A TOOL KIT FOR EFFECTIVE EIA PRACTICE -- REVIEW OF METHODS AND PERSPECTIVES ON THEIR APPLICATION

A Supplementary Report of the International Study of the Effectiveness of Environmental Assessment

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by

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IAIA International Association for Impact Assessment

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ABSTRACT

This report was prepared as a part of the recently completed International Study of the Effectiveness of Environmental Assessment. It focuses on the delineation of the types of methods used within the environmental impact assessment (EIA) process, and on various factors for consideration in the selection of one to several methods for usage within the phases of a specific impact study. Numerous types of methods have been developed and used in the EIA process for projects, plans, programs, and policies. However, no single type of method can be used to satisfy the variety of activities in an impact study; therefore, the key issue involves selecting appropriate methods for specific needs within an impact study. Accordingly, the information in this report can be considered as a "tool kit" which can be used by EIA practitioners in planning and implementing impact studies.

A total of 22 types of methods are described for project-level studies; their application, along with several other policy-related methods, are also addressed with reference to cumulative impact assessment and strategic environmental assessment. The most-used types of methods tend to be simpler ones, including analogs, checklists, expert opinion (professional judgment), mass balance calculations, and matrices. Further, EIA methods may not have uniform applicability in all countries due to differences in legislation, procedural frameworks, baseline data, environmental standards, and environmental management programs. Emerging types of methods include geographical information systems, expert systems, risk assessment, and economic valuation of environmental impacts. Irrespective of the methods used, uncertainty exists in various facets of the EIA process; such uncertainty should be described in impact study documentation.

Even though numerous types of methods are available, research is needed in several areas, including but not limited to: (1) appropriate methods for cumulative impact assessment and strategic environmental assessment; (2) effective use of emerging tools such as GIS and expert systems; and (3) integration of information within the synthesis phase of the EIA process.

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CHAPTER I

INTRODUCTION

The concern with methodology to address scientific and policy issues encountered in environmental impact assessment (EIA) has been ongoing since 1970. The attention given to this subject is illustrated by the inclusion of technical sessions on methods at most meetings sponsored by professional societies, such as the International Association for Impact Assessment (IAIA) and the National Association of Environmental Professionals (NAEP). In addition, numerous special conferences or studies have been conducted on the EIA process and associated methods. Recent examples are noted below, and additional ones are included in the subsequent chapters of this report.

The adequacy of the scientific and methodological basis of EIA was reviewed in the International Study of the Effectiveness of Environmental Assessment from a number of perspectives. For example, this aspect was a focus of a questionnaire survey of IAIA members worldwide. Key findings were: (1) that 50% or more of the respondents judged the scientific and methodological basis to have been moderately strengthened, at best, during the last five years; (2) a large majority of respondents consider the underlying state of the component sciences to be very or somewhat limiting on the effective performance of key areas of technical practice (e.g., prediction, mitigation, monitoring); and (3) this is especially the case with respect to cumulative effects (Sadler, 1996). Supporting studies identified methods-related needs for key EIA components and activities, including scoping, public participation, decision making, strategic environmental assessment, and linkages to other project evaluation techniques such as cost-benefit analysis, risk assessment, and human health assessment (CEMP, 1994; Hong Kong Environment Protection Department, 1996; and Environment Australia, 1997).

Despite the considerable information on EIA methods, many issues remain outstanding. A European Union-sponsored workshop on EIA methodology and research needs identified three key methods-related deficiencies (Cassios, 1995): (1) an incomplete understanding of ecological and other environmental systems, and lack of data on such systems; (2) limitations related to specific utilized methods such as checklists, matrices, and network analyses; and (3) the absence of methods which could be used for specific EIA stages such as scoping. Methodological needs were also identified relative to strategic environmental assessments, integrating physical/chemical and socio-economic concerns, and cumulative impact assessment. Finally, workshop participants indicated that priority should be given to case study surveys of "best practice" methods, and the dissemination of this information to EIA practitioners.

In the United States, a questionnaire survey was recently conducted to ascertain the perspectives of analysts with experience in teaching, research, and/or practice regarding the strengths and limitations of the National Environmental Policy Act (NEPA) (Canter, 1994). As part of their response, survey participants identified the priority issues which need improvement: (1) post-EIS (environmental impact statement) follow-up in terms of monitoring, implementation of mitigation measures, ecosystem management, and environmental auditing; (2) methodological approaches for addressing cumulative impacts and reductions in institutional barriers related to the analysis of cumulative impacts; (3) training of federal personnel involved in implementing the requirements of NEPA; (4) early consideration of the EIA process in project planning and decision making; and (5) the integrated consideration of biophysical and social/economic sciences, along with risk assessment, in the EIA process. Many of these concerns relate directly or indirectly to available or needed methods.

As illustrated by these examples, there is continued interest in the development of appropriate methods for use within the EIA process. Early methods development typically focused on systematic approaches to integrate a variety of environmental impact concerns associated with a proposed project, e.g., interaction matrices, networks, simple checklists, or weighting-scaling checklists. Over time, the use and definition of EIA methods has been broadened to also encompass quantified and descriptive models of the anticipated impacts of proposed actions on various environmental media and resources. Now, EIA methods encompass environmental transport and fate models, habitat methods and indices, spatial manipulation of information, and numerous other means of impact prediction. The term methods also can encompass approaches used to compare and select a proposed action from a series of alternatives, to determine the effectiveness of impact mitigation measures, and to facilitate public participation within the EIA process.

OBJECTIVE AND SCOPE OF STUDY

The objective of this study was to review and assemble information on the types of methods used within the EIA process and to illustrate various factors to be considered in their selection and application to the main phases and activities of an impact study. The study was initiated as a component of the recently completed International Study of the Effectiveness of Environmental Assessment. Subsequently, however, it was decided to produce an expanded "tool kit" version of the methods study, recognizing the strong and continuing interest of EIA practitioners in the field. As the title suggests, the term method will be used in a broad context; i.e., it includes both extant and emerging methods and their potential usefulness. The intent is to encompass a range of tools and techniques which can be used within different phases of the EIA process. One specific focus is on the selection process for the use of methods based upon professional knowledge and judgment by EIA practitioners, and on systematic approaches to synthesizing qualitative and/or quantitative information.

This tool kit and the perspectives on its application are based on a review of key literature related to the EIA process and associated methods, conversations with EIA practitioners throughout the world, and the professional knowledge and judgment of the authors, both of whom have more than 20 years of experience in teaching, research and the actual planning and conduction of environmental impact studies. Wherever possible, case experiences and hands on lessons regarding the usage of methods have been utilized. Much of the information is organized in summary form, namely classification of tools and techniques, lists of criteria and guidance on their application, examples of the methods that are commonly used, and notes on their constraints and limitations.

REPORT ORGANIZATION

This report is organized into 10 chapters and contains an extensive list of references and source materials.

Chapter II follows this introduction and comprises an overview of EIA methods, organized by type and usage at different stages of the EIA process. Brief descriptions are given of 22 methods and guidance is provided on their usage or non-usage, including incentives and constraints to their application in situations likely to be commonly encountered.

Chapter III highlights examples of methods, which are widely utilized within the EIA process. In that regard, specific reference is made to interaction matrices. A status report on other predictive methods is organized into three categories -- simple techniques, indices and experimental approaches and mathematical models. In addition, examples are given of emerging procedures that are helpful for decision analysis, i.e., comparison of alternatives to delineate trade-offs and to document clearly the proposed action selected.

Chapter IV describes four methods of impact analysis which recently have received increasing attention, namely: geographical information systems, expert systems, risk assessment, and economic valuation of environmental impacts. These methods are useful for describing environmental conditions as well as predicting and assessing the potential impacts of proposed actions. The advantages and disadvantages are specified, primarily with a view to assisting practitioners in discriminating and selecting the situations in which they might be applied most productively.

Chapter V addresses the special challenges that cumulative impacts present within the EIA process. These issues have been addressed by recent conferences and studies, and through increasing experience with cumulative impact analysis. A logical series of steps are identified for addressing cumulative impacts, together with the strengths and weaknesses of methods that can be applied at each state of the EIA process.

Chapter VI deals with another emerging issue, namely, strategic environmental assessment (SEA) of policies, plans, and programs. While practice is still at an early stage of development, some experience has been gained already in the use of methods derived from EIA and other forms of policy analysis. Specifically, the value of methods for impact identification and prediction at the strategic level are reviewed and guidance is provided on their application at different levels of decision making.

Chapter VII covers the application of methods in relation to key stages and components of the EIA process. In the effectiveness study, scoping, review of EIS and post-approval follow-up activities were identified as especially critical for quality control and assurance. The methodological aspects that require consideration at these "checkpoints" are reviewed and specific reference is made to public participation as an integral element of an effective EIA process in general and good scoping practice in particular.

Chapter VIII deals with approaches to planning and managing EIAs, focusing on methods that can be used to organize impact studies. Both formal selection processes and the rules for the application of professional knowledge and judgment are considered. Also included is guidance on examples of decision factors (or criteria) to aid consideration in the selection process.

Chapter IX identifies key research needs related to EIA methodologies and approaches to their prioritization. Despite the range of tools and techniques noted in this report, numerous requirements for basic and applied methods of research can be found in the EIA literature. The importance of both "understanding fundamentals" and "integration of information" from different study components within the EIA process underlie the identified research needs.

Chapter X summarizes the lessons learned from the practice of EIA over the last 25 years and as a result of this study. Final points are provided for EIA practitioners as to the use of existing methods, their modification for particular application and the development of new and emerging approaches. Chapter X also notes special considerations that apply to the use of EIA methods in developing countries.

QUALIFICATIONS AND CAVEATS

The "tool kit" of methods and information assembled in this study represents a snapshot of the materials available to the authors. Inevitably, it reflects our knowledge, experience and network of contacts. The focus primarily is on methods for assessing biophysical impacts and directly related socio-economic consequences. Other types of methods used in impact studies may be referred to only briefly or not mentioned. These include, for example, methods used in policy and technology, demographic and other domains of impact assessment (for a review see Vanclay and Bronstein, 1995).

Accordingly, one of the purposes of a "tool kit" approach is to underscore the important of a format that can be supplemented and updated. This report therefore, should be viewed as a work-in-progress. For example, IAIA Annual Meetings can be used as a vehicle for gathering further information. Other initiatives that are expected to provide relevant inputs include the Environmental Methods Review to be published by the U.S. Army Environmental Policy Institute.

In this report, examples have been utilized rather than more detailed case studies. This choice was based on the following considerations: (1) case studies would expand an already lengthy report; (2)unless case studies are fully developed, they provide only a superficial illustration of the factors considered in the methods selection, and the advantages and/or difficulties associated with the use of specific tools and techniques; (3) the peer-reviewed literature is expanding and increasingly includes case study information (examples of relevant journals include Impact Assessment, Environmental Impact Assessment Review, The Environmental Professional, Project Appraisal, Environmental Monitoring and Assessment, Environmental Management, and environmental assessment (United Kingdom)); and (4) various EIA books and "conference proceedings" are available which include case studies (an example is Hildebrand and Cannon, 1993).

CHAPTER II

OVERVIEW OF EIA METHODS

This chapter provides an overview of the types of methods which have been used within the EIA process. The first section delineates 22 types of methods in relation to their usage in one or more of seven activities in an impact study. Regarding the types of methods, it should be noted that their is no standardized classification of methods within the practice of EIA. This can be easily ascertained via the review of several comparative studies of EIA methods (Bisset, 1980 and 1983; Nichols and Hyman, 1982; Lee, 1983; and Economic and Social Commission for Asia and the Pacific, 1990). The second section relates to reference sources (mainly books and reports) associated with the method types. The penultimate section contains a discussion of situations/perspectives which are either conducive to, or a deterrent to, the use of methods within the EIA process. The last section addresses uncertainty considerations in relation to methods usage.

TYPES OF METHODS AND THEIR USAGE

Numerous methodologies (tools) have been utilized over the last 25 years to meet the various activities required in the conduction of an environmental impact study. The objectives of the various activities differ, as do the usable methods for accomplishing the activities. The term method or methodology as used herein refers to structured scientific and/or policy-based approaches for achieving one or more of the basic activities. Table 1 delineates 22 types of methods arrayed against seven typical activities in an impact study (Canter, 1997). An "x" in Table 1 denotes that the listed method type is or may be directly useful for accomplishing a given activity. The absence of an x for any given type of method does not mean it has no usefulness for the activity; it merely suggests that it may not be specifically related to the activity.

The following represent brief descriptions of the features of the 22 types of methods, listed alphabetically and not in order of importance or usage, as depicted in Table 1:

(1) Analogs basically refer to information from existing projects of a similar type to that being addressed by an impact study. Monitoring information on actual impacts can be used as an analogy to the anticipated impacts of the proposed project. When impacts studies were first undertaken, information on actual impacts was minimal. However, over time a tremendous increase in information related to typical impacts of project types has occurred. In addition, similar types of projects can be utilized for a monitoring program in order to develop information on the impact footprints of a proposed project.

(2) There are many variations of checklists, this type of methodology is the most frequently utilized approach in the EIA process. Typically, checklists contain a series of items, impact issues, or questions which the user should address or answer as part of the impact study. Such checklists represent useful reminders of impacts and provide a systematic and reproducible basis for the EIA process.

(3) Decision-focused checklists represent a group of methods which are primarily related to comparing alternatives and conducting tradeoff analyses. In this regard, such methods are primarily

Table 1: Synopsis of EIA Methods and Study Activities (Canter, 1997)

Types of Methods in EIA	Define Issues (Scoping)	Impact Identification	Describe Affected Environment	Impact Prediction	Impact Assessment	Decision Making	Communication of Results
Analogs (look-alikes) (case studies)	x	x		x	x		
Checklists (simple, descriptive, questionnaire)		x	x				x
Decision-focused checklists (MCDM, MAUM, DA, scaling/rating/ranking, weighting)					x	x	x
Environmental cost-benefit analysis				x	x	x	
Expert opinion (professional judgment, Delphi, adaptive environmental assessment, simulation modeling)		x		x	x		
Expert systems (impact identification, prediction, assessment, decision making)	x	x	x	x	x	x	
Indices or indicators	x		x	x	x		x
Laboratory testing and scale models		x		x			
Landscape evaluation			x	x	x		
Literature reviews		x		x	x		
Mass balance calculations (inventories)				x	x		x
Matrices (simple, stepped, cross-impact, scoring)	x	x		x	x	x	x
Monitoring (baseline)			x		x		
Monitoring (field studies of receptors near analogs)				x	x		
Networks (impact trees/chains, cause/effect or consequence diagrams)		x	x	x			
Overlay mapping via GIS			x	x	x		x
Photographs/photomontages (historical and current)			x	x			x
Qualitative modeling (conceptual)			x	x			
Quantitative modeling (media, ecosystem, visual, archaeological, socio-economic, and simulation)			x	x			
Risk assessment (relative or quantitative and probabilistic)	x	x	x	x	x		
Scenario building				x		x	
Trend extrapolation			x	x			

Notes: x denotes potential for direct usage of method for listed activity
MCDM = multicriteria decision making
MAUM = multiattribute utility measurement
DA = decision analysis
GIS = geographical information system

useful for the synthesis of information from impact studies. Each viable alternative is subjected to study. Figure 1 depicts the EIA process as consisting of an analysis phase and a synthesis phase (McAllister, 1986). Decision-focused checklists can be useful for both phases, with particular value associated with the synthesis phase. There are several types of decision-focused checklists, and it is beyond the scope of this report to completely summarize all types.

