

Benefit-Cost Analysis In The Point Lepreau Refurbishment Planning Process

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Prepared for Presentation at the
23rd Annual Conference of the CNS

2-5 June 2002
Toronto

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1. INTRODUCTION

As an integral part of its operational philosophy the Canadian nuclear power industry carries out ongoing assessments of nuclear plant operation and maintenance as the plants continue to age and as new operational, analytical or research information is acquired. Particular emphasis is given to issues arising out of such assessments that have potentially significant safety and/or regulatory implications.

New Brunswick Power is considering the refurbishment of their Point Lepreau Generating Station. The 18 month outage that the Point Lepreau Refurbishment (PLR) project would require provides the opportunity for introducing system design changes aimed at the resolution of such issues. However, the alternatives available for the resolution of these issues can span the range from taking no action at all to major design modifications. The issues are generally complex, and the attributes that characterize the various alternatives (e.g., safety, regulatory and operational implications, the overall costs for implementing a proposed resolution, etc.) cannot always be readily quantified. Finally, selection of the most appropriate alternative may require difficult resource allocation decisions, as well as consideration of a number of intangible factors, and it is desirable that the implementation of a proposed change achieves the maximum safety benefit given the resource limitations that must be taken into account.

NB Power recognized the need for a rational, systematic methodology for the evaluation of design changes being proposed for implementation during the refurbishment outage in order to ensure that potential changes were being considered on a consistent basis and that the costs associated with these changes were commensurate with the benefits gained. It was also recognized that safety and cost considerations do not necessarily contradict each other. The most efficient plants are often those with the best safety performance. In any case, a balance between safety and cost must be achieved without violating existing standards and regulations and the public's right for adequate level of nuclear safety. There is, therefore, a continuing need to ensure that safety resources are used in a cost-effective way.

Benefit-Cost Analysis¹ (BCA) offers a systematic means to contribute to safety-related decision making. NB Power has therefore undertaken the development of a comprehensive BCA process that could be applied during the early stages of the PLR planning process to assist in providing information that would contribute to making appropriate risk informed decisions regarding changes being considered for the PLR project.

¹ BCA is also referred to as *Cost-Benefit Analysis* or *Value-Impact Analysis* in some jurisdictions; however its role in decision making and the underlying principles are essentially identical to those described here.

2. HIERARCHICAL APPROACH

The development of the BCA process took into account the regulatory policy and guidelines promulgated by the Federal Government, as well as regulatory policy of the Canadian Nuclear Safety Commission. The Government of Canada, through guidelines provided by the Treasury Board (TB) [1] and the Privy Council Office (PCO) [2] and through a policy statement issued by the Canadian Nuclear Safety Commission (CNSC) [3], has demonstrated a clear commitment to benefit-cost analysis as a tool to help provide a rational, systematic methodology for the evaluation of proposed alternatives for the resolution of complex issues to ensure that a consistent approach is being taken and that the costs of implementing a proposed course of action are commensurate with the benefits gained. BCA guidelines from several other Canadian and international agencies and institutions were also considered including, but not limited to, References [4]-[11].

Building on the policies, procedures and practices of these and other institutions, a hierarchical approach was taken to development of the BCA process for the PLR project. A high tier document entitled *Benefit-Cost Analysis Principles and Process* [12] was first prepared to serve as a policy and overview document for the project. It described the fundamental principles that form the foundation on which the BCA process is built and the key steps in that process. The document outlines the principles, high-level concepts and overall process for carrying out a BCA. It is intended to provide an understanding of how benefit-cost analysis can help in decision-making.

This was followed by a second tier working level document, the *Benefit-Cost Analysis Implementation Guidelines* [13]. The objectives of the *Implementation Guidelines* are: to provide guidance in carrying out Benefit-Cost Analyses in accordance with the general principles and process; to establish a framework and a detailed process that will lend consistency to analyses and facilitate their comparison; and to provide detailed guidance, for each step in the BCA process, on the basic elements of analysis, including a reference set of equations, attributes and assumptions that may be used in conducting benefit-cost analyses. The scope of the guidelines document was intended to cover primarily the assessment of possible solutions to issues that have a potentially significant safety and/or regulatory impact. The guidance provided gives one approach to satisfactorily assessing such issues. However, it was not intended to be prescriptive, and it was made clear that other approaches that provide a fair and consistent comparison amongst various alternative solutions to a potentially significant safety and/or regulatory issue could also be considered acceptable.

