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The Role of PRA Sensitivity and Importance Analyses in Decisionmaking

A.A. El-Bassioni, A.C. Thadini, R.K. Frahm
U.S. Nuclear Regulatory Commission, Division of Safety Technology, Washington, D.C. 20555, U.S.A.

Abstract

Probabilistic Risk Assessment's (PRA) main strength lies in its systematic and integral approach to safety and risk evaluations of Nuclear Power Plants. This makes it an increasingly important factor to be considered in regulatory decisionmaking. A number of weaknesses and limitations are known to exist in PRA methodology. PRA uncertainties are sometimes large and driven by subjectivity. Regulators considering alternative resolutions to an issue should be well informed about the quality and credibility of PRA information relevant to this issue. In that respect, the techniques of sensitivity and importance analyses should play a more significant role in enhancing the quality of information presented to decision makers and in a variety of regulatory applications.

1. Introduction

The USNRC is currently making extensive use of Probablistic Risk Assessment (PRA) studies of Nuclear Power Plants (NPPs). In general, this usage involves a two stage process. In the first stage, PRAs are used to provide information and insights about NPP design, operation, and risk profiles. The second stage includes utilization of this information, in support of risk management activities in general, and in formulating decisions regarding regulatory actions in particular. Regulatory risk management is the process of identifying and weighing safety related policy alternatives to select the most appropriate regulatory action. This process involves evaluation of PRA results and associated uncertainties and variabilities, PRA insights and their robustness, and integrating this information with other considerations like relevant engineering data and other economic, political and social concerns to arrive at an optimum decision. Consideration of these factors in the risk management stage ideally amounts to the definition of PRA as a realistic, objective source of factual information, devoid of value judgment and undue conservatism. Interjection of conservatism in the analysis results in distortions whose extent may not be available or possible to acquire for decisionmaking. On the other hand, it is quite appropriate for the informed regulator to act conservatively, especially when consequences of underestimating risk cannot be tolerated.

PRA strength lies in its logical framework for a systematic and integrated analysis of NPPs. However, PRA methodology still has some known weaknesses. This condition makes judgment on part of the analyst, an unavoidable component of risk assessment. Moreover, PRA results are known to reflect the incompleteness and inherent variability of the data used as well as modeling limitations and approximations. For these reasons, estimation of the uncertainties associated with these results constitute an essential task of any PRA study. However, in spite of the fast strides recently made in evaluation of PRA uncertainties, internal events PRAs consider parameter uncertainties only, while parameter and modeling uncertainties in external events are largely subjective.

Regulatory decision makers attempt to build upon the strong features of PRA studies without placing undue faith on the bottomline results and their uncertainties especially when subjectivity is suspected to bias these results. Decision makers may need to evaluate these results or compare them with some numerical standard of acceptability. They should be well informed about the quality of these results so it can be properly weighed in their decisions.

Sensitivity analysis results, which is a more basic piece of information in PRA investigations, have a lot to offer in that respect, if properly scoped and planned. It has been used to examine the impact of changes in modeling parameters or assumptions by comparing PRA results with and without these changes. It also serves the decision maker by providing a measure of robustness of derived insights, hence contributing to better informed decisionmaking.

Importance analysis may be regarded as a specialized form of sensitivity evaluation which prescribes changes in selected PRA model parameters and evaluates the impact on a model results level or on a more global level such as core-damage or risk estimates, using importance measures. The open literature [Engelbrecht 1, Fussel 2, Vesely 3] includes a variety of importance measures, each adequate for a specific type of application and each having its own physical interpretation.

The USNRC and the nuclear industry recognize the potential use and significance of sensitivity and importance analyses as decision aids and resource allocation tools. Table (I) shows a number of activities [NUREG-1050 4, NUREG-1093 5] in which these two techniques have a fundamental contribution.

2. Highlights of some Applications

Table (I) is indicative of the extent of diversity in the above mentioned applications. Few of these applications are discussed briefly here to familiarize the reader with their content. In addition, to the use of sensitivity analysis to support PRA modeling uncertainties evaluations, this information is also used to exclude some of the design and procedural modifications proposed for risk reduction from further considerations and identify those worthy of additional refined examinations.