(4) Environmental cost-benefit analysis (ECBA) represents an emerging type of method within the EIA process. ECBA methods supplement traditional cost-benefit analysis with increased attention to environmental resources and their economic value. Their application to the economic valuation of specific impacts of a proposed project and alternatives has considerable limitations. Estimation techniques vary in their complexity and scope, and place considerable demands on both practitioners and uses of such studies (Pearce, Markandya, and Barbier, 1989). Further research is needed to effectively implement ECBA within the EIA process.

(5) Expert opinion, which can also be referred to as professional judgment, represents a widely used type of method within the EIA process. This type of method is typically used for addressing the specific impacts of a proposed project on different components of the environment. Specific tools within the category of expert opinion which can be used to delineate information include Delphi studies and the use of the adaptive environmental assessment process. In this approach groups of experts identify appropriate information and build qualitative/quantitative models for impact prediction, or to simulate environmental processes.

(6) Expert systems are an emerging type of method which consists of drawing upon the professional knowledge and judgment of experts in particular topical areas. Such knowledge is encoded, via a series of rules or heuristics, into expert system shells in computer software. Expert systems are typically user friendly and require the user to answer a series of questions to conduct a particular analysis. Increasing attention is being given to the development of more comprehensive expert systems for the EIA process.

(7) Indices or indicators refer to selected features or parameters of environmental media or resources. They are utilized within impact studies to represent broader measures of media or resources. Specifically, indices refer to either numerical or categorized information for different environmental media or resources. Their usage assists in describing the affected environment, as well as impact prediction and assessment. Numerical or descriptive indices have been developed as measures of the vulnerability of environmental media or resources to pollution or other man-induced stresses and have proven useful in the comparison of sites for a proposed activity such as a new sanitary landfill. On this basis, required mitigation measures can be delineated and can include engineered and/or management controls.

(8) Laboratory testing and scale models can be applied to gain qualitative/quantitative information on the anticipated impacts of particular types of projects in given geographical locations. While these types of methods have not been

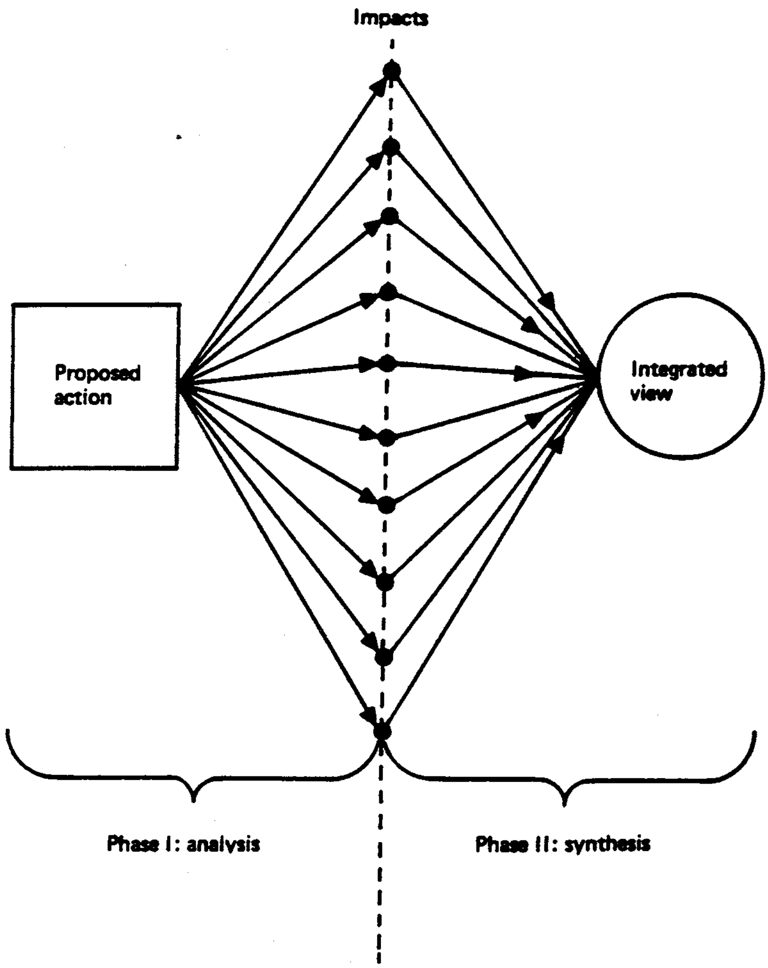

Figure 1: Two Phases of Evaluation in the EIA Process (McAllister, 1986)

extensively used, they are appropriate for certain types of projects. For example, elutriate tests can be conducted to identify the potential impacts of dredging on the aquatic environment by ascertaining the degree of contamination of the dredged material and the potential for release of such contaminants, following the physical disturbance of the bottom materials and their movement to open-water or upland disposal sites.

(9) Landscape evaluation methods are primarily useful for aesthetic or visual resources assessment. Such methods are typically based upon the development of information derived from a series of indicators and the subsequent aggregation of such information into an overall score or index for the environmental setting (similar to number 7 above). This information can be used as representative of baseline conditions. Potential aesthetic or visual impacts of a proposed project can then be estimated against the overall baseline score or index, i.e., with versus without project comparison.

(10) Literature reviews involve assembling information on types of projects and their typical impacts. As noted earlier in conjunction with analogs, this type of information can be very useful for the early delineation of potential impacts; it can also be used to quantify specific anticipated changes and to identify mitigation measures for minimizing undesirable effects. Considerable information is now available on the typical impacts of certain types of projects.

(11) Mass-balance calculations are primarily based upon inventories of existing conditions to compare changes that would result from a proposed action. Such inventories are frequently used in the EIA process in the context of air and water pollutant emissions, and solid and hazardous waste generation. Mass-balance calculations require the delineation of the study area for the establishment of the baseline conditions. One means of expressing impact is to then consider the absolute and percentage change in the inventory (or mass balance) as a result of a proposed action.

(12) Interaction matrices represent a widely used type of method within the EIA process. Variations of simple interaction matrices have been developed to emphasize particular desirable features. Examples will be highlighted in Chapter III. As can be seen by the examination of Table 1, matrices represent a useful type of method for several study activities within the EIA process.

(13) Monitoring refers to systematic measurements to establish the existing conditions of the affected environment as well as to serve as a baseline for interpreting the significance of anticipated changes from a proposed project. Monitoring could be focused upon the physical/chemical, biological, cultural, and/or socioeconomic environment. Selection of appropriate indicators for monitoring should be a function of the availability of existing information as well as the type of project and anticipated impacts.

(14) Monitoring (field studies) of receptors near analogs represents a particular specialized type of method. Specifically, monitoring and analysis of actual impacts

resulting from projects of a similar type to the project are used for impact prediction. Again, emphasis should be given to monitoring of selected indicators pertinent for the type of project.

(15) Networks refer to a group of methods that delineate connections or relationships between project actions and resultant impacts. These types of methods are referred to in several ways within EIA practice; for example, as impact trees, impact chains, cause-effect diagrams, or consequence diagrams. Networks are useful for showing primary, secondary, and tertiary impact relationships resulting from particular actions. They can also be utilized in conjunction with matrices as a tool for impact identification and qualitative impact prediction.

(16) Overlay mapping was used very early in the practice of EIA. Initial usage primarily consisted of the physical assemblage of maps displaying different environmental characteristics. The application of computer-based geographical information systems (GIS) has been emphasized in recent years. GIS technology represents an emerging type of method in the EIA process. Overlay mapping, either physical or computerized, can be used for describing existing conditions and displaying the potential changes resulting from a proposed action.

(17) Photographs or photomontages are useful tools for purposes of displaying the visual quality of the environmental setting and identifying the potential visual impacts of a proposed action. In that regard, this approach is related to landscape evaluation methods as described earlier.

(18) Qualitative modeling refers to a group of methods wherein descriptive information is utilized to address the linkages between various actions and resultant changes in environmental components. As such, it can be considered as an extended aspect of the networks category described earlier. The general focus of qualitative modeling is on understanding fundamental relationships, such as increases or decreases in certain environmental features as a result of particular activities. In many cases, qualitative modeling represents the only type of methodology available for impact prediction. Note that it is typically based upon expert opinion (professional judgment) as described earlier.

(19) Quantitative (mathematical) modeling refers to an extensive group of methods used to specifically address anticipated changes in environmental media or resources as a result of proposed actions. Such models can range from simplified versions to very complicated, three dimensional computer-based simulations that require extensive data input. It is important to recognize that quantitative models are available for many of the typical areas of impacts associated with particular projects. For example, there are several air quality dispersion models which can be used to address the anticipated air quality impacts of stack emissions from proposed hazardous waste incinerators or fossil fuel-fired power plants.

(20) Risk assessment is an emerging tool for the practice of EIA. It was initially used for establishing environmental standards based on human health concerns. Risk assessment typically

encompasses the identification of the risk, consideration of dose-response relationships, conduction of an exposure assessment, and evaluation of the associated risks. This approach can be applied to both human health and ecological risks.

(21) Scenario building involves considering alternative futures as a result of differing initial assumptions. This technique is utilized within the planning field; it also has EIA applicability, particularly in the context of SEA of policies, plans and programs.

(22) Trend extrapolation utilizes historical trends and extend them into the future based upon assumptions related to either continuing or changed conditions. Such methods are particularly valuable in focusing upon future environmental conditions without a proposed action.

Table 2 displays the 22 types of methods in relation to the evolution of the practice of EIA. The time periods represented are the first and second decades of EIA practice and the period from 1990 to the present date. As Table 2 indicates, the initial emphasis on certain types of methods is associated with a particular time frame; their continuing emphasis or utilization is also identified. Note that the types of methods actually used within the EIA process have expanded since the early years of practice. It should also be emphasized that Table 2 does not suggest precise time divisions, but is indicative of the emphasis given to different types of methods in different periods.

Table 3 displays the relative usage of the 22 types of methods in impact studies. Widespread usage is typically associated with analogs, checklists, expert opinion (professional judgment), mass balance calculations, and matrices. These five types of methods are perceived to be "simpler" than many of the other types of methods.

Based upon a systematic review of the specific information in Table 1 (and related information in Tables 2 and 3), the following observations can be made:

(1) Each listed type of method has potential usefulness in at least two, and as many as six EIA study activities.

(2) Each listed activity has from four to 19 listed method types which are potentially useful.

(3) In a given impact study, several types of methods will probably be used even though the resultant report, or environmental impact statement (EIS), may not completely document all of the utilized methods.

(4) Each of the listed types of methods have advantages and limitations; these should be considered in selecting specific methods for usage in a given study.

(5) While numerous types of methods have been developed and additional ones are being developed and tested, there is no "universal" method which can be applied to all types of proposed actions in all environmental settings and for all study activities. Accordingly, the most appropriate perspective is to consider methods as "tools" which can be selected and modified as appropriate to aid the EIA process.

Table 2: Changing Emphases on Types of Methods

Types of Methods in EIA	Emphasis in Time Period		
	1970-79	1980-89	1990-now
Analogs (look-alikes) (case studies)		I	C
Checklists (simple, descriptive, questionnaire)	I	C	C
Decision-focused checklists (MCDM, MAUM, DA, scaling/rating/ranking, weighting)	I	C	C
Environmental cost-benefit analysis			I
Expert opinion (professional judgment, Delphi, adaptive environmental assessment, simulation modeling)		I	C
Expert systems (impact identification, prediction, assessment, decision making)			I
Indices or indicators		I	C
Laboratory testing and scale models		I	C
Landscape evaluation		I	C
Literature reviews		I	C
Mass balance calculations (inventories)	I	C	C
Matrices (simple, stepped, cross-impact, scoring)	I	C	C
Monitoring (baseline)		I	C
Monitoring (field studies of receptors near analogs)		I	C
Networks (impact trees/chains, cause/effect or consequence diagrams)	I	C	C
Overlay mapping via GIS			I
Photographs/photomontages (historical and current)		I	C
Qualitative modeling (conceptual)	I	C	C
Quantitative modeling (media, ecosystem, visual, archaeological, socio-economic, and simulation)		I	C
Risk assessment (relative or quantitative and probabilistic)			I
Scenario building		I	C
Trend extrapolation		I	C

Notes: I = initial emphasis
C = continuing emphasis
MCDM = multicriteria decision making
MAUM = multiattribute utility measurement
DA = decision analysis
GIS = geographical information system

Table 3: Relative Usage of Types of Methods

Types of Methods	Relative Usage*		
	Selected	Moderate	Widespread
Analogs			X
Checklists			X
Decision-focused checklists	X		
Environmental cost-benefit analysis	X		
Expert opinion			X
Expert systems	X		
Indices or indicators		X	
Laboratory testing and scale models	X		
Landscape evaluation	X		
Literature reviews		X	
Mass balance calculations			X
Matrices			X
Monitoring (baseline)	X		
Monitoring (analogs)	X		
Networks		X	
Overlay mapping via GIS	X		
Photographs/photomontages		X	
Qualitative modeling		X	
Quantitative modeling	X		
Risk assessment	X		
Scenario building	X		
Trend extrapolation	X		

*"Selected" refers to limited usage of type of method; such limited usage could be due to data requirements, limited knowledge about the method, or the fact that it is an emerging method.
"Moderate" indicates that the type of method is used for different types of projects in different locations.
"Widespread" denotes that the type of method is widely used in a variety of countries with EIA requirements.

(6) Methods are not "cookbooks" in which a successful study is achieved by meeting the requirements of the methods. Their selection must be based on appropriate evaluation and professional judgment, as must the use of methods and the interpretation of results relative to data inputs and analysis. Although not listed as a separate type of method in Table 1, professional judgment in fact represents a "method" which pervades the entirety of the displayed information. In short, usage of methods does not ensure that all questions related to the impacts of a potential project or set of alternatives are addressed.

(7) Simpler methods, which are less demanding in terms of data, technical and personnel requirements, are probably more useful in the EIA process. To support the usefulness of simpler types of methods, selected results from a recent questionnaire survey will be noted. The questionnaire obtained qualitative and quantitative information related to practices and needs for addressing cumulative impacts in the EIA process from practitioners in the United States and internationally (Burris, 1994). A total of 57 respondents assigned an importance rating to eight types of methodologies based on their usefulness in addressing cumulative impacts. Professional judgment and case studies were identified as the most useful methods, on a relative basis, by both U.S. and international respondents.

