ASCE-ASME J. Risk Uncertainty Part B

Guest Editorial

Special Section on Risk Analysis and Management of Complex Systems

Complexity in engineering systems typically arises from the collective effect of a very large number of components. It is often essentially impossible to predict the detailed behavior of any particular component and its effect on the system behavior. The interaction between a great number of components may cause complex system operational patterns which may be affected by the uncertainty associated with components design and operational environment.

The complexity associated with engineering systems grows significantly once primary subsystems including equipment, communications, infrastructure, humans, among others, are integrated as a whole incorporating not only mechanical and electrical components but also software, control modules, and human–machine interfaces. During the design process, many assumptions are made that could affect risk profiles associated with the equipment/system operational life. During equipment/system design, operational safety relating to accidents or incidents resulting from the complex integration of subsystems is of main concern. Designing for safety entails risk management that involves eliminating hazards, if possible, reducing likelihoods associated with hazards and scenarios potentially leading to accidents or incidents, and reducing the severity of potential occurrences. To better understand the likelihood of occurrence of undesirable events, probabilistic methods provide the means to model the uncertainty associated with design and operational variables for equipment or systems, including random and epistemic uncertainty. Addressing such uncertainty factors affects the risk profiles over the lifecycles of system.

Some complex systems may also be designed to present a functional topology rearrangement aiming at keeping its operational pattern even in case of malfunction of some components. To achieve the goal of intelligent system reconfiguration, the complexity of system hierarchy structure increases with integration of sensors, actuators, and control modules. For complex systems the phenomenon of different component́s degradation interaction, usually named failure dependence, may be very important to define the effects on systems performance and to define possible reconfiguration architecture to avoid reduction of performance and operational safety. The complex interactions between components may increase the difficult associated with safety analysis which intends to define the effect of components failures on system operational performance and safety.

Analyzing and modeling the risk associated with these complex engineering systems have recently received significant interest among both academia and industry. It has been recognized that such comprehensive development requires innovative theories, approaches, and technologies for safe design and risk reduction for complex systems and networks at systems scale. Such developments will facilitate further robust economic growth through safe and efficient high-performance systems.

In this "Risk Management of Complex Systems" era, efforts should be made to deliver fundamental, conceptual, and applied papers.

The objective and scope of this special section is to present contributions from both academia and industry on recent advances in applicable theory and concepts for risk analysis, quantification and management, and uncertainty modeling associated with design, construction, and operation of complex systems.

Some infrastructure systems involve complex structural design whose safety is affected by epistemic and random uncertainty. The paper by Gasser et al., entitled "Seismic fragility curves of an arch dam with special regard to ultimate limit state," analyzes the seismic safety of an arch dam by calculating fragility curves for different damage and failure mechanisms. The model includes fluid–structure–foundation interaction and considers contact and material type nonlinearities. The ultimate limit state (failure) is studied by means of a plastic-damage concrete model, especially developed for cyclic loadings. Also aiming at reducing uncertainty associated with structural design Gomes, in the paper entitled "Structural reliability analysis using adaptive artificial neural networks," presents an adaptive approach for reliability analysis using surrogate models, proposed in the literature in the context of Kriging and Polynomial Chaos Expansions, adapted for the case of multilayer perceptron artificial neural networks. Faes et al., in the paper entitled "On the robust estimation of small failure probabilities for strong nonlinear models," compare the performance of the most recent state-of-the-art advance Monte Carlo techniques and surrogate models when applied to strongly nonlinear performance functions. Also associated with structural safety, Teixeira et al., in the paper entitled "Evaluation of parametric models dedicated to a magnetorheological actuator including uncertainty and sensitivity analyses," present parametric and non-parametric approaches to model magnetorheological actuators used in smart suspension of bridges aiming at controlling vibrations.

The optimization of complex systems failure probability is also important aiming at reduction of operational risk and manufacturing costs. In the present issue, two papers discuss the optimization problem. The paper by Braydi et al., entitled "Study of uncertainties and objective function modeling effects on probabilistic optimization results", presents the effect of uncertainties modeling and the choice of objective function on the results of optimization design problems in deterministic and probabilistic contexts. The paper by Hose et al., entitled "Robust optimization in possibility theory", presents the optimization of systems under uncertainty coupling fuzzy-valued constraints and the adoption of a multi-criteria decision making technique for the fuzzy-valued objective function.

The reliability analysis of complex system is also an important task to assure operational safety. A couple of papers discuss this issue. The paper by Lugo et al., entitled "Pseudo credal networks for inference with probability intervals," discusses the problem of using the theory of sets of probabilities to allow a decision-maker to represent imprecise and incomplete beliefs through a set of measures based on credal networks. Daub and Duddeck, in the paper entitled "Maximizing flexibility for complex systems design to compensate lack-of-knowledge uncertainty," present a method to consider lack-of-knowledge uncertainties specific for early phase developments in the framework of complex systems design aiming at increasing their reliability since the beginning of design process. Behrensdorf et al., in the paper entitled “Reliability analysis of networks interconnected with copulas,” present a new approach for the reliability analysis of complex interconnected networks through Monte Carlo simulation and survival signature. Associated to reliability analysis, risk analysis is also an important topic in complex systems design aiming at avoiding accidents. The paper by Kamij et al., entitled “Dynamic risk analysis using imprecise and incomplete information,” proposes the coupling of evidence theory with Bayesian network to address inconsistency, conflict, and incompleteness in the expert opinions. It combines the acquired knowledge from various subjective sources, thereby rendering accuracy in probability estimation associated with risk scenarios.

In summary, this collection of papers provides a glance of the current research trends in risk analysis and management of complex systems, which often are challenging and computationally demanding tasks. We thank the authors for their contributions and the diligence to present their work in its best form. We also are in debt toward our reviewers who rigorously examined the submissions and provided helpful feedback to improve the quality of the included papers.

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