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A Handbook for Value-Impact Assessment

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ABSTRACT

The basic purpose of this handbook is to document a set of systematic procedures for providing information that can be used in performing value-impact assessments of Nuclear Regulatory Commission (NRC) regulatory actions. The handbook describes a structured but flexible process for performing the assessment.

Chapter 1 is an introduction to the value-impact assessment process. Chapter 2 describes the attributes most frequently affected by proposed NRC actions, provides guidance concerning the appropriate level of effort to be devoted to the assessment, suggests a standard format for documenting the assessment, and discusses the treatment of uncertainty. Chapter 3 contains detailed methods for evaluating each of the attributes affected by a regulatory action. The handbook has five appendixes containing background information, technical data, and example applications of the value-impact assessment procedures.

This edition of the handbook focuses primarily on assessing nuclear power reactor safety issues.

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The project has benefited greatly from the support, thoughtful advice and constructive criticism of many individuals in the NRC and among the NRC contractors. The authors would especially like to thank A. J. DiPalo, J. C. Malaro, M. L. Ernst, M. A. Taylor, G. Sege and T. H. Cox, who provided valuable advice and criticism; their continuing strong interest in this project is gratefully acknowledged. The authors would also like to thank the many individuals who reviewed earlier versions of the handbook; their comments and suggestions have been very helpful. The project manager would also like to acknowledge the valuable contributions of Scott Heaberlin and John Burnham; their efforts were instrumental in producing this handbook.

FOREWORD

From the outset, producing a credible, useful value-impact handbook has been accepted as an evolutionary process. The present version of the handbook is intended to provide a basis for applications by a wide range of users both within the NRC and elsewhere. As experience is gained using the procedures described in the handbook, it is likely that a variety of possible extensions and refinements of the procedures will be identified. In order to ensure that insights obtained through experience are fully reflected in future revisions of the handbook, readers are invited to send their comments to A. J. DiPalo, Division of Risk Analysis, Office of Nuclear Regulatory Research, NRC, and M. F. Mullen, Energy Systems Department, Pacific Northwest Laboratory.

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1.0 INTRODUCTION

In January 1983, the NRC published guidelines for performing the regulatory analyses required for a broad range of NRC regulatory actions (U.S. NRC 1983). The principal purpose of the guidelines is

> "to ensure that the NRC regulatory decisions are based on adequate information concerning the need for and consequences of a proposed regulatory action and to ensure that cost-effective regulatory actions, consistent with providing the necessary protection of the public health and safety and common defense and security, are identified."

The guidelines establish a structured framework for NRC regulatory analyses and describe in general terms the information that must be included. According to the guidelines, a central element in all regulatory analyses is an evaluation of the costs and benefits of the proposed regulatory action and any reasonable alternatives. In the NRC, such cost-benefit evaluations have traditionally been called value-impact assessments.

The basic objective of this handbook is to document a set of systematic procedures for providing information that can be used in performing value-impact assessments. The use of these procedures in such assessments is intended to support the purpose of the Regulatory Analysis Guidelines, quoted earlier, and to help provide a coherent, understandable, well-documented account of the basis for NRC regulatory actions.

The handbook is designed to assist the analyst in carrying out a value-impact assessment and displaying the results. A systematic but flexible procedure for performing the assessment is described. For each step in the procedure, several options are presented and specific guidance is given for each. The analyst is expected to tailor the assessment to fit the needs of the problem under consideration.

The handbook can be a useful guide for the analyst if properly used and interpreted; however, a few words of caution are appropriate. First, while a value-impact assessment can document an important part of the information needed to support regulatory decisions, the quantitative portions of such analyses cannot, and are not intended to, serve as the sole or even the principal basis for regulatory decisions. Other inputs are needed, including, for example, policy judgments, uncertainty considerations, budgetary constraints, and statutory requirements. Second, a value-impact assessment can provide only an approximate measure of the costs and benefits of proposed regulatory actions. Even a rough approximation can be very useful, but it is essential for the analyst to recognize and attempt to make explicit both the uncertainty in the analysis and its implications. The handbook provides guidance for treating uncertainties, but no routine procedure can eliminate the need for careful consideration by both analyst and decisionmaker of the dependence of the conclusions on uncertain data and assumptions.

Third, the most important ingredient in producing a high quality value-impact assessment is the judgment and understanding of the analyst. The handbook can assist the analyst, by setting out a uniform format, suggesting an overall approach, providing guidance for performing certain calculations or for obtaining certain kinds of data, and organizing these procedures in a convenient form. There is, however, no substitute for sound judgment on the part of the analyst.

Finally, the real strengths of a consistent, systematic analysis are the disciplined approach that it fosters and its clear display of the important information in understandable form so that the assumptions and analysis can be scrutinized and, if appropriate, challenged by interested parties. The analyst should view the handbook as a flexible tool that can assist in documenting the analysis and clearly displaying the results.[a]

1.1 OVERVIEW OF VALUE-IMPACT APPROACH

A simplified schematic of the value-impact assessment process and its role in the logic flow of NRC regulatory decisions is shown in Figure 1.1. The assessment process has three steps. First, based on an exact description of the proposed NRC action, the attributes affected by the action are identified.[b] The effect of the proposed action on each attribute is then evaluated. Next, these individual evaluations are summarized, and the value-impact results displayed. If appropriate, sensitivity studies are performed to show the effect of changing underlying assumptions or data in the value-impact assessment. For each alternative to be considered, the same three-step process is followed.[c] The insights from the value-impact assessment together with other regulatory considerations serve as input to the decision maker, who may then accept, reject, or modify the proposed regulatory action. Only those items within the dashed lines in Figure 1.1 are part of the value-impact assessment and within the scope of this handbook.

(a) Appendix A contains additional information on the background and role of value-impact assessment.
(b) The term "attributes" is commonly used in decision analysis to denote the categories of consequences that are relevant in assessing a particular decision. Examples of attributes are industry implementation consequences, offsite property consequences, and effects on public health.
(c) The identification and analysis of alternative regulatory actions are discussed further in Appendix A.

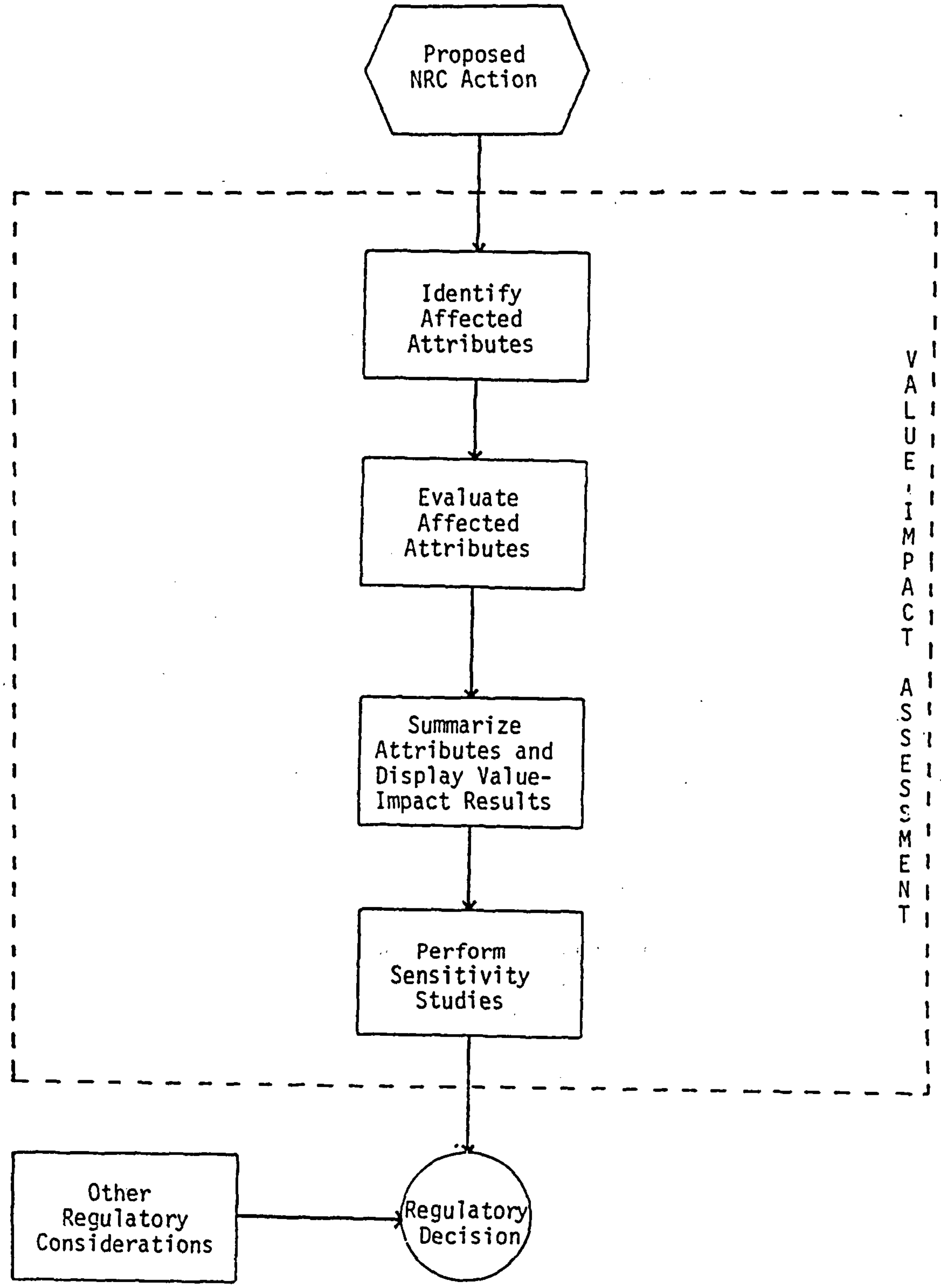

FIGURE 1.1. Logic Flow for Regulatory Decisions

For the purposes of this handbook, the terms "value" and "impact" are described as follows.[a] Values measure the public benefits that the NRC is required to seek as its statutory mission. Examples include safety improvements and improvements in safety-related knowledge. Impacts measure the other consequences of the proposed action. Examples include increases in NRC and industry implementation and operating costs resulting from the action. Consequences are measured in terms of a change from the existing condition. Hence, the base represents the status quo or "no action" alternative.

Any given NRC action can have a number of effects. Ideally, all significant effects should be considered in the assessment. In practice, however, the conclusions will not be affected very much if minor effects are disregarded. The attributes identified in this handbook (and listed in Table 1.1) are intended to capture the major potential effects of NRC actions. They were developed in conjunction with NRC staff from RES, NRR, and DEDROGR. Although these attributes were developed primarily for assessing reactor safety issues, they can be applied, with extensions and modifications, to other NRC regulatory decision-making activities. In any particular application, the analyst should carefully consider 1) whether these attributes are complete, i.e., whether they encompass all of the important consequences of the proposed action; and 2) whether they are all necessary or appropriate for the particular action under consideration. The analyst should then supplement or modify the attributes as appropriate. Chapter 2 contains a more complete discussion of the attributes and their role in value-impact assessment.

TABLE 1.1. Attributes

Public Health
Occupational Exposure (Accidental)
Occupational Exposure (Routine)
Offsite Property
Onsite Property
Regulatory Efficiency
Improvements in Knowledge
Industry Implementation
Industry Operation
NRC Development
NRC Implementation
NRC Operation

(a) These definitions coincide with those currently in use by NRR and are intended to emphasize the NRC's statutory responsibilities for protection of the public health and safety and for common defense and security.

Chapter 3 of this handbook describes evaluation procedures for each attribute. To the degree possible, specific guidance is given. Where detailed descriptions cannot be given, appropriate references are provided. The handbook has five appendixes with supporting information and examples of value-impact assessments.

Among the many methods available for summarizing and displaying the results of the attribute evaluations, two of the more widely used methods have been selected for treatment in the handbook:

- a <u>ratio method</u>. The total net public health value of the proposed action, expressed in terms of the expected reduction in public exposure, is divided by the total costs (NRC, industry, and any other) of the action. The units of the ratio are person-rem (averted) per million dollars. Other factors and special considerations are displayed separately.

- a <u>net-benefit method</u>. To the extent possible, all attributes are quantified in monetary terms and the dollar values are added together (with the appropriate algebraic signs). The result is the net benefit, in units of dollars. Other factors and special considerations are displayed separately. When the net-benefit method is used, the factors used to convert non-monetary attributes to dollars should be explicitly stated.

In selecting these two methods for inclusion in the handbook, the criteria were that the methods must be understandable, well-accepted and have adequate sophistication without undue complexity. The economics and decision analysis literature abounds with alternative methods, some of which are very valuable in particular applications. The reader interested in exploring these alternatives should consult such references as Fischhoff et al. (1981), Keeney and Raiffa (1976) and Mishan (1976). The ratio and net-benefit methods are described in more detail in Chapter 2.

1.2 ADVANTAGES OF THE HANDBOOK FOR THE DECISION MAKER

The value-impact assessment methodology described in this handbook will help ensure that the decision maker has a clear definition of all of the attributes affected by a proposed regulatory action. While the present version of the handbook concentrates on power reactor safety issues, the same attributes can be expanded to cover a broader range of regulatory decisions. The quantification of the attributes applicable to a given decision will help the decision maker evaluate the proposed action. The exposition of the decision attributes in a clear, concise manner will help ensure that all applicable attributes have been considered. The definition of the methods for calculating the attributes will demonstrate that the attributes have been evaluated in a consistent manner. The methods described in the handbook provide enough flexibility that the evaluation can be adapted to meet the needs of the issue under consideration.

1.3 ADVANTAGES OF THE HANDBOOK FOR THE ANALYST

The handbook provides a uniform framework for performing a value-impact assessment and presenting the results. It defines a standard set of attributes that can be used or modified according to the issue, and provides guidance on evaluating the attributes. It suggests ways to summarize and display the results. It allows enough flexibility to adapt to the particular decision at hand. The analyst is provided with guidance on the appropriate level of effort to be expended. Suggested data values are given to assist in making approximate or limited analyses. Finally, references are provided to alternative analytical methods and to potentially useful data bases.

CHAPTER 1 REFERENCES

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Keeney, R. L., and H. Raiffa. 1976. Decisions with Multiple Objectives: Preferences and Value Tradeoffs. John Wiley and Sons, New York.

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2.0 STRUCTURE OF VALUE-IMPACT ASSESSMENT

This chapter describes the structure of the value-impact assessment, providing both general guidance and specific instructions. It begins with a discussion of the basic methodology, describing the attributes considered, the evaluation of these attributes, and methods for summarizing and presenting the results of the assessment. It continues with guidance for scoping or evaluating the appropriate level of effort to be committed to a given value-impact assessment. This is followed by specific instructions for the conduct of the assessment itself. The chapter concludes with a discussion of the treatment of uncertainty.

2.1 BASIC METHODOLOGY

Value-impact analysis identifies and estimates the relevant values and impacts likely to result from a proposed NRC action. The methodology outlined in this handbook guides the systematic definition and evaluation of values and impacts. It also provides guidance on the reporting of results.

The following sections present the basic attribute descriptions, attribute evaluation procedures, and two methods for summarizing and displaying attributes in a convenient and useful form.

2.1.1. Definition of Attributes

The principal components of value-impact assessment are the attributes that are used to characterize the consequences of a proposed action. Any given NRC action can affect a large number of factors within the public and private sectors. The attributes described below represent the factors that are most frequently affected by a proposed NRC action. The attributes affected by any given proposed action will vary, however, and the analyst will have to determine the appropriateness of each attribute. In each application, the analyst should also carefully consider whether there are other important consequences of the proposed action not covered by these attributes. If necessary, the analyst should extend or modify the attributes so that all important consequences are properly considered.

In this handbook, values and impacts are described as follows:[a]

(a) These definitions coincide with those currently in use by NRR and are intended to emphasize the NRC's statutory responsibilities for protection of the public health and safety and for common defense and security.

Values measure the public benefits that the NRC is required to seek as its statutory mission. Examples include safety improvements and improvements in safety-related knowledge.

Impacts measure the other consequences resulting from the proposed action. Examples include increases in industry implementation and operating costs.

Attributes can have either positive or negative algebraic signs, depending on whether the proposed action has a favorable or adverse effect on a particular attribute. The sign conventions are as follows: Favorable consequences are positive; adverse consequences are negative. Each attribute measures the change from the existing condition due to the proposed action. The following list briefly describes each attribute used in the handbook. This list is oriented primarily toward reactor safety issues. However, with some extensions and modifications, these attributes can also be used in assessing other kinds of issues. More detailed discussions of each attribute are given in Chapter 3.

Attributes

Public Health. Expected changes in public exposure to radiation due to offsite radioactive releases, measured for all affected plants during the remainder of their lifetimes. A positive sign would indicate a reduction in expected public exposure while a negative sign would indicate an increase.

Occupational Exposure (Accidental). Expected change in exposure to employees as a direct result of postulated accidents (summed over all affected plants for the remainder of their lifetimes). A positive sign would indicate a reduction in expected exposure while a negative sign would indicate an increase.

Occupational Exposure (Routine). Expected change in exposure to employees as a result of installation, modification, and maintenance of the proposed changes. A positive sign would indicate a reduction in routine occupational exposure as a result of the change while a negative sign would indicate an increase.

Offsite Property. The expected total monetary savings to offsite property resulting from the proposed action, i.e., from reduced accident frequencies and consequences. A positive sign would indicate a reduction in expected offsite property losses from postulated accidents while a negative sign would indicate an increase.

- Onsite Property. The expected monetary savings to all affected licensees from the proposed action, i.e., from averted plant damage costs--including replacement power, decontamination, and refurbishment costs. A positive sign would indicate a reduction in expected onsite property losses from the postulated accident while a negative sign would indicate an increase.

- Regulatory Efficiency. Expected regulatory and compliance improvements resulting from the proposed action. These may include changes in industry reporting requirements and the NRC's inspection and review efforts.

- Improvements in Knowledge. The potential value of new information, especially from research activities. Some NRC actions have as their goal the improvement in the state of knowledge for such factors as accident probabilities or consequences, with an ultimate objective of facilitating safety enhancement or uncertainty reduction.

- Industry Implementation. The projected net economic effect on the licensee to install or implement mandated changes. Costs will include capital equipment, staff labor, materials, and shutdown costs, including the cost of replacement power as appropriate. Additional costs above the status quo would have a negative sign (since they are adverse consequences of the proposed action) while cost savings would have a positive sign.

- Industry Operation. The projected net economic effect on the licensee due to changes in routine, periodic operation and maintenance caused by the proposed action. This shall include, if appropriate, replacement power costs attributable to required operating and maintenance tasks. Additional costs above the status quo would have a negative sign while cost savings would have a positive sign.

- NRC Development. The projected net economic effect on the NRC of preparing the proposed action for implementation. Research activities in support of a proposed action would be included here. However, costs already incurred are sunk costs and should not be included. Additional costs above the status quo would have a negative sign while cost savings would have a positive sign.

- NRC Implementation. The projected net economic effect on the NRC to place the proposed new requirements into operation. Additional costs above the status quo would have a negative sign while cost savings would have a positive sign.

- NRC Operation. The projected net economic effect on the NRC after the proposed action takes effect. Additional inspection activities would be one example of such costs. Additional costs above the status quo would have a negative sign while cost savings would have a positive sign.

2.1.2 Evaluation of Attributes

For each attribute, the analyst should assess the change relative to the existing condition (status quo). For example, measures of risk would reflect the risk averted or incurred, and measures of cost would show added costs or cost savings. Thus, consideration of the status quo alternative, required under the Regulatory Analysis Guidelines (U.S. NRC 1983c), is incorporated.

The preceding attributes considered in the value-impact assessment apply to a wide range of NRC decision problems. Depending upon the decision problem and the method of summarizing the attributes (i.e., ratio or net benefit), the attributes that need to be evaluated in any given analysis may differ. To assess proposed research, for example, more effort will be required to treat improvements in knowledge, while proposed safety actions will require greater evaluation and quantification for exposure reduction measures.

Evaluation of Attributes Involving Radiation Exposure

Three attributes involve radiation exposure: 1) public health, 2) occupational exposure (accidental), and 3) occupational exposure (routine). In quantifying each measure, the analyst should assess the change (or risk averted) relative to the existing condition.

For accident-related exposures, the measure will be probabilistically weighted; i.e., the potential consequence is multiplied by its probability of occurrence. The nonaccident terms, e.g., routine occupational exposure, are given in the terms of annual expected effect. Both types of terms would be integrated over the lifetime of the affected facilities to show the total effect.[a]

Each of the attributes involving radiation exposure can be characterized in terms of person-rem, either averted by or resulting from implementation of the proposed action. A difficult issue is the relationship between these attributes, in units of person-rem, and other attributes that are measured in units of dollars. The issue is controversial; no definitive resolution is available at present. In the following discussion, several variations in

(a) Discounting is not applied to these attributes.

approach are described and the portion of the NRC's Policy Statement on Safety Goals for the Operation of Nuclear Power Plants (U.S. NRC 1983a) that bears on this issue is quoted.

One approach is to define a monetary equivalent for a person-rem of exposure and then simply convert the attribute evaluations from person-rem to dollars. With all attributes expressed in dollars, the net benefit can be calculated and used, with appropriate caveats and qualifications, as a summary measure. (In principle, it would also be possible to calculate a ratio, which would measure dollars of benefit or value obtained per dollar of cost incurred.) The difficulty in this approach resides in choosing a suitable monetary equivalent for a person-rem of exposure.

A second approach is to refrain from defining a monetary equivalent for a person-rem of exposure, allowing the attributes involving radiation exposure to have different units than those involving costs. In this case, of course, the net benefit cannot be calculated, but as detailed below, a value-impact ratio can be calculated. It will typically have units of person-rem per million dollars, and will be a measure of the radiation exposure averted per million dollars of cost incurred. This can then be used, with appropriate caveats and qualifications, as a summary measure. Without additional guidance, however, this leaves unanswered the question of how values in person-rem can be related to impacts in dollars.

As part of its Policy Statement on Safety Goals (U.S. NRC 1983a), the Commission has established for evaluation during a two-year period (but not for regulatory use during that period) some proposed guidance on relating safety improvements measured in person-rem to costs in dollars. The guidance is contained in the Benefit-Cost Guideline, which states in part:

> "Benefit-Cost Guideline. The Commission has adopted a benefit-cost guideline for use as one consideration in decisions on safety improvements. It has decided that a guideline of $1,000 per person-rem averted be adopted for trial use. The value is to be in 1983 dollars. This value should be modified to reflect general inflation in the future.
>
> "The benefit of an incremental reduction of societal mortality risks should be compared with the associated costs on the basis on $1,000 per person-rem averted.
>
> "This guideline is intended to encourage the efficient allocation of resources in safety-related activities by providing that the expected reduction in public risk that would be achieved should be commensurate with the costs of the proposed safety improvements. The benefits as measured by an incremental reduction of societal mortality

risks in terms of person-rem averted should be compared with the reasonably quantifiable costs of achieving that benefit (e.g., design and construction of plant modifications, incremental cost of replacement power during mandated or extended outages, changes in operating procedures and manpower requirements)."

The benefit-cost guideline has stimulated considerable discussion from a variety of viewpoints. The numerical value of $1000 per person-rem averted has been the subject of a lively debate and alternative values have been suggested on both sides of the Commission's trial value. The debate is likely to continue for some time while the Safety Goal Policy Statement is under evaluation. In the meantime, the analyst should employ a range of values in the assessment so that the sensitivity of the results to the assumed numerical value can be examined. One of the values used in the sensitivity analysis should be $1000 per person-rem. Additional details on the evaluation of attributes involving radiation exposure are contained in Section 3.2.2.

Evaluation of Monetary Attributes

Monetary attributes should be discounted to present value.[a] While this operation involves an assumption regarding the remaining lifetime of a facility, it is the same assumption that must be made to derive a levelized cost (units of dollars/year). The total dollar figures capture both the number of facilities involved (in the case of generic rulemaking) and the economic lifetime of the affected facilities. The Regulatory Analysis Guidelines (U.S. NRC 1983c) specify constant-dollar present value as a measure for all monetary terms. Furthermore, they suggest the use of a 10% real discount rate, although the use of other rates for sensitivity testing is also advised. A 5% rate for sensitivity testing is suggested in Office of Nuclear Reactor Regulation (NRR) guidelines for value-impact assessments.[b]

Evaluation of Attributes with Undefined Units

Two of the attributes do not have defined units of measure, "Regulatory Efficiency" and "Improvements in Knowledge." It is likely that the evaluation of these attributes will not provide results in engineering units.

To the degree to which these attributes can be quantified, they should be, and that quantification should be documented. In some instances, quantification can be completed up to the point of conversion to dollars. A more likely occurrence is that the factor affected does not lend itself to quantification or that the nature of the proposed action precludes a clearly definable effect. In these more nebulous cases, the treatment of attributes should take

(a) Basic concepts and methods of discounting are reviewed in Appendix C.
(b) NRR Office Letter No. 16, 1983.

the form of a written evaluation in which the analyst describes as clearly and concisely as possible the precise effect of the proposed action on the attribute affected.

Importance of Uncertainty

A value-impact assessment provides an approximate measure of the consequences of a proposed regulatory action. In order for the assessment to be useful, an indication of the uncertainties in the results is needed. Section 2.4 discusses the treatment of uncertainties in value-impact assessment. Additional guidance is given in Chapter 3. As was noted in the introduction, however, no routine procedure can eliminate the need for careful consideration --by both the analyst and the decision maker--of the dependence of the conclusions on uncertain data and assumptions.

2.1.3 Summarization of Attributes

Once individual attributes have been evaluated, these evaluations are summarized and displayed. A large number of methods exist for summarizing attributes. In selecting methods for use in the handbook, the criteria used were that the method be credible, well-accepted and adequately sophisticated without being unnecessarily complex. The goal is to provide comprehensive methods that are tractable and useful. Two methods are identified which meet these criteria: the ratio method and the net-benefit method. While making use of essentially the same individual attribute evaluation procedures, the two methods are distinct.

This section provides an overview of the two methods described in this handbook for summarizing and displaying the results of a value-impact assessment. First, the role of such methods in the value-impact assessment process is defined. Second, the salient features of each method are outlined. Third, a comparative discussion of the two methods is presented.

The Role of the Two Methods

As indicated earlier, the value-impact assessment process starts from a precise definition of the issue to be evaluated and then proceeds in three key steps:

1. definition of attributes
2. evaluation of attributes
3. summarization and display of results.

The issue definition and first analytical step are fundamental and always warrant careful consideration since they determine what information will be included in the assessment. The handbook suggests a uniform set of widely useful attributes, thereby lending a degree of consistency to the process. Of course, this does not eliminate the need for careful consideration on the part of the analyst, taking account of the particular characteristics of each problem.

The second step, evaluation of attributes, generates the bulk of the technical analysis and information produced in the assessment process, and may occupy the largest fraction of the analyst's time and effort. The handbook treats these evaluations in considerable detail in Chapter 3.

At the conclusion of the second step, the analyst possesses a large amount of information in the form of quantitative and/or qualitative evaluations for each of the identified attributes. The purpose of the third step is to condense this information; the aim is 1) to put the information in perspective so that it can serve as a useful input to regulatory decision making, and 2) to ensure that the implications of the assessment are clearly and concisely documented.

Any summary of complex data entails a compromise between ease of understanding and level of detail. In many cases, a single bottom-line summary may obscure important information. In risk assessment, for example, estimates of average risk, if used by themselves, would not convey potentially important information about the distribution of risks (e.g., the relative contribution of accidents with large consequences as compared with those with small consequences).

This handbook recommends a flexible approach to summarizing and displaying the results of a value-impact assessment. Two methods are presented. As the discussion to follow will indicate, each has certain strengths and limitations but both can provide useful perspectives on the need for and consequences of proposed regulatory actions. In many cases, it will be worthwhile to examine the results with both methods.