EIA methods can be classified from a number of perspectives. Examples of bases for such classifications include: (1) phase or activity within the impact study wherein the method is expected to find the greatest usage; (2) methods with "historical" usage vs. emerging methods; (3) simple methods relative to information needs and time and fiscal requirements vs. advanced (or complex) methods which exhibit greater information, time and fiscal requirements; (4) qualitative or descriptive methods vs. quantitative methods; and (5) analytical methods for addressing a specific substantive area (e.g., air quality impacts) vs. synthesis methods which integrate information across a range of substantive areas. Table 4 lists several additional bases for classifications and terminology for expressing the range of methods for a given basis. It also illustrates that there are several perspectives via which EIA methods could be classified; however, the lines of demarkation are not absolute. Additional classification of methods using the bases shown in Table 4 will not be included herein; however, the following observations can be developed from Table 4:

(1) For each of the 22 types of methods listed in Table 1, examples can be identified to demonstrate the ranges delineated for each classification basis in Table 4.

(2) The ranges shown in Table 4 suggest that further recognition needs to be given to the advantages and limitations of the various types of methods. Accordingly, it is better to think of a continuum of tools which can find usage in impact studies.

(3) The last classification basis listed in Table 4 is impact evaluation. The assessment (or evaluation) of alternatives can be considered relative to using the results of the evaluation of each alternative. As shown earlier in Figure 1, McAllister (1986) has suggested that evaluation of an alternative (or project) can be divided into two phases:

Table 4: Additional Bases for Classification of EIA Methods

Basis for Classification	Terms to Denote Range of Methods
Historical development and application	Early to recent or current methods (current could include "modified early" methods)
EIA knowledge required of method user	Introductory to advanced
Specificity of method	Generic usage to project specific
Degree of modification of method prior to usage	Off-the-shelf (or established) to ad hoc
Data required to use method	Minimal to extensive
Scientific or technical complexity	Simple to complex
Computer requirements	Not-computer oriented to computer-based
Professional acceptability	Established to emerging (unproven)
Personnel requirements	Minimal to extensive
Impact evaluation	Analysis (or disaggregative) to synthesis (aggregative)

analysis, in which the whole is divided into parts, and synthesis, in which the parts are formed into a whole.

(4) In more specific terms the analysis phase defines and estimates the various impacts of the action (alternative). This is necessary in order to gain a detailed understanding of the many consequences of an action. At the same time, it poses a dilemma of achieving coherence from the many diverse parts. The synthesis phase attempts to solve this dilemma by bringing together the impacts into an integrated view so that a judgment can be formed on whether the action should or should not be supported. Hobbs (1985) referred to synthesis methods as amalgamation methods. Analysis tends to be more objective, whereas synthesis is more subjective. In this regard, based on Table 1, the first five listed activities involve analysis, whereas the decision making and communication of results activities encompass synthesis.

KEY REFERENCES RELATED TO METHODS

Selecting EIA methods to use in an impact study begins with a basic understanding of the types of methods. This can be accomplished via the review of pertinent reference sources, and possibly the assemblage of an EIA "library". Accordingly, Table 5 depicts the 22 types of methods displayed against a series of columns with designator codes. Definitions for each of the designator codes are included in the accompanying notes. Crosses (Xs) within Table 5 show where information on key references can be found. Each of the designator codes contains information on key references in Tables 6 through 16, respectively. References which are particularly useful in building an EIA library are identified with an asterisk in Tables 6 through 16 and are listed separately in Table 17.

USAGE/NONUSAGE OF METHODS

As demonstrated previously, numerous types of methods have been used in specific impact studies. Equally importantly however, many impact studies have not applied the types of methods delineated earlier. In other words, some studies use scientifically-based approaches to focus on the impacts of proposed actions on different environmental components, other studies tend to be general and exhibit minimal usage of methods for impact quantification and interpretation, and comparison of alternatives. A critical issue is thus related to situations or perspectives that tend to encourage or discourage the use of EIA methods.

Over the years, many studies have documented the usage of certain types of methods within selected impact studies. Some studies have included statistics, such as the percentage of studies out of the study group of x projects that included simple interaction matrices. In other cases, attention has been given to the use of impact prediction methods; four examples of such studies include Mitchell, et al. (1975), Environmental Resources Ltd. (1982 and 1984), and Culhane, Friesema, and Beecher (1987). However, to date, no studies have been conducted on the usage of methods in the context of the comprehensive listing of 22 types of methods delineated Table 1. More typically, previous studies have focused upon methods used for impact identification or, possibly, for decision making between alternatives. A general problem with all comparative studies is that certain types of methods might have been used but not actually documented within the final EIS or impact report.

Table 5: Types of Methods and Topical Categories for Pertinent References

Types of Methods in EIA	PrPr	M	P/CI	B/EI	A/VI	S/SE I	HI	EM	MA	PP	SA
Analogs (look-alikes) (case studies)											X
Checklists (simple, descriptive, questionnaire)	X	X									
Decision-focused checklists (MCDM, MAUM, DA, scaling/rating/ranking, weighting)		X									
Environmental cost-benefit analysis		O						X			
Expert opinion (professional judgment, Delphi, adaptive environmental assessment, simulation modeling)		X								X	
Expert systems (impact identification, prediction, assessment, decision making)		O						X			
Indices or indicators		X	X	X	X	X	X	X			
Laboratory testing and scale models			X	X							
Landscape evaluation					X						
Literature reviews											X
Mass balance calculations (inventories)		X	X			X					
Matrices (simple, stepped, cross-impact, scoring)	X	X									
Monitoring (baseline)		X							X		
Monitoring (field studies of receptors near analogs)		X							X		
Networks (impact trees/chains, cause/effect or consequence diagrams)		X									
Overlay mapping via GIS		O						X			
Photographs/photomontages (historical and current)					X						
Qualitative modeling (conceptual)		X	X	X	X	X	X	X			
Quantitative modeling (media, ecosystem, visual, archaeological, socio-economic, and simulation)		X	X	X	X	X	X	X			
Risk assessment (relative or quantitative and probabilistic)		O						X			
Scenario building		Y									
Trend extrapolation		Y									

The column heading codes are as follows:

PrPr = Principles and procedures related to EIA; key references related to this topic are listed in Table 6.
M = Methods for EIA, including those related to impact identification, impact predictions for substantive areas, and comparisons of alternatives and decision-making; key references related to this topic are listed in Table 7.
P/C I = Physical-chemical impacts (mainly air, surface and ground water, and noise); key references related to this topic are listed in Table 8.
B/E I = Biological-ecological impacts; key references related to this topic are listed in Table 9.
A/V I = Aesthetic or visual impacts; key references related to this topic are listed in Table 10.
S/SE I = Social or socio-economic impacts; key references related to this topic are listed in Table 11.
HI = Human health impacts; key references related to this topic are listed in Table 12.
EM = Emerging methods (geographical information systems, expert systems, risk assessment, and economic valuation of environmental impacts); key references related to these topics are listed in Table 13.
MA = Monitoring and auditing; key references related to these topics are listed in Table 14.
PP = Public participation; key references related to these topics are listed in Table 15.
SA = Specific types of actions; key references are listed in Table 16.
X = Denotes that key references related to the types of methods can be identified, as appropriate, in Tables 6 through 16.
O = Denotes that these are emerging methods.
Y = Information on this type of method is in Mitchell, et al. (1975).

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Table 7: Key References Related to Methods for Impact Identification, Prediction and Decision-making

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Table 17: Composite Listing of References Which Would Be Useful in "Building" an EIA Library

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World Bank, "Environmental Assessment Sourcebook -- Volume III: Guidelines for Environmental Assessment of Energy and Industry Projects," 1991, Washington, D.C.

World Bank, "Implementing Geographic Information Systems in Environmental Assessment," Environmental Assessment Sourcebook Update, No. 9, January, 1995b, Washington, D.C.

Firstly, national laws and regulations may require the use of scientifically-based methods and, in a few cases, may identify specific types of methods to be used. Table 18 identifies eight specific situations/perspectives that are conducive to an expanded usage of EIA methods. Each of these situations/perspectives will be briefly described. For example, in the United States, the National Environmental Policy Act requires agencies to develop methods and procedures for usage within the EIA process.

Secondly, the expanding body of knowledge on planning and implementing impact studies is conducive to methods usage. As noted earlier, the number of types of methods is expanding and as more information on their use becomes available, it can be anticipated that EIA regulators and practitioners will apply them to improve the effectiveness and efficiency of the EIA process. For their part, EIA regulators and practitioners must make a concerted effort to keep current on what is a rapidly expanding body of information.

Thirdly, individual professionals will want to utilize the most appropriate methods for various phases of an impact study, whether done independently or as part of an interdisciplinary team. In fact, this premise is fundamental to the concept of best professional practice and building interdisciplinary teams, comprised of appropriate expertise, to address specific impact concerns.

A fourth situation conducive to more complete usage of methods occurs when impact studies are conducted earlier in the planning process rather than as an "after-the-fact" justification of prior decisions. Early inclusion of impact concerns in a rational planning process minimizes time constraints related to the impact study and promotes more thorough, pertinent studies. Impact studies are a viable part of the rational planning process, which incorporates the delineation of project need, potential engineering or policy means by which to meet such needs, and consideration of the economic requirements related to project implementation and operation. They form one of the three "Es" of rational planning; that is, engineering, economics, and environment, and also facilitate their appropriate integration.

A fifth situation conducive to methods usage is the development of simpler methods. Their ready availability and applicability encourage practitioners to use them and possibly graduate to more extended usage of methods or to integrate other more advanced tools and techniques.

Of necessity, complex projects which involve multiple components, cover large geographical areas, and exhibit numerous potential impact concerns also tend to be amenable to the application of a broad range of methods. These will likely include a combination of simple and more sophisticated methods. Furthermore, impact studies of complex projects often have additional time and funding for their planning and conduction.

Finally, a comprehensive approach, with wide usage of methods within the EIA process, is often dictated by either actual or potential litigation regarding the proposed action. The comparative review of the documentation associated with an impact study conducted prior to litigation versus documentation on the same project following litigation will typically demonstrate this affect. In like manner, if a proposed action is controversial and likely to be subject to litigation, this frequently encourages the prompt utilization of more comprehensive methods for an impact study.

In contrast to the incentives to use EIA methods shown in Table 18, Table 19 delineates eight situations/perspectives that tend to act as

Table 18: Situations/Perspectives Conducive to the Usage of EIA Methods

- EIA legislation, regulations, and/or guidelines specify methods usage.
- Expanding body of information on methods, and dissemination of such information to EIA practitioners.
- EIA practitioners recognize that methods usage is an aspect of responsible professional practice.
- The EIA process is conducted during project planning and not as an "after thought" to other studies to justify previous decisions.
- The EIA process is viewed by the project proponent and EIA regulators as a component of the rational planning process (model).
- Simpler methods are available for meeting the information needs within a particular phase of the EIA study.
- The proposed action is complex regarding its components and the potential impacts within the environmental setting.
- Adversarial litigation regarding the proposed action has already occurred or is anticipated.

Table 19: Situations/Perspectives Which are Deterrents to the Usage of EIA Methods

- Perception that the time required for impact study planning and conduction will be extended due to the usage of methods.
- Actual evidence or perception that the usage of methods will increase budgetary requirements for the impact study.
- Information or data requirements for methods usage are extensive, and possibly even unavailable without excessive expenditures.
- EIA practitioners are not familiar with different types of methods and their advantages or limitations in impact studies.
- Uncertainties are recognized related to the EIA process as a whole, or to specific usage of methods such as those for impact prediction.
- The project proponent and/or EIA regulatory agency do not stress the usage of methods in the EIA process.
- The EIA process is perceived as a planning and/or policy tool, thus specific scientific and quantitative approaches are not needed.
- EIA practitioners perceive that methods will become over-scrutinized in the event of subsequent litigation against the proposed action.

deterrents to methods usage. A commonly held perspective is that the use of certain methods requires considerable time; thus they tend to not be utilized. Specifically, time constraints on methods usage are often critical when an impact study is being conducted following completion of all other engineering and economic studies of a proposed project.

Another concern is that the usage of methods entails additional budgetary requirements. While this may be true for certain types of methods, their appropriate selection and usage can actually yield efficiencies within the EIA process and possibly reduce budgetary requirements.

The third item in Table 19 relates to the data requirements for methods usage; for example, information on various environmental features may be unavailable for the study area. This suggests the need for monitoring; thus becoming a deterrent to the usage of EIA methods. However, note that not all methods require extensive quantitative data, and this fact should be considered in the methods selection process.

Perhaps the greatest deterrent to the use of EIA methods results from practitioners being unfamiliar with their role, type, and scope for improving the effectiveness and efficiency of an impact study. This often reflects a lack of comprehensive training and information dissemination programs within governmental agencies and professional associations.

A fifth issue which deters methods usage is the uncertainties associated with impact predictions, irrespective of whether the methods are simple or complex. Because uncertainty pervades the entire EIA process, the perspective may exist that there is no reason to make greater efforts to quantify anticipated impacts. When this view is prevalent, it tends to dictate a more qualitative approach in an impact study. Additional comments on uncertainty are in the final section of this chapter.

Proponents of proposed actions, as well as governmental agencies responsible for the EIA process, may not give sufficient emphasis to the use of methods in impact studies. Development groups or agencies often focus on the need for the project and the associated engineering and economic evaluations, thus giving minimal attention to methods related to impact studies. EIA agencies are typically concerned with procedures to be utilized; and hence they give secondary attention to methods for use in impact studies.

Some practitioners, academicians, and government agency staff consider EIA as primarily a part of planning and political processes, and discount the need for quantitative and systematic approaches in impact studies. In fact, there is continuing debate over whether EISs and impact study reports are to be viewed as scientific documents, or policy documents, or some combination thereof. The perspective that impact studies are associated with overall planning considerations arguably may contribute to the lack of emphasis on the use of certain types of EIA methods.

Finally, a deterrent to the use of certain methods can result from the potential for future litigation against the proposed action. For countries with EIA systems that have a litigation focus, such as the United States, some practitioners have the perspective that it is better not to use quantifiable methods since these may become subject to considerable scrutiny from future legal actions. Accordingly, this issue is in encouragement for descriptive approaches rather than the usage of systematic and quantitative EIA methods.

UNCERTAINTY IN FURTHER PERSPECTIVE

Uncertainty is a term which can be variously defined. For example, it can refer to doubt, indeterminacy, or to a scientific possibility associated with the estimated amount by which an observed or calculated value may depart from the true value. Uncertainty, as related to the EIA process, refers herein to the characteristics of insufficient information on a project and environmental setting; or lack of knowledge relevant to impact interpretation, mitigation, and decision making. It results in imprecision and inaccuracy in impact prediction. Table 20 includes examples of causes of uncertainties in relation to 10 typical activities in an impact study (Canter, 1996b).