Finally, at the third tier, three “documents” were prepared for the project. The first, *Basis for Recommended Inputs for BCA* [14], was written to provide the rationale for specific input data recommended for the PLR project BCA studies. The second was an Excel model, the *Benefit-Cost Analysis Workbook* [15], which was developed to carry out the calculations described in the *Implementation Guidelines*. The third was a *Benefit-Cost Analysis Workbook Users Manual* [16] produced to describe in detail the use of the *Workbook*.

This hierarchical system of project documentation is illustrated schematically in Figure 1.

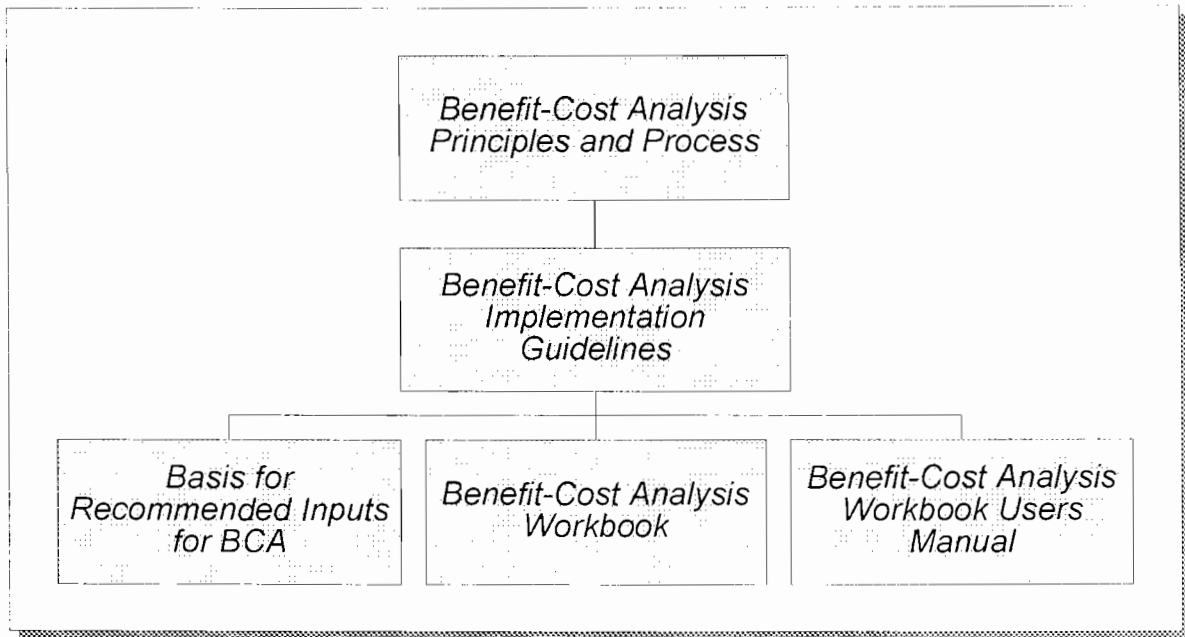


Figure 1: Hierarchical BCA Document Structure for PLR Project

3. BENEFIT-COST ANALYSIS PRINCIPLES

Several key principles were established to guide the conduct of benefit-cost analysis for PLR project planning. These included:

- Benefit-cost analysis will be used by NB Power as one of its tools to evaluate and make decisions with respect to the various alternatives that may be available for the resolution of issues having potential safety and/or regulatory implications.
- The objective of benefit-cost analysis is to present relevant information, both qualitative and quantitative, in a manner that allows fair comparison and that can contribute to making an **informed** decision with respect to a proposed set of alternatives. It is not “quantification of everything” in order to arrive at a single number that will dictate a solution.
- Amongst the alternatives being considered for the resolution of an issue having safety and/or regulatory implications, the preferred alternative will normally be the one that optimizes benefits relative to costs.
- In order to allow for a fair comparison, the various benefits and costs will normally be evaluated in quantitative terms using common units (usually dollars), resorting to qualitative terms only when conversion to monetary equivalents cannot be meaningfully carried out.

4. DEFINITIONS

With the above principles as guidelines, the available literature was reviewed in detail to identify best practices and common features amongst current practitioners that might be incorporated into the PLR benefit-cost analysis process. One of the early observations in doing so was that there is a wide disparity in the use of terminology throughout the “BCA industry”.

In order to ensure a common, consistent understanding for the PLR project of both the BCA process and its results, it is necessary that there be a common understanding of the terminology. The following definitions were used throughout this hierarchy of documentation.