Ratio Method

The Office of Nuclear Reactor Regulation has issued guidelines for use by NRR for regulatory analyses;[a] these guidelines supplement the NRC Regulatory Analysis Guidelines (U.S. NRC 1983c). Among other things, the supplementary guidelines recommend the calculation of a "Value/Impact Ratio," described as follows:

> "The total net safety value of the proposed action, typically in person-rem of public dose avoided, is related to total costs (NRC, industry, plus any other) in terms of a ratio, typically person-rem/$ million. This

(a) NRR Office Letter No. 16, 1983.

ratio, along with safety importance, can be used as a partial basis for comparing alternatives, including evaluation against the no-action alternative, and ranking for implementation priority in relation to other issues."

The NRR guidelines emphasize the importance of complementing the quantitative value-impact ratios with other considerations that may be important but are not adequately reflected in the quantitative ratios.

Net-Benefit Method

The net-benefit method is one of several widely used methods in cost-benefit analysis and is required in regulatory impact analyses prepared in accordance with Executive Order 12291 of February 17, 1981.[a] To the extent possible, all values and impacts (or costs and benefits) are quantified in monetary terms and added together (with the appropriate algebraic signs) to obtain the net benefit in dollars. Like the ratio method, the net-benefit method provides for a supplementary evaluation of those effects that are not adequately reflected in the quantitative net-benefit measure.

Comparison of the Methods

Each of the methods has two aspects that must be clearly distinguished if meaningful comparisons are to be made. First, each calculates a numerical value that is intended to summarize the balance between the favorable and unfavorable consequences of the proposed action. Second, each method provides for additional considerations to complement the numerical values. Since the primary purpose of these supplementary considerations is to remedy any shortcomings or limitations of the numerical summaries, the differences between the two methods are not as sharp as they would be if only the numerical summaries were compared. In fact, if the numerical summaries are judiciously interpreted and accompanied by appropriate supplementary considerations, there should be little if any practical difference in the conclusions reached by the two methods. After all, the two methods are based on essentially the same information.

Nevertheless, the two methods are different in the sense that they reflect different perspectives on what is a "cost effective regulatory action," to use the language of the Regulatory Analysis Guidelines (U.S. NRC 1983c). It is worthwhile to clarify the distinction between the two methods, not to determine which is "better," but rather to gain some insight into how each can be interpreted. A sharper distinction can be drawn if one compares the numerical

(a) Executive Order 12291. "Federal Regulation." Federal Register. February 18, 1981. This executive order applies to Executive Branch agencies; the NRC, as an independent agency, is not bound by these requirements.

summary measures alone, ignoring the supplementary considerations. For purposes of discussion, then, the following comparisons are based only on the numerical summary measures.

First, it is important to stress that the net benefit and the value-impact ratio do not measure the same thing, although both are concerned with "cost-effectiveness." The basic perspective of the net-benefit measure is national economic efficiency. All costs and benefits are added together and the total is intended to reflect the aggregate impact of the proposed action on the national economy as a whole. The net-benefit measure does not, and is not intended to, provide any information about the <u>distribution</u> of benefits and costs within the national economy. The costs and benefits to all affected parties are simply added together.

The value-impact ratio reflects a somewhat different perspective. The numerator of the ratio is intended to measure the "safety value" of the proposed action, typically expressed as averted public dose. The emphasis is on the NRC's statutory responsibilities for protection of the public health and safety and common defense and security. The denominator is intended to reflect the aggregate cost impact, and like the net-benefit measure does not provide any information about the distribution of those costs within the national economy.

In order to calculate a net benefit, all attributes must be expressed in common units, typically dollars. In calculating a value-impact ratio, however, the numerator and denominator need not be in the same units. As a consequence, when using value-impact ratios with person-rem of averted public exposure as the measure of safety value, it is possible to avoid defining a monetary equivalent for a person-rem of exposure. The problem of relating values in person-rem to impacts in dollars may then be left for a later stage in the process. With the net-benefit method, the dollars/person-rem equivalence factor must be stated explicitly. As noted earlier, this problem of relating person-rem to dollars is difficult and controversial.

Even if all attributes were expressed in the same units and the differences in perspective mentioned above did not exist, there would still be several distinctions between the two measures. Net benefit is an <u>absolute</u> measure. It indicates the <u>magnitude</u> of the proposed action's contribution toward the specified goals. The value-impact ratio, on the other hand, is a relative measure. It describes the value received <u>per dollar of cost incurred</u>. By itself, it does not indicate the size of the proposed action's contribution to the goals. That indication must be provided separately by quantitative statement of the action's safety importance.

A value-impact ratio is particularly useful for prioritizing a large collection of proposed actions in the presence of a cost constraint. If a large number of independent actions are under consideration but there is a constraint on the total cost that can be incurred, the "optimal" decision is to select, in descending order, those actions with the largest ratios, continuing to add actions until the cost constraint is attained.[a]

On the other hand, if one is faced with a choice between two mutually exclusive actions, either of which is feasible in terms of cost, the "optimal" decision is to select the action with the larger net benefit.

Detailed technical discussions of such decision criteria can be found in the cost-benefit literature. More complicated situations can be treated, with multiple objectives and constraints. From the viewpoint of NRC value-impact assessments, however, it is apparent that such criteria are based on oversimplified models of regulatory decision making. Thus, the "optimal" properties of the two measures should not be overemphasized.

To recap this comparative discussion, neither of the two summary numerical values is intended to be used alone as the sole basis for regulatory decisions. Each provides a perspective on the "cost-effectiveness" of proposed regulatory actions. Both make use of the attribute evaluation methods described in detail in Chapter 3 of this handbook.

2.2 SCOPING

One of the first steps in the value-impact assessment of any given proposed action is an evaluation of the appropriate scope and magnitude of analysis effort. This evaluation is required in order to assure the efficient use of NRC funds and staff resources. Furthermore, it offers an opportunity to develop and communicate to all involved parties a clear understanding of the issues involved and the nature of the proposed action and potential alternative actions. Depending on the viability of those potential alternatives, the scoping analysis may be sufficient to justify rejection of the alternatives.

The basic principle used in determining the appropriate level of assessment effort is that the resources expended should be commensurate with the value of the information to be obtained. In practice, a variety of factors may enter into such a determination, for example, the importance of the action under consideration, the availability of information, the availability of resources to devote to the assessment, the complexity of the issue, the closeness of the outcome, and the time pressures for a decision. As a result, considerable judgment will typically be required to establish an appropriate level

(a) If the actions are not independent (i.e., if the values and impacts of the actions vary depending on the order in which the actions are adopted), then a more complex optimization would be required.

of effort. In some cases several iterations will be needed, with each iteration providing a more detailed and refined analysis.

In most situations it will be useful to consider at least two factors as a minimum basis for determining the appropriate level of effort: the importance of the action and the availability of information. Of these two, importance is the primary criterion.

One measure of the importance of a proposed action is its potential benefit and cost. Actions with either large potential benefit or cost are generally worthy of considerable attention unless the costs and benefits are so obviously out of balance that no significant analysis is needed. Likewise, actions with limited effects should be afforded only limited assessment.

The worksheet given in Table 2.1 can be used to develop a first approximation of benefits and costs. This approximation is not a replacement for the value-impact process, but a rough scoping tool.

The level of assessment effort is also dependent upon the available information. If information is readily available, little resource investment will be required to achieve an adequate level of detail. Conversely, if data is lacking, a greater effort will be needed to bring the assessment to the same level. In completing the First Approximation worksheet, the analyst will gain a partial appreciation for the amount of information available. Further investigation may be necessary, including (if appropriate) contacting other affected NRC branches.

The methods for evaluation of each attribute described in Chapter 3 are presented for three levels of effort, ranging from a limited effort (minimal resource commitment) to a major effort (major NRC program). The development of the first approximation of value and impact and the preliminary investigation into the availability of data will assist in determining the appropriate magnitude of NRC resources to commit to the value-impact assessment.[a] Considerable judgment must be applied; however, the guidance given here will assist in that determination.

(a) The overall level of effort would depend on the action's importance and the sum of available data. The level of effort devoted to any particular attribute would depend (within the bounds of the total effort) on the amount of available information concerning that attribute. Thus, varied attributes could require varied levels.

TABLE 2.1. Worksheet for First Approximation of Benefits and Costs[a]

This worksheet can be used to develop first approximations of the benefits and costs of a proposed action. Its purpose is limited to broad scoping only. If firm data exist, they are to be used; however, engineering judgment is adequate for this level of detail. Appendix B gives rules of thumb that can be used if the analyst does not have better information.

1. Title of Proposed Action

2. Number of Facilities Affected (N)

3. Average Remaining Lifetime of Facilities (T)

4. Mean Accident Frequency Reduction Resulting from Proposed Action (ΔF)

   (events/facility-year)

5. Mean Public Risk Consequence of Accident (A_p)

   (person-rem/event)

6. Mean Occupational Risk Consequence of Accident (A_o)

   (person-rem/event)

7. Expected Integral Exposure Change (E)[b]

   (person-rem) $E = (NT)(\Delta F)(A_p + A_o)$

8. Mean Damage to Onsite Property in Event of Accident (P_o)

   (\$) Include replacement power if appropriate.

9. Mean Damage to Offsite Property in Event of Accident (P_F)

   (\$) Include evacuation, relocation, decontamination, and interdiction costs.

10. First Approximation of Benefits[c,d]

    $B = (E)(XC) + NT(\Delta F)(P_o + P_F)$

    or

    $V = (E)(XC)$

    where XC (in units of dollars per person-rem) is the factor for converting person-rem to dollars.

TABLE 2.1. (contd)

11. NRC Cost (C_N)

($) Include development, implementation, and operation costs.

12. Industry Implementation Cost Per Facility (I_I)

($/facility) Include replacement power if appropriate.

13. Industry Annual Operation Cost Per Facility (I_O)

($/facility-year)

14. First Approximation of Costs[d]

$$C = C_N + N(I_I + TI_O)$$

(a) This method is similar to that employed in NUREG/CR-2800 (Andrews et al. 1983). The staff allocation for that project was two person-weeks per issue, indicating that the first approximation estimates can be made with a minimal investment.

(b) Note that routine occupational exposure is not reflected in this computation. In many cases, the effect on occupational exposure due to a proposed action will be small compared to the effect on public risk. However, this will not always be the case and the analyst should be alert to this possibility. If appropriate, estimates can be made using the procedures described in Section 3.4. Also, note that if the action changes the consequence of the accident rather than the frequency, replace $\Delta F(A_p + A_o)$ by $F[\Delta (A_p + A_o)]$.

(c) The first equation corresponds to the net-benefit approach. The second corresponds to the value-impact ratio. In either case, a range of values of XC can be used to test the sensitivity to this parameter. If the second equation is used (i.e., V = (E)(XC)), Steps 8 and 9 may be omitted.

(d) Note that discounting is not used for this first approximation.

2.3 VALUE-IMPACT PROCESS

As previously described, the conduct of a value-impact assessment has three steps, definition of attributes of value and impact to be considered, evaluation of the effect which the action under consideration has on the attributes, and aggregation of the attributes. This section provides a framework and set of instructions that can be used to guide the analyst through those steps.

In Section 2.1 two methods (ratio and net-benefit) were presented for comparing values to impacts. For most of the value-impact assessment process, the analysis is the same for either method. For those steps that differ, the steps for both methods are described in Section 2.3.2.

Two sample value-impact assessments are provided in Appendices D and E. Their purpose is to illustrate the assessment process.

2.3.1 Value-Impact Framework

The assessment process and the documentation of that process can be described in nine parts. These are listed below, with instructions for each given in the following subsection.

1. Summary Cover Page
2. Proposed Action and Potential Alternatives
3. Identification of Affected Attributes
4. Supplementary Considerations
5. Development of Quantification
6. Value-Impact Results Display
7. Sensitivity Studies
8. Initial/Residual Risk (Optional)
9. Recommendations

2.3.2 Instructions for Performing the Assessment

1. Summary Cover Page

The summary cover page (Table 2.2) is a concise statement of the major results of the assessment. It identifies the action under consideration, the author of the assessment and the date of completion. The Summary of Problem and Proposed Solution should be a very brief but careful abstract of the issue of concern and its treatment by the action under consideration. The intent is to provide the reader with an initial description.

The main body of the table provides a location to summarize the results of the attribute assessments. Exposure-related attributes (Public Health and Occupational Exposures) are measured in person-rem. If the net-benefit method is being used, a dollar evaluation should also be given. Throughout the table, in addition to best estimates, high and low estimates should be given to indicate the degree of uncertainty (see Section 2.4).

Not all the spaces in the table need to be filled. Some attributes may not be affected by the proposed action. Others may be affected but not quantified, treated instead as supplementary considerations. For example, if the

TABLE 2.2. Value-Impact Summary Cover Page

Title of Proposed Action
Name and Affiliation of Author
Date

Summary of Problem and Proposed Solution:

ATTRIBUTE	Dose Reduction (person-rem) Best Estimate	High Estimate	Low Estimate	Evaluation ($)[a] Best Estimate	High Estimate	Low Estimate
Public Health						
Occupational Exposure (Accidental)						
Occupational Exposure (Routine)						
Offsite Property						
Onsite Property						
Regulatory Efficiency						
Improvements in Knowledge						
Industry Implementation						
Industry Operation						
NRC Development						
NRC Implementation						
NRC Operation						

NET BENEFIT: Sum Over All Affected Attributes ($)

RATIO: Public Dose Reduction/|Sum of All NRC and Industry Costs|(person-rem/$\$10^6$)[b]

NA = Not Affected
NQ = Not Quantified
(a) Note: Favorable or beneficial consequences of a proposed action have a positive sign. Unfavorable or adverse consequences have a negative sign. For instance, an increase in industry or NRC operating costs would be considered an unfavorable consequence and should be entered in the table with a negative sign.
(b) Strictly speaking, because the ratio should be expressed as a positive number, the analyst should use the absolute value of the sum of all costs (industry, NRC, and other) in the denominator.

ratio method is used, only the public health and the NRC and industry cost attributes need be assessed. The other attributes (e.g., occupational exposure and onsite and offsite property) are not required to calculate a value-impact ratio. However, they can still be assessed and treated as supplementary considerations.

The table concludes with spaces for the net-benefit and ratio results. The net benefit is obtained by summing over all affected attributes. The ratio is the expected public dose reduction divided by the NRC and industry cost of achieving the reduced risk. It is expressed as person-rem/$\$10^6$. Uncertainties should be propagated through to these final calculations (see Section 2.4).

2. Proposed Action and Potential Alternatives

The proposed action should be precisely described in terms of the nature and scope of the action, why it is needed, what it will accomplish and how it is to be brought into force (as a regulatory instrument). Potential alternatives to the proposed action should also be described. If the alternatives are not to be treated with a complete value-impact assessment, a rationale should be provided here for their rejection and for preference of the proposed action. The scoping exercise described in Section 2.2 can be helpful in developing this rationale.

3. Identification of Affected Attributes

Table 2.3 can be used as a checklist to identify attributes that are affected by the proposed action. If the ratio method is being used, only the public health attribute and NRC, industry, and any other cost attributes enter into the formula. However, with both the ratio and net-benefit methods, attributes that are affected but are not in the formula can be identified here and treated as supplementary considerations.

4. Supplementary Considerations

Both the ratio and the net-benefit methods have provisions for treating attributes or other factors that do not fall within the quantified assessment. In principle, the value-impact analysis should be as quantitative as possible. However, the quantitative approach is limited in its ability to capture all important considerations. Other considerations which may be important for a given issue may not be reflected in the quantitative formulation. Such special factors or considerations should be identified so they may be included in the overall assessment. Below are some special factors that may be important. The list is not inclusive; if other special factors are identified they should be added.

- uncertainty bounds, imbalance in uncertainty factors (for example, the certainty of costs relative to the uncertainty in estimated benefits)

TABLE 2.3. Checklist for Identification of Affected Attributes

Attribute	Quantified Change	Unquantified[a] Change	No Change
Public Health			
Occupational Exposure (Accidental)			
Occupational Exposure (Routine)			
Offsite Property			
Onsite Property			
Regulatory Efficiency			
Improvements in Knowledge			
Industry Implementation			
Industry Operation			
NRC Development			
NRC Implementation			
NRC Operation			
Other (specify)			

(a) In the net-benefit context, "quantified" means expressible in dollars, and "unquantified" means not readily estimated in dollars.

- situations where uncertainty is extraordinarily large (in accident probability or consequences or in cost, or any or all of these)
- circumstances imparting unusual significance to accident consequences (such as ingestion-pathway effects) that may not be directly included in the public dose calculations

- occupational doses involved in the "fixes" proposed[a]

- averted cost of plant damage from the postulated accident[a]

- loss or severe degradation of a layer in the defense-in-depth concept (e.g., one mode of core cooling or containment cooling)

- issues for which solutions of widely differing costs may be applicable to different classes of plants, or for which various plants are otherwise affected in vastly different ways

- distributional effects (i.e., who bears the costs and who enjoys the benefits)

- acute professional controversy concerning the importance of an issue or modes of dealing with it.

To the degree possible, the analyst should seek quantitative evaluations for these special factors. Where quantification is not practical, concise qualitative evaluations should be given.

5. Development of Quantification

For each of the affected attributes quantified, a brief description should be given of the development of that quantification. Data sources should be identified and appropriate references given. Sufficient detail of the calculation should also be provided to show the reader how the quantification was derived and to give the rationale for any assumptions.

6. Value-Impact Results Display

The results of the value-impact assessment, for either the ratio or net-benefit method, can be displayed in the form of tables, graphs, or both. One summary table is the Summary Cover Page (see Table 2.2). Other tables can be used for additional perspectives. In most cases, one or more graphical displays should be provided. For the ratio method, this could involve locating the indicated results on the prioritization chart used in Appendix D. For the net-benefit method, a bar chart can show the relative contribution of each attribute and the ranges of uncertainty (see Appendix D).

(a) In the net-benefit method, this attribute is included in the net-benefit calculation and thus is not a "supplementary consideration."

7. Sensitivity Studies

The "results" given in the preceding step are only part of the value-impact assessment. These are developed using what might be called "baseline assumptions," which underlie every portion of the assessment. Alternatives to the baseline assumptions exist. In this portion of the assessment, the sensitivity to changes in the baseline assumptions is tested.

Assumptions internal to the public health risk analysis are appropriate candidates for sensitivity tests (e.g., source term magnitudes, population densities, etc.). The results may also be sensitive to cost assumptions, especially to the requirement of plant outages for equipment installation. In the net-benefit approach, an important area for sensitivity testing, in addition to those just mentioned, is the monetary evaluation of radiation exposure.

8. Initial/Residual Risk

This optional step will provide the decision maker with added insight. The analyst should display the risk before the proposed action is put into effect (initial) and afterwards (residual). One way to express the risk is in terms of the acute and latent fatality risk (fatalities/reactor-year) and the major-core-melt frequency (events/reactor-year).

9. Recommendations

In this final portion the analyst should state, if appropriate, the recommendations indicated by the assessment. The rationale for the recommendations should be given, with references to supporting information within the assessment.

2.4 TREATMENT OF UNCERTAINTY

The estimation and presentation of uncertainties are vital parts of a value-impact assessment. Any meaningful interpretation of the results of a value-impact assessment requires an appreciation of how the results may depend on uncertain data and assumptions. A variety of techniques are available for analyzing uncertainty. Some of these are quite useful for developing insight into the nature and consequences of uncertainty. However, the problems posed by uncertainty are fundamental and cannot be entirely eliminated, even by the most sophisticated methods.

Several ways of classifying uncertainties have been suggested. A basic distinction can be drawn between uncertainties in the model being used and uncertainties in the parameters that serve as inputs to the model. Models can be regarded as concise, mathematical descriptions of one's knowledge and assumptions. Models ordinarily have parameters whose precise values are left unspecified within the model itself; the precise values are supplied as input data when the model is used.

Given a particular model, uncertainties in the parameters can be treated by various statistical techniques; some of these will be outlined below. Uncertainties in the model are more difficult to treat, however. The standard approach is through sensitivity analyses in which the models and assumptions are varied and the effect of these variations on the results and conclusions is studied. Sensitivity analyses can be done with varying degrees of formality and rigor.

A sensitivity analysis typically consists of several steps. First, a systematic attempt should be made to identify all of the pertinent factors (assumptions, data, models) that could affect the results. Since the number of such factors is usually very large, not all of them can be treated in detail. Nevertheless, it is useful to make a systematic effort at least to identify them. As a second step, the list of factors should be screened to select a subset for detailed examination. The screening process should concentrate on eliminating unimportant factors (for example, those that are known to contribute little to the overall uncertainty) and reducing the list to manageable size. Typically, the screening will be done on the basis of judgment and experience, but more formal methods and calculations may be appropriate in some circumstances. The third step in a sensitivity analysis is to define a set of cases to be evaluated. The most common approach is to define a base case, establish a range of interest for each factor, and then systematically vary the factors, one at a time. The results are then expressed as a range (low value, base case, high value) for each factor. The range indicates the effect on the output of variations in the factor and thus provides some insight concerning uncertainties and their effects. Theoretically, there are many refinements that can be incorporated into the sensitivity analysis. For example, specialized experimental designs can be used to vary the factors, empirical models (response surfaces) can be used to analyze the results, or the ranges of interest defined for each factor can be characterized statistically. In practice, however, there is sometimes a tradeoff between the complexity of the sensitivity analysis and the ability to communicate the conclusions. This problem can be minimized by concentrating on a relatively small number of dominant sources of uncertainty and by expressing the conclusions in terms of concrete illustrations of variations in results due to changes in assumptions, data, or models.

In principle, the effect of any particular assumption can always be assessed through a sensitivity analysis. However, in practice, not all assumptions are explicitly recognized. As a result, uncertainty analyses, even those based on elaborate sensitivity studies and error propagations, frequently underestimate the true uncertainty. With time and experience, as models and assumptions become better understood, more realistic estimates of uncertainties can be obtained. This requires a sustained, systematic effort to critically assess the strengths and limitations of existing models and data, and where appropriate to improve them.

Although the available uncertainty analyses are often imperfect, they are nevertheless useful if they are cautiously interpreted. In many applications, a simple and adequate way to display uncertainties is to provide a range within which the true value is believed to lie. More rigorous statistical presentations can also be used, but they are more difficult to communicate to nonspecialists. In this handbook, uncertainties are generally expressed as a range and no attempt is made to be precise about the statistical interpretation to be ascribed to the range. In particular applications, a more rigorous approach may be called for. In such a situation, the analyst should seek the assistance of a statistical consultant. A general review of methods of uncertainty analysis from the viewpoint of probabilistic risk assessment is given by Cox and Baybutt (1981).

In the following paragraphs, a brief sketch is provided of some techniques available for uncertainty analysis. These techniques can be used to assess how uncertainties in input parameters are transmitted through a given model, resulting in uncertainties in the output of the model. The techniques do not accommodate uncertainties in the models themselves (i.e., uncertainties in the assumptions). For these model uncertainties, sensitivity analyses can be performed. The techniques described below also assume that the uncertainties in the input parameters have already been adequately characterized; in practice, characterizing the uncertainties in the input parameters is often a difficult problem in its own right.

Mathematical Analysis. If the input parameters can be regarded as random variables and the form of the model is explicitly known, then it may be possible to derive the distribution of the output variable or variables analytically. Determining the distribution of functions of random variables is a standard topic in statistics, and many exact and approximate techniques and standard results are available. For value-impact assessments, unless the model under consideration has a fairly simple, functional form, the problem is likely to be intractable. Thus, this approach will not often be very useful in value-impact assessment. However, it provides a part of the theoretical base for other approaches.

Monte Carlo. Monte Carlo or simulation methods can be employed if analytical methods are not workable. Essentially, Monte Carlo methods can accomplish numerically what cannot be done analytically. The principal drawback of Monte Carlo methods is that they can require large amounts of computer time. Specialized techniques are available to make Monte Carlo methods more efficient; but for large, complex models, considerable effort and expertise are required. Hahn and Shapiro (1967) describe Monte Carlo methods in some detail. NRC (1983b) and Cox and Baybutt (1981) provide overviews and lists of references.

Engineering Judgment and Propagation of Extremes. Engineering judgment may be used to estimate reasonable high and low values for each attribute. The criteria for such bounds would be the analyst's judgment that the true value of the attribute is highly likely to fall between them. Admittedly, this approach is not statistically rigorous, but in many situations it will be reasonable and adequate. Propagation of extremes is done by using the individual high and low estimates independently to calculate aggregated high and low results. For instance, to calculate the high estimate for total impact, the individual high estimates for each impact attribute would be summed. The high estimate for the ratio would be the high estimate for the numerator divided by the low estimate for the denominator and so on.

Theoretically, this method can lead to uncertainty bounds that are too wide--the method gives undue weight to the extreme cases. However, the initial goal of assuring that the true value is highly likely to fall within the bounds is met. Furthermore, in view of the uncertainties in model and assumptions that are not reflected in the uncertainty propagation, some conservatism in the calculated bounds may be acceptable as long as they are interpreted cautiously.

Direct Assessment. A direct assessment of uncertainty bounds for the value-impact assessment can be performed if no other method is available or appropriate. Since such an estimation is likely to be subjective, the analyst should explain the rationale for the choice of bounds.

CHAPTER 2 REFERENCES

Andrews, W. S., et al. 1983. Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development. NUREG/CR-2800, Pacific Northwest Laboratory, Richland, Washington.

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3.0 EVALUATION METHODS

This chapter describes methods which can be used to assist the analyst in the evaluation of each of the individual attributes. To the maximum degree possible, specific guidance is given. However, when this is not possible because of the volume of detail required, the analyst is directed to appropriate references. When specific guidance cannot be given because of limited existing evaluation methods, the analyst is given the best procedural guidance available.

Section 3.1 treats the estimation of changes in accident frequency. Estimates of this parameter are needed for several of the attribute evaluations and therefore are discussed first. Sections 3.2 through 3.13 present evaluation methods for each of the twelve attributes.

A certain amount of redundancy exists among sections. This is required to make the sections independent and allow the analyst to use only those sections that are appropriate to the proposed action under consideration. In each section, alternative sets of formulations are given. These correspond to levels of effort associated with the estimation. The responsible program manager must evaluate the importance of the issue being addressed and size the value-impact assessment effort appropriately (see Section 2.2). Generally, in the guidance given, three levels of effort are described.

- Limited Effort. This would correspond to the lowest level of effort that could be mounted to achieve a useful estimation. Commitment of resources would be minimal, but this savings would be obtained at the expense of technical detail and enlarged uncertainties.

- Intermediate Effort. This would entail the use of approximations and simplifying assumptions, to reduce significantly the scope and costs as compared to a major effort. The technical depth of the assessment would normally be less and uncertainties greater relative to a major effort.

- Major Effort. This defines a scope of effort that would employ the best available analytical methods. Such an effort could have substantial costs, becoming a major program within the NRC. A major effort would normally be expected only for the most important value-impact assessments, corresponding to issues which potentially have high values or high impacts.

Supplementing the formulations given in this chapter are the more detailed descriptions and references of Appendix C. When appropriate, those are cross-referenced here.

3.1 ESTIMATION OF CHANGES IN ACCIDENT FREQUENCY

All discussions in this section assume familiarity with the concepts of risk as related to nuclear power plants, as well as knowledge of event-fault-tree terminology. The reader unfamiliar with these concepts or in need of review is directed to the Reactor Safety Study (U.S. NRC 1975), the PRA (Probabilistic Risk Assessment) Procedures Guide (U.S. NRC 1983b), the Fault Tree Handbook (Vesely et al. 1981), and Reliability and Risk Analysis (McCormick 1981), to name a few sources. Assistance might also be obtained from the Safety Program Evaluation Branch/NRR or Regulatory Analysis Branch/RES.

Estimates of the change in major core-melt accident frequency resulting from a proposed NRC action are based on the effects of the action on appropriate parameters in the equation for core-melt frequency.[a] Examples of these parameters might be system or component failure probabilities. The estimation process involves two steps:

1. Identification of the parameters affected by a proposed NRC action (see Section 3.1.1)

2. Estimation of the values of these affected parameters before and after the implementation of the action (see Section 3.1.2).