While there are no standardized categories of uncertainty in relation to the EIA process, it can be instructive to consider groupings of uncertainty, particularly with regard to impact significance determinations (De Jongh, 1988). For example, Petts and Eduljee (1994) have proposed two categories, data uncertainty and decision uncertainty:

(1) Data uncertainty can be related to project definition and characteristics, incomplete and/or irrelevant baseline information, model error, problems in defining dose-response relationships, and/or inaccurate collection of data, for example, during measurement and sampling.

(2) Decision uncertainty can occur due to failure to undertake an adequate scoping exercise, use of formalized scoring and weighting systems, data manipulation to meet different interests, pressure to use the "worst-case" scenario, contingent decisions (that is, while the EIA process for a particular policy, plan, or project is proceeding, many other decisions that may have an influence could be taken totally external to the process and by different parties), and/or the lack of strategic plans and policies, thus leaving the project impact study in a decision-making vacuum.

Uncertainty can be significant in planning and implementing SEAs; not least because the chain of consequences from proposed actions to potential effects is more attenuated and open ended than in project EIA. Such uncertainty can relate to the plan, program, or policy; to the environmental setting; to potential impacts; and to alternatives and their effectiveness in reducing undesirable impacts. The following methods have been identified for addressing uncertainty in SEA (Sadler and Verheem, 1996):

(1) use of scenarios -- to demonstrate ranges of uncertainty, e.g., full-scale response versus no response to a policy guideline;

(2) sensitivity analysis -- to identify uncertainty in final results by looking at the effect of different choices regarding assumptions or weights; and

(3) expert qualitative judgment -- to address uncertainty, by drawing on experience, knowledge, case studies and the results of similar actions in the past.

It is important to recognize and attempt to minimize uncertainties in the EIA process (De Jongh, 1988). If uncertainties are overstated in an impact study, then identification of excessive requirements for mitigation measures might occur. Conversely, if uncertainties are

Table 20: Examples of Causes of Uncertainties Related to Various Activities in the EIA Process (Canter, 1996b)

ACTIVITY*	EXAMPLES OF CAUSES OF UNCERTAINTIES
PDN	Incomplete information on need for project, design features of project (size and pollution control measures), and viable alternatives.
PII	Required time schedules for compliance with environmental media laws.
IPI	Relationships between changes in the biophysical and socioeconomic environments, and methods to use for cumulative impact assessment.
DAE	Ranges in natural variability of extant environmental data; absence of site-specific data.
IP	Selection of appropriate models to predict changes; absence of baseline data for model calibration; inadequate models for quantifying or even descriptively addressing impacts.
IA	Absence of quantitative criteria for impact interpretation; conflicting societal viewpoints on significance of environmental changes.
IM	Limited information on effectiveness of planned mitigation measures; lack of project proponent commitment to implementation of mitigation measures.
SPA	Importance considerations for identified decision factors; lack of comprehensive information on all alternatives being evaluated.
PWD	Need to communicate relative risk of proposed project and alternatives.
EM	Lack of information for statistical design of monitoring systems to incorporate environmental changes from project implementation.

*Definitions are as follows:
PDN = preparation of a description of the project, the need for the project, and appropriate alternatives; PII = assemblage of pertinent institutional information; IPI = identification of potential impacts; DAE = description of affected environment; IP = impact prediction; IA = impact assessment; IM = impact mitigation; SPA = selection of proposed action; PWD = preparation of written documentation; EM = environmental monitoring.

understated, and impacts inappropriately identified, inadequate mitigation measures may be specified. At a minimum, impact study documentation should incorporate a discussion of uncertainties. The implications of such uncertainties should be addressed in relation to impact predictions and their assessment, to the selection of the proposed action, and to the delineation of mitigation measures.

CONCLUSION

In summary, while many EIA methods exist, they are not uniformly used in all impact studies. Conversely, perhaps the greatest encouragement comes from information dissemination on different EIA methods and their interrelationships. This can be a major inducement to the usage of appropriate methods in impact studies. However, uncertainty is a pervasive, ever present characteristic of impact studies; and it requires a systematic response. Specific measures should be taken to document and state the level of confidence in impact predictions and identify qualifications (which, in turn, will point toward monitoring and follow-up requirements -- see Chapter VII).

CHAPTER III

EVOLVING METHODS FOR IMPACT ANALYSIS

EIA methods have been adjusted and modified with continuing process development and practical experience. New tools have been and are being developed for usage within the EIA process. This section highlights modified and emerging tools related to several types of methods listed directly or indirectly in Table 1, namely, interaction matrices, impact prediction methods, and decision analysis methods.

INTERACTION MATRICES FOR IMPACT IDENTIFICATION

Simple interaction matrices have been widely used in the EIA process. While the review of the matrix concept as developed by Leopold, et al. (1971) is a useful starting point, specific examples are typically developed for the actions being reviewed. The following steps can be used by an individual or in interdisciplinary team in preparing a simple interaction matrix (Canter, 1996a):

(1) List all anticipated project actions and group via temporal phases such as construction, operation, and post-operation.

(2) List pertinent environmental factors from the environmental setting and group according to physical/chemical, biological, cultural, and socioeconomic categories; and spatial considerations, such as site and region, or upstream, site, and downstream, as appropriate.

(3) Discuss preliminary matrix with study team members and/or advisors to team or study manager.

(4) Decide on impact "rating" scheme (numbers, or letters, or colors, etc.) to be used.

(5) Talk through the matrix as a team and assign ratings and develop notes which document the utilized rationale. The resultant matrix can be used to identify and summarize impacts (documentation).

Because of the collective experience which exists on the usage of interaction matrices, the following non-prioritized observations and lessons can be noted (Canter, 1996a):

(1) It is critical to carefully define the type and spatial boundaries associated with environmental factors, as well as each environmental factor; the temporal phases and specific actions associated with the proposed project; and the impact rating or summarization scales used in the matrix.

(2) A matrix should be considered as a tool for purposes of analysis, with the key need being to clearly state the rationale utilized for the impact ratings assigned to a given temporal phase and project action, and a given spatial boundary and environmental factor.

(3) The development of one or more preliminary matrices can be a useful technique in discussing a proposed action and its potential environmental impacts. This can be helpful in the

early stages of a study to assist each team member in understanding the implications of the project and developing detailed plans for more extensive studies on particular factors and impacts.

(4) The interpretation of impact ratings should be undertaken carefully, particularly when there may be large differences in spatial boundaries, as well as temporal phases, for a proposed project.

(5) Interaction matrices can be useful for delineating the impacts of a two-phase or multiphase project; the cumulative impacts of a project when considered relative to other past, present, and reasonably foreseeable future actions in the area; and the potential beneficial effects of mitigation measures. Creative codes can be used in the matrix to delineate this information; examples are shown in Figure 2 (Canter, 1996a).

(6) If interaction matrices are used to display comparisons between different alternatives, it is necessary to use the same basic matrix in terms of spatial boundaries and environmental factors, and temporal phases and project actions for each alternative being analyzed. Completing such matrices can provide a basis for trade-off analysis.

(7) Impact quantification and comparisons to relevant standards can provide a valuable basis for the assignment of impact ratings to different project actions and environmental factors.

(8) Color codes can be used to display/communicate information on anticipated impacts. Beneficial impacts could be shown by using green or shades of green; whereas, detrimental or adverse effects could be depicted with red or shades of red. Impact matrices can be used without the incorporation of number, letter, or color ratings. For example, circles of varying size could be used to denote ranges of impacts.

(9) One of the concerns relative to interaction matrices is that project actions and/or environmental factors are artificially separated, when they should be considered together. It is possible to use footnotes in a matrix to identify groups of actions, factors and/or impacts which should be considered together. This would allow the delineation of primary and secondary effects of projects.

(10) The development of a preliminary interaction matrix does not mean that it has to be included in a subsequent impact document. The preliminary matrix can be used as an internal working tool in study planning and development.

(11) It is possible to utilize importance weighting for environmental factors and project actions in a simple interaction matrix. If this approach is chosen, carefully delineate the rationale upon which differential importance weights have been assigned. Composite indices can be developed for various alternatives by summing the products of the importance weights and the impact ratings.

(12) Use of an interaction matrix forces the consideration of actions and impacts related to a proposed project within the context of other related actions and impacts. In other words,

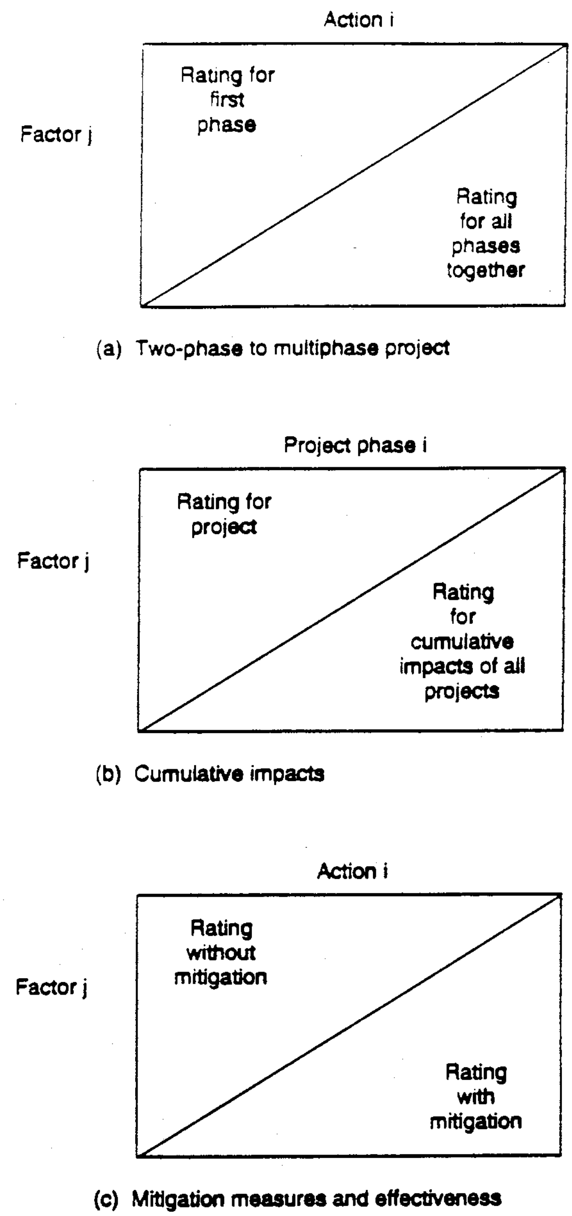

Figure 2: Examples of Codes for Displaying Impacts in Simple Interaction Matrices (Canter, 1996a)

the matrix would aid in preventing overriding attention being given to one particular action or environmental factor.

IMPACT PREDICTION METHODS

The "technical heart" of the EIA process involves the prediction of changes over time in various environmental factors as a result of a proposed project, plan, or program. The foundation for such predictions is the professional knowledge and judgment of appropriate substantive area experts; this knowledge and judgment can be facilitated by the use of a variety of tools.

Note that the terms "predicting impacts" and "forecasting impacts" are typically considered to be synonymous. However, Culhane, Friesema, and Beecher (1987) have suggested that "forecasting impacts" is more appropriate for impact studies since: (1) predict means to foretell with the precision of calculation, knowledge, or shrewd inference from facts or experience; and (2) forecast, in contrast, suggests that conjecture rather than real insight or knowledge is apt to be involved. Thus, they suggest that changes resulting from a project addressed in an EIS should be more appropriately termed as "forecasts." However, these definitions are not universally accepted. For example, relative to hydrological systems, Anderson and Burt (1985) noted that forecasting refers to real-time considerations of their future performance, while prediction refers to prognoses of their future performance without specific time reference.

A reasonable judgment of many early-day EISs was that impact predictions were not based on the application of formalized and repeatable methods with predefined relationships such as mathematical equations, physical models, and other structured approaches. This situation still exists. Accordingly, many impact studies have been criticized based on their lack of scientific approach and technical validity. This criticism is diminishing as greater knowledge is gained based on the actual usage of quantitatively based prediction techniques in impact studies, and the development of additional techniques through routine scientific research projects.

A questionnaire survey related to impact prediction methods was recently conducted in the member countries of the European Community (Senior Advisors to ECE Governments on Environmental and Water Problems, 1992). The survey found that both quantitative and qualitative methods are available; however, their usage may be limited due to lack of awareness of their availability, requirements, and features. As a result of the findings, several recommendations to EC governments were developed as requisite to promoting the use of effective and efficient methods and strengthening the EIA process; the recommendations are listed in Table 21 (Senior Advisors to ECE Governments on Environmental and Water Problems, 1992).

The range of useful impact prediction techniques (methods) is broad and encompasses the use of analogs through sophisticated quantitative models; the range, which represents an expansion of certain listed types of methods in Table 1, is shown in Table 22. In a specific impact study, several prediction techniques may be required depending upon the impacts of concern, data availability or lack thereof, and the appropriate specificity of quantitative models. The techniques can be considered in three categories: (1) simple; (2) indices and experimental methods; and (3) mathematical models.

Table 21: Recommendations to EC Governments Related to Enhancing the Use of Impact Prediction Methods (Senior Advisors to ECE Governments on Environmental and Water Problems, 1992)

1. Sustainable development should be the leading principle for all human activity. Prediction methods should be further developed and applied within the EIA process on such a temporal and spatial scale, and on such a variety of trophic levels, that sustainable development is assured.

2. Methods and techniques for the prediction of environmental impacts for use in EIA in a transboundary context should be developed cooperatively by EC member countries.

3. Environmental prediction methods should be applied not only to projects but also, where practicable, to new policies, plans and programmes that can significantly affect the environment.

4. Environmental information and the results of predictions of environmental impacts of human activity should be made public in order to avoid misunderstanding and to ensure constructive public participation.

5. In order to improve the use of environmental predictions by decision makers, there should be more interaction between those who generate impact predictions and those who use the results in decision making.

6. International cooperation in the development, standardization and application of environmental impact prediction methods should be enhanced, particularly in relation to large-scale environmental issues.

7. EIA legislation should contain provisions to support efforts for the improvement of methods and techniques related to environmental prediction.

8. Institutional and organizational arrangements within EIA legislation should be improved in order to ensure a more coordinated and integrated approach to the prediction of environmental impacts.

9. In order to allow appropriate action to be taken, the analysis of data collected and the results of monitoring programmes should be published.

10. The collection, storage and distribution of existing and future environmental baseline data on physical, chemical and ecological parameters necessary for the proper undertaking of impact prediction within EIA should be promoted and performed in a consistent manner.

11. Routine data collection programmes are an essential prerequisite for improving impact prediction capabilities and should be developed at national and international levels, particularly in a transboundary context. These programmes should be developed for specific industries and for domestic and agricultural activities with potentially significant impacts.

12. Depending on the type of activity and the local situation, routine monitoring data collection programmes should be multicompartmental (effluent, air, soil, sediment, water, biota).

Table 21 (continued):

13. In order to be able to compare data reliably between sites and to establish shared databases, each monitoring parameter should be accompanied by a standard measurement procedure.