1. The **benefits** of a proposed course of action are the desirable positive outcomes that are anticipated as a result of its implementation.
2. The **costs** of a proposed course of action are the value of the resources that must be consumed to effect its implementation, as well as the undesirable outcomes that are anticipated as a result of its implementation.
3. The **attributes** associated with a proposed course of action are those factors which may change as a result of its implementation, and which may therefore have an impact on either the benefits or the costs associated with the proposed course of action.
4. The **implementation** of a proposed course of action is understood to include all relevant activities that are required immediately or in the near term, as well as all associated ongoing activities that are required in the longer term.

5. BENEFIT-COST ANALYSIS PROCESS

Another observation that emerged from a review of the literature was that there are several key steps that are common to most of the BCA procedures reviewed. This was particularly true of those for various technologies in which safety was in important consideration. These included, for example, the nuclear industry in the U.S., the transportation industries in the U.S. and Canada (airline and automotive), public health, and law enforcement/justice. In all cases, resource constraints limit the available funding and projects must be prioritized with respect to their expected contribution to public health and safety.

This review, guided by the principles articulated above, led to the development of a seven step BCA process for the PLR project, as described in the *BCA Principles and Process*:

1. Statement Of Issue
2. Assessment of Safety Significance
3. Identification Of Alternatives
4. Specification of Attributes
5. Screening Assessment
6. Detailed Benefit-Cost Analysis