The parameter values are substituted in the equation for core-melt frequency to yield the base- and adjusted-case core-melt accident sequence frequencies. The sum of their differences is the change in core-melt accident frequency due to the proposed NRC action.

The process can be viewed as follows. The core-melt frequency for accident sequence ij[b] is

$$F_{ij} = \sum_{\ell} \sum_{m} M_{ij\ell m}$$

where

$M_{ij\ell m}$ = the frequency of the minimal cut set for accident sequence i initiated by event j and followed by failure of component m in system ℓ.

(a) A key premise throughout this section is that the risk due to reactor accidents is dominated by core-melt accidents. This is a useful and reasonable assumption in many situations (Hall et al. 1979). However, the analyst should be alert to the possibility that for some issues, a more comprehensive analysis might be required.

(b) The double index notation indicates that any one initiating event j can lead to several accident sequences i.

The affected parameters comprise one or more of the multiplicative terms in the minimal cut sets. Thus, the change in accident sequence ij's frequency is

$$\Delta F_{ij} = (F_{ij})_{base} - (F_{ij})_{adjusted} = \sum_{\ell} \sum_{m} [(M_{ij\ell m})_{base} - (M_{ij\ell m})_{adjusted}]$$

The change in core-melt accident frequency is the sum of the changes for each affected accident sequence; i.e.,

$$\Delta F = \sum_{i} \sum_{j} [(F_{ij})_{base} - (F_{ij})_{adjusted}]$$

$$= \sum_{i} \sum_{j} \sum_{\ell} \sum_{m} [(M_{ij\ell m})_{base} - (M_{ij\ell m})_{adjusted}]$$

3.1.1 Identification of Affected Parameters

The level of effort required to identify the parameters affected by action implementation depends primarily on the availability of one or more existing risk/reliability studies which include those parameters. Table 3.1 provides a list of currently available (or soon to be available) nuclear power plant risk/reliability studies. The following characteristics are included for each study:

- plant type (BWR/PWR and vendor)
- year of commercial operation
- external events inclusion (yes/no)
- program under which performed (if any)
- report reference
- adaptability to "limited" effort identification of affected parameters (easy/moderate/difficult--discussed in next section).

The analyst should note that additional studies are currently underway and may become available in the future for use in value-impact assessments.

TABLE 3.1. Summary of Plants with Existing Risk/Reliability Assessments

Plant	Plant[(a)] Type	Year Commercial	External Events Inclusion	Program[(a)]	Reference	Limited Effort Adaptability for Parameter Identification
Arkansas Nuclear One-1	B&W PWR	1974	No	IREP	Kolb et al. 1982	Easy
Browns Ferry-1	GE BWR	1974	No	IREP	Mays et al. 1982	Moderate
Calvert[(c)] Cliffs-2	CE PWR	1977	No No	RSSMAP IREP	Hatch et al. 1982 (b)	Easy (b)
Crystal River-3	B&W PWR	1977	No	IREP	Garcia et al. 1981	Easy
Grand Gulf-1	GE BWR	1983	No	RSSMAP	Hatch et al. 1981	Easy
Indian Point-2	W PWR	1974	Yes	Utility	PASNY 1982	Difficult
Indian Point-3	W PWR	1976	Yes	Utility	PASNY 1982	Difficult
Limerick-1/2	GE BWRs	1985/7	No	Utility	Philadelphia Electric Co. 1981	Moderate
Millstone-1	GE BWR	1970	No	IREP	Garcia et al. 1983	Easy
Oconee-3[(c)]	B&W PWR	1974	No Yes	RSSMAP EPRI	Kolb et al. 1981 (b)	Easy (b)
Peach Bottom-2	GE BWR	1974	Yes	RSS	US NRC 1975	Moderate
Sequoyah-1	W PWR	1981	No	RSSMAP	Carlson et al. 1981	Moderate
Surry-1	W PWR	1972	Yes	RSS	US NRC 1975	Moderate
Zion-1/2	W PWRs	1973/4	Yes	Utility	Commonwealth Edison 1981	Difficult

(a) Abbreviations: B&W = Babcock & Wilcox, CE = Combustion Engineering, EPRI = Electric Power Research Institute, GE = General Electric, IREP = Interim Reliability Evaluation Program, RSS = Reactor Safety Study, RSSMAP = RSS Methodology Applications Program, W = Westinghouse.

(b) Study to be completed (anticipated publication in 1983).

(c) Each of these plants is being evaluated under two separate programs, therefore, two entries are given for each.

In addition to these assessments of total plant risk/reliability, some studies focus on specific systems, accident initiators, or accident sequences. For certain actions, such specialized studies may be more appropriate for identifying affected parameters than the various plant-wide assessments.

The identification of affected parameters at three levels of effort (limited, intermediate, and major) is discussed below.

Limited Effort

A limited effort implies that appropriate risk/reliability studies from which the affected parameters are easily identified are readily available. For example, all currently available risk/reliability studies include accident sequences involving loss of emergency AC power. If the minimal cut sets used in the analytical modeling of these sequences contain parameters appropriate to an action related to loss of emergency AC power, then no further effort is needed to locate appropriate studies. The affected parameters can be readily identified, and the estimation of changes in accident frequency can proceed to the next step (parameter value estimation).

The term "limited effort" does not necessarily imply an inappropriate or compromised degree of detail to identify affected parameters. On the contrary, if the parameters related to the action are adequately modeled in the available studies, then any further modeling effort may be unnecessary.

The adaptability of existing risk/reliability assessments to a limited effort identification of parameters is judged in Table 3.1. In addition, specialized studies, such as the Accident Precursor Study (Minarick and Kukielka 1982), may often be easily adapted to a limited effort to identify affected parameters for actions generic to light water reactors (LWRs).

Intermediate Effort

An intermediate effort implies that the identification of affected parameters requires more than direct use of existing risk/reliability studies. In this level of effort, existing studies may be substantially modified without sacrificing their analytical consistency. The effort may involve performing an expanded or independent analysis of the accident sequences associated with an action, using previous studies only as a guideline, or several existing risk/reliability studies may be combined to form some "composite" study more applicable to a generic action. Alternatively, one or more of the currently available studies may be involved from which the identification of affected parameters is beyond the limited level of effort (e.g., the Zion risk assessment). In any case, the degree of detail and depth of analysis made possible through an intermediate effort to identify affected parameters must be significantly better than those provided by a limited effort on the same action. If not, an intermediate level of effort is unjustified.

Major Effort

The implication of a major effort is that the identification of affected parameters requires the type of analysis associated with the intermediate effort, but at a much greater level of detail and, most likely, a significantly expanded scope. Typical of major efforts are NRC programs related to unresolved safety issues, like those for Station Blackout[a] and Pressurized Thermal Shock at older PWRs (Kryter et al. 1981; Pedersen et al. 1982).[b] Such programs tend to be multiyear tasks conducted by one or more NRC contractors. Clearly, the expected degree of detail and quality of analysis made possible through a major effort to identify affected parameters should be "state-of-the-art," significantly better than could be obtained from an intermediate effort.

3.1.2 Estimation of Affected Parameter Values

Presumably, the analyst has identified the parameters affected by action implementation, whether through a limited, intermediate, or major level of effort. (If not, it is still possible to estimate changes in accident frequencies through expert opinion, discussed in the next section as part of the "limited" level of effort.) The next step is to estimate the base- and adjusted-case frequencies/likelihoods of the affected parameters, which are then used to estimate the base- and adjusted-case core-melt accident sequence (or release category) frequencies. The sum of the differences between the base and adjusted cases is then the change in accident frequency resulting from the action.

The level of effort required to estimate the affected parameter values depends primarily on the availability of pertinent data. As for parameter identification, three levels of effort are discussed: limited, intermediate, and major.

(a) Baranowsky, P. 1981. "Completion of Station Blackout (USI A-44) Task 1." May 22, 1981, Memo to K. Kniel, U.S. Nuclear Regulatory Commission, Washington, D.C.

(b) See also the following:

Battle, R. and D. Campbell. 1982. Reliability of Emergency AC Power Systems at Nuclear Power Plants (draft). Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kolaczkowski, A., and A. Payne, Jr. 1982. Station Blackout Accident Analyses (draft). Sandia National Laboratories, Albuquerque, New Mexico.

U.S. Nuclear Regulatory Commission. "NRC Staff Evaluation of Pressurized Thermal Shock," November 1982. Washington, D.C.

Limited Effort

A limited effort implies that frequencies/likelihoods for affected parameters are readily available or can be derived easily. The most convenient sources of data are the existing risk/reliability assessments; these provide parameter frequencies/likelihoods in forms appropriate for accident frequency calculations (e.g., frequencies for initiators and unavailabilities or demand failure probabilities for subsequent system/component failures). The Accident Precursor Study provides similar but less extensive data (Minarick and Kukielka 1982). Numerous other data sources are available: Swain and Guttmann (1981); Green and Bourne (1972); McClymont and Poehlman (1982a,b), McClymont and McLagan (1982); IEEE Std 500-1977; the Nuclear Plant Reliability Data System (NPRDS)[a]; and the LERs. These may or may not report data in the forms directly applicable as parameter frequencies/likelihoods.

To remain within the scope of a limited effort, derivation of frequencies/likelihoods from available data should require no more than standard statistical analysis techniques. In addition to statistics textbooks, other sources provide methods for deriving failure rates and probabilities more specifically for use in risk/reliability analyses: Green and Bourne (1972); McCormick (1981); Vesely et al. (1981); Martz and Waller (1978); Shooman (1968); Barlow and Proschan (1975); and NUREG/CR-2300 (U.S. NRC 1983b). If derivation requires more detailed modeling, the analyst should consider the possibility of estimating frequencies/likelihoods through expert opinion before commitment to an intermediate level of effort. A formalized procedure like the Delphi technique may yield adequate estimates (Dalkey and Helmer 1963).

Earlier, it was mentioned that an analyst unable to identify affected parameters for an action still can estimate changes in accident frequency. This removes the need for propagating the effect of change in individual risk parameters through the risk equation to obtain the accident frequency. It involves expert judgment of changes in accident frequency based on the total core-melt frequency of a representative plant. A formalized procedure like the Delphi method could be used to provide an overall consensus from expert estimates of percent changes in core-melt frequency due to action implementation. However, caution is advised, since direct estimation of core-melt frequency, as compared to more detailed calculations, can result in inaccurate estimates.

Expert opinion may also play a prime role in estimating adjusted-case parameter values for a limited level of effort. Typically, existing data are applied to yield base-case values, leaving only engineering judgment for arriving at adjusted-case values. Consensus can reduce uncertainties, and the magnitudes of parameter values normally encountered in risk/reliability studies can serve as rough guidelines.

(a) Developed by the Southwest Research Institute, San Antonio, Texas.

Intermediate Effort

An intermediate effort implies that frequencies/likelihoods for affected parameters are not readily available. The analyst would be expected to conduct reasonably detailed statistical modeling or extensive data compilation. Direct postulation of parameter values would not be appropriate for an intermediate level of effort. While existing risk/reliability assessments may provide some data for use in statistical modeling, the level of detail required in an intermediate effort would normally be greater than they could provide. Statistical modeling characteristic of an intermediate effort may use Monte Carlo methods. An intermediate effort may also involve relatively basic statistical analysis techniques but utilizes extensive data.

Standard statistical analysis techniques may be applicable for an intermediate as well as a limited level of effort to estimate parameter values. The seven references listed earlier in the section on limited effort (Green and Bourne, etc.) may also be applicable. Here too, expert opinion may play a major role in estimating adjusted-case parameter values. The detailed modeling of limited data or extensive data compilation may only provide frequencies/likelihoods for the base case. Only engineering judgment may remain for estimating adjusted-case values.

Major Effort

A major effort implies that the estimation of affected parameter values requires the type of analysis associated with the intermediate effort but with much greater detail and a significantly expanded scope. When frequencies/likelihoods are unavailable for affected parameters, a major analytical effort is required. The analyst may need to develop specialized statistical models or possibly seek experimental data. On the other hand, data may be so abundant as to require extensive statistical analysis to produce a more workable base. Typically, both detailed statistical modeling and extensive data compilation will be required as part of a major effort. "State-of-the-art" data analysis techniques should be employed.

Unlike those of intermediate and limited efforts, estimation of adjusted-case affected parameter values should involve more than just expert opinion for a major effort. Engineering judgment can be incorporated into an overall framework, but this framework should be analytical, not judgmental. If the need for expert opinion proves inevitable, only a rigorous application of the Delphi or other such methods will suffice for a major effort.

3.1.3 Uncertainty in Change in Accident Frequency

Along with the "best estimate" of the change in core-melt accident frequency ($\Delta \hat{F}$), the error bounds on this estimate must be provided. Rigorous evaluation of these bounds requires detailed statistical analysis or use of Monte Carlo simulation. Simplified estimates can be obtained through the use of expert opinion and may often suffice, especially for a limited effort, to estimate the change in core-melt frequency. For a somewhat more sophisticated approach, the conservative approximations developed in Andrews et al. (1983) can be employed, as follows:

$$(\Delta F)_u = \hat{F}_b f_F$$

$$(\Delta F)_\ell = 0$$

where

$\hat{F}_b$ = the best estimate of the base-case core-melt frequency attributable to the affected parameters (i.e., the portion of the core-melt frequency calculated from the sum of only the minimal cut sets containing affected parameters)

f_F = the error factor on the core-melt frequency

ℓ and u = subscripts denoting the lower estimate and upper estimate.

The above approximation applies only if the adjusted-case core-melt frequency is less than that of the base case; the proposed NRC action must indicate a reduction in the frequency of a core melt, i.e., a benefit. The f_F may be taken to be 5 (at a 90% confidence level) in lieu of a rigorously derived estimate. This is typical of the magnitude calculated for f_F in existing risk/reliability assessments (e.g., U.S. NRC 1975; Kolb et al. 1982; Mays et al. 1982) and yields the following bounds.

$$(\Delta F)_u = 5\hat{F}_b$$

$$(\Delta F)_\ell = 0$$

If the analyst has access to better or more rigorously derived uncertainty estimates, they should be used in place of the approximation above.

3.1.4 Related Programs for Estimating Changes in Accident Frequency

This section discusses three major programs currently developing techniques and/or information directly applicable to estimating changes in core-melt accident frequency.

Accident Sequence Evaluation Program

The Accident Sequence Evaluation Program (ASEP) is developing generic event trees, nomenclature, and Boolean equations for the various core-melt accident sequences characterizing different classes of plant design.[a] A review of all existing risk/reliability assessments is being performed to develop these generic sequences. Recovery likelihoods are being incorporated into them. Containment failure likelihoods are also being prescribed for the generic sequences to assign them to various release categories for the classes of containment found at LWRs.

The information developed from this project should provide readily available accident sequences for use in identifying affected parameters for proposed concerns. These may be especially useful for actions dealing with generic concerns. The summary of data from existing risk/reliability studies will provide a good base from which to estimate affected parameter frequencies/-likelihoods.

Interim Reliability Evaluation Program

The Interim Reliability Evaluation Program (IREP) is a source of plant-specific assessments for core-melt accident sequences and release categories. Utilizing standardized analysis techniques, the core-melt accident sequence and release category frequencies have been and are being estimated for several plants (see Table 3.1).[b] The studies are well documented, and they resolve minimal cut sets to the component level. This makes them most useful for identifying affected parameters for action implementation. The similarity in analytical technique and detail among the various IREP studies facilitates their use as a consistent set of plant-specific studies. They also serve as a source of data, both plant-specific and generic, for estimating affected parameter values.

(a) Harper, F., et al. 1982. Accident Sequence Evaluation Program, Phase II Workshop Report (draft). Sandia National Laboratories, Albuquerque, New Mexico.

(b) Carlson, D. 1982. Interim Reliability Evaluation Program Phase II, Procedures Guide (draft). NUREG/CR-2728, Sandia National Laboratories, Albuquerque, New Mexico.

Current plans are to extend the IREP analyses to several other plants as part of the follow-on National Reliability Evaluation Program (NREP). Completion of NREP studies will enlarge the list of available risk/reliability assessments.

Prioritization of NRC Safety Issues Program

The Prioritization of NRC Safety Issues Program (PSIP) is estimating the risk reduction, dose, and cost associated with resolving various NRC safety issues (Andrews et al. 1983). The estimates are being used to rank issues for the purpose of NRC resource allocation. This project has developed standardized techniques for estimating changes in core-melt accident frequency based on the use of existing risk/reliability studies. The level of effort characteristic of changes in accident frequency estimated in the PSIP is "limited" due to its scope and constraints. However, the methodology developed could be used in an intermediate effort as well.

The report not only develops the methodology but also displays the dominant accident sequences and minimal cut sets for the Oconee-3 PWR and the Grand Gulf-1 BWR (based on the Reactor Safety Study Methodology Applications Program) in standardized formats. In addition, there are three examples of issue assessments and data on lifetimes of operating and future LWRs.

3.2 PUBLIC HEALTH

This section presents two options for evaluating the effect on public health of proposed regulatory actions. The two options correspond to the two methods described earlier for summarizing and displaying attributes, namely, the ratio method and the net-benefit method. The ratio method estimates the change in the public health risk associated with the action and reports this as total person-rem avoided exposure. In the net-benefit method this estimate is also made, but another step is added to make a monetary evaluation.

The steps for the ratio method are as follows:

1. Estimate change in accident frequency (see Section 3.1)
2. Estimate change in public health risk (see Subsection 3.2.1)
3. Calculate public health risk avoided as

$$V^*_{PH} = NTD_p$$

The steps for the net-benefit method are as follows:

1. Estimate change in accident frequency (see Section 3.1).
2. Estimate change in public health effects (see Subsection 3.2.1).
3. Choose monetary valuation of health effects (see Subsection 3.2.2).
4. Calculate value of public health risk avoided as

$$V_{PH} = NT\ (D_P \times R)$$

where

V^*_{PH} = public health risk avoided for ratio method (person-rem)

V_{PH} = value of public health risk avoided for net-benefit method ($)

N = number of affected reactors (reactors)

T = average remaining lifetime of affected facilities (years)

D_P = avoided public dose per reactor-year (person-rem/reactor year)

R = monetary equivalent of unit dose ($/person-rem).

If individual facility values rather than generic values are used, the formulations can be replaced with

$$V^*_{PH} = \sum_i N_i T_i D_{Pi}$$

$$V_{PH} = R \sum_i N_i T_i D_{Pi}$$

where

i = reactor (or group of reactors) index.

3.2.1 Estimation of Public Health Effects

The results of the formulations given in Section 3.1 are changes in accident probability, given as probability by release-category frequency or overall core-melt frequency. These form the first portion of the public health risk estimate. The discussion below is divided into three parts corresponding to the level of effort to be dedicated to the value-impact assessment for this attribute. A note concerning mitigation of accident consequences is also included.

Limited Effort

For a limited value-impact assessment effort, the change in accident probability is likely to be expressed as a change in overall major core-melt frequency. A single dose conversion factor that is generically applicable to all reactors and all accident types is perhaps meaningless. However, coarse estimates could be made. For example:

Best Estimate	2E7 person-rem/event
High Estimate	1E8 person-rem/event
Low Estimate	5E6 person-rem/event

(See Section C.2 of Appendix C for the development of these estimates.)

These are conservative estimates, based on major accidents (SST1), and the bounds reflect only site-related variations. Plant design-related variations must be reflected in the probability estimate bounds.

For this level of effort, the calculation of avoided public dose reduces to

$$\underset{\text{(person-rem/reactor-year)}}{\text{Avoided Public Dose}} = \underset{\text{(events/reactor-year)}}{\text{Change in major core-melt frequency}} \times \underset{\text{(person-rem/event)}}{\text{Dose Conversion Factor}}$$

Intermediate Effort

An intermediate effort would employ data developed in existing risk studies which include offsite effects (RSSMAP and IREP studies do not; RSS, Zion, Indian Point, Limerick, and EPRI Oconee studies do). Such studies provide dose conversion factors that can be applied to release category frequencies to yield dose estimates.

$$\underset{\text{(person-rem/reactor yr)}}{\text{Avoided Public Dose}} = \sum_{\substack{\text{Release}\\\text{Categories}}} \underset{\text{(events/reactor-yr)}}{\text{Change in Release Category Frequency}} \times \underset{\text{(person-rem/event)}}{\text{Dose Conversion Factor for Release Category}}$$

The dose conversion factors employed by SPEB/NRR for the prioritization of safety issues are given in Table 3.2. Uncertainty bounds in the range of one to two orders of magnitude are appropriate for the avoided public dose.

TABLE 3.2. SPEB/NRR Dose Conversion Factors[a]

Release Category	Factor (person-rem/event)	Release Category	Factor (person-rem/event)
PWR-1	5.4E+6	BWR-1	5.4E+6
PWR-2	4.8E+6	BWR-2	7.1E+6
PWR-3	5.4E+6	BWR-3	5.1E+6
PWR-4	2.7E+6	BWR-4	6.1E+5
PWR-5	1.0E+6		
PWR-6	1.5E+5		
PWR-7	2.3E+3		

(a) From CRAC, with guidelines and quantities of radioactive isotopes used in WASH-1400. Estimates are based on the meteorology of a typical Midwest site (Byron-Braidwood) with a uniform population density of 340 people/square mile, no evacuation and 50-mile radius release model. The calculated factors can be quite sensitive to changes in these assumptions. As noted in the text, large uncertainty bounds apply to the numbers in the table.

Major Effort

For a major value-impact assessment effort, an analysis would be completed of the affected accident types for the affected reactor sites. Use of representative subsets of accident types and sites would make the effort more manageable. A number of techniques exist for the analysis of radioisotope generation, release, and dispersion. It is beyond the scope of this handbook to describe those methods. Furthermore, they and the data they employ are undergoing significant revision at this time. The analyst should contact the Division of Risk Analysis/RES for further information.

Mitigation of Consequences

It is possible that the proposed action will affect public health through a mitigation of consequences, as well as (or instead of) through a reduction in accident frequency. Should this be the case, the general formulations above are replaced by the following:

$$\text{Avoided Public Dose} = \left[\text{Core-Melt Frequency} \times \text{Dose Conversion Factor}\right]_{\text{Status Quo}} - \left[\text{Core-Melt Frequency} \times \text{Dose Conversion Factor}\right]_{\text{After Action}}$$

If the ratio method is being used, the analysis for public health is complete at this step. If the net-benefit method is being used, the analyst should proceed to the next subsection.

3.2.2 Monetary Valuation of Health Effects

This subsection is not divided into descriptions of limited, intermediate, and major efforts; rather, it contains general guidance.

Monetary valuation of health effects is a difficult and controversial subject about which there is no consensus. A variety of approaches have been suggested and a wide range of numerical values have been estimated as monetary equivalents for each kind of health effect.

In evaluating the health effects of radiation exposure, a basic point of reference is the numerical value of $1000 per person-rem, which appears in the NRC's Policy Statement on Safety Goals (U.S. NRC 1983a, quoted in Section 2.1.2 of this handbook) and in 10 CFR 50, Appendix I as a benefit-cost guideline. The Safety Goals specify that the value is in 1983 dollars and that the guideline is for evaluation during a two-year period for possible subsequent use as "one consideration in decisions on safety improvements." The Safety Goals state further, "The benefits as measured by an incremental reduction of societal mortality risks in terms of person-rem averted should be compared with the reasonably quantifiable costs of achieving that benefit."

The numerical value of $1000 per person-rem has been questioned, and lower values, on the order of $100 per person-rem, have been considered. (See for example, Appendix A of NUREG-0880, U.S. NRC 1982; Voillequé and Pavlick 1982; and Benjamin and Strip 1982.). Values higher than $1000 per person-rem have also been proposed in some contexts, particularly where early fatalities resulting from a reactor accident are concerned.

Given the problematic nature of this issue, the debate about the numerical value of $1000 per person-rem is likely to continue. The best guidance for the analyst is to use a range of values in the analysis so that the sensitivity of the results to different numerical values can be assessed and presented. However, one of the values used in the analysis should be $1000 per person-rem. In any event, the conversion factor used in the net-benefit formula must always be explicitly stated.

An alternative approach, which has some advantages as well as some drawbacks, is to consider a more detailed accounting for health effects. This can be done in several ways. One possibility is to classify health effects into early fatalities, early injuries, delayed cancers, and genetic effects; a monetary equivalent could then be assigned to each of these kinds of effects. A second possibility is to proceed to an even more detailed breakdown, distinguishing between the different kinds of cancers, early radiation injuries and genetic effects, and developing a monetary equivalent for each.

Several efforts along these lines have been attempted. Nieves et al. (1983), for example, have developed a computer model, designed to interface with the CRAC2 reactor accident consequence code, that yields detailed estimates of the economic costs (the direct costs of providing health care, and the indirect costs of productivity losses resulting from illness or premature mortality) of reactor accident health effects, with the costs broken down by type of cancer, type of radiation injury, age, sex and cost category (direct or indirect).

Although more detailed accounting for health effects can provide valuable additional information and insight, further investigations will be needed before any definitive guidance can be developed. The principal advantage of these detailed approaches is that they can provide a more comprehensive picture of health risks and risk reduction. However, they still require difficult evaluations of the monetary equivalents of the various types of health effects.

3.3 OCCUPATIONAL HEALTH (ACCIDENTAL)

The formulations given in this section are for the net-benefit method. The ratio method includes only public exposure in its person-rem evaluation; however, occupational exposure can be calculated and included as a special consideration. The formulation to use with the ratio method is

$$V^{*}_{OHA} = NTD_{OA}$$

where

V^{*}_{OHA} = avoided occupational health risk due to accidents (person-rem).

There are four steps (for the net-benefit method) to developing an assessment of occupational health as it relates to accidents:

1. Estimate the change in accident frequency (see Section 3.1).
2. Estimate occupational exposure (see Subsection 3.3.1).
3. Choose monetary valuation of exposure (see Subsection 3.3.2).
4. Calculate value of occupational health risk avoided as

$$V_{OHA} = NT(D_{OA} \times R)$$

where

V_{OHA} = value of occupational health risk due to accidents avoided ($)

N = number of affected reactors (reactors)

T = average remaining lifetime of affected facilities (years)

D_{OA} = avoided occupational dose per reactor year (person-rem/reactor-year)

R = monetary value of unit dose ($/person-rem).

If individual facility values rather than generic values are used, the formulation above can be replaced with

$$V_{OHA} = R \sum_i N_i \ T_i \ D_{OA_i}$$

where

i = reactor (or group of reactors) index.

3.3.1 Estimation of Occupational Exposure Related to Accidents

There are two types of occupational exposure related to accidents, immediate and long-term. The first occurs at the time of the accident and during the immediate management of the emergency. The second is a long-term exposure, presumably at significantly lower individual rates, associated with the cleanup and refurbishment or decommissioning of the damaged facility. The value gained in the avoidance of both types of exposure must be conditioned on the change in probability of the accident's occurrence (see Section 3.1). Within the discussion of each exposure type, three levels of assessment effort are addressed.

"Immediate" Doses

Licensing of nuclear power plants requires the license applicant to consider and attempt to minimize occupational doses. Radiation protection in the control room is required to limit dose to 5-rem whole body under accident conditions (10 CFR 50, Appendix A, Criterion 19). The experience at TMI indicated that potential for significant occupational exposures exists for activities outside the control room during an accident. (However, there were no individual occupational exposures exceeding 5-rem whole body at TMI.)

An intermediate or limited effort can employ the TMI experience. Generic estimates can be made using the following TMI data. The average occupational exposure related to the incident was ~1 rem. A collective dose of 1000 person-rem could be attributed to the accident. This occurred over a four-month span, after which time occupational exposure was approaching pre-accident levels. An upper bound can be estimated by assuming that the average individual receives a dose equal to that of the maximum individual dose at TMI. The ratio of maximum to average dose for TMI is 4.2 rem/1 rem; therefore, the upper bound for the collective dose can be taken as 4200 person-rem. A lower bound of zero indicates a case where no increase over the normal occupational dose occurs.