14. Although the standardization of measurement procedures is an important objective, the overall monitoring programme content should be flexible in order to meet site-specific requirements.

15. A standardized data management system should be developed for each monitoring programme and should contain quality-assurance/quality-control requirements.

16. In environmental predictions, the identification and quantification of the sources of uncertainty should be an important step in the application of the methods. The results of environmental predictions should indicate the margin of uncertainty involved.

17. For many complex environmental problems, the prediction methods should take into account the interaction of various trophic levels and biotic/abiotic factors and be reliable and comprehensive. When possible, simple, quick and inexpensive methods should be preferred.

18. Experience with methods related to the transfer of pollutants from one environmental compartment to another should be promoted in order to improve environmental prediction and EIA. Many environmental concerns, including those in a transboundary context, demonstrate the need for transcompartmental prediction methods. An intensive research effort should be undertaken to further clarify this topic.

19. Prediction methods used within EIA should be validated and verified against reliable monitoring.

20. The methods for the assessment and comparison of prediction results should be investigated.

21. Critical environmental limits for identified pollutants are becoming an important part of impact prediction and decision-making processes. Where they do not exist, they should be developed and, depending on circumstances, combined with social, economic and other values to establish environmental quality standards and objectives at local, national and international levels.

22. For the further improvement of methods and techniques for the prediction of environmental impacts, an integrated approach to research, environmental monitoring, data assessment and prediction methods should be adopted.

23. Soil and sediment processes play an important regulating role in the long-term fate of pollutants. More research should be devoted to the identification of rates and capacities of the major soil and sediment processes.

24. Research related to methods and techniques on the prediction of environmental impacts should be enhanced at national and international levels. In particular, an inventory of the key gaps and uncertainties should be prepared, after which priorities for further research could be selected.

Table 22: Impact Prediction Techniques Currently Used in the EIA Process

<u>Simple Techniques</u>
Analogs (case studies of similar actions)
Inventory of Resources in Study Area (could use geographic information systems)
Checklists (simple, questionnaire, descriptive)
Matrices (simple, stepped) or Networks (impact trees, cause/effect or consequence diagrams)
<u>Indices and Experimental Methods</u>
Environmental Media Indices (air, surface and/or ground water quality or vulnerability, land or soil quality, noise)
Habitat Indices (HEP, HES) or Biological Diversity Indices
Other Indices (visual, quality of life)
Experimental Methods (laboratory, field, physical models)
<u>Mathematical Models</u>
Air Quality Dispersion
Hydrologic Processes
Surface and Ground Water Quality and Quantity
Expert Systems
Noise Propagation
Biological Impact (HEP, HES, WET, population, nutrients, chemical cycling, energy system diagrams)
Ecological and Health-based Risk Assessment
Archeological (predictive)
Visual Impact
Socioeconomic (population, econometric, multiplier factors)

Simple Techniques

Perhaps the simplest approach to impact prediction is to use analogs or comparisons to the experienced effects of existing similar projects or related actions. Professional judgment is necessary when using case study information for predicting specific impacts. An inventory technique involves the compilation of environmental and resources information for the study area through either the assemblage of existing data or baseline monitoring. The presumption that the resource base or existing environmental components will be degraded or lost as a result of the proposed action can be used as a "worst-case" prediction.

Indices and Experimental Methods

An environmental index refers to a mathematical and/or descriptive presentation of information on a series of factors which are used for purposes of classification of environmental quality or sensitivity, and for predicting the impacts of a proposed action (Canter, 1996a). The purpose would be to quantify, or qualitatively describe, the change in the index as a result of the proposed action, and to then consider the difference in the index from the with and without project (or other actions) conditions as one measure of impact. Indices exist for air quality, water quality, soil quality, noise, visual quality, land usage compatibility, and quality-of-life (QOL refers to a socioeconomic index which can include a large number of specific factors). Biological indices based on habitat quality and size considerations have also been developed; two examples are the Habitat Evaluation Procedures (HEP) and the Habitat Evaluation System (HES) (U.S. Fish and Wildlife Service, 1980; and U.S. Army Corps of Engineers, 1980). Several specific reports on components of HEP and HES have been issued since 1980.

Mathematical Models

The most sophisticated approach to impact prediction involves the selection and use of quantitative models for predicting pollutant transport and fate and environmental cycling. In addition, models exist for addressing environmental features and the functioning of ecosystems, and their responses to man-induced perturbations. Demographic and socioeconomic models have also been used in impact studies. In considering the use of mathematical models, attention should be given to the assumptions, limitations, and uncertainties related to the models; and to the calibration requirements of the models, including necessary baseline data (Borassa, 1989).

Summary Observations on Prediction Methods

Table 23 delineates substantive area examples of specific methods (techniques) that could be used for impact prediction within the EIA process (Canter, 1997). The listed techniques are not all mathematical models, nor do they represent a comprehensive delineation of all potential methods. For a given impact study, decisions have to be made regarding the best available predictive technology in view of the location, size, and type of proposed project or other action, as well as the available budget and time constraints. As a result, sophisticated quantitative models may not be widely utilized due to their need for extensive data input and calibration.

Numerous techniques have been (or can be) used to systematically describe and/or quantify anticipated environmental changes from proposed

Table 23: Examples of Impact Prediction Techniques Organized by Substantive Areas (Canter, 1997)

• Air (1) emission inventory (2) urban area statistical models (3) receptor monitoring (4) box models (5) single to multiple source dispersion models (6) monitoring from analogs (7) air quality indices
• Surface Water (1) point and nonpoint waste loads (2) QUAL-IIE and many other quantitative models (3) segment box models (4) waste load allocations (5) water quality indices (6) statistical models for selected parameters (7) water usage studies
• Ground Water (1) pollution source surveys (2) soil and/or ground water vulnerability indices (3) pollution source indices (4) leachate testing (5) flow and solute transport models (6) relative subsurface transport models
• Noise (1) individual source propagation models plus additive model (2) statistical model of noise based on population (3) noise impact indices
• Biological (1) chronic toxicity testing (2) habitat-based methods (3) species population models (4) diversity indices (5) indicators (6) biological assessments (7) ecologically-based risk assessment
• Historical/archaeological (1) inventory of resources and effects (2) predictive modeling (3) prioritization of resources
• Visual (1) baseline inventory (2) questionnaire checklist (3) photographic or photomontage approach (4) computer simulation modeling (5) visual impact index methods
• Socioeconomic (1) demographic models (2) econometric models (3) descriptive checklists (4) multiplier factors based on population or economic changes (5) quality-of-life (QOL) indices (6) health-based risk assessment

actions. Available techniques require a range of input data, mathematical sophistication on the part of users, and need for professional interpretation. Many of the quantitative models described earlier are available in PC-software. Table 24 delineates several analytical challenges relating to the prediction of direct, indirect, and cumulative impacts (Canter, 1997). Some challenges are scientifically or technically based, while others relate to decisions on resource availability and interpretation of prediction results.

Final comments on predicting impacts are:

(1) do not make predictions to χ decimal points;

(2) if necessary, reconcile changes in project features with changes in predictions;

(3) recognize that data needs for predictions may not be available and model calibration may be extensive;

(4) address uncertainty in predictions;

(5) consider short-term and long-term effects;

(6) establish environmental system relationships; and

(7) identify qualifications and limitations on prediction, e.g., for both technical and policy reasons.

DECISION ANALYSIS METHODS

During the last 10-15 years a number of decision analysis methods have been developed within the context of environmental management. Such methods can focus on site selection for hazardous waste or sanitary landfills or incinerators; open-water or upland disposal sites for dredged material; or industrial plants or fossil-fuel fired power plants. They can also facilitate the prioritization of uncontrolled hazardous waste sites needing remediation efforts, the development of forest management plans based on alternative operating scenarios, or incremental cost analysis for mitigation planning for water resources projects, to name a few. Common features of these methods include the systematic comparison of alternatives (choices) and the selection of an alternative to become the proposed action. Many of these methods can be used either directly or in a modified form in the comparison of alternatives in the EIA process.

Several newer decision analysis techniques are receiving attention within the EIA process. Three examples will be highlighted. One illustration of a newer tool for comparison of alternatives is the Analytical Hierarchy Process (AHP) (Keoleian, et al., 1994). Qualitative or quantitative information on each alternative relative to each decision factor can serve as the basis for the AHP. The fundamental theory and mathematical basis for AHP was initially described by Saaty (1977); a further discussion of AHP in the context of decision making based on utility theory can be found in Saaty (1990).

The first step in the AHP is to consider the relative importance of the decision factors in the context of the overall project goal. Decision factors must be on the same level so that pairwise comparisons can be made. Sublevels of decision factors, also known as an hierarchy of factors, can be used to further assign importance weights in a stepwise fashion. Comparing similar level decision factors is accomplished in a pairwise fashion; the key question is -- how much more does one factor

Table 24: Examples of Analytical Challenges (Canter, 1997)

- Identification and selection of appropriate impact prediction techniques.
- Consideration of assumptions, limitations, and uncertainties related to selected prediction techniques.
- Calibration requirements related to selected quantitative models, including necessary baseline data.
- Impact prediction and interpretation in the absence of adequate baseline data, including information needed for addressing cumulative impacts.
- Delineation of appropriate temporal and spatial boundaries to address cumulative impacts.
- Identification and selection of appropriate impact indicators.
- Incorporation of an holistic perspective regarding impacts and their environmental system relationships.
- Consideration of cumulative and synergistic impacts, along with possible transboundary impacts, in programmatic (strategic) impact studies.
- Interpretation of predicted impacts based on institutional requirements, public values, and professional judgment.

contribute to achieving the stated goal (or satisfying the requirement) than another? The answer is first expressed verbally and then translated into a numerical value based on a scale of 1 through 9. A value of 1 means both elements (factors) are of equal importance, while a value of 9 means that one element takes absolute preference over another; the meanings of the different numerical choices are shown in Table 25 (Keoleian, et al., 1994). The results of these pairwise comparisons are then unitized, with the resultant relative importance weights for the decision factors representing fractions which total to 1.0.

The second step in the AHP is to consider the relative contribution (importance) of each alternative in relation to each decision factor. Again, pairwise comparisons are used, with the contributions assigned numbers as per Table 25. The results of these pairwise comparisons are also unitized, with the resultant contributions for the alternatives representing fractions which total to 1.0.

The final "score" for each alternative is represented as follows:

$$Score_j = \sum_{i=1}^{n} (RIW)_i \ (CA_j)$$

where

$Score_j$ = composited score for the jth alternative

i = ith decision factor

RIW_i = unitized relative importance weight for the ith decision factor

CA_j = unitized contribution score for the jth alternative for the ith decision factor

The AHP is being increasingly used in environmentally related decision making; for example, it has been used in siting municipal solid waste facilities (Junio, 1994). However, specific examples of the use of the AHP in the EIA process could not be identified as this report was assembled. Despite the interest in the AHP, it has been criticized relative to the numerical comparison scale and its translation. Translation from numbers back into descriptive comparisons should follow the concept of original scale. That is, if one alternative earns a score that is three times higher than another, it should be judged as only slightly more favorable. To be clearly preferable, the overall score for an alternative would have to be five times that of another alternative (Keoleian, et al., 1994).

Decision-focused checklists are typically used to assess the "aggregate worth" of various alternatives in terms of environmental factors (and possibly economic and engineering factors). The aggregate worth can be expressed in either a qualitative or quantitative manner, with the latter typically based on a composite index derived from the considered factors. However, such comparisons are based on numerous uncertainties and imprecision. One tool which acknowledges these limitations is termed a "fuzzy logic evaluation method" (Smith, 1995-96b). The method is based on fuzzy sets, fuzzy logic, and approximate reasoning; these concepts are theoretically based in mathematics (Wenger and Rong, 1987; Smith, 1995-96a; and Smith, 1995-96b). A fuzzy logic approach basically recognizes that propositions (or comparisons between alternatives) may not be absolutely "true" or absolutely "false."

Table 25: Importance Scores for Use in the AHP (Keoleian, et al., 1994)

Intensity of Importance	Meaning
1	Elements equal
3	Weak importance: judgment slightly favors one element
5	Strong importance: one element strongly favored
7	Very strong: dominance of one element demonstrated by fact
9	Absolute importance: incontrovertible evidence

Finally, based upon a review of 30 EISs in relation to the decision making tools used in the evaluation of alternatives, Lahlou and Canter (1993) proposed a generic decision making method which combines several individual tools. Specifically, the generic method includes six tools for use at three decision points. First, the method incorporates the use of conjunctive and/or compensatory screening in a preliminary screening phase to eliminate nonfeasible alternatives, the use of the weighted Reasonable Social Welfare Function and/or selected fuzzy outranking techniques to eliminate inferior alternatives, and the use of a weighting summation model or compromise programming to select either the optimum alternative or the balanced alternative. The generic method has been computerized and is IBM PC compatible and user friendly; it has been validated on several case studies. The computer program provides a generic system to assist in the flexible evaluation and identification of the most preferred course of action. The usefulness of this system resides in its flexibility of application at various phases within the EIA process.

CHAPTER IV

EMERGING METHODS FOR IMPACT ANALYSIS

In the 1990s, several methods developed for usage in various areas of environmental management are being applied within the EIA process. Four types of emerging methods will be briefly described herein: (1) geographic information systems, (2) expert systems, (3) risk assessment, and (4) economic valuation of environmental impacts. The latter type is only now being applied to the EIA process.

GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) can be useful in several phases of the EIA process. These computer automated data management systems can capture, manage, manipulate, analyze, model and map spatial data to solve complex planning and management problems. Any GIS application and/or operation contains five essential elements: data acquisition; preprocessing; data management; manipulation and analysis; and production generation (Star and Estes, 1990). Data acquisition refers to the process of identifying and gathering the data required for the application. After data gathering, the procedures used to convert a dataset into a suitable format for input into the GIS is called preprocessing. Data format conversion, such as digitization of maps and printed records and recording this information into a computer database, is the key step in preprocessing. Preprocessing also includes map projection, data reduction and generalization, error detection, and interpolation.

Database management provides users with the means to define the contents of a database, insert new data, delete old data, identify database contents and modify the contents of the database. The datasets can be manipulated as required by the analysis. Some of the operations used in data manipulation are similar to those used in preprocessing. Many types of analyses are possible with a GIS; among these are mathematical combinations of layers, Boolean operations and, with external programs using the GIS as a database, complex simulations. Finally, the structure of a GIS contains software for displaying maps, graphs and tabular information on a variety of output media; this enables the user to maximize the effect of results presentation. Commonly used GIS systems in the public domain include GRASS (Geographic Resources Analysis Support System), ARC/INFO, ERDAS, and IDRISI (U.S. Soil Conservation Service, undated).

