-term effects. In addition, various natural and human-induced hazards are prone to compromise the functionality, serviceability, and even safety of these structures. Therefore, in order to achieve structural longevity, performance of structures should be analyzed in the life-cycle context, and informed life-cycle decisions for structures must be made regarding their planning, design, construction, operation, inspection/monitoring, maintenance, rehabilitation, demolition, recycling and reuse.

Due to the relatively long service life of civil structures compared to other engineering products, one major challenge for structural longevity is to consider the various uncertainties involved in their life-cycle assessment and management, including the uncertainties arising from initial structural capacity, deterioration initiation and propagation, maintenance and other intervention actions (Figure 1).

This keynote lecture introduces the decades-long and ongoing research endeavor in the first author's research group on utilizing probabilistic life-cycle civil engineering to achieve longevity of civil structures [1-4]. In particular, reliability- and risk-based life-cycle performance indicators are first introduced including time-dependent reliability, lifetime functions, redundancy, life-cycle failure risk, and lifetime resilience, among others. These proposed indicators provide a rational appraisal system that can consider both the likelihood and the consequences of structural distress. Based on these indicators, life-cycle performance of civil structures can be managed by making informed decisions regarding life-cycle intervention actions. Herein, two major topics are covered. First, the use of multi-attribute utility theory (MAUT) in sustainability-informed life-cycle management is presented. The proposed frameworks based on MAUT can consider different aspects of structural failure (e.g. economic, social, and environmental) as well as different risk attitudes of decision-makers, forming a consistent and rational decision-making system. Second, application of multi-objective optimization is discussed. Using this technique, optimal compromise of different and sometime conflicting life-cycle objectives (e.g. life-cycle performance and life-cycle maintenance cost) can be sought. Finally, the ongoing work on decision-making under deep uncertainties is briefly introduced in the context of structural longevity under climate change effects.

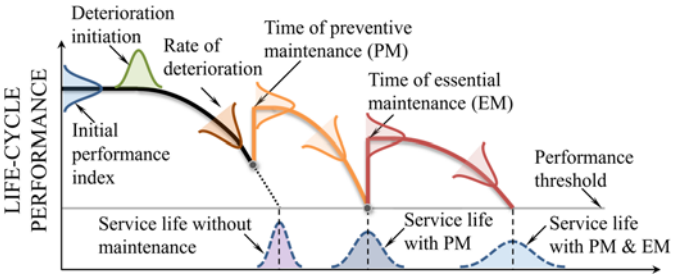

Figure 1 Life-cycle performance of civil structures

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Bio: Dr. Dan Frangopol is the inaugural holder of the Fazlur R. Khan Endowed Chair of Structural Engineering and Architecture at Lehigh University. Before joining Lehigh University in 2006, he was Professor of Civil Engineering at the University of Colorado at Boulder, where he is now Professor Emeritus. He is recognized as a leader in the field of life-cycle engineering of civil and marine structures. His main research interests are in the application of probabilistic concepts and methods to civil and marine engineering including structural reliability, probability-based design and optimization of buildings, bridges and naval ships, structural health monitoring, life-cycle performance maintenance, management and cost of structures and infrastructures under uncertainty, risk-based assessment and decision-making, infrastructure sustainability and resilience to disasters, and stochastic mechanics. Dr. Frangopol is the Founding President of the International Associations for Bridge Maintenance and Safety (IABMAS) and Life-Cycle Civil Engineering (IALCCE). He has authored/co-authored 3 books and over 370 articles in archival journals including 9 award-winning papers. He is the Founding Editor of Structure and Infrastructure Engineering. Dr. Frangopol is the recipient of several medals, awards, and prizes, from ASCE, IABSE, IASSAR, and other professional organizations, such as the OPAL Award, the Newmark Medal, the Alfredo Ang Award, the T.Y. Lin Medal, the F. R. Khan Medal, and the Croes Medal (twice), to name a few. He holds 4 honorary doctorates and 12 honorary professorships from major universities. He is a foreign member of the Academia Europaea (Academy of Europe, London) and the Royal Academy of Belgium, an Honorary Member of the Romanian Academy, and a Distinguished Member of ASCE.