7. Presentation of Results

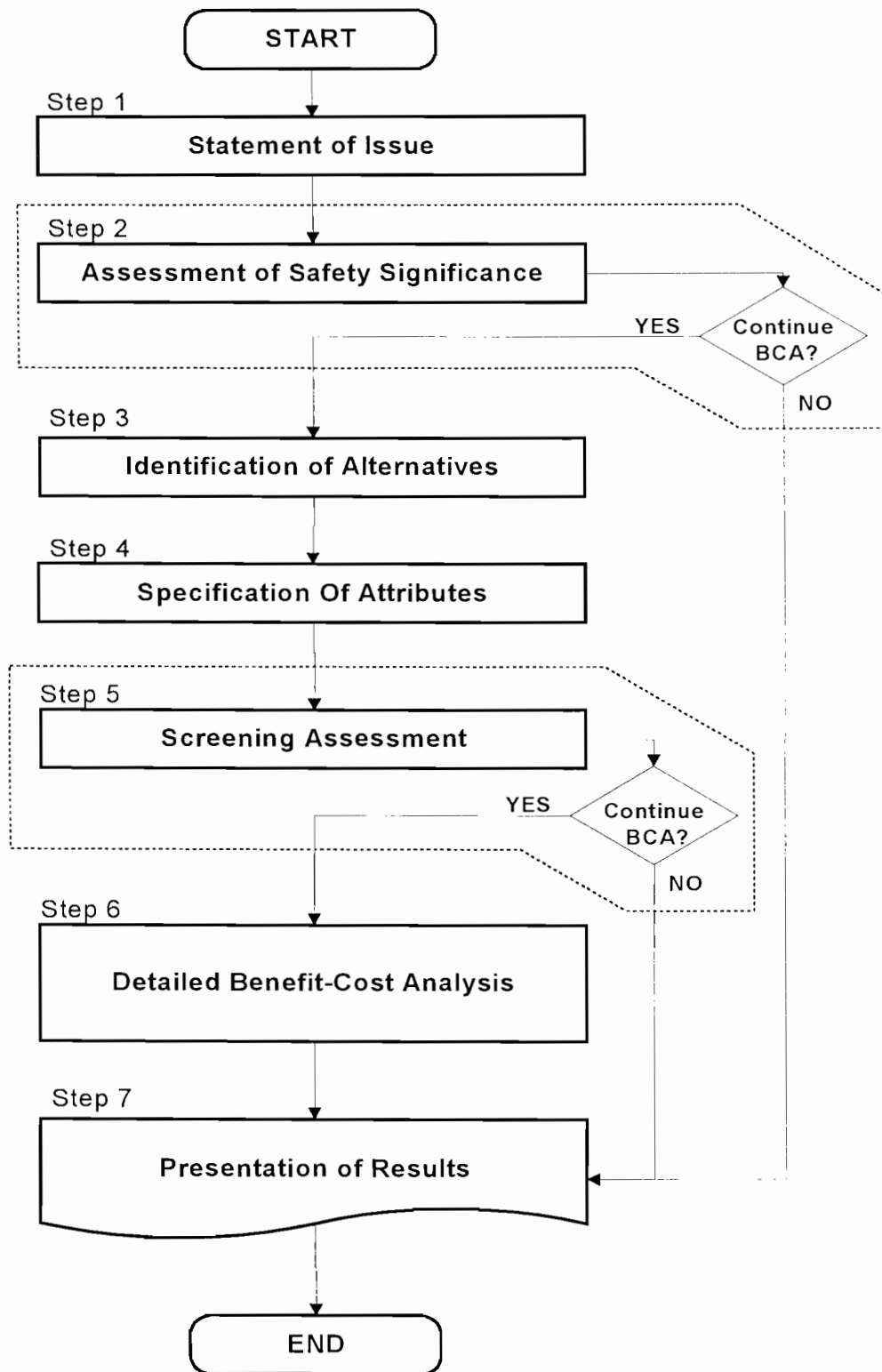


Figure 2: Schematic Illustration of the Benefit-Cost Analysis Process

It is important to note that not all issues arising out of the ongoing assessment of nuclear power plant operation and maintenance will require use of the detailed BCA methodology as a part of the resolution process. In fact, the BCA process includes two screening steps, “Assessment of Safety Significance” and “Screening Assessment” that use simplified evaluation techniques and decision criteria to evaluate whether an issue needs to continue through the detailed BCA process. For those in which there is an advantage in applying the formality of this process, it is expected that the process will be systematically applied in a consistent fashion for all cases. It is important to recognize that this does not mean that every BCA will be carried out to the same level of detail, or even that the same attributes will be evaluated in each case. It does mean that each case will be systematically and methodically examined, that the attributes to be considered in a specific case are commensurate with the complexity of the issue and the anticipated extent of the associated benefits and/or costs, and that the process of establishing which attributes are to be considered will be well documented. A list of attributes that were considered for the PLR project is provided in Table 1.

6. USE OF BCA ON THE POINT LEPREAU REFURBISHMENT PROJECT

The process described above has been successfully applied during the PLR planning to evaluate a large number of potential design changes. The information gained during conduct of the BCA has been used along with other relevant information to decide on which design changes should be implemented if the refurbishment proceeds.

Potential design changes were identified through:

- An exhaustive plant condition assessment that looked at systems important to both safety and production, with particular emphasis on age related degradation and obsolescence.
- A comprehensive safety and licensing review, with particular emphasis on known regulatory and safety issues, a review against new codes and standards, and comparison against new plants and anticipated outcomes from a probabilistic safety analysis (PSA).

All potential changes identified through these studies were entered into a conditions assessment database. A Consolidation Team then reviewed the potential changes based on defence in depth considerations, preliminary BCA studies, and recent CANDU experience. This team then recommended a selection of items for further consideration, including detailed costing, engineering and BCA studies. Plant design packages (PDPs) were prepared, including the BCA results, for review by the Project Management Team (PMT). The PMT reviewed the PDPs and made recommendations to a Change Control Board (CCB). The CCB had final authority for deciding which changes should be implemented as part of the refurbishment.

Table 1: List of Attributes Considered in BCA Studies

Attribute	Element	Sub-element
Public Health & Safety Effects	Accident risk (direct)	Expected decrease (or increase) in health effects due to radiation doses from accidents
		Expected decrease (or increase) in prompt casualties (injuries or fatalities)
Occupational (Worker) (Plant Staff) Health and Safety Effects	Accident risk (direct)	Expected decrease (or increase) in worker radiation exposure due to accident conditions
		Expected decrease (or increase) in occupational dose due to accident recovery operations.
		Expected decrease (or increase) in prompt casualties (injuries and fatalities – radiological and industrial causes)
		<i>Expected change in industrial safety following an accident</i>
		Estimated increase (or decrease) in worker radiation exposure associated with implementation of proposed change
Normal Operation	Normal Operation	Estimated increase (or decrease) in worker radiation exposure due to changes in inspection, test and maintenance requirements
		<i>Expected increase (or decrease) in replacement power worker safety effects</i>
		<i>Expected change in industrial safety risk during implementation</i>

Attribute	Element	Sub-element
Implementation And Operational Effects Costs	Planning & engineering	Estimated direct and indirect costs for planning and engineering change
	Labour cost	Estimated direct and indirect labour costs to implement proposed change
	Material cost	Estimated material and equipment costs to implement proposed change
	Replacement power cost	Estimated cost of replacement power during installation outage
	Labour O & M costs	Estimated increase (or decrease) in operating, maintenance and training costs
	Plant reliability	Estimated cost of change in plant capacity factor
Off-Site And On Site Economic Effects	Off site economic effects	Expected decrease (or increase) in costs associated with evacuation, cleanup and decontamination
	On site economic effects	Expected decrease (or increase) in property damage (repair, refurbishment, cleanup, decontamination, waste disposal)
		Expected decrease (or increase) in the cost of replacement power during post-accident outage or shutdown
	Off-site intangibles	The expected cost associated with changes in off-site intangibles resulting from the implementation of the proposed change
	On-site intangibles	The expected cost associated with changes in on-site intangibles resulting from the implementation of the proposed change
	Safeguards	
Other Potential Effects (Qualitative and/or Intangible)	Security	
	Environmental	
	Other	