Within recent years the application of GIS technology to the EIA process has been accomplished. Relative to the seven EIA phases described earlier, GIS can have application, either directly or as a supporting tool, to all of them. In addition, GIS can be used as a tool in follow-on impact monitoring and project management. More specifically, Eedy (1995) described the usefulness of GIS for the EIA process as follows: (1) data management; (2) data overlay and analysis relative to site impact prediction, wider area impact prediction, corridor analysis, cumulative effects analysis, and impact audits; (3) trend analyses; (4) integration into impact models such as chemical or radionuclear dispersion and pathway models, climatic change models, and decision analysis using the Multi Attribute Tradeoff System; (5) habitat analysis using the Habitat Evaluation Procedures; (6) aesthetic resources and impact analysis; and (7) public consultation.

Development and implementation of a GIS for use in the EIA process typically involves identification and conceptualization, planning and design, procurement and development, installation and operation, and review and audit (World Bank, 1995b). This process needs to be carefully planned if the benefits of GIS as a data management tool are to be fully realized. Numerous public agencies and private sector companies have developed GIS capabilities. An example of the former is the U.S. Army Construction Engineering Research Lab (CERL) located in Champaign, Illinois. CERL has developed and implemented a number of GIS programs for impact assessment and resource management at military installations. Environmental Systems Research Institute, Inc. (ESRI) is an example of a private entity with offices in a number of locations throughout the world. Additional examples of GIS software vendors include, but are not limited to, Intergraph, Electronic Data System, GeoVision Systems, Inc., ERDAS, Inc., MAPINFO Corp., GENASYS II Inc., Tydac Technologies Corp., Generation 5 Technologies Inc., PMAP Technologies, Inc., and Digital Resource Systems Ltd. (World Bank, 1995b).

Table 26 contains a non-exhaustive listing of nine GIS applications (case studies) in the EIA process or related resource management. The listed applications are examples; they do not represent a comprehensive survey. However, they do suggest a wide range of uses of GIS within the EIA process.

While GIS offers many advantages as a tool in impact studies, there are some limitations. Three examples are (Joao, 1994): (1) GIS modeling technology has not yet been developed sufficiently to achieve certain complex environmental modeling; (2) links to other software packages or to special purpose programs may need to be developed especially for an EIA application; and (3) very little of the information required for EIA studies is also available in a form which may be loaded directly into GIS.

EXPERT SYSTEMS

The complexity of environmental systems and the requirement of multidisciplinary knowledge in identifying, predicting and assessing environmental impacts of proposed projects have made this a suitable problem domain area for the development of expert systems. Expert systems refer to special computer programs that are encoded with and apply the knowledge of experts to provide solutions to problems within specialized fields. A key advantage is the ability to use the collective knowledge of a number of experts rather than one single expert; the knowledge is reflected via a series of "rules" or "heuristics."

Numerous expert systems have been developed in environmental fields in the last few years and the number is expected to continue to increase. For example, a recent comprehensive review identified 69 environmental expert systems (Hushon, 1990). Although many expert systems have been developed, most are in the prototype level and only a few are actually being used in a routine manner. Further, to date, most have been developed for, or related to, waste management or ground water protection and management (Canter, et al., 1993).

Several examples of expert systems related to EIA will be described briefly. Firstly, Lein (1988) developed a prototype expert system (IMPACT-EXPERT) consisting of 120 rules that can be used to evaluate 11 types of recognized environmental impacts. The users interact with the knowledge base through 36 screening questions that have been kept purposely broad to accommodate the review of a wide range of activities. Each question has been assigned to a specific environmental factor, consequence, attribute or effect. The present version of IMPACT-EXPERT is limited in range because its knowledge-base is comparatively small.

Table 26: Examples of the Usage of GIS Within the EIA Process

Reference	Comments
Atkinson, et al. (1995)	Use of GIS in the development of a siting compatibility index for sanitary landfills; could be used in impact prediction and evaluation of alternative sites.
Canter, Chowdhury, and Vieux (1994)	Description of eight case studies involving the use of GIS in ground water protection programs; could be used in land use planning and project appraisal in protection zones around water supply wells.
Jensen and Gault (1992)	Use of GIS in impact predictions related to the routing of a high-voltage transmission line.
Johnston, et al. (1988)	Use of GIS to assess the cumulative impacts of land developments in an urban area on local wetlands and stream water quality.
Openshaw, Carver, and Fernie (1989)	Use of GIS for determining site compatibility for radioactive waste disposal; could also be used to delineate potential impacts and necessary mitigation measures.
Rajan (1991)	Description of the use of GIS technology for natural resource management in the Asian and Pacific Region; could be used for impact studies on large-scale development projects.
Sarasota County Natural Resources Department (1992)	Use of GIS-based computer model to estimate relative contributions of runoff and chemical loadings, by sub-basin, to the Myakka River in Florida; could be used in impact prediction for development projects involving major land use changes.
Savitsky, et al. (1995)	Use of GIS for GAP analysis in Costa Rica (GAP analysis involves correlating species distributions with boundaries of ecosystems and protected areas to identify efficient linkages for conservation efforts).
U.S. Department of the Army (1990)	Use of GIS in an impact study involving land acquisition and military training activities at a firing range.

However, it provides a useful guide for the development of more sophisticated expert systems in this area of application (Lein, 1988).

The second example is a simple expert system, called ENDOW (for Environmental Design of Waterways), developed by the U.S. Army Corps of Engineers (Shields, 1988). ENDOW is useful for rapidly identifying environmental alternatives for inclusion in project plans, designs, or procedures for operation and maintenance. It contains modules for streambank protection, flood-control channel projects, and levee projects. When running ENDOW, a user answers queries from the program regarding the project setting and environmental objectives. ENDOW then responds with a list of project features for further study and possible inclusion. Help screens that provide detailed descriptions of features and information about cost and performance can be requested for any feature selected.

The environmental impacts of development projects are addressed in a knowledge-based management system named ECOZONE (Edwards-Jones and Gough, 1994). This expert system can be used to identify primary and higher order impacts via the use of a rule-based causal network. Types of projects which can be addressed are delineated in Table 27, with Figure 3 depicting the organization of the rulebases within ECOZONE (Edwards-Jones and Gough, 1994). ECOZONE encompasses three geographical regions -- upland, lowland and coastal -- and two climatic regimes -- arid and humid. It also incorporates five different project types within which may occur a varying number of activities. In total, 61 activities are addressed, and within each sector those available for selection by the user are determined by the combination of geographic region and climatic regime.

In addition, other EIA-related expert systems have been or are being developed. These include an expert system for use by nonexperts in the evaluation of alternatives contained in EIA documents (Schibuola and Byer 1991). The system, named REVIEW, was tested via three Canadian case studies -- two roadway extensions and a proposed liquefied natural gas facility. The testing process revealed both useful features and limitations of the REVIEW system. Further, two systems (SCREENER and EVA) have been developed for project screening and scoping, and three additional systems (IMPACT, SAFEE, and ORBI) relate to impact considerations on specific environmental features Lein (1993).

One final example is Calyx EA (ESSA Software Ltd., undated). This system consists of a family of PC-based decision support applications related to the EIA process. Such applications include project screening and scoping, knowledge capture and management, scenario gaming, training, and reporting.

In summary, expert systems are computer programs that encode the knowledge and reasoning used by specialists to solve difficult problems in narrowly defined domains. They rely more on heuristic rules-of-thumb and pattern matching to achieve their results, rather than numerical models and algorithms. Reasons why the EIA field lends itself to the application of expert systems include:

(1) It is a multidisciplinary field whose impacts and associated problems can require specialized expertise.

(2) It includes many different substantive areas such as engineering, chemistry, biology, planning, geography, statistics, geology, economics, toxicology, epidemiology, and law. Individual EIA professionals will not always be well versed in all of these areas. Therefore, expert systems can assist in providing solution-directed knowledge on unfamiliar subjects.

Table 27: Description of the Different Sectors (Project Types) Which Can Be Addressed Within ECOZONE (Edwards-Jones and Gough, 1994)

Agriculture:	Activities associated with cropping and the intensification of agricultural systems.
Aquaculture:	Activities associated with the production of fish and shellfish from artificial lakes, ponds and cages.
Forestry:	Activities associated with the felling of natural forests, plantation forestry, agroforestry and the harvesting of forest products.
Livestock:	Activities largely associated with the intensification of livestock production.
Water Resources:	Activities associated with building dams, irrigation, abstraction and drainage.

Ecozone choice

one of

Upland humid	Upland arid
Lowland humid	Lowland arid
Coastal humid	Coastal arid

Sector choice

one of

Agriculture Aquaculture Forestry Livestock Water resources

Sector to activity rulebases

	UH	LH	CH	UA	LA	CA
No. of activities	52	58	57	44	56	56

Activity to primary impact rulebases

	UH	LH	CH	UA	LA	CA
No. of rules	298	430	375	258	298	342

Further impact rulebases

	Humid regions	Arid regions
No. of rules	490	500

Note: The system contains 3268 separate rules organised into 14 separate rulebases. As the user progresses through the system three different groups of rulebases are accessed in turn, namely Sector-to-Activity, Activity-to-Primary impact and Further-Impact respectively. The relevant rulebases are selected according to the user's choice of ecological zone and sector. Arrows show the direction of movement through the system.
UH = upland humid, LH = lowland humid,
CH = costal humid, UA = upland arid, LA = lowland arid, CH = coastal arid.

Figure 3: Organisation of Rulebases Within ECOZONE (Edwards-Jones and Gough, 1994)

The EIA field is also highly dependent on empiricism. The complex chemical and biological behavior of environmental systems, and the multiple relationships within socio-economic systems, cannot always be described through formal mathematical models. In many cases there is a greater reliance on experience and intuition. Expert systems can help transfer these approaches to less experienced personnel and can also assist the EIA professional dealing with uncertain, incomplete, and qualitative data. Finally, EIA professionals have to deal with numerous governmental rules and regulations. These provisions make them readily compatible with the rule-based representation of knowledge used in many expert systems. In sum, expert systems can help EIA study managers meet regulatory requirements, and assist EIA reviewers and environmental regulators to ensure compliance with rules and regulations.

RISK ASSESSMENT

The fundamental principles associated with risk assessment studies were enunciated in the 1970s, with the planning and conduction of such studies moving toward maturity in the 1980s. Risk assessment (RA) traditionally encompasses components on hazard (risk) identification, dose-response assessment, exposure assessment, and risk characterization. By contrast, EIA studies initiated in the 1970s had their primary focus on impacts on physical/chemical and ecological components of the environment. A closer integration of EIA and risk assessment is now being sought.

Various similarities and differences between EIA and RA have been discussed by O'Riordan (1979), Andrews (1988), and Carpenter (1995). Andrews (1988) suggested that a protocol for a unified EIA and RA should be developed. A subset focus is needed on protocols and guidance on procedures and methods for what Giroult (1988) calls environmental health impact assessment (EHIA) and on approaches to the integration of health impact concerns in the EIA process (Davies and Sadler, 1997). The "state of the art" of risk assessment with reference to health and ecological factors is expertly summarized by Carpenter (1995).

The published literature on health and/or ecological risk assessment as a method within the EIA process is expanding. Table 28 includes a nonexhaustive listing of some reference sources related to this topic organized into six categories.

Risk assessment within the EIA process can be accomplished using one to several of the following approaches: (1) addressing actual or perceived risks using a descriptive or qualitative approach; (2) calculation or determination of a relative risk index based on information on several selected factors; (3) relative comparisons of the perceived risks of the alternatives being evaluated; and/or (4) a quantitative, probabilistic approach focused on actual risks of the alternative being evaluated. Risk assessment considerations can include human health and/or ecological risks, and combinations thereof. Such considerations can be focused on only one aspect of the project being addressed (e.g., use of pesticides in vegetation management), or on one phase (e.g., construction or operation or decommissioning), or on the entirety of all phases and aspects.

Based upon the recent developments in both RA and EIA studies, increasing efforts are being made to incorporate RA principles in the EIA process. The possibilities include: the determination of relative risk indices for single issues, such as the choice of pesticides or herbicides in forestry or range management plans; the use of environmental pathways modeling and risk calculations for industrial plant and/or waste site emissions; and the use of quantitative probabilistic calculations for

Table 28: Examples of Reference Sources Related to Health Risk Assessment and/or Ecological Risk Assessment

Topical Category	References with Information on Topical Category
Fundamentals of health-based risk assessment	Cohrssen and Covello (1989) U.S. Environmental Protection Agency (1984) World Health Organization (1987)
Fundamentals of ecological risk assessment	Suter (1993) U.S. Environmental Protection Agency (1994)
EIA and risk assessment	Arquiaga, Canter, and Nelson (1994) Arquiaga, Canter and Nelson (1992) Canter (1993a) Suter, Barnthouse, and O'Neill (1987)
Risk interpretation	National Academy of Sciences (1994)
Risk communication	Committee on Risk Perception and Communication (1989) Hance, Chess, and Sandman (1990)
Case studies of health risk assessment and/or ecological risk assessment	Cutter (1993) Ellis (1989) Paustenbach (1989)

industrial or power plant accidents or for highway/railway accidents and associated chemical spills. The potential benefits of the inclusion of RA principles include: (1) the encouragement of integrated thinking (such as for environmental transport pathways and associated health/ecological effects) by the interdisciplinary teams conducting EIA studies; (2) the opportunity to focus attention on risk reduction activities such as waste minimization, pollution prevention, and mitigation measures; and (3) the inclusion of emphases on emergency response measures in the event of accidents and associated environmental damage.

Risk assessment as traditionally used for health effects and regulatory decision making can be divided into four major steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization (Cohrssen and Covello, 1989). Of the four steps, hazard identification is the most easily recognized in the actions of regulatory agencies (U.S. Environmental Protection Agency, 1984). Hazard identification is defined as the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defect, etc.). It involves characterizing the nature and strength of the evidence of causation.

Dose-response assessment is the process of characterizing the relation between the dose of an agent administered or received and the incidence of an adverse health effect in exposed populations, and estimating the incidence of the effect as a function of human exposure to the agent (National Research Council, 1983). It takes account of intensity of exposure, age pattern of exposure, and possibly other variables that might affect response, such as sex, lifestyle, and other modifying factors. A dose-response assessment usually requires extrapolation from high to low dose and extrapolation from animals to humans. A dose-response assessment should describe and justify the methods of extrapolation used to predict incidence and should characterize the statistical and biologic uncertainties in these methods.

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposures to an agent currently present in the environment or of estimating hypothetical exposures that might arise from the release of new chemicals into the environment (National Research Council, 1983). In its most complete form, exposure assessment describes the magnitude, duration, schedule, and route of exposure; the size, nature, and classes of human populations exposed; and the uncertainties in all estimates. It is often used to identify feasible prospective control options and to predict the effects of available control technologies on exposure.

Risk characterization is the process of estimating the incidence of a health effect under the various conditions of human exposure described in exposure assessment (National Research Council, 1983). It is performed by combining the exposure and dose-response assessments. Risks could be classified in this step according to type of activity (e.g., explosion, continuous discharge); exposure (e.g., instantaneous, chronic); probability of occurrence; severity; reversibility; visibility; duration; and ubiquity of effect (Sors, 1982). The summary effects of the uncertainties in the preceding steps should be described in this step.