Suggested D_{IO} (Immediate Occupational Dose) is then:

Best estimate	1000 person-rem
High estimate	4200 person-rem
Low estimate	0 person-rem

In a major effort, specific calculations to estimate onsite exposures for various accidents could be performed. Computer codes for this function exist (Byoun et al. 1976; Gilbert/Commonwealth 1976).

Long-Term Doses

After the immediate response to a major accident, a long process of cleanup and refurbishment or decommissioning will follow. Significant occupational dose will result (individual exposures controlled by normal occupational dose guidelines).

Rather than describe the normal three levels of value-impact assessment effort, we provide a single recommendation below. This is based on a study (Murphy and Holter 1982) of decommissioning a reference LWR following postulated accidents. Table 3.3 summarizes the occupational doses estimated by the study and is presented for perspective.

This handbook focuses on avoidance of major large-scale accidents. Therefore, use of the following long-term doses is suggested.

D_{LTO} (Long-Term Occupational):

Best estimate	20,000 person-rem
High estimate[a]	30,000 person-rem
Low estimate[a]	10,000 person-rem

(a) Estimated by Murphy and Holter (1982) in NUREG/CR-2601.

TABLE 3.3. Estimated Occupational Radiation Dose from Cleanup and Decommissioning (person-rem)

Activity	Accident Scenario 1[a]	Accident Scenario 2[a]	Accident Scenario 3[a]
Cleanup	670	4,580	12,100
Immediate Dismantlement Decommissioning	1,230	3,060	7,660
Total	1,900	7,640	19,760

- Scenario 1 - a small LOCA in which ECCS functions as intended. Some fuel cladding ruptures, but no fuel melts. The containment building is moderately contaminated, but there is minimal physical damage.

- Scenario 2 - a small LOCA in which ECCS is delayed. Fifty percent of the fuel cladding ruptures, and some fuel melts. The containment building is extensively contaminated, but there is minimal physical damage. (This scenario is presumed to simulate the TMI-2 accident.)

- Scenario 3 - a major LOCA in which ECCS is delayed. All fuel cladding ruptures, and there is significant fuel melting and core damage. The containment building is extensively contaminated and physically damaged. The auxiliary building undergoes some contamination.

(a) Other decommissioning options would yield smaller exposures (see NUREG/CR-2601). Exposures of roughly the same magnitude would be expected if repair and refurbishment were chosen instead of decommissioning. The total manpower would be greater for repair. However, it is assumed that, since the plant would be returned to operation, the cleanup would go further, yielding lower exposure rates for the repair effort as opposed to decommissioning.

Combined Accident-Related Occupational Exposure

To calculate the combined accident-related occupational exposure, the "immediate" and long-term occupational doses must be added. This sum is then multiplied by the change in accident frequency (see Section 3.1) which is postulated as a result of the proposed action.

$$D_{OA} = \Delta F(D_{IO} + D_{LTO})$$

where

ΔF = change in accident frequency (events/reactor-year)
D_{OA}, D_{IO}, D_{LTO} as defined above.

It is possible that the proposed action will mitigate accident-related occupational exposures instead of (or as well as) changing the accident probability. In any case, it is the change from current condition to that following implementation of the proposed actions that is sought. The formulation above can be replaced with the more explicit formulation below:

$$D_{OA} = [F(D_{IO} + D_{LTO})]_S - [F(D_{IO} + D_{LTO})]_A$$

where

S = status quo (current conditions)
A = after proposed action is implemented.

3.3.2 Monetary Valuation of Accident-Related Occupational Exposure

It is recognized that accident-related occupational exposure contains a diversity of exposure levels and that monetary evaluation of any type of exposure is very difficult. However, it may be assumed that the monetary calculations used for public health are adequate measures for accident-related occupational exposures. As discussed in Section 3.2.2, the analyst should use a range of values in the analysis so that the sensitivity of the results to different numerical values can be assessed. One of the values used in the analysis should be $1000 per person-rem.

The analyst may wish to weight occupational exposures relative to public exposures; for example, by assigning different weights to occupational exposures to reflect the argument that workers are compensated, at least in part, for the risks incurred. However, justification should be provided for the weights employed.

3.4 OCCUPATIONAL HEALTH (ROUTINE)

The formulations given in this section are for the net-benefit method. The ratio method includes only public exposure in its person-rem evaluation; however, occupational exposure can be calculated and included as a special consideration. In that event the formulation to use is

$$V^*_{OHR} = N(TD_{ORO} - D_{ORI})$$

where

V^*_{OHR} = change in occupational health risk from routine activities (person-rem).

N, T, D_{ORO}, D_{ORI} as defined below.

There are three steps to developing an assessment of the change in routine occupational exposure due to the proposed actions:

1. Estimate the change in occupational exposure associated with the implementation and operation of the proposed actions (see Subsection 3.4.1).

2. Choose a monetary valuation of exposure (see Subsection 3.4.2).

3. Calculate the value of the change in occupational health risk as

$$V_{OHR} = NR(TD_{ORO} - D_{ORI})$$

where

V_{OHR} = value of the change in occupational health risk ($)

N = number of affected reactors (reactors)

R = monetary value of unit dose ($/person-rem)

T = average remaining lifetime of affected facilities (years)

D_{ORI}[a] = per-reactor increase in occupational dose required to implement the proposed action (person-rem/reactor)

D_{ORO}[a] = annual per-reactor change in occupational dose to operate following implementation of the proposed action (person-rem/reactor-year).

(a) Note algebraic sign. Any change which causes a reduction in occupational exposure is a benefit and has a positive sign. If, however, the change increases occupational exposure, that is a disvalue and has a negative sign. The dose for implementation should be an increase and is therefore entered into the equation above with a negative sign.

If individual facility values rather than generic values are used, the formulation above can be replaced with

$$V_{OHR} = R \sum_i N_i \; (T_i \; D_{ORO_i} - D_{ORI_i})$$

where

i = reactor (or group of reactors) index.

3.4.1 Estimation of Change in Occupational Exposure Associated with Implementation and Operation

A proposed NRC action can affect routine occupational exposures in two ways. It may cause a one-time increase in occupational dose due to implementation of the action (e.g., installing a retrofit). It may also cause a change (either increase or decrease) in the recurring occupational exposures after the action is implemented. A new coolant system decontamination technique, for example, may cause a small implementation dose but may result in a decrease in annual exposures from maintenance thereafter. The discussion below is divided into three portions corresponding to the level of effort to be dedicated to the value-impact assessment.

Limited Effort

In a limited effort, estimates for the implementation doses would follow the same prescription as for the intermediate effort below, though at a less rigorous level. To estimate changes in operational dose, the analyst may directly estimate fractional changes for operational doses. The average annual collective occupational dose for light water reactors in 1980 was 791 person-rem/reactor. Individual facilities varied from a range of 200-300 person-rem/reactor-year to more than 1000 person-rem/reactor-year (see Brooks 1980). See Section C.4 of Appendix C for more data on occupational exposure experience.

Intermediate Effort

In an intermediate effort, the analyst (if sufficiently knowledgeable) may attempt to make exposure estimates. In any event, within an intermediate effort, the analyst should attempt to obtain at least a sample of utility input or other technical data for a validation of the estimates developed.

There are two components in the development of an exposure estimate: estimating the radiation field (rem/hour) and estimating the labor hours required. Clearly, the product is the exposure (person-rem). In developing operational estimates, the annual frequency of the activity is also required.

General estimates of radiation fields can be obtained from a number of sources. Chapter 12 of every power plant's FSAR will contain a partitioning of the power plant into estimated radiation zones. Both summary tables and plant layout drawings are usually provided. Some FSARs provide exposure estimates for specific operational activities. The analyst must be cautioned that the FSAR values are calculated, not measured. Actual data from operating facilities, as might be obtained from facility surveys, would have greater accuracy.

In estimating labor requirements, knowledgeable industry staff members (utilities or consultants) are again the best sources. If the analyst develops estimates, the following four suggestions are offered:

- Remember that work is probably to be performed in clumsy radiation protection gear.
- Remember that work is likely to be performed in close quarters and in awkward positions.
- Be aware that Murphy's Law applies (anything that can go wrong will go wrong).
- Set uncertainty bounds realistically, based on consideration of the factors above and a realistic assessment of the information available.

Keeping these factors in mind, the analyst can proceed with the estimation of implementation and operational doses.

The implementation dose would be

$$D_{ORI} = F_R \times W_I$$

where

D_{ORI} = per-reactor occupational dose required to implement the proposed action (person-rem/reactor)

F_R = radiation field in area of activity (rem/hour)

W_I = work force required for implementation (labor-hours/reactor).

The operational dose is the change from the current level;[a] its formulation is

$$D_{ORO} = (F_R\ W_O\ A_F)_S - (F_R\ W_O\ A_F)_A$$

where

D_{ORO} = annual per-reactor change in occupational dose to operate following implementation of the proposed action (person-rem/reactor-year)

F_R = radiation field in area of activity (rem/hour)

W_O = work force required for activity (labor-hours/reactor-activity)

A_F = number of activities (e.g., maintenance, tests, inspections) per year (activities/year)

S = status quo (current level)

A = after implementation of proposed action.

Major Effort

In a major effort to estimate both the implementation and operational exposures, the best source of data would be a thorough survey of health physicists at the affected plants. This survey could be screened for bias and potential inflated value by a knowledgeable third party. OMB approval of such a survey may be required.

3.4.2 Monetary Valuation of Routine Occupational Exposure

It is recognized that individual routine occupational exposures are controlled. However, it may be assumed that the monetary calculations used for public health in the event of accidents are adequate measures for routine occupational exposures. As discussed in Subsection 3.2.2, the analyst should use a range of values in the analysis so that the sensitivity of the results to different numerical values can be assessed. One of the values used in the analysis should be $1000 per person-rem.

(a) Note the sign convention. When the dose is reduced, the sign is positive; when increased, it is negative.

The analyst may wish to weight occupational exposures relative to public exposures; for example, by assigning different weights to occupational exposures to reflect the argument that workers are compensated, at least in part, for the risks incurred. However, justification should be provided for the weights employed.

3.5 OFFSITE PROPERTY

The ratio method does not explicitly include offsite property. However, it may be included as a supplementary consideration. The formulations below apply to either a ratio method supplementary consideration or the net-benefit method.

In estimating the effect of the proposed action upon offsite property, three steps are involved:

1. Estimate change in accident frequency (see Section 3.1).
2. Estimate level of property damage.
3. Calculate change in risk to offsite property as

$$V_{FP} = N \Delta F D$$

where

V_{FP} = value of avoided offsite property damage
N = number of affected facilities
ΔF = change in accident frequency
D = present value of property damage which occurs with frequency F.

It is possible that the proposed action mitigates the consequences of an accident as well as, or instead of, reducing the accident probability. The value of the action is then

$$V_{FP} = (NFD)_S - (NFD)_A$$

where

S = status quo (before the action)
A = status after the action.

An important tool used by the NRC to estimate accident consequences is the computer program CRAC2. This program provides rough estimates of evacuation costs, relocation costs for displaced persons, property decontamination costs, the loss of use of contaminated property through interdiction, crop and milk losses and health effects. Additional information can be found in Section C.4 of Appendix C.

Three levels of analysis, each more complex but providing more reliable estimates than the preceding, are described below for estimating the offsite accident consequences.

3.5.1 Limited Effort

For this level of analysis, it is recommended that estimates be obtained directly from NUREG/CR-2723 (Strip 1982). This study reports the present discounted value of offsite health costs, offsite property costs, onsite costs and replacement power costs for accidents of release categories SST1 thru SST3 for 91 sites in the U.S. with licensed reactors or construction permits.[a] The offsite property costs are based directly on CRAC2 results. The results reported in the study are based on a number of simplifying assumptions, but they are judged satisfactory for a limited analysis.

Strip (1982) provides discounted offsite property cost values. However, these are discounted at a real discount rate of 4%. The Regulatory Analysis Guidelines suggest a 10% real discount rate. Strip's data permits discounting at any rate, using the following procedure. The analyst must identify (from Strip 1982) the "Scaled Result: Mean Offsite Effects Conditional on Release" for the reactor site in question. This is the mean cost of the set of accidents making up the accident category. The present value of this generic accident can be calculated as

$$D = C \times B$$

where

D = present value of property damage conditional upon release

$$C = \frac{e^{-rt_i} - e^{-rt_f}}{r}$$

(a) See Strip (1982) for a description of accident groups 1 through 5 and the five release categories with which they are associated.

t_f = 35 - 1983 + A(years remaining until end of reactor life, assuming a 35-year lifetime)[a]

$t_i = \begin{cases} A - 1983 & \text{if } A > 1983 \\ 0 & \text{if } A < 1983 \end{cases}$ (years before reactor begins operating)

r = real discount rate (for 10%, r = .10)

B = "Scaled Result: Mean Offsite Effects Conditional on Release: Property Damage"

A = Date of Operation.

The quantity, D, must be interpreted carefully to avoid misunderstandings. It does not represent the expected property damage due to a single accident. Rather, it is the present value of a stream of potential losses extending over the remaining lifetime of the reactor. Thus, it reflects the expected loss due to a single accident (this is given by the quantity, B); the possibility that such an accident could occur, with some small probability, at any time over the remaining reactor life; and the effects of discounting these potential future losses to present value. When the quantity, D, is multiplied by the probability of an accident of the specified type, the result is the expected loss over the reactor life, discounted to present value.

If the number of reactors affected is small, the analyst can, in a limited effort, evaluate each one individually and sum to achieve a total. However, if this is not practical a mean value calculated from the 154 reactors examined in Strip (1982) can be used.[b] Table 3.4 shows this calculated mean as a scaled result discounted at 10% and 4% for an SST1 release. Also given in the table are values for Indian Point No. 2 and Palo Verde No. 3 to indicate bounds. Use of the 10% values is suggested by the Regulatory Analysis Guidelines, although other values should also be used for sensitivity testing. The analyst is cautioned that use of the SST1 values may tend to overestimate risk.

The conditional property damage value does not have meaning unless it is multiplied by the accident frequency. Their product is the value of the expected risk.

(a) Strip uses a 40-year reactor lifetime. The formulations here suggest 35 years.
(b) A number of these reactors have been canceled. However, for generic use the mean value should be adequate.

TABLE 3.4. Generic SST1 Release Offsite Property Damage--Conditional on Release

Reactor	Year of Operation	Scaled Value ($)	Discounted[a] 10% ($)	Discounted[a] 4% ($)
Mean	1980[b]	1.67E9	1.6E10	3.0E10
Indian Point No. 2	1974	9.20E9	8.5E10	1.5E11
Palo Verde No. 3	1986	8.30E8	6.0E9	1.4E10

(a) These are discounted present values of potential losses summed over plant life, and therefore are not the costs of any single accident. If the frequency of an SST1 release were estimated to be 1.0E-5, then the lifetime risk for Indian Point (discounted at 4%) would be $1.5E6. The discount rates shown are real discount rates, i.e., they do not include inflation.
(b) This operation date is the mean of the 154 reactors given in Strip (1982).

3.5.2 Intermediate Effort

For this level of analysis, it is recommended that the analyst identify the affected reactors and release categories, then calculate the proper sum effect rather than relying on the SST1 generic values employed in the limited effort above. The following steps are required:

1. Identify affected reactors.
2. Identify changes in accident frequency by release category.
3. Recalculate present value of property damage with an appropriate real discount rate (10% is suggested by the Regulatory Analysis Guidelines, although other values should also be used for sensitivity testing).
4. For each reactor, calculate avoided property damage value.
5. Sum avoided property damage over affected reactors.

3.5.3 Major Effort

For this level of analysis, it is recommended that the estimates be derived from more site-specific information than used in Strip (1982). The estimates in Strip are based on 1970 population estimates and state-wide land use. For this level of analysis, the CRAC2 calculation should be redone, using 1980 population and land-use data at least down to county level. This degree of effort would be relatively costly to conduct, both in terms of computer costs and data collection and interpretation costs. However, it would provide the highest degree of reliability.

3.6 ONSITE PROPERTY

The ratio method does not explicitly include onsite property. However, it may be included as a special consideration. The formulations below apply to either the net-benefit method or a special consideration for the ratio method.

In estimating the effect of the proposed action upon onsite property, three steps are involved:

1. Estimate change in accident frequency (see Section 3.1).
2. Estimate onsite property damage.
3. Calculate change in risk to onsite property as

$$V_{OP} = N\Delta FU$$

where

V_{OP} = value of avoided onsite property damage
N = number of affected facilities
ΔF = change in accident frequency
U = present value of property damage occurring with frequency F.

It is possible that the proposed action mitigates the consequence of an accident, as well as (or instead of) reducing the accident probability. In that event, the value of the action is

$$V_{OP} = (NFU)_S - (NFU)_A$$

where

S = status quo (before the action)
A = status after the action.

It is convenient to treat onsite property costs under three categories: 1) the cost of interdicting/decontaminating onsite property, 2) the cost of replacement power, and 3) repair and refurbishment costs. Each of these categories is considered below. Throughout this analysis, the focus is on large-scale core-melt accidents. Additional information and references can be found in Section C.4 of Appendix C.

The analysis of these components can be approached with a variety of effort levels. A limited effort and its expansion for higher levels are given below.

3.6.1 Limited Effort

For this level of analysis, generic estimates (Andrews et al. 1983) can be used for cleanup, repair and refurbishment, and replacement power costs (see Table 3.5). The repair and refurbishment costs are based on the cost of decommissioning an LWR following a postulated accident and are felt to be a reasonable approximation of the repair and refurbishment costs that would be incurred.

TABLE 3.5. Estimated Costs for Cleanup, Repair and Refurbishment, and Replacement Power (Andrews et al. 1983)[a]

Scenario	Costs
1	= \$72M cleanup + \$49M repair/refurbish + \$600M replacement power = \$720M over a 5 1/2-year period
2	= \$165M cleanup + \$48M repair/refurbish + \$822M replacement power = \$1035M over a 7 1/2-year period
3	= \$373M cleanup + \$106M repair/refurbish + \$1172M replacement power = \$1650M over a 10-year period

- Scenario 1 - a small LOCA in which ECCS functions as intended. Some fuel cladding ruptures, but no fuel melts. The containment building is moderately contaminated, but there is minimal physical damage.
- Scenario 2 - a small LOCA in which ECCS is delayed. Fifty percent of the fuel cladding ruptures, and some fuel melts. The containment building is extensively contaminated, but there is minimal physical damage. (This scenario is presumed to simulate the TMI-2 accident).
- Scenario 3 - a major LOCA in which ECCS is delayed. All fuel cladding ruptures, and there is significant fuel melting and core damage. The containment building is extensively contaminated and physically damaged. The auxiliary building undergoes some contamination.

(a) The estimates in Andrews et al. (1983) were derived from the detailed study by Murphy and Holter (1982), which includes comparative information on Three Mile Island cleanup costs.

None of the costs in Table 3.5 have been discounted. A present value of onsite damage can be calculated by discounting the combined cost of the recovery and replacement power, taking into account the years required for recovery and the years at risk. The result does not have meaning unless multiplied by the accident frequency. Their product is the expected value of the risk. The formulation (see Section C.1.3 of Appendix C for discussion of continuous discounting)

$$U = \frac{(C_c + C_r + C_{rp})}{m} \left(\frac{e^{-rt_i}}{r^2}\right) \left(1 - e^{-r(t_f - t_i)}\right) \left(1 - e^{-rm}\right)$$

where

U = present value of onsite property damage conditional upon release

C_c = cleanup cost

C_r = repair/refurbishment cost

C_{rp} = replacement power cost

t_f = 35 - 1983 + A (years remaining until end of reactor life, assuming 35-year lifetime)

$t_i = \begin{Bmatrix} A - 1983 & \text{if } A > 1983 \\ 0 & \text{if } A < 1983 \end{Bmatrix}$ (years before reactor begins operating)

r = discount rate (for 10%, r = .10)

A = date of operation

m = years required to return utility to pre-accident state.

Applying this formulation (at a 10% real discount rate, assuming 1980 start-up date) to the data in Table 3.5 results in the suggested values below. The best estimate is based on Scenario 3. The low estimate is based on Scenario 2, and the high estimate is taken as three times the best estimate.

The suggested values for U (present value of onsite property damage, conditional upon release; i.e., must be multiplied by accident frequency) are

Best estimate	\$1.0E+10
High estimate	\$3.0E+10
Low estimate	\$7.0E+9

The quantity, U, must be interpreted carefully to avoid misunderstandings. It does not represent the expected onsite property damage due to a single accident. Rather, it is the present value of a stream of potential losses extending over the remaining lifetime of the reactor. Thus, it reflects the expected loss due to a single accident; the possibility that such an accident could occur, with some small probability, at any time over the remaining reactor life; and the effects of discounting these potential future losses to present value. When the quantity, U, is multiplied by the accident frequency, the result is the expected loss over the reactor life, discounted to present value.

3.6.2 Intermediate and Major-Level Efforts

High-level analyses provide a greater level of detail, and there are two general ways to achieve this: 1) the analysis can be conducted for individual plants or groups of similar plants, using site-specific information; 2) the analysis can provide cost information in much greater detail. With regard to the first approach, the most relevant site-specific information includes the cost of replacement power and the value of the plant and equipment at risk, taking into account the remaining useful life of the plant.

Greater accuracy can be achieved by using the formulation for determining cost-of-replacement-power developed by Argonne National Laboratory (ANL) (Buehring and Peerenboom 1982). A simplified version of the ANL approach calculates costs of replacement power based on the replacement fuel cost and power availability in each National Electric Reliability Council (NERC) region. This includes a credit for the avoided variable fuel cycle cost of the shut-down reactor. The simplified formula is[a]

$$C = (0.13 \times R + 0.12)10^6 \text{ \$/MW year}$$

Table 3.6 gives values of the R parameter, which is the fraction of replacement energy by oil-fired or noneconomical power purchases, for each NERC region. The fractions in Table 3.6 reflect 1981 conditions and may change over time. Note also that the fractions represent average conditions within a region; individual utilities may vary. Figure 3.1 shows the NERC regions.

In applying the simplified formula for estimating replacement power costs, the analyst should be aware of the several important assumptions and qualifications. The formula provides an estimate in 1981 dollars of the increase in production costs associated with a one-year reactor outage. It incorporates

(a) W. Buehring, Argonne National Laboratory. Personal communication, September 1983.

TABLE 3.6. Fraction of Replacement by Oil-Fired or Noneconomical Power Purchases

NERC Region		R
MARCA		0.20
NPCC		0.95
MAAC		0.50
MAIN		0.15
ERCOT		0.50
SPP		0.40
WSCC	California	0.95
	Not California	0.25
SERC		0.15
ECAR		0.05
National Average		0.41

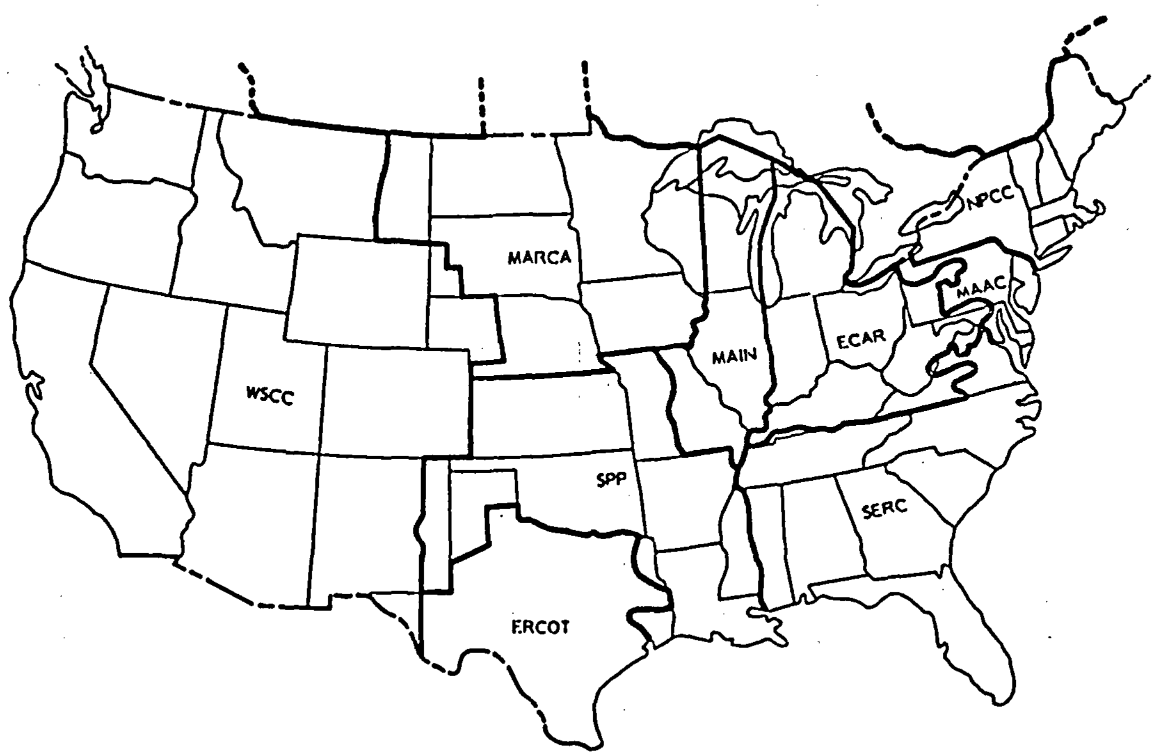

FIGURE 3.1. NERC Regions

replacement fuel costs, including the costs of purchased power, and the change in variable operation and maintenance costs. Although the relationship is reasonable for short-term outages (less than 5 years), it may be less reasonable for longer term outages, especially if there are changes in a utility's capacity expansion plans. Also the relationship was developed for a reactor with an assumed capacity factor of 65%. For different assumed capacity factors, the results should be multiplied by the ratio: assumed capacity factor (in percent) divided by 65%. For more precise estimates of replacement power costs, Appendix C.4 describes a computer simulation model developed by ANL.

Finally, with regard to providing greater detail on the cost information, the major cost elements (in addition to replacement power) are likely to include decontamination and other cleanup costs and repair or replacement of plant and equipment that is physically damaged. Other costs relate to transporting and disposing of contaminated materials and equipment, and startup costs. Costs for monitoring the site for radiation and fixing contamination at the site will likely be insignificant relative to the other costs. The analyst is referred to Murphy and Holter (1982) for detailed cost estimates for decontaminating a nuclear reactor following a postulated accident.

3.7 REGULATORY EFFICIENCY

The discussions of other attributes have described the methods by which these factors can be quantified and, for the net-benefit method, expressed in terms of dollars. However, a number of attributes may be difficult to quantify; one of these is improvements in regulatory efficiency. If quantification is not practical, regulatory efficiency can be treated as a supplementary consideration. The fact that this attribute may be difficult to quantify in monetary terms does not mean that it has little significance.

In some instances, one can be explicit about the way in which a regulatory action leads to measurable improvements. For example, an action to reduce the industry's reporting requirements would have two major positive effects: it would reduce the industry's costs of report preparation, and it would reduce the NRC's cost of processing and storing information contained in the reports. However, the societal cost would have to be evaluated if the NRC did not have the information contained in the reports. If, for instance, during a certain type of accident, property damage would likely be increased by 50% because the NRC did not possess the information necessary to take the appropriate remedial action, then the expected annual loss to society would be this increase in property damage multiplied by the probability of that accident's occurring in each year. The societal cost of no longer requiring the information would simply be the present value of the expected annual losses. To arrive at the net effort, this cost would be compared to the present value of the benefits to the NRC and to the industry.

