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Development of default uncertainties for the value/benefit attributes in the regulatory analysis technical evaluation handbook

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HIGHLIGHTS

- Uncertainties for values/benefits.
- Upper bound four times higher than mean.
- Distributional histograms.

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ABSTRACT

NUREG/BR-0184, *Regulatory Analysis Technical Evaluation (RATE) Handbook*, was produced in 1997 as an update to the original NUREG/CR-3568, *A Handbook for Value-Impact Assessment* (1983). Both documents, especially the later RATE Handbook, have been used extensively by the USNRC and its contractors not only for regulatory analyses to support backfit considerations but also for similar applications, such as Severe Accident Management Alternative (SAMA) analyses as part of license renewals. While both provided high-level guidance on the performance of uncertainty analyses for the various value/benefit attributes, detailed quantification was not of prime interest at the times of the Handbooks' development, defaulting only to best estimates with low and high bounds on these attributes. As the USNRC examines the possibility of updating the RATE Handbook, renewed interest in a more quantitative approach to uncertainty analyses for the attributes has surfaced. As the result of an effort to enhance the RATE Handbook to permit at least default uncertainty analyses for the value/benefit attributes, it has proven feasible to assign default uncertainties in terms of 95th %ile upper bounds (and absolute lower bounds) on the five dominant value/benefit attributes, and their sum, when performing a regulatory analysis via the RATE Handbook. Appropriate default lower bounds of zero (no value/benefit) and an upper bound (95th %ile) that is four times higher than the mean (for individual value/benefit attributes) or three times higher (for their summation) can be recommended. Distributions in the form of histograms on the summed value/benefit attributes are also provided which could be combined, after appropriate scaling and most likely via simulation, with their counterpart(s) from the impact/cost analysis to yield a final distribution on the net overall value/impact (benefit/cost).

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1. Introduction[1]

At the request of the US Nuclear Regulatory Commission (NRC), Battelle Pacific Northwest National Laboratories (PNNL) assembled NUREG/BR-0184, *Regulatory Analysis Technical Evaluation (RATE) Handbook*, in 1997, as an update to the original NUREG/CR-3568, *A Handbook for Value-Impact Assessment*, also assembled by PNNL for the USNRC in 1983 USNRC (1997, 1983). Both documents, especially the later RATE Handbook, have been used extensively by the USNRC and its contractors not only for regulatory analyses to support backfit considerations but also for similar applications, such as Severe Accident Management Alternative (SAMA) analyses as part of license renewals. While at PNNL, I was a primary author of the value/impact/cost sections of both Handbooks, including Appendix C, "Supplemental Information for Non-Reactor Regulatory Analyses," of the RATE Handbook. While both provided high-level guidance on the performance of uncertainty analyses for the various value/benefit attributes, detailed quantification was not of prime interest at the times of the Handbooks' development, defaulting only to best estimate with low and high bounds

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[1] This paper was prepared by an employee of the U.S. NRC. The views presented do not represent an official staff position.

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Table 1
Parameter estimates provided for value/benefit attributes in the RATE Handbook.

Attribute		Low	Best	High	Units
Occupational Health (Accident)	Immediate dose	1.0E+03	3.3E+03	1.4E+04	p-rem
	Long term dose	1.0E+04	2.0E+04	3.0E+04	
Onsite Property*	Cleanup & decontamination cost	1.0E+09	1.5E+09	2.0E+09	$
	Long-term replacement power cost	1.5E+10	1.9E+10	2.3E+10	

* Costs associated with long-term replacement power and repair/refurbishment for recoverable accidents are much less than the ones listed in the table and, therefore, excluded from further consideration for the uncertainty analysis.

Table 2
Distributional analysis for occupational health (accident) and onsite property attributes.[1]

Attribute		Mean	Mu	Sigma	Dist
Occupational Health (Accident)	Immediate dose	4.6E+03	8.1E+00	8.0E-01	Lognormal
	Long term dose	2.0E+04	2.0E+04	6.1E+03	Normal
	Total (via simulation)	2.5E+04	2.4E+04	scale = 4.1E+3	Logistic*
Onsite Property	Cleanup & decontamination cost	1.5E+09	1.5E+09	3.0E+08	Normal
	Long-term replacement power cost	1.9E+10	1.9E+10	2.4E+09	Normal
	Total (via summation)	2.1E+10	2.1E+10	2.5E+09	Normal

* In probability theory and statistics, the logistic distribution is a continuous probability distribution. Its cumulative distribution function is the logistic function, which appears in logistic regression and feed-forward neural networks. It resembles the normal distribution in shape but has heavier tails (higher kurtosis). (http://en.wikipedia.org/wiki/Logistic_distribution).