A methodology which integrates human health and ecological risks in environmental impact studies is shown in Figure 4 (Arquiaga and Canter, 1991). The methodology includes focused scoping to determine if health impact issues should be addressed, and the delineation of pertinent institutional laws, regulations, executive orders, policies, and guidelines related to potential health impact concerns. Next, health impact-related features of the project and relevant alternatives and

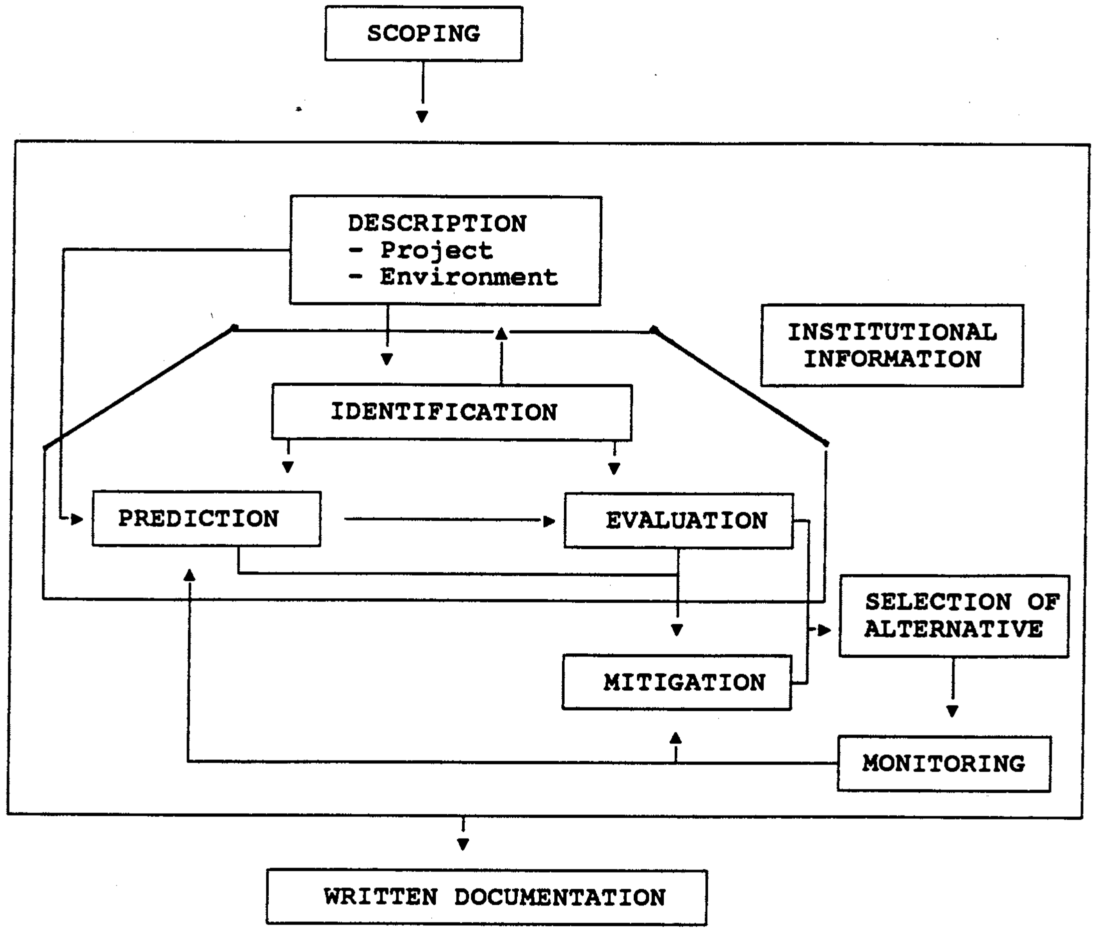

Figure 4: Conceptual Framework for Proposed Health Impact Prediction and Assessment Methodology (Arquiaga and Canter, 1991)

affected environments are addressed. Their typical features can be related to the physical/chemical, biological, cultural, and socio-economic impacts. The technical core of the proposed methodology includes impact identification via the preparation of lists of health-related factors and exposure scenarios; impact prediction via the use of exposure assessment, dose-response assessment, and health impact characterization; and impact evaluation by considering regulatory limits and other factors. Significant adverse health impacts then should be addressed via mitigation through control of sources, control of exposure, and/or health services development. Health impact information is addressed in decision-making by selecting the proposed action. The methodology also includes activities on planning and implementing a health impact monitoring system and on systematically integrating the results in an EIS.

Environmental risk assessment (ERA) has been equated with a probabilistic approach, and is also referred to as probabilistic risk assessment (PRA) and probabilistic quantitative risk assessment (PQRA) (Carpenter, 1995). The following five step sequence has been suggested for ERA (Carpenter, 1995): (1) hazard identification, (2) hazard accounting, (3) scenarios of exposure, (4) risk characterization, and (5) risk management.

Examples of situations being addressed in an impact study which might require ERA include (Carpenter, 1995): (1) potential release of hazardous materials (rate and amount); (2) accidental fires and explosions; (3) dilution and dispersion mechanisms and rates; (4) transport and fate of pollutants in the environment; (5) failure rates of equipment and structures; (6) dose/response relationships based on animal studies; (7) human behavior (reactions, errors); (8) natural hazard occurrence and frequency; and (9) alterations in the landscape due to changes in landuse patterns.

From a pragmatic perspective, the EIA process should address the probability of accidents associated with the proposed project/plan/program, and the potential health and ecological consequences of such accidents. For example, such analyses would be pertinent for chemical plants, power plants, transportation-related chemical or oil spills, and pipeline accidents. Dam safety associated with flood control and hydroelectric projects could also be analyzed. The primary focus of the analyses should be on mitigation measures to reduce the likelihood of accidents and to respond to the potential environmental consequences. Examples of mitigation measures include project design features, retrofitting of existing systems, inclusion of monitoring and forecasting and warning systems, and contingency planning and preparedness for accidents (Smith, 1989).

Practical suggestions for incorporating RA principles and steps in EIA studies include: (1) selection of indicator chemicals based on toxicological, environmental, and practical criteria; (2) careful extrapolation of human, animal, and plant toxicity data to relevant environmental conditions in the studies; (3) prediction of human exposures and/or environmental conditions based on knowledge of sources, environmental pathways/fate, monitoring results of concentrations in environmental media, modeling results, and knowledge about population habits; and (4) evaluation of human health and/or ecological risks based on relative comparisons with known daily risks, time variations, pertinent standards, average versus peak conditions, etc. Uncertainty related to impact identification, quantification, interpretation, and mitigation should also be addressed.

Economic Valuation Of Environmental Impacts

Traditionally, proposed public projects have been subjected to economic evaluations to determine if they are feasible and can be justified. Environmental impact studies were intended to supplement engineering and economic evaluations by giving attention to resource and ecological values and amenities in project planning and decision making. Recently, increasing consideration has been given to placing economic values on environmental benefits and costs. For example, decision makers are increasingly confronted with the need to put economic values on environmental 'intangibles' such as wildlife and recreation experiences, in order that they may be taken into account when determining priorities for government when it is grant-aiding investments. Furthermore, environmental pollution control and remediation investment itself is increasing, and yet decision makers and their advisors are not sure that they have the data and techniques that lead to decisions that give the best value for the money (Penning-Rowsell, 1992).

As a result of these trends, there is increasing consideration being given to the economic evaluation of the environmental impacts of proposed projects/plans/programs/policies. World Bank activities in integrating environmental (and resource) externalities and addressing the value of the environment in the development process have been particularly influential, not least because of their wide application in developing countries as "lending conditionalities" (Seralgeldin and Steer, 1994). In the United States, for example, regulatory impact assessment requirements are directed toward an analysis of the benefits and costs of proposed regulations. Similar procedures are followed in the UK on an informal basis, i.e., as discretionary policy.

Perspectives on and approaches to economic evaluation of environment impacts vary. One assumption is that "environmental cost-benefit analysis," or ECBA, should not and/or cannot be based on societal values and lack of appropriate methodologies for the valuation of many types of impacts. Conversely, many economists and some EIA practitioners see ECBA as a new tool to be integrated with traditional cost-benefit analysis (CBA); this perspective also assumes sufficient valuation methodologies for most, if not all, environmental impacts typically experienced as a result of projects/plans/programs/policies. In reality a middle perspective is probably more realistic; that is, those impacts which can be evaluated should be, and the results incorporated as appropriate and considered in planning and decision making. This approach recognizes that some impacts and environmental values are not economically quantifiable; and some intangibles will remain.

The middle perspective can be achieved by the development of a separate ECBA study for a proposed project/plan/program/policy. More appropriate would be the inclusion of environmental benefits and costs into traditional CBA studies. Such benefits and costs should be based on the Total Economic Value (TEV) of the impacted resources, with TEV including both use and nonuse values. Either approach would provide more systematic information for public participation programs and use by agency decision makers. A helpful comparative review of the techniques available can be found in Pearce, Markandya, and Barbier (1989), and Winpenny (1991).

Lee and Kirkpatrick (1996) discuss the current usefulness and limitations of the joint usage of EIA and CBA as inputs to project appraisal and decision making. While benefits accrue from expanding CBA to include economic valuation of environmental impacts (ECBA), concerns remain about the scope of these tools and related uncertainties. Specifically, there are content and method inconsistencies both within and between EIA and CBA. These inconsistencies can arise from (Lee and Kirkpatrick, 1996):

(1) differences in the scope of EIA and CBA and from double-counting problems,

(2) conflicts between the market valuation methods used in CBA and the methods used for determining the significance of environmental impacts within EIA;

(3) differences between the single criterion (NPV -- or net present value) appraisal approach of CBA and the more disaggregated and multi-criteria approaches commonly used in EIA; and

(4) differences between EIA and CBA in approaches to time preference and discounting, the handling of uncertainty and the treatment of distributional issues.

Finally, the published literature on ECBA and economic valuation of project impacts is expanding. For example, Table 29 lists examples of such reference sources organized into six topical categories.

Table 29: Examples of Reference Sources Related to CBA or ECBA

Topical Category	References with Information on Topical Category
Traditional CBA	Clowes (1990) Petersen (1984) Water Resources Council (1983) Squire and van der Tak (1988)
Environmental Economics (including resource economics)	Barde and Pearce (1991) Field (1994) Freeman (1993) Hanley and Spash (1993) Hufschmidt, et al. (1983) Kopp and Smith (1993) Munasinghe and Lutz (1992) National Research Council (1994) Pearce and Turner (1990)
Economic Instruments for Environmental Management	Opschoor and Vos (1989) Organisation for Economic Co-operation and Development (1992)
Incremental Cost Analysis for Mitigation Planning	Carlson and Palesh (1993) Orth (1994)
Pollution Control	Carpenter and Maragos (1989) Freeman (1982) Office of Technology Assessment (1994) U.S. Environmental Protection Agency (1990)
Valuation of Environmental Impacts	Coker and Richards (1992) Dixon and Hufschmidt (1986) Dixon, et al. (1988) Go (1988) Himanen, et al. (1989) James and Boer (1988) Lee and Kirkpatrick (1996) Maddison, et al., (1996) Organisation for Economic Co-operation and Development (1995) Pearce, et al. (1989) Ranasinghe (1994) Stokoe (1991) Weiss (1994) Winpenny (1991)

CHAPTER V

CUMULATIVE IMPACT ASSESSMENT -- A SPECIAL ISSUE

In the United States the Council on Environmental Quality (CEQ) defines a cumulative impact as the "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions" (Council on Environmental Quality, 1978). Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time. The importance of this topic was underlined by Clark (1993) when he noted that ". . . perhaps the most ecologically devastating environmental effects may result not from the direct effects of a particular proposal, but from the combination of existing stresses and the individually minor effects of multiple actions over time."

A number of frameworks and approaches for defining and addressing cumulative impacts have been proposed. Many of these build on work by the Canadian Environmental Assessment Research Council and the U.S. National Academy of Sciences (1988). Table 30 illustrates their initial characterization of cumulative effects. Cumulative impacts can be classified as homotypic or heterotypic (Irving, et al., 1986). In the first case, the impacts are by multiple developments of the same type. An example would be building of multiple dams in a river basin. In the second type, heterotypic, the impacts are caused by a combination of two or more different developments or land uses. For example, the water quality in a river system may decline because of residential development, agricultural or forestry practices, and industrial effluents.

Depending on the type of impact response, cumulative impacts may also be direct, indirect, or multivariate (Bain, et al., 1986). Project activities (e.g., construction and operation) affect resources through changes in environmental variables (the stimuli), which cause responses (positive or negative). Direct responses are a simple stimulus and response relationship. Indirect responses are secondary or higher order relationships that act through intermediate sets of stimuli and responses. Multivariate responses are multiple stimuli with interrelationships that act in concert to produce a response. Direct responses are probably the easiest to understand and the simplest to represent. Both indirect and multivariate responses are more complex, less understood, and difficult to quantify. Consequently, their inclusion in impact studies has been limited and there is little indication that this will change in the immediate future (Bain, et al., 1986).

There are three basic ways that cumulative impacts can occur (Irving, et al., 1986). The first is via an additive or incremental impact. That is, as the number of projects increase the total cumulative impact is equal to the sum of the incremental impacts of each project. An example might be the loss of resident trout habitat in widely separated basins where no interactions occur between projects. A second way that cumulative impacts occur is via supra-additive (also called synergistic) impacts. Supra-additive impacts occur when the total cumulative impact to a species or resource is greater than the sum of individual impacts alone. Finally, infra-additive (also called agnostic) impacts occur when a species or resource is exposed to a series of impacts wherein the total cumulative impacts to a species or resource is less than the sum of the individual impacts. Therefore, total impact can be expressed as follows:

Total Impact = Sum of Project Impacts ± Interaction Impacts

Table 30: A Typology of Cumulative Environmental Effects (Canadian Environmental Assessment Research Council and U.S. National Academy of Sciences, 1988)

Type	Main Characteristics	Examples
Time crowding	Frequent and repetitive impacts on a single environmental medium	Wastes sequentially discharged into lakes, rivers, or airsheds
Space crowding	High density of impacts on a single environmental medium	Habitat fragmentation in forests, estuaries
Compounding effects	Synergistic effects arising from multiple sources on a single environmental medium	Gaseous emissions into the atmosphere
Time lags	Long delays in experiencing impacts	Carcinogenic effects
Extended boundaries	Impacts resulting some distance from source	Major dams; gaseous emissions into the atmosphere
Triggers and thresholds	Disruptions to ecological processes that fundamentally change system behavior	The greenhouse effect; effect of rising level of CO_2 on global climate
Indirect effects	Secondary impacts resulting from a primary activity	New road developments opening frontier areas
Patchiness effects	Fragmentation of ecosystems	Forest harvesting; port and marina development on coastal wetlands

The positive sign in the above equation represents the supra-additive case, and the negative sign represents the infra-additive case.