Sensitivity studies associated with the Safety Goal [NUREG-0880 6] program examine the impacts of modeling assumptions, approximations and omissions, and PRA uncertainties on the proposed design objectives and in defining compliance with safety goals. These studies also play a central role in an effort to explore the feasibility of allocating safety goals [CHO 7] to the NPP safety systems and major equipment.

Table (I): Sample of Regulatory Activities Involving Sensitivity and Importance Analyses

- °PRA Insights Derivation and Evaluation
- °Evaluation of PRA uncertainties
- °Evaluation of design alternatives and modifications
- °Safety Goal activities
- °Prioritization and resolution of regulatory issues
- °Development of operating, testing, and maintenance requirements
- °Upgrading emergency and operating procedures and promotion of recovery actions
- °Inspection and enforcement activities
- °Development of limiting conditions for operations, surveillance testing requirements, and evaluation of changes in technical specifications
- °Quality assurance activities
- °Support of exemptions from existing requirement or imposition of additional requirements

The removal of a piece of equipment or train of equipment during maintenance, repair, and testing activities in NPPs reduces the level of built-in redundancy and increases the unavailability of involved safety systems. Outage times for these activities represent a period of increased vulnerability to accidents, until the equipment or trains are restored back to service. Constraints on Allowed Outage Times (AOTs) are imposed as part of operating licenses. These constraints are referred to as Limiting Conditions for Operations (LCOs). Exemptions from LCOs and extensions of outage times beyond those allowed by technical specifications are frequently requested by licensees. Sensitivity evaluations of PRA models are used to assess their impact on system unavailability, safety function unavailability or a risk indicator like core-damage frequency. Results of the analysis are then used to provide basis for granting or denying these requests.

Regulatory issues identify suspected difficiencies in the design, construction, or operation of a particular plant or a class of plants. Importance analysis is utilized for priority ranking of these regulatory issues. Rank assigned to specific issue is based on its potential safety significance and cost of implementation. The primary purpose of this priority ranking is to assist in timely and efficient allocation of resources to those safety issues that have a high potential of reducing risk.

Sensitivity and importance evaluations are also used on a limited basis in support of the regional testing and inspection programs. NPP systems and equipment are ranked according to their impact on risk parameters. This ranking is then used to establish priorities for systems and system components tests that should receive NRC verification inspection during preoperational and startup testing, and to enhance regulatory guidance for quality assurance programs.

3. Discussion and Conclusions

The current trend at NRC is to stress the versatility of PRA models. These models are used, updated as needed and reused in support of the various regulatory activities. This shift from overemphasizing the bottomline results provide an opportunity to reconsider and enhance the role played by uncertainty, sensitivity and importance analyses in support of decisionmaking.

Sensitivity analysis is used to evaluate modeling uncertainties. It does not provide an explicit estimate of these uncertainties, but rather the extent of variability in model output corresponding to postulated variations in the input parameters. Sensitivity analysis is therefore vulnerable to subjectivity which is exercised in selecting ranges for parameter variations, in selecting the parameters to be varied, and in providing expert interpretation of the results. This interpretation can thus be misleading, and the analyses have the potential of being burdensome to PRA studies if not carefully planned and scoped.

The last few years are marked by broader applications for importance ranking. A fairly large number of importance measures are used and new ones are being structured [Vesely 3]. These measures provide a methematical framework that defines an accident sequence, a system, or a basic event contribution to risk indicators. However, this technique is faced with some problems. These include selection of measures most adequate for a particular application, and defining the level of accuracy most appropriate for the application. The usual information base for importance analysis consist of minimal cutset information for accident sequences. Systemic and functional importances should be considered with caution due to cutset truncations, and due to ambiguities in the definition of system boundaries. Furthermore, importances are based on point estimates of failure probabilities without accounting for their associated uncertainties.

In spite of these limitations, sensitivity and importance evaluations still have undeniable value [Vesely 9, El-Bassioni 10]. The research arm of NRC is sponsoring several programs that involve refining these techniques [NUREG-1093 5]. Moreover, the Probabilistic Safety Analysis Procedure Guide [Papazoglou 11] is giving them a broader look. Their PRA role, which is generally not well organized in published PRAs, is being stepped up and optimized. A new approach that integrates the techniques of uncertainty, sensitivity and importance analyses should be developed to enhance and discipline the process of derivation of insights, to promote inter and intra PRA comparisons, and to provide better support for decisionmaking.

4. References

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