Safety Corner

Why is Uncertainty Analysis Important to a Safety Engineering Assessment?

ISO 31000:2009 “Risk Management – Principles and Guidelines on Implementation” and ISO Guide 73:2009 “Risk Management – Vocabulary” define risk as the “effect of uncertainty on objectives”. This definition has strengthened the importance of managing uncertainty in safety engineering. Since you can't manage what you don't measure, the characterization and quantification of uncertainty is of paramount importance in a safety risk assessment.

In practice, a system under analysis often cannot be characterized exactly and the knowledge of the undergoing phenomena is incomplete. This leads to uncertainties on both the values of the model parameters and the underlying model structure. To illustrate the presence of parameter uncertainty related to the imprecise knowledge of the model parameters, let’s take the popular model $F = \lambda t$ in calculating the failure probability (F) of a component in a fault tree analysis. Because the true failure rate (λ) is not known, several plausible values could be used for the analysis. While the fault tree may include many components each of which will have its own uncertainty in failure rate, the uncertainties associated with these parameters propagating within the fault tree will cause variability and uncertainty in the output of the fault tree.

On the other hand, the assumption that the component failure rate is constant by adopting exponential distribution for its probability density function, as well as the approximation of $F = \lambda t$, attribute a certain degree of uncertainty to the assessment. Whether the fault tree can correctly model the situation introduces further uncertainty to the assessment. These uncertainties in the structure of a risk assessment are examples of modeling uncertainty.

The aim of uncertainty analysis is to propagate uncertainties from the input model parameters and the model structure to the output of a risk assessment. While parameter uncertainty has been widely investigated and methods with different levels of sophistication have been developed to address it, research is still ongoing to obtain effective and agreed methods to address modeling uncertainty. Thus, for practical purpose, most risk assessments concentrate on the analysis of parameter uncertainty. One must also note that a sensitivity analysis cannot replace an uncertainty analysis as they serve different purposes.

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