To the extent that the costs and benefits of regulatory actions can be made explicit, as in the above example, they should be treated by other attributes described in this handbook. If this is done, it would be inappropriate to treat increased regulatory efficiency as an additional benefit from the action, as this would double count the benefits. On the other hand, if the effects from the action are not easily quantified, then the analyst still has the burden of identifying benefits and costs and providing some indication of their likely magnitude. Merely stating that the action will improve regulatory efficiency falls short of adequate justification. Rather, an effort should be made to identify the types and recipients of benefits and costs likely to accrue. Finally, it would be helpful if such benefits and costs could be compared with those that are quantified in the analysis, using terms like "much greater than," "somewhat greater than," "about the same as," "somewhat less than," and "much less than." This technique is illustrated by the following statement:

> The proposed regulation would require each of the affected utilities to hire an extra person to carry out the proposed regulation. However, since these utilities generally support the proposed regulatory change, it may be inferred that they expect to derive benefits from improved regulatory efficiency that are at least comparable to their costs.

If the proposed NRC action is expected to have major effects on regulatory efficiency, then a proper evaluation of these effects may require a level of effort commensurate with their magnitude. This may mean expending resources to obtain the judgments of experts outside of the NRC if the necessary expertise is not available in-house.

To obtain useful information, one can solicit expert opinion in a number of ways.[a] One way is to convene the experts in a roundtable discussion with the objective of reaching a consensus. This technique has some of the drawbacks of a committee meeting; often the assumptions are not made explicit, and strong-willed (or strong-voiced) individuals often carry undue weight.

Another way of pooling expert opinions in a systematic manner is to use one of the numerous procedures for iterative group decision making. For example, the Delphi Technique is a procedure that features an anonymous exchange of information or expert opinion. This approach is designed to encourage the modification of earlier answers by each expert so that a group consensus can be achieved. Even if consensus is not achieved, information is produced that allows the analyst to compile statistical estimates of the responses.

(a) A general discussion of these methods and others is found in Quade (1975), especially Chapter 12, "When Quantitative Models are Inadequate."

Whether the assessment is performed by a panel of experts or by the analyst, the following are questions that might be considered in order to focus that assessent.

- Does this action conflict with any other NRC/federal/state directives?
- Are there any nuclear plants for which (or conditions under which) this action might have unexpected or undesirable consequences?
- Do you foresee any major enforcement problems with this action or regulation?
- What sort of adjustments might industry undertake to avoid the regulation's intended effect(s)?
- How will the regulation impact productivity in the nuclear/electric utility industries?
- How will this action affect plant licensing times?
- How will this action affect the regulatory process within the NRC?

Other questions should include references to the specific action being proposed.

3.8 IMPROVEMENTS IN KNOWLEDGE

This attribute relates primarily to proposals for conducting research. A significant share of the NRC's budget is devoted to research which has as its primary goal the improvement in knowledge of nuclear-related processes under both normal and abnormal operating conditions. At least three major potential benefits are derived from the knowledge produced by such research: 1) improvement of the materials used in reactor facilities; 2) improvement or development of safety procedures and devices; and 3) production of more robust risk assessments and safety evaluations--because the knowledge reduces uncertainty about the relevant processes.

If the research is directed toward a very narrow problem--for example, reducing the fracture failure rate of a particular component in a specific application--then it may be reasonable to quantify the expected benefits from the research in terms of safety, or in terms of a monetary equivalent. The relevant benefits might include lower frequency of replacement and lower risk of an accident. On the cost side might be higher materials and fabrication costs. The dollar value for each of these components can be estimated, as described elsewhere in this handbook.

To the extent that the costs and benefits of regulatory actions can be made explicit, as in the above example, they should be treated by other attributes described in this handbook. Then, it would not be appropriate to treat improvement in knowledge as an additional benefit, since the benefits would then be double counted. On the other hand, if the potential benefits from the research are difficult to identify or are otherwise not easily quantified, then the analyst still has the burden of justifying the research effort by identifying possible benefits and providing some indication of their likely value. This justification would take the form of a supplementary consideration. In addressing this attribute, merely stating that the research would improve understanding of reactor processes falls short of adequate justification. Rather, an effort should be made to identify the types of benefits and costs that are likely to accrue and to whom.[a]

Consider the following statement:

> This research effort has a reasonable prospect of reducing our uncertainty regarding the likelihood of containment failure resulting from hydrogen burning. Such an accident may be a significant source of risk. The knowledge from the proposed research would enable us to assess more accurately the overall accident risk posed by nuclear reactors, and this in turn should benefit the public through better policy decisions.

While this statement describes why the proposed research is needed, no information is provided for evaluating the merits of the proposed research. Providing answers to the following questions would help to fill this information gap.

- What are the likely consequences of a hydrogen-burning accident? Onsite property damage? Offsite property damage? Health effects?
- What is currently known about the likelihood of a hydrogen-burning accident occurring? To what extent would the proposed research reduce the uncertainty in our knowledge?
- Given our current information, what is the contribution of hydrogen burning to overall accident risk?

The above questions are specific to a particular research topic. For the broader problem of providing a value-impact analysis of a research proposal, it is recommended that the analyst be responsive to the following list of more general questions.

(a) A systematic approach for prioritizing NRC research needs and research programs is discussed in Vesely et al. (1983).

- What are the research objectives?
- If the research is successful in meeting its objectives, what will be the social benefits?
- Is there a time constraint on the usefulness of the research results; that is, must the objectives be met by a certain time if the results are to be useful?
- Who will benefit from the research results? How large will be the benefits? When will the benefits accrue?
- What is the likelihood that the research will fail to meet its objectives within the time and budget constraints? In the event of failure, will some partial benefits still remain?
- What will be the social costs (and benefits) if the research is not successful, or if the research is not undertaken?

Some final observations may be useful to the analyst in providing a value-impact analysis of proposed research. First, an output of Research Project A may be used directly in the regulatory process, and/or it may be used as input into Research Project B. If the latter is the case, then it may be extremely difficult to separate the value of Research Project A from that of Project B. This situation often characterizes basic research.

Secondly, evaluating the benefits from basic research is substantially more difficult than evaluating the benefits from applied research, because with basic research, the benefits often occur many years after the original research investment; typically, there is a moderate to high risk that the anticipated benefits will fail to materialize; and the most important consequences of the research are sometimes highly successful applications that were never anticipated by the original sponsors and researchers.

These three characteristics have implications for the analyst. The first means that the present value of the benefits from basic research may be only a small fraction of the contemporaneous benefits because of discounting. The second characteristic means that a realistic assessment may require assigning a low probability that the research will succeed. The history of success and failure within the relevant research area and by the proposed research team can be a useful guide. The third characteristic suggests that other societal benefits may result from the research, but that because such benefits cannot be anticipated, one cannot assign a value to them. However, the possibility of unanticipated benefits can be mentioned within the analysis.

Finally, if the goal of the research is to increase plant safety, then one possible approach that the analyst may wish to consider is to estimate the risk posed by the relevant accident sequences. In this approach, the probabilities of the accident sequences are estimated as described in Section 3.1; the onsite and offsite accident consequences are estimated as described in Sections 3.2, 3.3, 3.5 and 3.6. The accident risk, which can be expressed as the product of accident probability multiplied by the consequences, can then be used as an upper bound on the potential for the research to reduce accident risk. Given the nature of the proposed research, the analyst may be able to narrow its potential further.

3.9 INDUSTRY IMPLEMENTATION

This section of the handbook provides procedures for computing estimates of the industry's incremental costs to comply with the proposed action. The incremental costs measure the additional cost to industry imposed by the regulation; they are costs that would not have been incurred in the absence of that regulation. In general, there are four steps that the analyst should follow in order to estimate implementation costs:

Step 1. Estimate the plant equipment, materials, and/or labor that will be affected by the proposed action.

Step 2. Compute capital costs.

Step 3. Compute replacement power costs.

Step 4. Sum the implementation costs and discount if appropriate.

Three levels of analytical effort describing these steps are presented later. Each level refers back to the accounting cost sheet that is included (Table 3.7). Additional information sources are contained in the bibliography at the end of Section 3.10.

In preparing an estimate of industry implementation costs, the analyst should also carefully consider other cost categories that may be affected as a result of implementing the action. In practice, this may be only one line of the cost accounting table (see Table 3.7). While elements of the table are broadly classified, the analyst should also carefully consider other cost categories that may be affected as a result of implementing the action.

The analyst should be aware of the NRC's Cost Analysis Group as a potential source of information. It is in the process of developing an information base of cost estimates that might be helpful in a regulatory or value-impact analysis.

TABLE 3.7. Industry Implementation: Cost Accounting Table

	Incremental Cost of a Regulation			
	Capital (1)	Labor (2)	Materials (3)	Total (4)
Direct Costs				
Land and land rights				
Structures and site facilities				
Reactor plant equipment				
Turbine plant equipment				
Electric plant equipment				
Miscellaneous plant equipment				
Special materials				
Total Direct Costs				
Spare parts[a]				
Contingency allowance[a]				
Subtotal				
Indirect Costs[b]				
Construction facilities, equipment and services[a]				
Engineering and construction management[a]				
Owner's cost[a]				
State and local sales taxes[c]				
Interest during construction[a]				
Escalation during construction[a]				
Total Indirect Costs				
Total Capital Costs	___	___	___	___
Replacement Power Costs[d]	___	___	___	___
Total Industry Implementation Costs				

(a) See Schulte, Willke and Young (1978) for an explanation of these terms. Essentially, the terms are accounting concepts and are usually estimated as a percentage of total direct costs. Rather than using accounting principles to estimate these costs, actual cash expenditures (e.g., for spare parts) should be used.

(b) Many indirect costs occur primarily for plants under construction. Indirect costs are included in the table for completeness.

(c) From the perspective of national economic efficiency, taxes can be ignored because they are merely transfer payments. To the economy as a whole they are neither costs nor benefits. From a local or industry perspective, however, taxes are important. Taxes are included in the table for completeness.

(d) Includes fuel cycle cost savings.

3.9.1 Limited Effort

This level of effort uses highly aggregated or consolidated information to estimate the cost to industry for implementing the action.

Step 1. Estimate the plant, equipment, materials, and/or labor that will be affected by the proposed action. The analyst should attempt to identify all components of cost that will be affected by the action. These include not only physical equipment and craft labor, but professional staff labor for design, engineering, quality assurance, and licensing associated with the action. If the action requires work in a radiation zone, the analyst should account for the extra labor required by radiation exposure limits and low worker efficiency due to awkward radiation protection gear and tight quarters. The analyst should include contingencies and be generous in the estimation of uncertainty bounds.

Step 2. Compute capital costs. Capital costs for nuclear power plants consist of both direct and indirect components. Direct costs include plant, materials, equipment, and labor used for the construction and operation of the plant. Indirect costs include services and financing required for construction. The analyst should specify those entries in the cost accounting framework (Table 3.7) that are directly affected by the proposed action, and should then identify any significant secondary costs that may arise as a result.[a]

Scheduled component replacement costs are the expected annual costs for routine maintenance and replacement of major (cost greater than $10,000) reactor components. All labor costs associated with replacing equipment should be accounted for here. Costs of minor materials, however, are to be included in the operation costs accounts in Section 3.10. For additional information on capital costs and component costs, see Schulte, Willke, and Young (1978) and United Engineers and Constructors (1979).

Step 3. Compute replacement power costs. If the action requires, for instance, that a piece of new equipment be installed, and this can be completed within a previously scheduled outage time, then no replacement power cost should be assigned to the action. Alternatively, if the time required to install this equipment exceeds the time already scheduled for outage, then costs for the additional replacement power needed beyond the already scheduled outage time should be included in the cost estimate.

(a) The NRC's Cost Analysis Group is currently developing capital-cost estimates for a number of repairs and common procedures associated with modifications to steam generators. These generic estimates will be useful for value-impact assessments. Results are expected by late 1983.

Replacement power costs for any unscheduled outage that is used to replace, retire, or add equipment because of an NRC requirement should be counted in full. See Section 3.6 for replacement power cost estimation.[a]

Step 4. Sum the implementation costs and discount if appropriate. If costs are spread over a number of years or occur at some future time, they should be discounted to yield present value. (See Section C.1.2 of Appendix C.) If all costs occur in the first year or if present value costs can be directly estimated, discounting is not required.

3.9.2 Intermediate Effort

This level of analysis is performed in greater detail than a limited effort.

Step 1. At this level of effort, the analyst should consult engineering and costing experts, contractors, architect engineering firms or utilities. Also, other NRC branches and the Cost Analysis Group may provide guidance.

Step 2. See Limited Effort.

Step 3. See Limited Effort.

Step 4. See Limited Effort.

3.9.3 Major Effort

This level of analysis involves very detailed information, both in terms of the cost breakdowns and the total capital cost categories.

Step 1. For this level, the analyst should definitely seek expertise beyond the NRC, possibly guidance from NRC contractors or industry sources experienced in this area (AE firms, etc.); the NRC's Cost Analysis Group has on-call contractor support in the area of cost analysis.

Step 2. The incremental costs of the action are classified by the costs for capital equipment, labor, and materials. The direct and indirect costs, however, are defined at a finer level of detail. The analyst, having determined what indirect and direct costs are affected by the action, should refer to the code of accounts in Schulte, Willke and Young (1978) to prepare a detailed account of implementation costs. An example of this procedure is presented below.

(a) The NRC's Cost Analysis Group is currently developing replacement power cost estimates for near-term, short-duration outages of this nature. Results, on a plant-by-plant basis, are expected by late 1983.

Consider that a certain regulation initially affects only "Radioactive Waste Treatment and Disposal." In that case, the analyst should refer to the code of accounts in Schulte, Willke and Young (1978) for "Reactor Plant Equipment." The cost account will be slightly modified since the analyst will subclassify reactor plant equipment in the following manner:

Reactor Plant Equipment	Incremental Cost of a Regulation			
	Capital (1)	Labor (2)	Materials (3)	Total (4)
Radioactive Waste Treatment and Disposal				
Liquid Waste Processing and Equipment				
Gaseous Wastes and Off-Gas Processing System				
Solid Wastes Processing Equipment				
	___	___	___	___

Step 3. See Limited Effort.

Step 4. See Limited Effort.

3.10 INDUSTRY OPERATION

This section of the handbook provides procedures for computing estimates of the industry's incremental costs, capital and operational, during the operating phase (i.e., after implementation) of the proposed action. The incremental cost measures the additional cost, or possibly cost savings, to industry imposed by the proposed action; it is a cost that would not have been incurred in the absence of the action.

In general, there are four steps that the analyst should follow in order to obtain industry operating cost estimates:

Step 1. Estimate the plant equipment, materials, and/or labor that will be affected by the proposed action.

Step 2. Consider any additional capital costs (see Section 3.9) that may be incurred after the proposed action is implemented.

Step 3. Compute the incremental operating and maintenance costs to the industry from the proposed action.

Step 4. Discount the costs over the remaining lifetimes of the affected facilities.

Costs incurred for operating and maintaining nuclear power plants include direct and indirect components. Direct costs include materials and labor needed for the immediate operation and maintenance of the plant, such as plant operators and maintenance staff. Indirect costs are those associated with the overall operation of the plant, such as taxes, insurance, and administrative and general expenses. References to additional information are contained in the bibliography at the end of this section.

The discussion below is divided into three portions which correspond to the level of effort to be dedicated to the value-impact assessment.

3.10.1 Limited Effort

Step 1. Estimate operating costs of plant, equipment, materials, and/or labor that will be affected by the proposed regulation.

The analyst should attempt to identify all the ways in which the proposed action will affect industry costs after it is implemented. Professional staff time associated with reporting requirements and compliance activities should not be overlooked. Possible impacts on plant capacity factor should also be considered. The analyst should also be alert for instances in which the proposed action will result in a cost savings for industry.

Step 2. Review the cost accounting table for capital costs (Table 3.7) for any capital or replacement costs that might appear on a recurring basis after the action is implemented. Include these as operating cost items.

Step 3. Review the cost accounting table for operation (Table 3.8). One or more cost categories may be affected by the proposed action. The analyst should consider primary and secondary effects of the action; for example, that action could have a major initial impact on plant labor, which, in turn, could affect administrative costs.

Step 4. Discount the total costs over the remaining lifetime of the affected facilities (see the discrete discounting formulations given in Section C.1.2 of Appendix C).

3.10.2 Intermediate Effort

Step 1. At this level of effort, the analyst should consider consultation with engineering and costing experts. The analyst could seek guidance from other NRC branches and the Cost Analysis Group or consult contractors, architect engineering firms or utilities.

Step 2. See Limited Effort.

TABLE 3.8. Industry Operation: Cost Accounting Table

	Incremental Cost of a Regulation			
	Capital[a] (1)	Labor (2)	Materials (3)	Total (4)
Direct Costs				
Annual Salaries of Facility Personnel				
Plant Labor				
Operations Division Labor				
Training				
Travel and Transportation				
Fuel Oil[a]				
Environmental and Safety Monitoring				
Operating Materials and Supplies				
Maintenance Materials and Supplies				
Consulting Services and Fees				
General and Administrative Costs				
Fuel Handling Costs				
Subtotal	___	___	___	___
Indirect Costs				
Administrative and General Expenses				
Capital Additions and Replacements[a]				
Insurance				
Taxes				
Subtotal	___	___	___	___
Total Industry Operation Costs			===	

(a) The user should guard against double counting by cross-checking the calculations for capital costs computed in Section 3.9.

Step 3. See Limited Effort.

Step 4. See Limited Effort.

3.10.3 Major Effort

Step 1. For this level, the analyst should definitely seek expertise beyond the NRC, possibly guidance from contractor or industry sources experienced in this area; the NRC's Cost Analysis Group has on-call contractor support in the area of cost analysis.

Step 2. See Limited Effort.

Step 3. The user may wish to use contractors who have developed explicit methodologies for estimating operating and maintenance costs. Methodologies have been developed by Electric Power Research Institute, Pacific Northwest Laboratory, United Engineers and Contractors, Oak Ridge, and others. NRR currently has on-call support from Oak Ridge to provide operating and maintenance cost estimates. (See the bibliography at the end of this section.)

Step 4. See Limited Effort.

3.10.4 Bibliography

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3.11 NRC DEVELOPMENT

This section describes procedures for estimating NRC development costs, the costs of preparations prior to implementation. These costs may include expenditures to

- prepare documents
- conduct a legal review
- publish notices of rulemaking
- hold public hearings
- draft responses to public comments
- issue a final rule.

Development costs will usually consist of labor costs and overhead within the NRC and the cost of procuring contractors to perform tasks not undertaken within the NRC. Additional background on NRC costs can be found in Section C.5 of Appendix C. Four steps are to be taken in estimating development costs:

Step 1. Determine the current state of development of the action.

Step 2. Estimate the magnitude of the development effort remaining before implementation can occur.

Step 3. Estimate NRC staff labor, contractor support and any special equipment and materials required.

Step 4. Estimate the cost of the required resources, sum the total and discount if appropriate.

The analyst should be careful to include only the incremental costs resulting from adoption of the proposed action. Some "development costs" may be incurred regardless of whether the proposed action is adopted or rejected. Such costs should be excluded from the value-impact assessment, since they will be incurred both for the proposed action and for the alternative.

The discussion below is divided into three portions corresponding to the level of effort to be dedicated to the value-impact assessment.

3.11.1 Limited Effort

For this level of analysis, the analyst should survey the affected NRC branches and formulate a general estimate. Development costs for a recently adopted rule or regulation that is similar to the proposed measure could be used as a proxy. Similarity should be based on the level of effort required to get the proposed measure adopted. Development costs extending beyond a one-year period need to be discounted, as described in Section C.1.2 of Appendix C.

3.11.2 Intermediate Effort

For this level of analysis, the analyst should identify each major task that must be performed to get the proposed action adopted. Each task should then be assessed to estimate the approximate level of effort (in professional staff person-years) necessary to complete it. The number of professional staff years for each task can be multiplied by $100,000 and then summed over all of the tasks. The costs to complete any tasks that would be contracted out also need to be approximated. In order to obtain a reasonably good approximation of in-house and contractor costs, the analyst should contact those agencies within the NRC that would be responsible for the tasks. Again, any expenditures on materials or equipment not included in labor overheads should be added. Development costs extending beyond a one-year period need to be discounted, as described in Section C.1.3 of Appendix C.

3.11.3 Major Effort

An analysis conducted at this level would proceed along the lines described above for an intermediate analysis. However, more detailed and complete accounting would be expected. Contractor costs can either be estimated using the procedure recommended for intermediate analysis, or the analyst can request the responsible NRC agency to provide detailed estimates of the contractor costs, perhaps after consultation with potential contractors. Any expenditures on materials or equipment not included in labor overheads should be added. Development costs extending beyond a one-year period need to be discounted, as described in Section C.1.2 of Appendix C.

3.12 NRC IMPLEMENTATION

Once a proposed action is defined and the Commission endorses its application, the NRC will incur costs to implement the action. Implementation costs refer to those "front-end" costs necessary to realize the proposed action. Implementation costs to the NRC may arise from developing procedures, preparing aids, and taking other actions to assist in or assure compliance with the proposed action.

Examples of these respective costs are 1) developing guidelines for interpreting the proposed action and developing enforcement procedures, 2) preparing handbooks for use by the NRC staff responsible for enforcement and handbooks for use by utilities responsible for compliance, and 3) conducting initial plant inspections to validate implementation. Implementation costs may include labor costs and overheads, purchases of equipment, acquisition of materials, and the cost of tasks to be carried out by outside contractors. Equipment and materials that would be eventually replaced during operation should be included under operating costs (see Section 3.13) rather than implementation costs.

Three steps are necessary for estimating implementation costs:

Step 1. Determine what steps the NRC must take to put the proposed action into effect.

Step 2. Determine the requirements for NRC staff, outside contractors and materials and equipment not included in labor overheads.

Step 3. Estimate the cost of the required resources, sum the total, and discount if appropriate. (See Section C.1.2 of Appendix C.)

Implementation is likely to affect a number of NRC branches and offices. For example, RES may develop a Regulatory Guide, NRR may review the NTOL response to the guidance, and IE may inspect against some portion of the Guide in operating facilities. In developing estimates for the implementation costs, the analyst is strongly encouraged to contact all of the NRC components likely to be affected by the proposed action. Additional background on NRC costs can be found in Section C.5 of Appendix C.

The discussion below is divided into three portions corresponding to the level of effort to be dedicated to the value-impact assessment.

3.12.1 Limited Effort

For this level of analysis, the analyst may assume that for a noncontroversial amendment to an existing rule or regulation, implementation will require the following: a total of one professional NRC staff person-year at a cost of $100,000/person-year, including all overheads; no additional equipment; no additional materials. The potential variation suggests bounds of one-half to one and a half person-years for implementation.

For a new rule or regulation, it is much more difficult to supply a rough but reasonable estimate of the implementation costs, because the level of effort, types and quantities of machinery and materials can vary dramatically. One recourse would be to use as a proxy the implementation costs for a recently adopted rule or regulation that is similar to the proposed measure. Similarity should be judged with respect to the level of effort required to implement the proposed measure.

3.12.2 Intermediate Effort

For this level of analysis, the analyst should identify the major tasks that must be performed to get the proposed rule implemented, major pieces of equipment (if any) that must be acquired, and major costs of materials. Major tasks are then assessed to estimate the approximate level of effort (in professional staff person-years) necessary to complete them. As with a limited-effort analysis, the number of professional staff years for each task is multiplied by $100,000 and then summed over all of the tasks. Similarly, the costs to complete tasks that would be contracted out also need to be approximated. In order to obtain a reasonably good approximation of in-house and contractor costs, the analyst should contact the agencies within the NRC that would be responsible for carrying out or contracting for the tasks. Finally, the costs of major pieces of equipment and quantities of materials are added to the labor and contract costs.

3.12.3 Major Effort

An analysis conducted at this level would proceed along the lines described above for an intermediate analysis. However, a more detailed and complete accounting would be expected. Contractor costs can either be estimated using the procedure recommended for an intermediate analysis, or the analyst can request the responsible NRC agency to provide detailed estimates of the contractor costs, perhaps after some consultation with potential contractors. It may also be desirable to include the costs of materials and equipment that are significant but not major.

3.13 NRC OPERATION

After a proposed action is implemented, the NRC is likely to incur operating costs, or possibly, cost savings. These are the recurring costs that are necessary to ensure continued compliance with the proposed rule. For example, adding a new regulation may require that IE perform periodic inspections to ensure compliance. There are three steps for estimating operating costs:

Step 1. Determine the activities that the NRC must perform after the proposed action is implemented.

Step 2. Estimate NRC staff labor, contractor support and any special equipment and materials required.

Step 3. Estimate the cost of the required resources, sum the total, and discount to yield present value.

In determining the required post-implementation activities, the analyst should carefully examine the proposed action, asking such questions as the following:

- How is compliance with the proposed action to be assured?
- Is periodic review of industry performance required?
- What is an appropriate schedule for such review?
- Does the action affect ongoing NRC programs, and if so will it affect the costs of those programs?

Since recurring costs attributable to the proposed action may be incurred by several NRC branches and offices, the analyst is strongly encouraged to contact all of the NRC components likely to be affected. Additional background on NRC costs can be found in Section C.5 of Appendix C.

The discussion below is divided into three portions corresponding to the level of effort to be dedicated to the value-impact assessment.

3.13.1 Limited Effort

For this level of analysis, the analyst should obtain estimates of the number of full-time equivalent professional NRC staff person-years that would be required to ensure compliance with the proposed rule. Each professional person-year should be costed at $100,000. This figure includes secretarial support, floor space, and other overheads. However, it does not include any special equipment or materials; major expenditures on these must be added. Also, any outside contractor costs must be included; the same rate applied to NRC professional staff can be applied to outside contractors. Finally, since operating costs are recurring, they must be discounted as described in Section C.1.2 of Appendix C.

3.13.2 Intermediate Effort

An intermediate analysis differs from a limited analysis in that the professional staff requirements should be more carefully identified. Major recurring expenditures for special equipment and materials, and for contractors, should be added. In order to obtain a reasonable approximation of in-house and contractor costs, the analyst should contact those agencies within the NRC that would be responsible for ensuring compliance under the proposed rule, or, in the event that such agencies are not yet in existence, agencies within the NRC that carry out similar functions. Since operating costs are recurring, they must be discounted as described in Section C.1.2 of Appendix C.

3.13.3 Major Effort

An analysis conducted at this level would proceed along the lines described above for an intermediate analysis, except that greater detail would be provided to account for acquisitions of special equipment and materials.

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APPENDIX A

VALUE-IMPACT BACKGROUND

APPENDIX A

VALUE-IMPACT BACKGROUND

This appendix provides general background on the incentives for conducting value-impact assessments and on the nature of value-impact assessments as a decision analysis aid. The appendix concludes with suggestions regarding the consideration of alternatives.

A.1 INCENTIVES FOR VALUE-IMPACT ASSESSMENTS

Cost-benefit analyses have long been considered as valuable tools in decision making for government and business. Executive Order 12291 explicitly requires cost-benefit analyses for major government decisions. The NRC is not required to meet this order; however, the NRC's Regulatory Analysis Guidelines (U.S. NRC 1983) generally satisfy its requirements. The Regulatory Analysis Guidelines are intended for use for major decisions. These are defined by the Guidelines as follows:

a. An annual effect on the economy of $100,000,000 in direct and indirect costs, or

b. a significant adverse impact on health, safety or the environment, or

c. a substantial increase in the cost or prices for individuals, businesses, non-profit organizations, federal, state or local governments, and geographical regions.

Less detailed regulatory analyses may also be performed in certain circumstances for actions that do not meet the above thresholds.

A.2 VALUE-IMPACT ANALYSIS AS A DECISION ANALYSIS METHOD

Value-impact analysis is one form of formal decision analysis. For the reader unfamiliar with formal decision methods, a few philosophical words of encouragement and caution may be helpful.

Formal decision methods can

- help the analyst clearly define and think through the problem
- segment complex problems into conceptually manageable portions
- provide a logical structure for the combination of issues contributing to a decision
- clearly display positive and negative aspects of a decision
- provide a record of the decision rationale, helping to provide documentation, defensibility and reproducibility
- focus debate on the specific issues of contention, thereby assisting resolution.
- provide a framework for the sensitivity testing of data and assumptions.