[1] The likelihood of generating negative values for the normal distributions, maximum for long-term dose where the ratio of mu to sigma is minimum at 3.3, does not exceed 0.05%. Given this very low likelihood, the normal distributions were not truncated during subsequent simulations.

on these attributes. As the USNRC examines the possibility of updating the RATE Handbook, renewed interest in a more quantitative approach to uncertainty analyses for the attributes has surfaced. As an original author now employed by the USNRC, I have endeavored to enhance the RATE Handbook to permit at least default uncertainty analyses for the value/benefit attributes.

2. Value/benefit attributes

The RATE Handbook defines 17 attributes to be evaluated on a monetary basis as part of the value/impact (benefit/cost) analysis, six of which are associated with value/benefit. (The remaining 11 address costs/impacts associated with implementing or maintaining the modification that is the subject of the regulatory analysis.) Each attribute is evaluated on a per-plant basis, then summed for the number of plants affected by the topic of concern to yield the total contribution from that attribute.[2] Four of these deal with the value/benefit, in terms of reduced accident frequency, from "accident avoidance:" Public Health (Accident), Occupational Health (Accident), Onsite Property and Offsite Property. The remaining two address reductions in routine radiological exposure to the public and worker: Public Health (Routine) and Occupational Health (Routine). The four Public and Occupational Health attributes estimate the reduction in radiological dose (person[p]-rem) from the proposed modification, subsequently converting this on a monetary basis using a best estimate of 2000 $/p-rem to place them on an equal basis with the impact/cost attributes for subsequent summation. The other two value/benefit attributes, Onsite and Offsite Property, are calculated directly on a monetary basis so as to require no conversion (other than present value discounting). Since Public Health (Routine) is usually a minimal contributor to the total value/impact, it will not be examined further for development of default uncertainties, i.e., only the remaining five value/benefit attributes will be processed for default uncertainty considerations. The cost/impact attributes are not examined, being beyond the scope of my effort.

[2] Multi-unit sites are also addressed on a per-plant basis, such that for each attribute related to a topic affecting multiple units at a single site, the results would be summed.

2.1. Occupational Health (Accident) and Onsite Property

Since the goal here is to develop default uncertainties for the five attributes, the effects of present value discounting are not examined. The assumption is that any variability in the parameters associated with this will be dwarfed by variability in the primary parameters associated with risk reduction (assumed to be represented solely by reduction in core damage frequency [CDF]) and consequence (radiological dose or cost), thereby simplifying what will prove to be an already complex analysis. For two of these attributes, best estimates and lower and upper bounds are provided in the RATE Handbook as shown in Table 1. For the remaining three, data used in the Handbook need to be processed to develop corresponding values.

For these two attributes, each of the consequences (i.e., immediate and long-term dose for Occupational Health [Accident] and cleanup & decontamination and long-term replacement power costs for Onsite Property) were assumed to follow the probabilistic distribution shown in Table 2. To obtain the summed distribution, simulation via Oracle CrystalBall® with 10,000 trials was used for Occupational Health (Accident) while a strict summation of normal distributions was used for Onsite Property Oracle (2009). The final resultant distribution for each is shown in Table 2.

2.2. Public Health (Accident), Offsite Property and Occupational Health (Routine)

For the Public Health (Accident), Offsite Property and Occupational Health (Routine) value/benefit attributes, tables of representative values are provided in the RATE Handbook, namely Tables 5.3 ("Expected Population Doses for Power Reactor Release Categories"), 5.6 ("Weighted Costs for Offsite Property Damage for the Five NUREG-1150 Power Reactors") and B.10 and B.11 ("Summary of 1973-1993 Annual Occupational Exposure Information Reported by Commercial BWRS and PWRs," respectively). For these data, distributions were fit as shown in Tables 3 through 5.