The BCA documentation has consistently and repeatedly emphasized that information gained from the BCA studies is only one input to the decision-making process. Experience with the Point Lepreau review of potential safety-related design changes was entirely consistent with this viewpoint. Without going into the details of the potential changes themselves, the disposition of potential changes can be summarized in Table 2. Again, without being specific about the nature of the other considerations that entered the decision-making process, the table has been structured to facilitate an illustration of the role played by the BCA results in the decisions.

Table 2: Summary of Final Disposition of Potential Safety-Related Design Changes

Total number of potential safety-related changes considered for final disposition	24
• Number of changes approved	11
○ <i>BCA results favour making the change based on safety impact</i>	2
○ <i>BCA results favour making the change based on economic impact</i>	2
○ <i>BCA results favour the change based solely on defence-in-depth considerations</i>	4
○ <i>BCA results did not favour the change; approval based on other considerations</i>	3
• Number of changes not approved	9
○ <i>BCA results favour making the change based on safety impact</i>	0
○ <i>BCA result showed mild support for change based on economic consideration</i>	1
○ <i>Neither BCA results nor other considerations favoured making the change</i>	8
• Number of changes for which the current disposition is neither of the above	4
○ <i>Issue is being addressed by analysis rather than design change</i>	1
○ <i>Issue to be evaluated subject to hardware qualification results</i>	1
○ <i>Evaluation continuing in PLR phase 2</i>	2

It can be seen from the table that 11 of the potential changes considered for final disposition were approved. Of these, only 4 of the 11 had BCA results that could be quantified: 2 indicated a high safety impact and 2 indicated a high economic impact. In 4 other cases the change was approved on the basis of intangible (defence-in-depth) considerations for which a qualitative judgement of the monetary impact was made, leading to a supportive BCA result. In the remaining 3 cases the change was approved on the basis of other intangible considerations that could not be quantified monetarily.

For the changes that were not approved, none showed a safety-related impact from the BCA that would suggest the change should be made. One showed mild BCA support on the basis of economic considerations but was not approved due to other consideration. The remaining 8 changes all showed negligible impact from the BCA standpoint, and final disposition was decided on the basis of other intangible considerations such as, for example, the possibility of making the change at a regular maintenance outage rather than during the refurbishment outage without having a significant impact on quantifiable costs or benefits.

7. OBSERVATIONS AND CONCLUSIONS

The BCA process developed for the Point Lepreau Refurbishment project has been successfully applied during the PLR planning to evaluate a number of potential safety-related design changes.

Experience with using BCA showed that it was being used as intended – namely, it was used to gather and present relevant information in a structured and cohesive manner, but was only one of several important factors in the decision-making process. A number of design changes were approved that were supported by the BCA and a number were not approved that were not supported by the BCA. However, there were also instances in which potential design changes that were not supported by the BCA were approved. These changes were approved on the basis of other considerations such as, for example, compliance with Point Lepreau Operating Principles and Policies or compliance with regulatory requirements.

Another very significant finding was that the very rigour inherent in the process led to the identification and approval of some design changes which will contribute to enhanced safety that would not otherwise have been considered. Implementation of the BCA process for evaluation of safety-related changes proved to be so successful that the process was also applied to potential changes being considered purely for economic reasons. Even though the *BCA Workbook* was developed primarily to evaluate the impact of safety-related changes it is sufficiently flexible that it can be used to evaluate other such changes.

Although the focus here is on the Point Lepreau BCA process, it is noted that an industry working group has been formed under the auspices of COG to develop the process as a generic methodology that can be used to guide the conduct of benefit-cost analyses throughout the Canadian nuclear power industry.

8. ACKNOWLEDGEMENTS

The support and assistance of a number of people not included as authors is gratefully acknowledged. This includes K. Dinnie, D. Vecchiarelli, R. Jeppeson, and G. Archinoff, all of whom contributed directly to the development and testing of this methodology. Also acknowledged is the effort of the analysts at AECL and NB Power who provided hands-on testing and feed back by carrying out the analyses summarized above.

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