However, limitations must be noted. Formal decision methods cannot

- completely remove subjectivity
- guarantee that all factors affecting an issue are considered
- produce unambiguous results in the face of closely valued alternatives and/or large uncertainties
- be used without critical appraisal of results; to use a decision-analysis method as a black-box decision maker is both wrong and dangerous.

A.3 CONSIDERATION OF ALTERNATIVES

One of the goals of the Regulatory Analysis Guidelines (U.S. NRC 1983) is the early identification and thoughtful consideration of potential alternatives to the proposed action. The guidelines explicitly call for the discussion of "any reasonable alternative" and specify as possible alternatives: taking no action (status quo), making more effective use of existing enforcement mechanisms, establishing performance standards, and deregulation.

The full treatment of the value-impact analysis could be applied to each identified alternative. However, the Regulatory Analysis Guidelines allow some discretion: "The extent to which costs and benefits should be assessed for alternatives is to be determined by the responsible program manager."

In the development of alternatives, a number of guidelines should be followed. The following are characteristics of good alternatives:

- consistent with regulatory objectives
- reasonably competitive
- feasible
- small in number.

While the merit of these characteristics is immediately obvious, some further discussion may prove helpful.

Consistency with the regulatory objective can be a more subtle problem than it might appear. If the objective is to mitigate the consequences of auto accidents, then seat belts are a valid alternative. Driver training may not be a good alternative, since it operates on the probability of accidents rather than on severity. Roadway improvements may or may not be valid, since they could affect either likelihood or consequence.

Decision-analysis methods are generally applied to select among competing alternatives. If the alternatives are grossly disparate in value, the decision maker need not resort to formal methods to reject those less-valued options. Only reasonably competitive alternatives should be brought into the formal analysis process. As a corollary to competitiveness, alternatives should be feasible. Encasing automobiles in three feet of resilient plastic may be an alternative to improve safety, but the lack of feasibility should quickly remove it from serious consideration.

It is important that the selected alternatives adequately represent the range of possible options for solution to the problems. The analyst could attempt to list every conceivable option, but such an exercise would be exhaustive and expensive. Furthermore, trying to use a large number of alternatives in the decision-analysis process will generate confusion and can degrade the quality of the final selection. It is better to select a small number of representative alternatives. Prior screening can reduce the list of candidates. Care must be taken, however, to ensure that a reasonable spectrum of choices is represented and that no outstanding option is excluded. It is important to remember that a new contender can always be added later. Formal decision methods, by recording the decision process, ease the reconsideration that is required if a new candidate is added.

In listing potential alternatives, two kinds of choices may appear, technical options and regulatory options. Technical options are competing hardware and/or operational fixes to achieve a solution. Examples might be hydrogen recombiners or spark igniters to solve hydrogen deflagration concerns. Regulatory options are competing regulatory actions that could be taken to implement a technical option. Such options could include the following:

- more stringent enforcement of existing regulations
- publication of regulatory guides (including guides endorsing industry standards)
- issuance of policy statement(s)
- revisions or additions to Standard Technical Specifications
- issuance of bulletins or circulars
- generic letters or orders
- revisions, additions or deletions to the Code of Federal Regulations (CFRs).

APPENDIX A REFERENCES

U.S. Nuclear Regulatory Commission (U.S. NRC). 1983. Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission. NUREG/BR-0058, Office of the Executive Director for Operations, Washington D.C.

APPENDIX B

RULES OF THUMB FOR FIRST APPROXIMATION OF BENEFITS AND COSTS

APPENDIX B

RULES OF THUMB FOR FIRST APPROXIMATION OF BENEFITS AND COSTS

The First Approximation of Benefits and Costs is meant for use only as a broad scoping tool. To assist the analyst in using that tool, the rough generic data below are presented. If the analyst has access to better data, they should be used.

Table B.1 shows the number and lifetime of reactors by type and supplier. It assumes a 35-year lifetime for currently operating facilities and a 30-year lifetime for planned facilities.

Table B.2 gives mean values for base-case core-melt frequency and consequences of major core melt in terms of public risk occupational risk, onsite property and offsite property. Table B.3 gives cost factors for radiation exposure and NRC and industry staff labor.

TABLE B.1. Type and Life of Nuclear Power Plants[(a)]

		Number of Units (N)		Average Remaining Life (T)(years)	
Reactor Supplier	Type	Completed	Planned	Completed	Planned
1. Westinghouse	PWR	31	30	27.5	30
2. General Electric	BWR	24	20	25.2	30
3. Babcock & Wilcox	PWR	8	5	27.8	30
4. Combustion Engineering	PWR	8	8	27.9	30

	N	T(years)
All PWRs	90	28.8
Operating	47	27.7
Planned	43	30
All BWRs	44	27.4
Operating	24	25.2
Planned	20	30
All Plants	134	28.3
Operating	71	26.9
Planned	63	30

(a) Excluding Humboldt Bay, TMI-2, Shippingport, La Crosse BWR, Fort St. Vrain, and Hanford-N, September 1982.

TABLE B.2. Approximate Values for Major Core-Melt Parameters

Factor	Rough Generic Value	Units
Base-Case Core-Melt Frequency	5E-5	Events/reactor-year
Public Risk Consequence	2E7	Person-rem/event
Occupational Risk Consequence	2E4	Person-rem/event
Onsite Property Damage (includes replacement power)	2E9	$/event
Offsite Property Damage	2E9	$/event

TABLE B.3. Approximate Values for Cost Factors[a]

Factor	Rough Generic Value	Units
Health Risk	1000	$/person-rem[b]
NRC Labor	1E5	$/person-year
Industry Labor	1E5	$/person-year

(a) Estimated considering current literature, including NUREG/CR-2239 and NUREG/CR-2723 (Sandia siting study reports) and NUREG/CR-2800.

(b) A range of values should be used. See Subsection 3.2.2.

APPENDIX C

TECHNICAL ANALYSIS AND DATA DEVELOPMENT

APPENDIX C

TECHNICAL ANALYSIS AND DATA DEVELOPMENT

The information presented in this appendix supports the methods descriptions given in Chapter 3, "Evaluation Methods," and provides the analyst with more background, references, and other sources of information. The analyst need not study all (or necessarily any) of this information. Rather, it is provided as assistance to be used at the analyst's discretion.

C.1 ECONOMIC DISCOUNTING AND CALCULATION OF PRESENT VALUE

To evaluate the economic consequences of proposed regulatory actions, the costs and benefits incurred over a period of years must be summed. This summation cannot be done directly because an amount of money available today has greater value than the same amount at a future date. Likewise, an accurate analysis must differentiate between the certain costs spent today on a fix and the probable future cost avoided because of the fix. There are several reasons for this difference in value:

- The present amount of money can be invested and the total amount increased through accumulated interest.
- Certain consumption today is superior to contingent consumption in the future.
- The option of present or future consumption is superior to future consumption alone.

A method known as "discounting" is used to compare amounts of money expended at different times. The result of discounting is called the "present value" or the "present discounted value." Present value is the amount of money that must be invested today to achieve a specified sum in the future. To perform the discounting procedure, the analyst must know three parameters:

- the discount rate
- the time period over which discounting is to be performed
- the amount of money or value that is to be discounted.

C.1.1 The Discount Rate

The appropriate discount rate to use is one of the most controversial issues in the application of cost-benefit or value-impact analysis. The Regulatory Analysis Guidelines suggest using a real discount rate (r) of 10% per year, and most analysts within the NRC are currently using this rate. It may be appropriate, however, for the analyst to also discount at some other rates in order to indicate the sensitivity of the results to the choice of discount rate. NRR suggests that 5% be used for sensitivity.[a]

The real discount rate is the rate of interest after adjustments for inflation have been taken into account. In practicality, future rates of inflation are extremely difficult to predict; therefore, economic calculations are often done in constant (inflation-free) dollars. In such calculations, it is appropriate to use a real discount rate. Of course, in the real world, there is no single interest rate; rather, there is a whole structure of rates, and differences in them result from different risks.

C.1.2 Discrete Discounting

The following formula is used to determine the present value (PV) of an amount (F_t) at the end of a future time period:

$$PV = \frac{F_t}{(1 + r)^t}$$

where:

r = the real annual discount rate

t = the number of years in the future in which the costs occur.

For example, to determine how much $750 [to be received 25 years (t) hence] is worth today, using a 10% real discount rate (r), the formula yields

$$PV = \frac{\$750}{(1 + .10)^{25}} = \frac{750}{10.83} = \$69.22.$$

Table C.1 contains values of the discount factor $1/(1 + r)^t$ for values of r, the discount rate of 5% and 10%; and for various values of t, the number of years. To find the present value of a stream of costs and revenues, the analyst should record the costs and revenues occurring in each year. Then, for each year, the net cost is determined by simply adding algebraically the costs and revenues for that year. After this has been done for each year, the net

(a) NRR Office Letter No. 16, 1983.

TABLE C.1. Present Value of a Future Dollar

Year	5%	10%
1	0.952	0.909
2	0.907	0.827
3	0.864	0.751
4	0.823	0.683
5	0.784	0.621
6	0.746	0.565
7	0.711	0.513
8	0.677	0.467
9	0.645	0.424
10	0.614	0.386
11	0.585	0.351
12	0.557	0.319
13	0.530	0.290
14	0.505	0.263
15	0.481	0.239
16	0.458	0.218
17	0.436	0.198
18	0.416	0.180
19	0.396	0.164
20	0.377	0.149
25	0.295	0.0923
30	0.231	0.0573
40	0.142	0.0221
50	0.087	0.00852

cost in each year is discounted to the present, using Table C.1. The sum of these present discounted values is the present discounted value of the entire stream of costs and revenues. A sample use of this formula in value-impact analysis would be in determining the PV of implementation costs for industry and the NRC which occur in the future.

The above formula is used for discounting single amounts backward in time. Some of the costs encountered in value-impact analysis, i.e., industry operating costs and NRC operating costs, recur on an annual basis. Such costs, only if they are the same amount for each time period, can be discounted by the use of the following annuity formula:

$$PV = C_A\left[\frac{(1 + r)^t - 1}{r(1 + r)^t}\right]$$

where

C_A = identical annual costs

r = the real discount rate

t = the number of years over which the costs recur.

For example, if the increase in annual industry costs is $1000, due to increased maintenance expenses, with a 10% real discount rate for 20 years, starting at the present time, the present value of these costs is

$$PV = (\$1000)\ \frac{(1 + .10)^{20} - 1}{(.10)(1 + .10)^{20}} = \$1000(8.51) = \$8510$$

Table C.2 contains values of the annuity discount factor

$$[(1 + r)^t - 1]/[(r)\ (1 + r)^t]$$

for values of r, the real discount rate of 5% and 10%; and for various values of t, the number of years or the time interval in which the costs are incurred.

In most cases, the industry and NRC operating costs will start to be incurred at some date in the future, after which the real costs will be constant on an annual basis for the remaining life of the reactor. To discount the costs in this situation, a combination of the above two methods or formulas is needed. For example, given the same $1000 annual cost for a 20-year period at a 10% real discount rate but starting five years in the future, the formula to calculate the PV is

$$PV = \$1000\left[\frac{(1 + r)^{t_2} - 1}{(r)(1 + r)^{t_2}}\right]\left[\frac{1}{(1 + r)^{t_1}}\right]$$

where

r = 10% discount rate

t_1 = 5 years, and

t_2 = 20 years for annuity period.

Therefore,

$$PV = (1000)(8.51)(.621) = \$5285.$$

TABLE C.2. Present Value of Annuity of a Dollar, Received at End of Each Year

Year	5%	10%
1	0.952	0.909
2	1.86	1.74
3	2.72	2.49
4	3.55	3.17
5	4.33	3.79
6	5.08	4.36
7	5.79	4.87
8	6.46	5.33
9	7.11	5.76
10	7.72	6.14
11	8.31	6.50
12	8.86	6.81
13	9.39	7.10
14	9.90	7.37
15	10.4	7.61
16	10.8	7.82
17	11.3	8.02
18	11.7	8.20
19	12.1	8.36
20	12.5	8.51
25	14.1	9.08
30	15.4	9.43
40	17.2	9.78
50	18.3	9.91

Tables C.1 and C.2 contain the appropriate discount factors to be multiplied together. This combination approach is most likely to be applicable to the NRC and industry operation attributes.

C.1.3 Continuous Discounting

Discrete discounting, as discussed above, deals with costs or benefits that occur at the beginning or end of a long period of time. Continuous discounting should be used for the offsite property values and onsite property values because these values incorporate an accident frequency change that can occur over a period of time, usually the remaining life of the plant. The accident probability or frequency is a continuous variable, although the real cost of the accident consequences is constant.

The formula for continuous discounting is derived from the discrete discounting formula as follows. Assume that in one period (t), the time will be subdivided into n intervals. The formula for discounting at a real discount rate of r is $1/(1 + r/n)^n$. As we subdivide the time period into an infinite number of intervals in the limit, we would abandon discrete intervals altogether and so set the limit as

$$\lim_{n\to\infty}\left[\frac{1}{(1 + r/n)^n}\right] = e^{-r}.$$

For t periods, instead of one period as above, the formula becomes e^{-rt} where r and t are defined over the same time period.

To calculate the present value of offsite property damage, when the cost C_0 can occur with a frequency f, the following formula can be derived:

$$\int_{t_i}^{t_f} e^{-rt}\, C_0 f\, dt = C_0 f\left[\frac{(e^{-rt_i}) - (e^{-rt_f})}{r}\right]$$

where

t_i = time of onset of accident risk
t_f = time of end of accident risk.

To determine the value of a reduction in risk, the frequency above is replaced with the frequency reduction (Δf). An example of this in the case of offsite property values is given below. Let the frequency reduction (Δf) be 1.0E-5 events/reactor-year and the cost (C_0) be \$1.0E9/event. The annual discount rate is 10%, and the reduction in accident frequency takes place 5 years in the future (t_i = 5) and will remain in place for 20 years (t_f = 5 + 20 = 25). The present value of the avoided public property damage is

$$PV = (1.0E9)(1.0E-5)\left[\frac{e^{-(.10)(5)} - e^{-(.10)(25)}}{.10}\right]$$

$= (1.0E4)(5.244)$
$= \$5.24E4$/reactor-year.

To calculate the onsite property costs avoided due to a reduction in accident frequency, the continuous discounting formula must be reintegrated to account for the fact that the accident costs will be spread evenly over a time period (m). In the case of onsite property costs, this time period for cleanup is 10 years. Although the frequency is continuous, the cost is an annual amount (C_o). The formula is

$$\int_{t_i}^{t_f} f \int_{t^*}^{t^*+m} C_A \left(e^{-rt^*} \right) dt^* \, dt$$

$$= \frac{C_A \, f \left(e^{-rt_i} \right)}{r^2} \left[1 - e^{-r(t_f - t_i)} \right] \left(1 - e^{-rm} \right).$$

As an example, assume a frequency reduction (f) of 1.0E-5 event/reactor-year, a cost (C_o) of \$1.65E9/event, a 10-year cleanup period (m), therefore an annual cost (C_A) of \$1.6E8/yr, a discount rate (r) of 10%, a time of onset of accident risk (t_i) of 5 years, and a time of end of accident risk (t_f) of 25 years. The PV is calculated as

$$\frac{(1.65E8)(1.0E-5) \; e^{-(.10)(5)}}{(.10)^2} \left[1 - e^{-(.10)(25-5)} \right] \left[1 - e^{-10(.10)} \right]$$

$= (1.0E5)(.8647)(.6321)$
$= \$5.47E4$/reactor-year.

The above two formulas for continuous discounting in value-impact analysis should be used only when there is a frequency change, such as in the value or benefit sections, never in the cost section. The costs should be calculated using discrete discounting formulas only.

C.1.4 Further Information

For more information on discrete discounting, the following sources are recommended: EPRI 1982; DOE 1982; Wright 1973; Higgins 1977.

For more information on continuous discounting, the following sources are recommended: Strip 1982b; Corcoran 1978.

C.2 DEVELOPMENT OF COARSE GENERIC DOSE CONVERSION FACTOR

A CRAC2 calculation was performed using Braidwood meteorology, a uniform population density of 340 people per square mile, summary evacuation and a 50-mile radius release model. The WASH-1400 guidelines, assumptions, and quantities of radioisotopes were used. This produced the following results for release category PWR-2:

Latent Fatalities/event	= 497
Person-rem/event	= 5.56E6
Ratio person-rem/latent fatalities	= 1.1E4

The Sandia siting study (NUREG/CR-2239, Aldrich et al. 1982) lists results of CRAC2 analyses performed at 91 reactor sites. These calculations employed site-specific meteorology and population data. However, a generic reactor (1120 MWe) and release terms were used. A summary evacuation and a release model radius exceeding 50 miles were assumed. The study lists mean latent fatalities per event for each site by generic accident release type. An approximation of a generic dose conversion factor with site-related variations can be made with the following assumptions:

- SST1 (severe core damage) can be equated to the PWR-2 release category.
- Person-rem exposure is proportional to latent fatalities.
- The differences in release model radii do not affect the results beyond the uncertainty bounds. (The effect should be less than a factor of two) (Strip 1982a).

Table C.3 presents extreme and mean latent fatalities from the Sandia study (NUREG/CR-2239). It also gives the implied dose conversion factor using the person-rem/latent-fatalities ratio estimated above.

TABLE C.3. Development of Dose Conversion Factor

	SST1 Latent Fatalities/Event	Implied Person-rem/Event
Indian Point	8100	9.1E7
Palo Verde	450	5.0E6
Mean	1733	1.9E7

In a separate publication (Strip 1982b), Sandia reported the public dose for Indian Point as 1.25E8 man-rem/event for the same assumptions. This indicates that the model above is at least roughly accurate. However, all of the cautions given in NUREG/CR-2239 apply. Plant-specific differences could significantly alter the results. Updates and corrections to risk analyses will also cause changes. The new source terms could have a significant effect on the estimates of consequences.

C.3 OCCUPATIONAL EXPOSURE EXPERIENCE

The following information is presented to orient the analyst on occupational exposures. Table C.4 and Figure C.1 show the overall trends for U.S. commercial power plants. These show a general trend toward increasing collective doses, with a particularly sharp increase in recent years. Part of this increase is attributable to upgrades resulting from TMI, many of which have been completed. Furthermore, improved decontamination procedures for BWRs are beginning to be employed. Forecasting future trends is very difficult; a leveling-out or at least a decrease in the rate of rise could be predicted. On the other hand, major generic problems requiring radiation zone maintenance (e.g., PWR steam generators, BWR pipe cracks) could cause significant occupational exposure increases.

Tables C.5, C.6, and C.7 show the distribution of occupational exposure among the various types of radiation workers.

C.4 BACKGROUND FOR PROPERTY DAMAGE

The avoidance or mitigation of offsite and onsite property damage may play a significant role in evaluating a proposed NRC action. This section provides additional information on the assessments of these attributes.

C.4.1 Offsite Property

One of the major impact categories for safety-related issues is that of offsite property losses. In severe accidents, offsite property damage can exceed onsite damage. A practical approach to estimating offsite damage involves use of the sophisticated CRAC2 computer program. Although CRAC2 has some shortcomings, it does utilize a broad data base and, compared with the costs of obtaining similar results from alternative methods, it is inexpensive to run.

Inputs to CRAC2 include the following: the inventory of isotopes (using up to 54 pre-specified isotopes) in the reactor core; the proportion of the inventory (by isotope group) released to the environment; meteorological and

TABLE C.4. Summary of Annual Occupational Radiation Doses for Commercial Light Water Reactors in the United States, 1973-1980 (Brooks 1980)

Year	Number of Reactors Included	Average Collective Dose Per Reactor-Year (person-rem)	Average person-rem/ MW year	Number of Workers with Measurable Doses	Average Worker (rem)
1973	24	582	1.9	14,780	0.94
1974	34	404	1.3	18,466	0.74
1975	44	475	1.2	25,491	0.82
1976	53	499	1.2	35,447	0.75
1977	57	570	1.2	42,266	0.77
1978	64	497	1.0	45,998	0.67
1979	67	593	1.3	64,073	0.62
1980	68	791	1.8	80,331	0.67

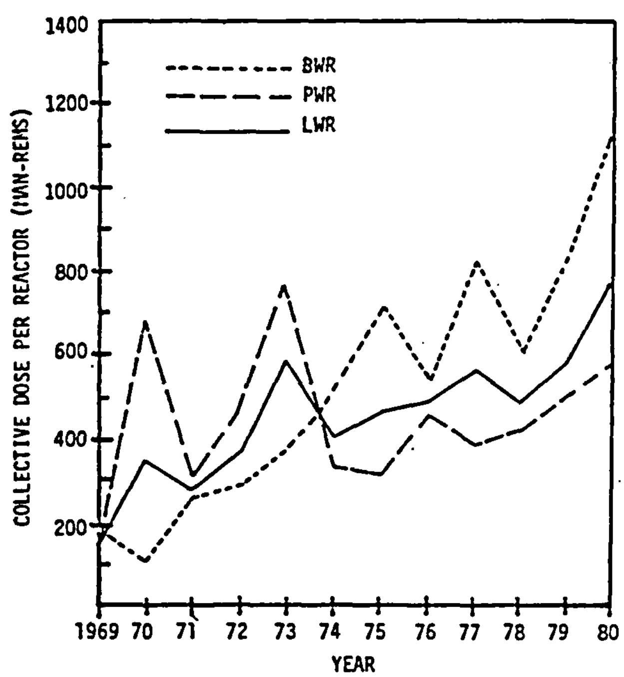

FIGURE C.1. Average Annual Collective Doses to Workers Per Reactor, 1969-1980 (Brooks 1980)

TABLE C.5. Annual Collective Doses by Work Function and Personnel Type (Brooks 1980)

Work Function	Station Employees		Utility Employees and Others		Contract Workers		Total Per Function	
	person-rem	% of Total	person-rem	% of Total	person-rem	% of Total	person-rem	% of Total
All Light Water Reactors								
Reactor Operations and Surveillance	3399.1	6.6%	177.3	0.3%	1243.6	2.4%	4820.0	9.3%
Routine Maintenance	4207.0	8.2%	2075.4	4.0%	11988.2	23.3%	18270.6	35.5%
Inservice Inspection	267.0	0.5%	269.8	0.5%	2293.4	4.5%	2830.2	5.5%
Special Maintenance	1764.8	3.4%	1648.4	3.2%	17478.1	34.0%	20891.3	40.6%
Waste Processing	858.1	4.7%	43.7	0.1%	608.4	1.2%	1510.2	3.0%
Refueling	1160.9	2.3%	386.4	0.8%	1546.1	3.0%	3093.4	6.1%
Totals	11658.9	22.7%	4601.0	8.9%	35157.8	68.4%	51415.7	100.0%

TABLE C.6. Summary of Nuclear Power Plant Service Contractor Personnel Radiation Exposure Patterns[a] (AIF 1981)

Occupational Category	No. of Data Sources[b]	Average Yearly No. of Personnel with Measurable Doses (>0.1 rem)	Range of Average Annual Doses (rem)	Range Individual Annual Doses (rem)	Number of Workers by Dose Range in rem/year: 0.1 - 2	2 - 3	3 - 4	4 - 5	>5	Average Annual Dose for Workers with Dose >3 rem/yr (rem)
Service Engineer	7	557	0.2 - 1.8	0[c] -7.5	475	38	25	12	7	4.0
Service Specialist	4	633	1.5 - 3.2	0.01[c] -5.8	389	116	67	41	20	3.9
Non-Destructive Testing and/or In-Service Inspection	3	243	1.3 - 2.2	0.1 -8.1	155	48	19	12	9	4.2
Steam Generator Service	2	259	1.6 - 3.2	0.1 -8.5	84	55	26	26	68	4.1
Specialty Welder	2	53	1.0 - 4.0	0.3 -4.2	12	11	10	9	11	3.8
Health Physics Services	1	29	1.3 - 3.0	0.06[c] -4.8	16	6	5	2	0	3.6

(a) Data generally represent averages of previous 5 years (1976-1980) exposure history.
(b) Number of data sources is number of different companies providing data on each occupational category. Some companies did not report workers in certain categories.
(c) Some data reported lower values than 0.1 rem.

TABLE C.7. Summary of Utility Nuclear Power Plant Personnel Exposure Patterns[a] (AIF 1981)

Occupational Category	No. of Data Sources[b]	Average Yearly No. of Personnel with Measurable Doses (>0.1 rem)	Range of Average Annual Doses (rem)	Range Individual Annual Doses (rem)	Number of Workers by Dose Range in rem/year					Average Annual Dose for Workers with Dose >3 rem/yr (rem)
					0.1 - 2	2 - 3	3 - 4	4 - 5	>5	
Maintenance										
Mechanical	5	1082	0.6 - 1.7	0[c] - 5.6	714	212	107	35	14	3.6
Electrical	5	235	0.6 - 0.9	0 - 4.9	203	23	5	3	1	3.5
Operators	5	463	0.9 - 1.5	0 - 5.5	33	71	33	21	8	3.6
Health Physics	5	237	0.7 - 1.7	0 - 5.7	148	47	35	6	1	3.8
Engineering	4	197	0.2 - 0.6	0 - 4.4	191	4	2	21	0	3.5
Quality Assurance	2	36	1.2 - 1.6	0.1 - 4.1	28	5	3	21	0	3.4

(a) Data generally represent averages of previous 5 years (1976-1980).
(b) Number of data sources is number of different companies providing data on each occupational category. Some companies did not report workers in certain categories.
(c) Some data reported lower values than 0.1 rem.

topographical information; cost information on decontamination, evacuation and relocation; the value of residential, business, agricultural (divided into milk and nondairy categories) and public property; demographic inputs, including population and urbanization information; evacuation scenario information; and information for specifying the health impact models. All or part of the above information can be obtained directly from the reference case supplied with the program (see Ritchie et al. 1982).

Outputs of CRAC2 include evacuation costs, decontamination costs, interdiction costs, relocation costs, and health impacts. The health impacts include early fatalities and injuries and latent cancer fatalities. However, the cost of replacement power, litigation costs, impacts on areas receiving evacuees, and institutional costs are important offsite accident impacts that are not provided by CRAC2.

Results of the CRAC2 analysis are most sensitive to 1) the population distribution around the plant; 2) the source term for the release to the environment; and 3) the weather conditions prevailing at the time of the accident. Accurate population information is currently being developed by Oak Ridge National Laboratory for all reactor sites from the 1980 Census.

Isotope leakages from the reactor core can vary considerably, depending upon the particular accident sequence. An NRC-sponsored program, the Accident Sequence Evaluation Program, is currently re-evaluating a large number of existing risk studies. The results are to be synthesized using a common nomenclature and structured within a generic framework. The existing nuclear power plants will be divided into perhaps a dozen categories, with one set of accident sequences corresponding to each category. When complete, the program will enable one to take any existing nuclear power plant in the U.S. and identify the probability of any dominant or high-probability accident sequence for that plant, including the isotope leakages associated with that accident sequence. Preliminary results of the program are available in draft form.[a]

The third type of input to which the CRAC2 results are highly sensitive consists of the meteorological conditions prevailing at the time of a severe radiological accident. This sensitivity is understandable, since the downwind population will receive most of the exposure; also, deposition of radioactive particles will be greatly increased during periods of precipitation. CRAC2 is particularly versatile with respect to handling meteorological information. Options available to the user include a single trial with fixed meteorology, hourly weather data over a five-day period to process a single trial, and

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(a) Kolaczkowski, A. M. 1983. Interim Report on Accident Sequence Likelihood Reassessment (Accident Sequence Evaluation Program) (draft). Sandia National Laboratories, Albuquerque, New Mexico.

hourly weather data over a one-year period, with the weather data sorted into 29 meteorological bins and then sampled to generate stochastic accident consequences. For more detailed information on CRAC2's ability to handle meteorological information, see Ritchie et al. (1982), pp. 2-14 through 2-20.

C.4.2 Onsite Property

Very little research has been done on the onsite costs of radiological accidents. There is no computer code similar to CRAC that can be applied to estimate the onsite financial consequences of accidents. However, the onsite consequences can be extremely important. One study (Benjamin and Strip 1982) that evaluated the potential benefits of filtered-vented containment systems indicated replacement power costs to be the largest financial consequence of an accident. In the same study, onsite cleanup costs were roughly the same magnitude as offsite property damage. Thus, these costs, if included, could have a significant influence on decisions.[a]

In Section 3.6 three categories of onsite property costs were identified: 1) the cost of interdicting and/or decontaminating onsite property; 2) the cost of replacement power; and 3) repair and refurbishment costs. Each is discussed more fully below.

Interdiction/Decontamination Costs

The options that need to be considered with regard to contaminated property are a) immediate decontamination of the property; b) eventual decontamination of the property with interdiction in the interim; and c) disposal of contaminated property other than land. If the first option is exercised, the relevant costs are the actual cost of decontamination and that due to loss of property use prior to decontamination.

Under the second option, eventual decontamination of the property, the costs are the same as under the first option, except that the decontamination cost must be discounted (see Section C.1). There will also be the cost due to loss of the property use. This may be the cost of replacement power if the plant is shut down, or it may be the cost of using a back-up unit or leasing a replacement unit until the contaminated unit can be brought back into service. Until the property is decontaminated, however, access to it will be restricted; that is, the property will be interdicted. Interdiction costs can include that of fixing the contamination at the site, the loss of property use during the interdiction period, radiation monitoring costs, and the costs of keeping the interdicted area secure.

(a) It is recognized that there is some question on the use of onsite property in NRC decision making. This handbook takes no position on the issue, but provides guidance on how onsite property may be incorporated if desired.

Under the third option, disposal in a secure area, the property is removed to a secure radioactive burial site. Costs include preparation for transportation, transport itself, burial and security costs.

Replacement Power

The value of lost power will probably be the most significant onsite cost resulting from an accident. The economic cost can be approximated as the difference between the wholesale cost of replacement power and the utility's variable fuel cycle costs for producing the same quantity of power.

Repair and Refurbishment

Repair and refurbishment costs can be assessed as the cost required to restore the facility to its pre-accident condition. This can be a complex question in that the utility may or may not choose to repair the facility. They may choose to decommission the facility, in which case the costs associated with the accident are the value of the foregone remaining life of the plant (which can be valued as the cost of replacement power over the remaining lifetime of the plant) plus the lost-opportunity cost associated with early decommissioning. Alternatively, the utility may choose to replace the lost power by constructing a different facility. For this assessment, however, we recommend use of the simplifying assumption that the utility's lost capital can be measured by the facility's restoration cost.

The equation given in Section 3.6.2 for estimating changes in variable costs (i.e., replacement power and variable operation and maintenance) is derived from an Argonne National Labortatory (ANL) study of the consequences of nuclear plant shutdowns (Buehring and Peerenboom 1982). The Argonne study estimated the effects of shutdowns at several sites, including Zion, Oconee, Prairie Island, Browns Ferry, Indian Point, and Three Mile Island. The study concluded that changes in variable costs are dependent on the specific characteristics of the utility system, the reactor that is unavailable, and the regional power pool. A simulation model, called ICARUS (Investigation of Cost and Reliability in Utility Systems), and a detailed data base of U.S. generating units have been developed at ANL to facilitate the evaluation of potential nuclear plant shutdowns. This model can be used to estimate the short-term replacement energy costs for all U.S. power reactors.

C.5 BACKGROUND FOR ESTIMATING NRC COST

The approach proposed in Sections 3.11, 3.12, and 3.13 for estimating the federal costs of a regulation is consistent with the methods used by the Office of Management and Budget (OMB), the Environmental Protection Agency (EPA), and the Department of Transportation/National Highway Traffic Safety Administration

(NHTSA). OMB has not established uniform cost principles or guidelines for determining the costs to the government for a regulation. These agencies were contacted individually.

At NHTSA, Mr. Thomas Charlton, Chief of Standards in the Office of Regulations, explained that almost 90% of their regulations are not new, but rather involve changes to existing regulations. No formal accounting procedure is used by NHTSA to determine their rule-making costs. Rather, NHTSA, which is responsible for developing the regulation (other agencies, such as the Federal Aviation Administration, are responsible for enforcing these regulations), sums the number of person-hours for the regulatory specialist to prepare and write the regulation; total person-hours are then multiplied by an hourly charge rate. Ultimately, it is this figure that is included and entered on OMB circular SF-83, which is used to supply information to OMB on rule-making costs to government.

At EPA, Mr. Al Jennings (Office of Policy and Resource Management, Division of Standards and Regulations) has approached this problem in a similar fashion. For EPA's costs of a regulation, a budget approach is taken wherein contractors' costs and EPA staff costs are summed from the time when a regulation commences development throughout its period of operation.

The methodology for NRC's estimates of its costs for developing and implementing a rule or regulation varies among divisions. Mr. Al Berkson of Planning and Program Support supplied much of our information on how the NRC presently estimates agency costs.

The NRC (or at least certain program offices of the NRC) estimates agency costs by first estimating professional person-years required to implement the regulation. These estimates should include contractor time that might be required. The person-years are multiplied by an estimate of the average cost per person-year. The cost figure includes secretarial and administrative support, fringe benefits and a variety of other overheads. Presently, estimates of $85,000 to $125,000 per person-year are used. Additional information can be found in the bibliography below.

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U.S. General Accounting Office. 1982. Improved Quality, Adequate Resources, and Consistent Oversight Needed if Regulatory Analysis is to Help Control Costs of Regulation. By the Comptroller General, Report to the Chairman, Committee on Governmental Affairs, United States Senate. GAO/PAD-83-6. November 2, 1982.

Note: This report found that the average costs for regulatory analyses by independent regulatory agencies would be the same as those performed by executive agencies - an average of $212,000 for new regulations and as high for existing regulations. The report cited a CBO analysis which estimated that independent regulatory agencies could conduct analyses of new regulations at a cost of $150,000 while studies for existing regulations would cost $80,000 each. (These estimates were based on analyses that would follow rules established by the regulatory reform bill S.1080).

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APPENDIX D

VALUE-IMPACT ASSESSMENT EXAMPLE: USI A-43, "CONTAINMENT EMERGENCY SUMP PERFORMANCE"

APPENDIX D

VALUE-IMPACT ASSESSMENT EXAMPLE: USI A-43, "CONTAINMENT EMERGENCY SUMP PERFORMANCE"

In this appendix, a sample value-impact assessment is presented, using the methods suggested in this handbook. The example is based on the Unresolved Safety Issue (USI) A-43, "Containment Emergency Sump Performance." The assessment relies heavily upon the Value-Impact Analysis prepared by NRR for this issue and the documents that support that analysis. The purpose of the appendix is to illustrate the value-impact assessment methods rather than to provide the definitive analysis of USI A-43. The example begins with a scoping assessment, shown in Section D.1. The complete value-impact assessment is given in Section D.2.

D.1 SCOPING

In order to obtain some insight into the potential importance of this issue, a brief scoping analysis was performed using the First Approximation of Benefits and Costs Worksheet. The worksheet, shown in Table D.1, indicates a potential benefit of $7.6E+8 and a potential cost of $2.7E+7. This would indicate that the issue is relatively significant and that at least moderate NRC resources should be committed to the value-impact assessment.

TABLE D.1. Worksheet for First Approximation of Benefits and Costs[a]

1. Title of Proposed Action

   Revisions to Standard Review Plan Section 6.2.2 and Regulatory Guide 1.82, as related to USI A-43, "Containment Emergency Sump Performance."

2. Number of Facilities Affected (N)

   67 plants (50% of all plants operating or planned)

3. Average Remaining Lifetime of Facilities (T)

   28.3 years

(a) The values employed in this worksheet are intended to simulate an earlier state of knowledge, at which time the problem appeared more significant than was borne out in later analysis.

TABLE D.1. (contd)

4. Mean Accident Frequency Reduction Resulting from Proposed Action (ΔF)

2E-5 events/reactor-year (40% reduction in base-case core-melt frequency)

5. Mean Public Risk Consequence of Accident (A_p)

2E7 person-rem/event

6. Mean Occupational Risk Consequence for Accident (A_o)

2.1E4 person-rem/event

7. Expected Integral Exposure Change (E)

$E = (N)(T)(\Delta F)(A_p+A_o)$
= (67 reactors)(28.3 yr)(2E-5 events/reactor-yr)(2E7+2.1E4 person-rem/event)
= 7.6E5 person-rem

8. Mean Damage to Onsite Property in Event of Accident (P_o)[a]

$1.7E9 (Includes 10 yr of replacement power)

9. Mean Damage to Offsite Property in Event of Accident (P_F)[a]

$2E9

10. First Approximation of Benefits[a]

V = (E)(XC)

where

XC (in units of dollars per person-rem) is the factor for converting person-rem to dollars

V = (7.6E5)(1000)
= $7.6E8

(a) In this example, mean damage to onsite property and mean damage to offsite property are regarded as supplementary considerations and are not included in the first approximation of benefits. If they were included they would contribute an additional $1.4E8 [=(67)(28.3)(2E-5)(1.7E9 + 2E9)].

TABLE D.1. (contd)

11. NRC COST (C_N)

Development = 0
Implementation = \$1E5
Operation = 0
Total = \$1E5

12. Industry Implementation Cost per Facility (I_I)

\$4E5

13. Industry Annual Operation Cost per Facility (I_O)

Zero

14. First Approximation of Costs

$$C = C_N + N(I_I+TI_O)$$
$$= \$1E5 + 67(\$4E5) = \$2.7E7$$

D.2 VALUE-IMPACT ASSESSMENT

The complete value-impact assessment for this proposed action follows. begins with a summary cover page.

VALUE-IMPACT SUMMARY COVER PAGE

Revisions to Standard Review Plan Section 6.2.2 and Regulatory Guide 1.82, as related to USI A-43, "Containment Emergency Sump Performance."

Prepared by J. Doe/GIB/DST/NRR
May 1983

SUMMARY OF PROBLEM AND PROPOSED SOLUTION

During the post-LOCA period, when long-term recirculation cooling must be maintained to prevent core melt, the containment emergency sump must perform adequately. The current analysis treatment of sump performance can be improved. The proposed revisions to SRP Section 6.2.2 and RG 1.82 will provide a more realistic treatment and with minimal industry impacts, will lead to enhanced plant safety.

	Dose Reduction (person-rem)			Evaluation ($)[a]		
ATTRIBUTE	Best Estimate	High Estimate	Low Estimate	Best Estimate	High Estimate	Low Estimate
Public Health	7.5E3	1.8E5	9.7E2	7.5E6	1.8E8	9.7E5
Occupational Exposure (Accidental)	1.2E2	9.5E2	28	1.2E5	9.5E5	2.8E4
Occupational Exposure (Routine)	-2.5E2	-50	-5.0E2	-2.5E5	-5.0E4	-5.0E5
Offsite Property				3.2E6	8.6E7	7.8E5
Onsite Property				2.0E6	1.5E7	4.8E5
Regulatory Efficiency				NA		
Improvements in Knowledge				NA		
Industry Implementation				-3.8E6	-9.8E5	-5.5E6
Industry Operation				NA		
NRC Development				NA		
NRC Implementation				-1.1E5	-7.5E4	-3.0E5
NRC Operation				NA		
NET BENEFIT: Sum Over All Affected Attributes($)				8.7E6	2.8E8	-4.0E6
RATIO: Public Dose Reduction/|Sum of All NRC and Industry Costs|(person-rem/$$10^6$)[b]				1.9E3	1.6E5	170

NA = Not affected.

(a) Note: Favorable or beneficial consequences of a proposed action have a positive sign. Unfavorable or adverse consequences have a negative sign. For instance, an increase in NRC operating costs would be considered an unfavorable consequence and should be entered in the table with a negative sign.

(b) Strictly speaking, because the ratio should be expressed as a positive number, the analyst should use the absolute value of the sum of all costs (industry, NRC, and other) in the denominator.

PROPOSED ACTION AND POTENTIAL ALTERNATIVES

USI A-43 deals with safety concerns related to containment emergency sump performance during the post-LOCA period, wherein long-term recirculation cooling must be maintained to prevent core melt. These concerns can be summarized in the following question:

> In the recirculation mode, will the sump design provide water to the residual heat removal (RHR) pumps in sufficient quantity, and will this water be sufficiently free of LOCA-generated debris and air ingestion so as not to impair pump performance while providing adequate net positive suction head (NPSH)?

The concerns have been addressed in three parts, namely:

a. Sump hydraulic performance under post-LOCA adverse conditions such as air ingestion, elevated temperatures, break and drain flow, etc.

b. LOCA-generated debris arising from the break jet dislodging large quantities of insulation, this insulation debris being transported to the sump screen(s), and the resulting screen blockage being sufficient to reduce NPSH significantly below that required to maintain adequate pumping.

c. The performance capability of RHR and CSS pumps to continue pumping when subjected to air ingestion, debris ingestion and effects of particulates.

Proposed Action

The proposed action is to revise the NRC Standard Review Plan (SRP), Section 6.2.2, "Containment Heat Removal Systems," and Section 6.3, "Emergency Core Cooling Systems," to incorporate the technical findings and sump design review guidelines set forth in NUREG-0897, "Containment Emergency Sump Performance," (U.S. NRC 1982). This action will provide for review consistency based on the extensive data base acquired for the resolution of USI A-43, and can remove the need for "in-plant" sump tests or sump model tests.

Revise Regulatory Guide (RG)1.82, to reflect the findings contained in NUREG-0897. In particular, the 50% screen blockage guidance should be removed and replaced with a requirement for plant-specific debris evaluations.

Operating plants should be assessed for determination of the extent of debris blockage potential; and based on the outcome of those plant analyses, action should be taken to correct unacceptable conditions. A generic letter should be employed to call for this assessment.

Revision of the SRP Section 6.2.2, RG 1.82, based on the research performed for USI A-43, will result in more technically correct treatment of the emergency sump performance question. Potential non-conservative treatments under the existing SRP and RG 1.82 will be corrected; therefore, public health, safety and welfare will be enhanced. Both industry and the NRC will incur modest cost impacts associated with the plant-specific analysis required for operating and NTOL plants. Some plants will incur additional costs associated with insulation replacement and sump modification.

There are multiple levels at which facilities are affected. It is assumed that all operating plants (75 plants) will be required to perform analyses of sump hydraulic performance and initial debris assessment. A smaller subset (estimated at 10 plants) will also have to undergo analysis of detailed debris blockage potential. It is estimated that seven plants will be required to install vortex suppressors to improve sump hydraulic performance; furthermore, ten plants will require major backfits. Five of these are estimated to be sump modifications (e.g., screens), and five will be extensive insulation replacements.

Alternative 1

Issue NUREG-0897 and associated references.

Implement use of the revised SRP Section 6.2.2 and RG 1.82 for only those plants not having an SER at the time of implementation ("forward fit" only, approximately 60 plants). The exception of operating plants and NTOLs having an SER would yield a much smaller value. Existing plants would be allowed to continue operations based on sump performance evaluation which may be non-conservative. Cost impact would be also significantly reduced. Not only would a large number of plants be excluded, but "forward-fit" upgrades of sump design and/or insulation materials is likely to be less costly than "backfit" modification.

Both benefits and costs are smaller for Alternative 1 than for the proposed action. The alternative is rejected without further analysis for the following reasons: The technical findings presented in NUREG-0897 and references reveal a significantly different picture than previously hypothesized and show that the previously accepted levels of risk may not exist in some plants. However, ignoring the implications of the results of the A-43 debris blockage effects with respect to OLs and NTOLs is not acceptable. ECCS analyses that have been performed assuming operable sumps may be incorrect; later analyses may indicate screen blockage potential for plants using unencapsulated fibrous insulations.

Alternative 2

Issue NUREG-0897 and associated references for information only, but take no other action.

Issuing NUREG-0897 and its references would provide information. However, without the correction to the SRP and RG 1.82, little value would be obtained. No facility would be required to take action. There would be no impact associated with this alternative.

This alternative has limited value and no impact. It is rejected without further analysis because continued use of the current RG 1.82 and SRP Section 6.2.2 would ignore the experimental data base and plant analyses which clearly point out the need for these recommended changes. This is not an acceptable alternative since A-43 plant-specific calculations have shown that the 50% screen blockage guidance in the current RG 1.82 can result in erroneous and nonconservative plant results.

CHECKLIST FOR IDENTIFICATION OF AFFECTED ATTRIBUTES

Attribute	Quantified Change	Unquantified Change[(a)]	No Change
Public Health	X		
Occupational Exposure (Accidental)	X		
Occupational Exposure (Routine)	X		
Offsite Property	X		
Onsite Property	X		
Regulatory Efficiency			X
Improvements in Knowledge			X
Industry Implementation	X		
Industry Operation			X
NRC Development			X
NRC Implementation	X		
NRC Operation			X

(a) In this context, "unquantified" means not readily estimated in dollars.

SUPPLEMENTARY CONSIDERATIONS

Were only the ratio method being employed, the treatment of occupational exposure and offsite/onsite property would be treated here. Since both the ratio and net-benefit methods are being shown, those attributes are treated within the quantified attributes which follow. There are no unquantified attributes in the assessment of this action.

DEVELOPMENT OF QUANTIFICATION

Public Health

A risk analysis was performed to assess the effects of loss of the containment emergency sump (for example, due to LOCA debris blockage). Three plants and their corresponding PRAs were selected: Crystal River, IREP-PRA; Calvert Cliffs, RSSMAP-PRA; and Surry, RSS-PRA. The PRA event trees were reanalyzed to determine the effects of sump loss following a large LOCA. Whereas previously these event trees assumed availability of the sump, this analysis assumed total sump failure for 20% of the large LOCAs; the resulting core-melt frequencies and release category frequencies were then computed. The 20% value was derived in the following fashion. In NUREG-0897, the sump blockage analysis method was applied to five plants for an assortment of large LOCAs. The mean fractional blockage was on the order of 50%. However, a significant number of these, despite blockages near or exceeding 50%, still had indicated acceptable sump performance. If these instances are treated as zero effective blockage (i.e., system functional), the resulting mean value is on the order of 20%. Of course, the limited survey leaves considerable uncertainty. Two of the facilities indicated complete blockage for certain LOCAs. Bounds were used of 100% and 10% for piping contributing to blockage. Table D.2 summarizes the results obtained. The release category frequencies were converted, utilizing the values in Table D.3, to public dose.

The best-estimate values were derived using the CRAC code and assuming the guidelines and quantities of radioactive isotopes used in the Reactor Safety Study (WASH-1400), the meteorology at a typical midwestern site (Byron-Braidwood), a uniform population density of 340 people per square mile (which is an average of all U.S. nuclear power plant sites) and no evacuation of population. The calculations were based on a 50-mile release radius model.

The high and low estimates were calculated in the following fashion, using data from NUREG/CR-2239 (Aldrich et al. 1982). It was assumed that total person-rem is proportional to latent fatalities from an SST1 event. Furthermore, it was assumed that extremes could be approximated by multiplying the best-estimate value by the ratio of the extremes in SST1 latent fatalities per event to the mean. The mean value for the 91 sites in the study was 1733/event. The representative extremes used were 8100/event (Indian Point) and 450/event (Palo Verde). This calculation yielded ratios of 4.7 and 0.26 for the high and low estimates, respectively, relative to the mean.

Application of the dose conversion factors in Table D.3 to the changes in release category frequencies given in Table D.2 results in the avoided public dose shown in Table D.4. The uncertainty is conservatively propagated by employing the extremes (e.g., high estimate dose conversion times upper bound release category frequency change).

TABLE D.2. Changes to Release Category Frequency (Reactor-yr)$^{-1}$

Reactor	Blockage Potential[a]	Release Category 1	2	3	4	5	6	7	Total Core-Melt
Crystal River	100% (Upper Bound)	1E-6	2E-5	0	7E-7	0	8E-5	0	1E-4
	20% (Best Estimate)	2E-7	4E-6	0	1.4E-7	0	1.6E-5	0	2E-5
	10% (Lower Bound)	1E-7	2E-6	0	7E-8	0	7.8E-6	0	1E-5
Calvert Cliffs w/o AFW Improvement	100% (Upper Bound)	1E-6	3E-5	0	7E-7	0	7E-5	0	1E-4
	20% (Best Estimate)	2E-7	6E-6	0	1.4E-7	0	1.4E-5	0	2E-5
	10% (Lower Bound)	1E-7	3E-6	0	7E-8	0	7E-6	0	1E-5
Calvert Cliffs[b] w/AFW Improvement	100% (Upper Bound)	1E-6	3E-5	0	7E-7	0	7E-5	0	1E-4
	20% (Best Estimate)	2E-7	6E-6	0	1.4E-7	0	1.4E-5	0	2E-5
	10% (Lower Bound)	1E-7	3E-6	0	7E-8	0	7E-5	0	1E-5
Surry	100% (Upper Bound)	1E-6	2.1E-5	0	0	0	7.8E-5	0	1E-4
	20% (Best Estimate)	2E-7	4.1E-6	0	0	0	1.6E-5	0	2E-5
	10% (Lower bound)	1E-7	2.1E-6	0	0	0	7.8E-6	0	1E-5

(a) Percentage of piping breaks which can yield sufficient debris to block sump.
(b) Base-case frequency is substantially different from w/o AFW improvement; however, changes from sump failure are similar.

TABLE D.3. Dose Conversion Factors (person-rem/release)

Release Category	Core-Melt Release Best Estimate	High Estimate	Low Estimate
PWR 1	5.4E6	2.5E7	1.4E6
PWR 2	4.8E6	2.2E7	1.2E6
PWR 3	5.4E6	2.5E7	1.4E6
PWR 4	2.7E6	1.3E7	7.0E5
PWR 5	1.0E6	4.7E6	2.6E5
PWR 6	1.5E5	7.0E5	3.9E4
PWR 7	2.3E3	1.1E4	6.0E2

If we treat the four cases as independent and representative, then the averages shown in Table D.4 can be used as estimates of the per-reactor-year avoided public dose resulting from the implementation of the proposed action.

To estimate the total effect, the per-reactor-year estimates must be multiplied by the number of affected facilities and by their average remaining lifetimes. It is estimated that the proposed actions will cause major backfits at ten plants. These are likely to be older PWRs. The average remaining lifetime for PWRs as a group is 27.7 years. Use of this value yields the total avoided public dose estimates shown in Table D.5. These are converted to their monetary evaluations. The conversion factors and the resulting values are also shown in Table D.5.

TABLE D.4. Avoided Calculated Public Dose (person-rem/reactor-year)

Reactor	Best Estimate	High Estimate	Low Estimate
Crystal River	23	530	2.9
Calvert Cliffs w/o AFW Improvement	32	740	4.1
Calvert Cliffs w/AFW Improvement	32	740	4.1
Surry	23	540	3.0
Average	27	640	3.5

TABLE D.5. Summary of Avoided Public Health Risk

	Total Avoided Dose (person-rem)	Conversion Factor[a] ($/person-rem)	Value of Avoided Risk ($)
Best Estimate	7.5E3	1000	7.5E6
High Estimate	1.8E5	1000	1.8E8
Low Estimate	9.7E2	1000	9.7E5

(a) A sensitivity analysis using a range of numerical values for this conversion factor is presented in a subsequent section devoted to sensitivity studies.

Occupational Exposure (Accidental)

The avoided occupational exposure from accidents can be estimated as the product of the change in total core-melt frequency and the occupational exposure likely to occur in the event of a major accident. The change in core-melt probability was estimated in Table D.2. The occupational exposure in the event of a major accident has two components. The first is the "immediate" exposure to the personnel onsite during the span of the event and its short-term control. The second is the longer-term exposure associated with the cleanup and recovery from the accident.

The final data required are the number of affected facilities and their remaining lifetimes. As described above, this is taken as ten plants which undergo major backfitting, with average remaining lifetimes of 27.7 years. The total avoided occupational exposure is then calculated as follows:

$$D_{TOA} = NTD_{OA}; \; D_{OA} = \Delta F(D_{IO}+D_{LTO})$$

where

D_{TOA} = total avoided occupational dose
N = number of affected facilities
T = average remaining lifetime
D_{OA} = avoided occupational dose per reactor-year
ΔF = change in core-melt probability
D_{IO} = "immediate" occupational dose
D_{LTO} = long-term occupational dose.

Table D.6 shows the values taken as best estimates and bounds for these parameters. Uncertainties are conservatively propagated by use of extremes (e.g., high estimate D_{IO} + high estimate D_{LTO}).

The total avoided occupational exposure is converted to monetary terms using the conversion factor in Table D.5. The resulting evaluation is also shown in Table D.6.

TABLE D.6. Summary of Avoided Occupational Exposure

	Change in Core-Melt Probability (events/reactor-yr)	Immediate Occupational Dose[a] (person-rem/event)	Long-Term Occupational Dose[b] (person-rem/event)	Total Avoided Occupational Exposure (person-rem)	Values of Avoided Risk ($)
Best Estimate	2E-5	1E3	2E4	120	1.2E5
High Estimate	1E-4	4.2E3	3E4	950	9.5E5
Low Estimate	1E-5	0	1E4	28	2.8E4

(a) Based on initial (4-month) occupational exposure following the accident at TMI.
(b) Based on cleanup and decommissioning estimates, NUREG/CR-2601 (Murphy 1982).

Occupational Exposure (Routine)

The routine occupational exposure associated with the proposed action entails a modest increase in exposure required to replace some insulation. Table D.7 shows the derivation of the insulation replacement exposure.

TABLE D.7. Estimates of Insulation Replacement Exposure

Plant	Unencapsulated Insulation (ft^2)	Estimated Exposure[a] (person-rem)
Salem Unit 1	13,200	99
Maine Yankee	6,700	47
Ginna	1,000	8
Millstone Unit 2	1,300	10

(a) Exposure data were derived from Surry 1 and Surry 2 data. Discussions with Surry site staff indicate that a 50 person-rem exposure level for insulation replacement is realistic if the job is preplanned. An equivalent dose of 7×10^{-3} person-rem/ft^2 of insulation replaced can be derived.

Clearly, there is a significant dependence on the amount of insulation which must be replaced. A range of 10 to 100 person-rem is indicated, and a best-estimate value of 50 person-rem/plant can be assumed. It can also be assumed that there is no change to the annual operation occupational exposure resulting from the proposed action. Therefore, the only change in the routine occupational exposure is the increased dose associated with implementation. It was assumed that five plants would require insulation replacement. The per-plant and total exposure estimates are summarized in Table D.8. Also shown is the monetary calculation of these exposures. These are calculated with the conversion factors shown in Table D.5. Note the negative sign indicating an exposure increase.

TABLE D.8. Summary of Routine Occupational Exposure

	Implementation Dose (person-rem/plant)	Total Routine Exposure Increase (person-rem)	Value of Risk Change ($)
Best Estimate	50	250	-2.5E5
High Estimate	10	50	-5.0E4
Low Estimate	100	500	-5.0E5

Offsite Property

The effect of the proposed action upon reducing risk to offsite property is calculated by multiplying the change in accident probability by a generic offsite property damage estimate. This estimate was derived from the mean value of results of CRAC2 calculations, assuming an SST1 release (major accident), for 154 reactors (Strip 1982). The damage estimate is converted to present value by discounting at 10%.[a]

The following discounting formula is employed:

$$D = V\left[\frac{e^{-0.10t_i} - e^{-0.10t_f}}{0.10}\right]$$

where

D = discounted value

V = damage estimate

t_i = years before reactor begins operation; 0 for operating reactor

t_f = years remaining until end of life.

(a) A sensitivity analysis showing the effects of changing the discount rate is presented in a subsequent section devoted to sensitivity studies.

For this proposed action, we assume only that operating PWRs are affected, and that the average number of years of remaining life is 27.7. Therefore, the discount D/V = 9.4. This must be multiplied by the number of affected facilities (10) to yield the total effect of the action. Table D.9 summarizes the results. The high and low estimates are values for Indian Point No. 2, and Palo Verde No. 3, calculated from Strip (1982).

TABLE D.9. Summary of Avoided Offsite Property Damage

	Offsite Property Damage ($/event)	Value of Avoided Offsite Property Damage ($)
Best Estimate	1.7E9	3.2E6
High Estimate	9.2E9	8.6E7
Low Estimate	8.3E8	7.8E5

Onsite Property

The effect of the proposed action on reducing the risk to onsite property is estimated by multiplying the change in accident probability by a discounted onsite property cost. This discounted property cost was developed from the generic onsite property cost taken from Andrews et al. (1983). It includes an estimate for replacement power.

This value is discounted at 10% using the following formula:[a]

$$D = V\left[\left(\frac{e^{-0.10t_i}}{0.01m}\right)\left(1-e^{-0.10(t_f-t_i)}\right)\left(1-e^{-0.10m}\right)\right]$$

where

- D = discounted value
- V = damage estimate
- t_i = years before reactor begins operation; 0 for operating reactor
- t_f = years remaining until end of life
- m = period of time over which damage cost is paid out (recovery period in years).

Assuming that only operating reactors are affected, that the remaining life is 27.7 years, and that the recovery period would be 10 years, the discount D/V = 5.9.

(a) A sensitivity analysis showing the effect of changing the discount rate is presented in a subsequent section devoted to sensitivity studies.

To obtain the total effect of the action, the per-reactor results are multiplied by the number of affected facilities (10). The results are summarized in Table D.10. The uncertainty bounds given in the table reflect a ±50% spread in the generic property cost coupled with the bounds on core-melt probability. This was estimated to be indicative of the uncertainty level.

TABLE D.10. Summary of Avoided Onsite Property Damage

	Onsite Property Damage Estimate ($/event)	Value of Avoided Onsite Property Damage ($)
Best Estimate	1.65E9	2.0E6
High Estimate	2.5E9	1.5E7
Low Estimate	8.2E8	4.8E5

Industry Implementation

Several levels of impact to industry are foreseen as resulting from the proposed action. First, all OLs (75 plants) will be required to conduct an assessment of the sump performance and an initial debris assessment. As a result of the sump assessment, it is conceivable that some plants may have to install a vortex suppressor. It is assumed that only seven plants are required to do so. Following the initial debris assessment, an estimated ten plants will have to undergo a detailed debris analysis.

It is estimated that ten plants will have to undergo backfits. Five of these are assumed to be relatively modest sump modifications, e.g., screens. The remaining five are assumed to be major projects involving insulation replacement.

Table D.11 summarizes the industry implementation costs. It is assumed that backfits are scheduled within refueling outages. This could result in the backfits stretching over a number of years. However, for this calculation it is assumed that the costs occur in the first year and no further discounting is required.

TABLE D.11. Summary of Industry Implementation Costs

Activity	Number of Affected Reactors	Cost Per Reactor ($) Best Estimate	High Estimate	Low Estimate	Total Cost ($) Best Estimate	High Estimate	Low Estimate
Sump Assessment	75	2.5E3	7E3	1.5E3	1.9E5	5.3E5	1.1E5
Add Vortex Suppressor	7	2E4	3E4	1E4	1.4E5	2.1E5	7E4
Initial Debris Assessment - BWR	25	5E3	7E3	3E3	1.3E5	1.8E5	7.5E4
Initial Debris Assessment - PWR	50	7.5E	1E4	5E3	3.8E5	5.0E5	2.5E5
Detailed Debris Analysis	10	1.2E4	1.5E4	1.0E4	1.2E5	1.5E5	1.0E5
Sump Modification	5	6.5E4	8.0E4	5.0E4	3.2E5	4.0E5	2.5E5
Insulation Replacement	5	5.0E5	7.0E5	2.5E4	2.5E6	3.5E6	1.2E5
Total					3.8E6	5.5E6	9.8E5

NRC Implementation

The "impact" of proposed changes with respect to staff review time will be minimal, making use of the guidelines contained in Appendix A of the Revised RG 1.82. NUREG-0897 and supporting references provide additional technical information which will assist the staff reviewer. It is estimated that less than 1 person-week of staff review time would be required (estimated cost = $1500/plant). It is estimated that this might range from $1000/plant to $4000/plant. For 75 plants, this yields a total NRC impact of $1.1E5 with bounds $7.5E4 to $3.0E5. Once again, while it is possible that these costs may stretch out, it is assumed the costs occur in the first year.

VALUE-IMPACT RESULTS DISPLAY

This assessment uses both the ratio and net-benefit methods. The results of the assessment were shown in the summary table at the beginning of Section D.2.

Figure D.1 shows the results of the ratio-method approach assessment plotted on the chart used by SPEB/NRR for tentative priority rankings of safety issues. The plotted points correspond to the per-reactor scale. Since only ten reactors are assumed to be affected by this action, the per-reactor criteria will dominate the total reactor population criteria. The core-melt values are taken from Table D.6.

Figure D.2 shows the results of the net-benefit assessment. The relative importance of each attribute can be seen. The bands show the uncertainty ranges with the best estimate indicated within the bands. A linear scale is employed.

SENSITIVITY STUDIES

The results presented above employ what might be termed "baseline" assumptions. Other assumptions might be made. Specific assumptions which can be studied are 1) the base-case radiological consequence, 2) the discount rate, 3) the monetary evaluation of health effects, and 4) the need for replacement power. The sensitivity of the value-impact assessment results to variations in each of these assumptions is examined below. The sensitivity is demonstrated by the change in the best- estimate ratio and net-benefit results caused by the use of alternative assumptions.

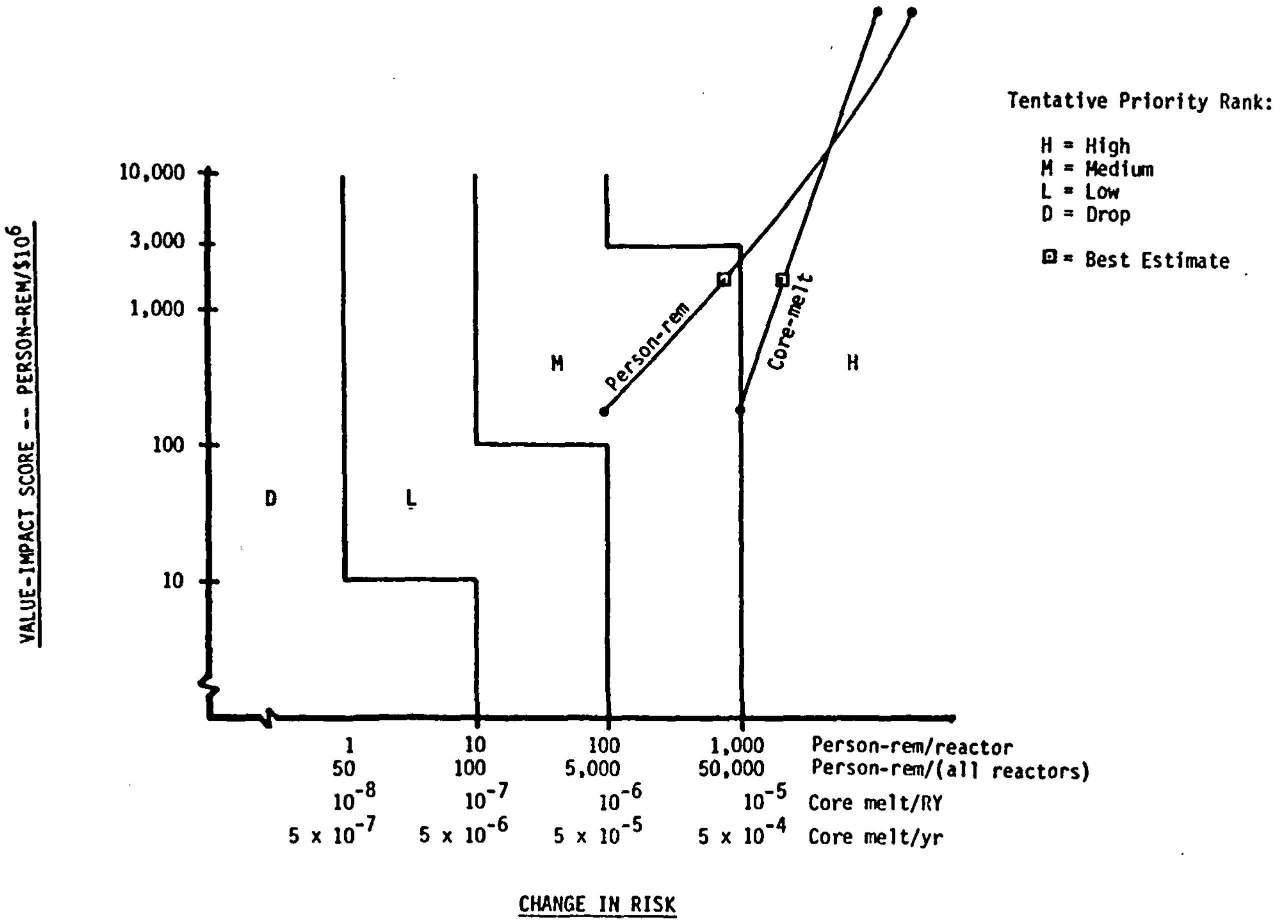

FIGURE D.1. Display of Ratio Results

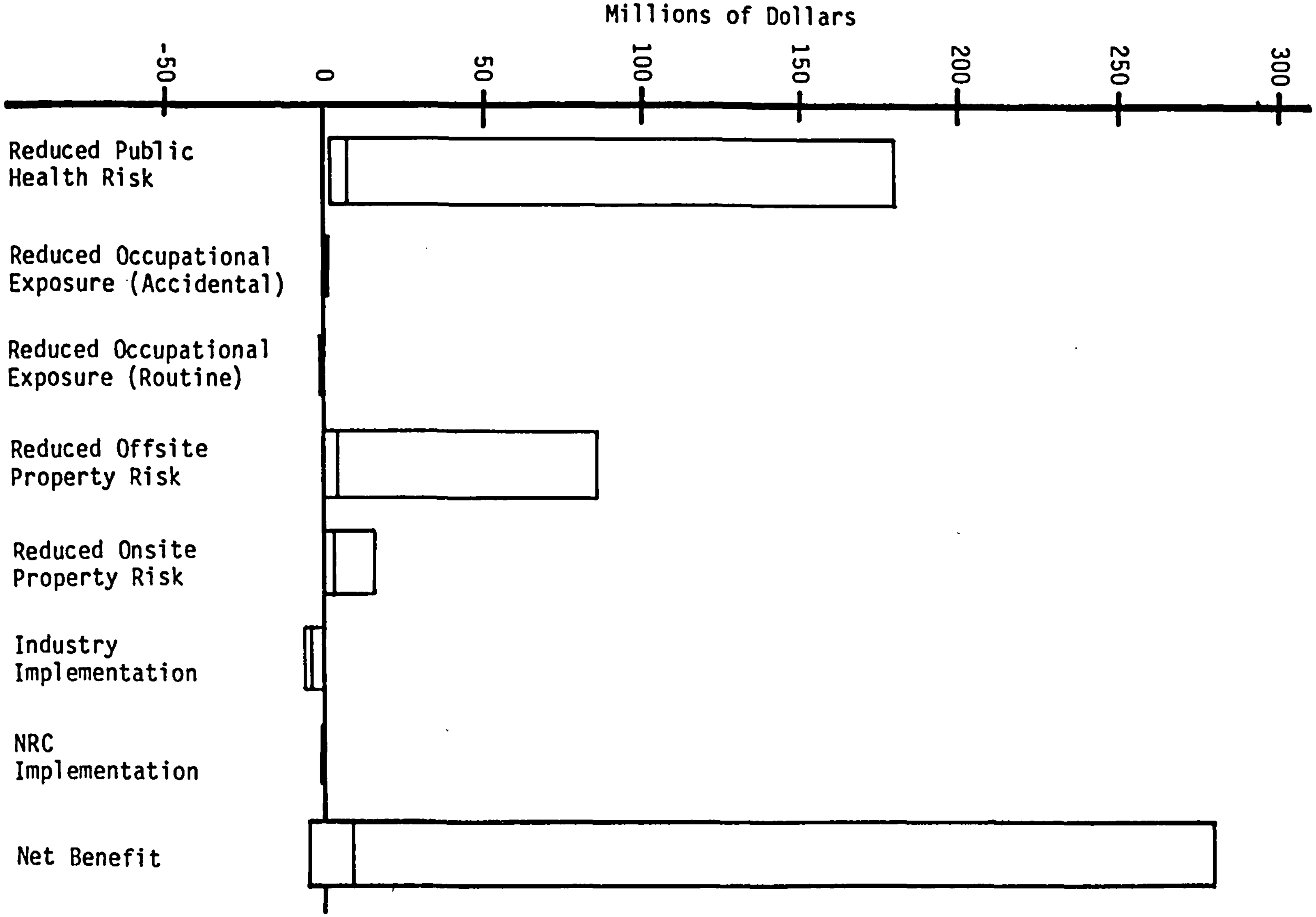

FIGURE D.2. Display of Net-Benefit Results

Base-Case Radiological Consequences

The value of reduced risk is dependent on the magnitude of the pre-existing risk. The re-evaluation of the radiological release source terms has the potential of a significant alteration in the assumed existing risk. This potential effect can be demonstrated by assuming that the radiological consequences in the event of a release can, upon re-evaluation, be reduced by a factor of ten. This would reduce the public exposure upon release by a factor of ten; and since the effect of this action is based solely on accident probability, the effective reduction in public dose would similarly be lowered by a factor of ten. It also can be assumed that reduced risk to offsite property would be lowered by a factor of ten. This yields a new best-estimate ratio of 190 (person-rem/$\$10^6$) and a new best-estimate net benefit of $-9.7E5.

Discount Rate

The baseline assumption for a discount rate was 10%. The effect of changing the discount rate can be seen by using a 5% rate. The only affected attributes are offsite and onsite property. Impacts are not affected since the estimates made are assumed to represent single-year expenditures. The ratio result is therefore not affected. The numerator of the ratio is avoided public dose and is not discounted. The denominator is total impact, which in this case is not affected. Recalculating the net benefit with the 5% discount rate yields a new best estimate of $1.2E7.

Monetary Evaluation of Health Effects

A major difficulty in the net-benefit method is the monetary evaluation of health effects. The sensitivity of this particular analysis to that evaluation can be demonstrated by substituting values of $100, $500, and $2000 per person-rem instead of $1000 per person-rem. The ratio estimates, of course, are not affected by these variations. Revised best estimates of the net benefit are $2.0E6, $4.9E6, and $1.6E7, respectively.

Replacement Power

The baseline assumption is that the required backfits can be scheduled within existing refueling outages. If either the backlog of maintenance items is too great or the importance of the backfit is felt sufficient, outages may be extended to accomplish the backfit. To demonstrate the effect of an outage extension, it will be assumed that a five-day extension is required at each of the ten affected plants. Assuming a $300,000/day replacement power cost, $1.5E7 is added to the industry implementation cost. This results in a new best estimate for the ratio of 400 (person-rem/$\$10^6$) and a new best estimate for the net benefit of $-6.3E6.

Table D.12 shows the results of the sensitivity studies. It indicates that both the ratio and the net benefit are quite sensitive to significant changes in the accident source term. Both are also sensitive to the need for replacement power, with the net benefit showing a more dramatic effect. Since benefits are not discounted in the ratio method and impacts are assumed to be unaffected by discounting, in this analysis the ratio is completely insensitive to discount rate. The net benefit shows a moderate sensitivity to discount rate. For this analysis, the net benefit is moderately sensitive to the factor used to convert person-rem to dollars.

TABLE D.12. Sensitivity Studies Results

	Best Estimate	
Assumption	Ratio (person-rem/$\$10^6$)	Net Benefit ($)
Baseline[a]	1900	8.7E6
Factor of 10 reduction in source term	190	-9.7E5
5% discount rate	no change	1.2E7
$100/person-rem	no change	2.0E6
$500/person-rem	no change	4.9E6
$2000/person-rem	no change	1.6E7
5 days replacement power/reactor	400	-6.3E6

(a) Baseline assumptions: existing source term; 10% discount rate; $1000 per person-rem; no replacement power.

INITIAL/RESIDUAL RISK

The initial (status quo) and residual (remaining after the backfit) risks for the ten affected reactors are shown in Table D.13. While information on the initial risk is not well defined in the table, it is evident that the action will not cause a major change in risk.

RECOMMENDATIONS

The primary results of the value-impact assessment are shown in the Value-Impact Summary Cover Page and in Figures D.1 and D.2. These results indicate that while at the lower estimates this action is difficult to justify, at the best and high estimates it can be recommended. The best estimate of the ratio method indicates a ranking near the boundary between medium and high priority

TABLE D.13. Initial/Residual Risk for USI A-43

Risk Measure	Initial Risk	Residual Risk
Major core-melt probability (events/reactor-year)	7.6E-4[a]	7.4E-4
Acute fatalities	(b)	~97% initial[c]
Latent fatalities	(b)	~97% initial[c]

(a) Approximate average of surveyed plants used in NRR value-impact.
(b) This information is not given in the NRR value-impact analysis.
(c) If action only affects risk through reduction in accident frequency, then fatality risk change will be proportional to core melt-probability change.

assignment. The net-benefit method supports this with a modest but positive best-estimate net benefit. At the high estimate, both methods strongly indicate support for the action. In general, then, moderate support for the action is indicated by the value-impact assessment.

These conclusions should be considered in light of the insights gained in the sensitivity studies. A significant reduction in source terms or any requirement for replacement power would cast the action in a more unfavorable light.

APPENDIX D REFERENCES

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APPENDIX E

VALUE-IMPACT ASSESSMENT EXAMPLE: TMI ACTION ITEM I.A.3.5, "ESTABLISH STATEMENT OF UNDERSTANDING WITH INPO AND DOE"

APPENDIX E

VALUE-IMPACT ASSESSMENT EXAMPLE: TMI ACTION ITEM I.A.3.5, "ESTABLISH STATEMENT OF UNDERSTANDING WITH INPO AND DOE"

In this appendix, a sample value-impact analysis using the methods suggested in this handbook is presented. Unlike the example given in Appendix D, which was supported by considerable analytical data, this case is not well defined. Establishment of better understanding of the relative roles of the NRC, INPO and DOE would seem a laudable goal. However, precise specification of the values and impacts associated with this action is very difficult. Therefore, the action effectively demonstrates application of the value-impact method for a "softer" issue.

In the analysis that follows, there is no numerical quantification of the effect of this action upon public exposure. The ratio method and the net-benefit method would both express the value in terms of supplementary considerations. For this assessment, therefore, the two methods essentially coalesce.

The intent of this appendix is to illustrate the methods, rather than to provide the definitive analysis of I.A.3.5. The evaluation assumes that a statement of understanding has been prepared and that the proposed action is NRC adoption of the statement. In actuality, according to the most recent information available to PNL, this item is inactive. Negotiations are underway toward the development of understanding with INPO; however, there is currently no schedule for their completion.

Since the apparent importance of this action is limited, a formal scoping analysis was waived. The value-impact assessment begins on the following page with the assessment summary cover page.

VALUE-IMPACT SUMMARY COVER PAGE

Establish Statement of Understanding with INPO and DOE: TMI Action Item I.A.3.5.

Prepared by J. Doe/DIR/DHFS/NRR
May 1983

SUMMARY OF PROBLEM AND PROPOSED SOLUTION

Current activities of NRC, DOE and INPO are poorly or incompletely coordinated. By establishing a formal statement of understanding these activities could be better integrated, resulting in more effective and efficient operations.

ATTRIBUTE	Dose Reduction (person-rem) Best Estimate	High Estimate	Low Estimate	Evaluation ($)[a] Best Estimate	High Estimate	Low Estimate
Public Health	NQ			NQ		
Occupational Exposure (Accidental)	NQ			NQ		
Occupational Exposure (Routine)	NQ			NQ		
Offsite Property	NQ			NQ		
Onsite Property	NQ			NQ		
Regulatory Efficiency	NQ			NQ		
Improvements in Knowledge	NQ			NQ		
Industry Implementation				-1.0E5	-7.0E4	-3.0E5
Industry Operation				5.0E5	2.0E6	1.0E5
NRC Development				-5.0E4	-2.0E4	-1.0E5
NRC Implementation				-1.0E5	-7.0E4	-3.0E5
NRC Operation				2.0E6	5.0E6	5.0E5
NET BENEFIT: Sum Over All Affected Attributes ($)				2.3E6	6.8E6	-1.0E5

RATIO: Public Dose Reduction/|Sum of All NRC and Industry Costs|(person-rem/$\$10^6$)[b] NQ

NA = Not Affected

NQ = Not Quantified

(a) Note: Favorable or beneficial consequences of a proposed action have a positive sign. Unfavorable or adverse consequences have a negative sign. For instance, an increase in industry or NRC operating costs would be considered an unfavorable consequence and should be entered in the table with a negative sign.

(b) Strictly speaking, because the ratio should be expressed as a positive number, the analyst should use the absolute value of the sum of all costs (industry, NRC, and other) in the denominator.

PROPOSED ACTION AND POTENTIAL ALTERNATIVES

Proposed Action[a]

The statement of understanding defines both general and specific functions of the three organizations relative to one another. It provides mechanisms for cooperation and reassessment of roles as the organizations evolve. The statement of understanding would enhance the synergistic relationship among the three organizations, thus, by helping to avoid duplication of efforts, assisting each organization to achieve its goals more efficiently. Furthermore, it would give each organization an opportunity to receive insights on its activities from fresh perspectives. Each organization would experience some modest costs associated with the implementation and ongoing operation of the coordination effort.

No licensee facility is directly affected by the proposed action. However, all INPO member utilities are indirectly affected as the action affects INPO.

Alternative

The only alternative considered is not to adopt the statement of understanding. This is the status quo alternative. Since the effect of the action is measured in terms of the change from the existing condition, the status quo alternative is automatically considered.

CHECKLIST FOR IDENTIFICATION OF AFFECTED ATTRIBUTES

Attribute	Quantified Change	Unquantified Change	No Change
Public Health		X	
Occupational Exposure (Accidental)		X	
Occupational Exposure (Routine)		X	
Public Property		X	
Onsite Property		X	
Regulatory Efficiency		X	
Improvements in Knowledge			X
Industry Implementation	X		
Industry Operation	X		
NRC Development	X		
NRC Implementation	X		
NRC Operation	X		

(a) This example assumes that the statement of understanding, when prepared, would have these features.

SUPPLEMENTARY CONSIDERATIONS

The attributes that are affected in a nonquantified manner can be divided into two portions. The first group consists of the accident-related factors and routine occupational exposure. The second portion consists of regulatory efficiency.

Accident-Related Attributes and Routine Occupational Exposure

The attributes of Public Health, Occupational Exposure (Accidental), Occupational Exposure (Routine), Offsite Property, and Onsite Property are affected indirectly by the proposed action. The action, if adopted, will improve the efficiency of the NRC activities; and, through improved cooperation, it will enhance the agency's ability to meet its goals. Such improved coordination and cooperation will result in some improvement in reactor safety. This will take the form of reduction in accident probability, mitigation of accident consequences, and reductions in occupational exposure. While the improvements resulting from the proposed action are likely to occur, it is not possible to provide quantification of their magnitude. In total, the effect is envisioned as positive, but modest in scale.

Regulatory Efficiency

A portion of the benefit from adopting the statement of understanding is captured by the cost savings expected to be realized. In addition to those quantified results, regulatory efficiency is expected to be enhanced in a manner that is not easily quantified.

Current activities among NRC, INPO, and DOE are not efficiently coordinated. This action would establish a statement of understanding among these organizations that would clearly define areas of responsibility and cooperation. This would prevent the duplication of efforts and more directly focus the activity of the organization towards fulfillment of common goals. Such coordination would reduce conflicts within the federal government and between the NRC and industry. It has the potential for assisting in the streamlining of licensing and other regulatory processes by providing industry insights and shared responsibilities. Research activities would be better coordinated between NRC and DOE, allowing for more productive and fruitful research efforts.

DEVELOPMENT OF QUANTIFICATION

Industry Implementation

The cost to industry of implementing the action is composed of the INPO staff labor to negotiate the agreement. This is estimated to require one person-year, or $100,000. A low estimate of $70,000 reflects the view that substantial reductions from the one-person-year effort are unlikely. The high estimate is taken to be three person-years, or $300,000.

Industry Operation

Industry is expected to incur both a cost increase and a cost savings associated with this action. Industry, through INPO, is estimated to invest one-half person-year, or $50,000, per year to maintain the cooperative integration activity. Cost savings will take the form of more efficient utilization of INPO resources and, to some extent, savings to individual utilities due to enhanced INPO influence on NRC regulation. This is estimated to be equivalent to an annual savings of one person-year, or $100,000, resulting in a net savings of $50,000 per year. If we discount this at 10% over the 40-year lifetime of a reactor beginning operation now, a present value of approximately $500,000 is calculated.

There is significant uncertainty associated with this estimate. Accordingly, bounds of $100,000 savings to $2,000,000 savings are suggested.

NRC Development

A modest effort is required to finalize background studies associated with this action. This effort is estimated to involve one-half a person-year or $50,000, with estimated bounds of $20,000 to $100,000.

NRC Implementation

Costs to the NRC to implement the proposed action are assumed to be equivalent to the industry costs described above, $100,000 with bounds of $70,000 to $300,000.

NRC Operation

The NRC will incur a modest annual cost to maintain the integration effort. This is estimated to be one person-year or $100,000. Cost savings are expected to take the form of more efficient NRC operation, reduced labor needs associated with relying on INPO certification and reviews, and cost savings associated with more efficient sharing of research activities with DOE. The total cost savings is estimated to be equivalent to an annual cost savings of $300,000, and yields an estimated annual net savings of $200,000. Discounting at 10% over the 40-year lifetime of a new power plant beginning operation yields a present value of approximately $2,000,000. There is considerable uncertainty associated with this estimate, and bounds of $500,000 to $5,000,000 cost savings are suggested.

VALUE-IMPACT RESULTS DISPLAY

Since the value-impact assessment for this action is highly qualitative, no separate display of results is presented. The attributes that can be quantified are summarized on the cover page.

SENSITIVITY STUDIES

The limited quantification of attributes in this assessment presents only limited opportunities for sensitivity testing. The exception is the discount rate used to evaluate operation costs for industry and the NRC. The baseline assumption used a 10% discount rate. If a 5% discount rate were used, the best estimate of the net benefit would change from 2.3E6 to 4.1E6, indicating a moderate sensitivity to the discount rate.

RECOMMENDATIONS

The best estimate of the quantified net benefit is $2.3E6. The bounds of uncertainty extend from 1.0E5 negative benefit to $6.8E6 positive benefit. Based on these considerations alone, it would appear that the action could be undertaken with fairly high confidence of obtaining a positive benefit. In addition to the quantified net benefit, the assessment of unquantified factors (e.g., reducing risk to public health) also supports the adoption of the action.

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16. ABSTRACT (200 words or less)

This handbook documents a set of uniform and acceptable procedures for providing information that can be used in performing value-impact assessments of NRC regulatory actions. It describes a systematic but flexible process for performing the assessment. Chapter 1 introduces the value-impact assessment process. Chapter 2 describes the attributes most frequently affected by proposed NRC actions, provides guidance concerning the appropriate level of effort to be devoted to the assessment, suggests a standard format for documenting the assessment, and discusses the treatment of uncertainty. Chapter 3 details methods for evaluating each attribute affected by a regulatory action. Five appendices contain background information, technical data, and example applications of the value-impact assessment procedures. This edition of the handbook focuses primarily on assessing nuclear power reactor safety issues.

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