PRINCIPLES OF CUMULATIVE IMPACT ASSESSMENT

While there may be variations in the definitions and terminology associated with cumulative impacts, most efforts to accomplish cumulative impact assessment within the EIA process have focused on considering the proposed action in relation to surrounding projects; appropriately defining the baseline conditions; and addressing combined impacts from the proposed action and surrounding activities on environmental media, natural resources, and socio-economic systems. Regarding EIA practice in the United States, eight principles as shown in Table 31 have recently been delineated for conducting cumulative impact assessments (Council on Environmental Quality, 1997). The principles were derived from the definition of cumulative impacts in the CEQ regulations, from surveys of the experiences of EIA practitioners, and from a review of published literature. These principles should be considered in the planning and conduction of cumulative impact assessment within the EIA process.

STEPS IN CUMULATIVE IMPACT ASSESSMENT

A conceptual framework for addressing cumulative impacts at either the project or strategic level consists of three steps: (1) delineating potential sources of cumulative change; (2) identifying the pathways of possible change (may involve direct, indirect, nonlinear or synergistic processes); and (3) classification of resultant cumulative changes (Spaling and Smit, 1993). Several classes of change have been proposed, including those related to time, space, environmental media or resource, and environmental processes. However, Clark (1993) noted that ". . . there is no single, universally accepted, conceptual approach, nor even general principles, accepted by all scientists and managers.

Four pragmatic steps for delineating potential sources of the cumulative environmental impacts of a proposed project include (Klein and Kingsley, 1994): (1) identify and describe all relevant aspects of the project; (2) identify all other land uses or projects, existing and pending, that may relate to the project under review; (3) identify the relevant environmental systems or components that might be effected by the project; and (4) identify any other interactions which may be important. Selection criteria related to Step (2) include (Klein and Kingsley, 1994): (a) likelihood of the project occurring (formal approval was considered a good indicator of this, but not the only measure); (b)temporal aspects, e.g., projects occurring sooner rather than later; (c) zone of influence, e.g., the proximity of the projects geographically, and the probability of both projects affecting the same environmental system; (d) spin-off effects, e.g., the potential of the project to have broad influence and lead to a wide range of effects or to lead to a number of associated projects; and (e) occurrence of related effects, e.g., if the effects of the other projects are similar to those of the project under review.

Clark (1993) identified the following seven steps in conducting a cumulative impact assessment:

(1) delineate both the proponent agency's planning goals and the planning goals of pertinent governmental agencies within the same area;

(2) establish spatial and temporal boundaries for the study;

Table 31: Principles of Cumulative Effects Analysis (Council on Environmental Quality, 1997)

1.	*Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions.* The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to effects (past, present, future) caused by all other actions that affect the same resource.
2.	*Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (federal, nonfederal, or private) has taken the actions.* Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.
3.	*Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected.* Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resource, ecosystem and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.
4.	*It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.* For cumulative effects analysis to help the decisionmaker and inform interested parties, it must be limited through scoping to effects that can be meaningfully evaluated. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties.
5.	*Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.* Resources typically are demarcated according to agency responsibilities, county lines, grazing allotments, and other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.

Table 31 (continued):

6.	*Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.* Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.
7.	*Cumulative effects may last for many years beyond the life of the action that caused the effects.* Some actions cause damage lasting far longer than the life of the action itself(e.g., acid mine drainage, radioactive waste contamination, species extinctions). Cumulative effects analysis needs to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.
8.	*Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters.* Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

(3) document the environmental baseline for the defined study area;

(4) define the environmental factors which might be subjected to cumulative impacts;

(5) define ecosystem functions and values and delineate a threshold at which ecosystem integrity is diminished to a level where its function is not adequately performed;

(6) analyze the impact of the alternatives and use this information in selecting a proposed action; and

(7) establish an appropriate monitoring program related to the key cumulative impacts.

From a pragmatic perspective, several specific steps can be defined for conducting a cumulative impact assessment within the EIA process. Table 32 displays 11 steps organized in accordance with three components of the EIA process (Council on Environmental Quality, 1997). The 11 steps, while focused on cumulative impact assessment, are conceptually similar to traditional steps used within the EIA process. A similar approach is proposed in draft guidance for addressing cumulative environmental effects under the "Canadian Environmental Assessment Act." This document advocates "thinking cumulatively" by considering (Federal Environmental Assessment Review Office, 1993):

(1) the temporal and geographical boundaries of assessment;

(2) interactions between the environmental effects of a project, as well as the sum total of environmental effects; and

(3) their interactive and sum combination with the environmental effects of other projects and activities.

The above-listed conceptual framework and pragmatic steps can be facilitated through the use of methodologies.

SYNOPTIC AND STRATEGIC APPROACHES

An "ecosystem or landscape level approach" is considered to be necessary to provide an overall or comprehensive assessment of cumulative impacts. The emphasis is on: (1) the loss and deterioration of valued ecological functions; (2) the extent to which various development-imposed stresses are responsible; and (3) the policy and management responses that can mitigate, avoid or offset these. In the United States, wetlands have been a particular focus of concern with respect to correlative impacts because of the scale of recent losses and deterioration and the permitting requirements of the "Clean Water Act" (as part of this process, the U.S. Environmental Protection Agency regulations call for consideration of cumulative impacts pursuant to Section 404). There are a number of regulatory and scientific issues associated with cumulative impacts of wetlands, thus underlining the values of a holistic approach to their assessment.

This "big picture" overview can be achieved by a strategic and synoptic approach. For example, an "indicator approach to cumulative effects assessment" is followed in Ontario, Canada. Indicators are chosen to focus on valued biophysical and socioeconomic components that are

Table 32: Steps in Cumulative Impact Assessment (CIA) to be Addressed in Components of the EIA Process (Council on Environmental Quality, 1997)

EIA Components	CIA Steps	
Scoping	1.	Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals.
	2.	Establish the geographic scope for the analysis.
	3.	Establish the time frame for the analysis.
	4.	Identify other actions affecting the resources, ecosystems, and human communities of concern.
Describing the Affected Environment	5.	Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to changes and capacity to withstand stresses.
	6.	Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds.
	7.	Develop a baseline condition for the resources, ecosystems, and human communities.
Determining the Environmental Consequences	8.	Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.
	9.	Determine the magnitude and significance of cumulative effects.
	10.	Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects.
	11.	Monitor the cumulative effects of the selected alternative and adapt management.

easily understood, analyze existing databases and capture substantial, transgenerational changes (Doyle, 1994). Table 33 summarizes the indicators matrix for biological components (Doyle, 1994). In applying this approach, the main steps in the process as outlined in the NEPA and CEAA examples above are followed at the project level. Hence, the approach draws from and can be applied also at broader sectoral and spatial planning levels.

An inexpensive, rapid synoptic approach to cumulative impact assessment has been developed by the U.S. Environmental Protection Agency (Leibowitz, et al. 1992). It is directed specifically at addressing loss of wetland functions under Section 404 of the Clean Water Act and recognizes that management and regulatory responsibilities are undertaken within tight budget, timeline and information constraints. The proposed approach consists of five major steps, namely: (1) define goals and criteria; (2) define synoptic indices; (3) select landscape indicators; (4) conduct an assessment; and (5) prepare a report. These steps are outlined further in Table 34 (Leibowitz, et al., 1992). Synoptic assessments can be prepared on a regional or state-wide level and can be used to compare cumulative loss of wetlands or other environmental functions between areas or subunits and to provide a context for case-by-case project assessment.

METHODS FOR CUMULATIVE IMPACT ASSESSMENT

A frequent explanation of the lack of attention to cumulative impact assessment is the absence of appropriate methodologies. This viewpoint is probably erroneous if consideration is given to modifying extant methods and applying them to address cumulative impact concerns. In fact, numerous methods can be identified. For example, Table 35 delineates seven primary methods and four special methods which can be applied to cumulative impact assessment (Council on Environmental Quality, 1997), and Table 36 identifies the strengths and weaknesses of nine methods which have been applied for such purposes (Sadler and Verheem, 1996).

Ten selected types of methods for use in cumulative impact assessment have been evaluated in relation to their specific ability to address multiple sources of cumulative environmental change, additive or interactive processes of accumulation, and various types of cumulative effects (Smit and Spaling, 1995). Table 37 summarizes features of the 10 types of methods, and Table 38 highlights six evaluation criteria (Smit and Spaling, 1995). The first six listed methods in Table 37 are analytical in nature, while the last four represent general planning methods. Table 39 displays the 10 types of methods regarding their extent of meeting each criterion (Smit and Spaling, 1995). The primary conclusion of the analysis was that there is no standard method of cumulative impact assessment among the variety of analytically and planning-oriented tools to analyze and evaluate cumulative impacts. Rather, the types of methods can be used for different purposes depending upon the needs of the specific study.

To illustrate actual usage of EIA methods for cumulative impact assessment, Cooper (1995) conducted a review of the predictive models/methods used for cumulative impact prediction in six U.S. Army Corps of Engineers projects. Table 40 summarizes the utilized models/methods for three of the projects. All of the listed models/methods have also been used to address the direct impacts of single projects in specific locations.

Table 33: Indicators Matrix for Biological Components in Cumulative Impact Studies (adapted from Doyle, 1994)

INDICATORS MATRIX						
Environmental components	Indicator	Rationale	Measurement	Pathway Representation	Type of Effect	Duration of Effect
BIOLOGICAL						
Terrestrial	Proportion of total wetland lost per annum	Maintenance of eco-system/provincial policy	Proportion of total wetland lost per annum	Wetlands; hydrologic cycle	Loss of unique habitat types	Permanent; rehabilitation to lower function site
Aquatic	Index of Biotic Integrity (IBI)	Measure of aquatic health	IBI	Hydrologic cycle	Change in fluvial quality	Dependent on changes in watershed
Wildlife (flora, fauna)	Wildlife species at risk - rare, endangered or threatened	Direct indicator of biotic health of ecosystems	Number of rare, threatened or endangered species	Food chain; habitat diversity	Reduction or loss of endangered species	Can result in permanent loss (extinction)
Birds	Provincial breeding bird surveys (levels of nesting bird)	Reflects stress on habitat	% change in levels of nesting birds	Bird populations; species diversity	Loss of nesting bird habitat	Permanent, subject to rehabilitation
Fish	Habitat suitability indices (HSI) for fish species	Alteration of aquatic systems	HSI	Fish populations; hydrologic cycle	Loss of fish habitat	Permanent, subject to rehabilitation

Table 34: Steps in Conducting a Synoptic Assessment (Leibowitz, et al., 1992)

Steps		Procedures
1. Define Goals and Criteria	1.1	Define Assessment Objectives
	1.2	Define Intended Use
	1.3	Assess Accuracy Needs
	1.4	Identify Assessment Constraints
2. Define Synoptic Indices	2.1	Identify Wetland Types
	2.2	Describe Natural Setting
	2.3	Define Landscape Boundary
	2.4	Define Wetland Functions
	2.5	Define Wetland Values
	2.6	Identify Significant Impacts
	2.7	Select Landscape Subunits
	2.8	Define Combination Rules
3. Select Landscape Indicators	3.1	Survey Data and Existing Methods
	3.2	Assess Data Adequacy
	3.3	Evaluate Costs of Better Data
	3.4	Compare and Select Indicators
	3.5	Describe Indicator Assumptions
	3.6	Finalize Subunit Selection
	3.7	Conduct Pre-Analysis Review
4. Conduct Assessment	4.1	Plan Quality Assurance/Quality Control
	4.2	Perform Map Measurements
	4.3	Analyze Data
	4.4	Produce Maps
	4.5	Assess Accuracy
	4.6	Conduct Post-Analysis Review
5. Prepare Synoptic Reports	5.1	Prepare User's Guide
	5.2	Prepare Assessment Documentation

Table 35: Primary and Special Methods for Analyzing Cumulative Effects (Council on Environmental Quality, 1997)

Primary Methods	Description	Strengths	Weaknesses
1. Questionnaires, Interviews, and Panels	Questionnaires, interviews, and panels are useful for gathering the wide range of information on multiple actions and resources needed to address cumulative effects. Brainstorming sessions, interviews with knowledgeable individuals, and group consensus building activities can help identify the important cumulative effects issues in the region.	•Flexible •Can deal with subjective information	•Cannot quantify •Comparison of alternatives is subjective
2. Checklists	Checklists help identify potential cumulative effects by providing a list of common or likely effects and juxtaposing multiple actions and resources. Checklists are potentially dangerous for the analyst that uses them as a shortcut to thorough scoping and conceptualization of cumulative effects problems.	•Systematic •Concise	•Can be inflexible •Do not address interactions or cause-effect relationships
3. Matrices	Matrices use the familiar tabular format to organize and quantify the interactions between human activities and resources of concern. Once even relatively complex numerical data are obtained, matrices are well-suited to combining the values in individual cells in the matrix (through matrix algebra) to evaluate the cumulative effects of multiple actions on individual resources, ecosystems, and human communities.	•Comprehensive presentation •Comparison of alternatives •Address multiple projects	•Do not address space or time •Can be cumbersome •Do not address cause-effect relationships
4. Networks and System Diagrams	Networks and system diagrams are an excellent method for delineating the cause-and-effect relationships resulting in cumulative effects. They allow the user to analyze the multiple, subsidiary effects of various actions, and trace indirect effects to resources that accumulate from direct impacts on other resources.	•Facilitate conceptualization •Addresses cause-effect relationships •Identify indirect effects	•No likelihood for secondary effects •Problem of comparable units •Do not address space or time
5. Modeling	Modeling is a powerful technique for quantifying the cause-and-effect relationships leading to cumulative effects. Modeling can take the form of mathematical equations describing cumulative processes such as soil erosion, or may constitute an expert system that computes the effect of various project scenarios based on a program of logical decisions.	•Can give unequivocal results •Addresses cause-effect relationships •Quantification •Can integrate time and space	•Need a lot of data •Can be expensive •Intractable with many interactions
6. Trends Analysis	Trends analysis assesses the status of a resource, ecosystem, and human community over time and usually results in a graphical projection of past or future conditions. Changes in the occurrence or intensity of stressors over the same time period can also be determined. Trends can help the analyst identify cumulative effects problems, establish appropriate environmental baselines, or project future cumulative effects.	•Addresses accumulation over time •Problem identification •Baseline determination	•Need a lot of data in relevant system •Extrapolation of system thresholds is still largely subjective
7. Overlay Mapping and GIS	Overlay mapping and geographic information systems (GIS) incorporate locational information into cumulative effects analysis and help set the boundaries of the analysis, analyze landscape parameters, and identify areas where effects will be the greatest. Map overlays can be based on either the accumulation of stresses in certain areas or on the suitability of each land unit for development.	•Addresses spatial pattern and proximity of effects •Effective visual presentation •Can optimize development options	•Limited to effects based on location •Do not explicitly address indirect effects •Difficult to address magnitude of effects

Table 35 (continued):

Special Methods	Description	Strengths	Weaknesses
8. Carrying Capacity Analysis	Carrying capacity analysis identifies thresholds (as constraints on development) and provides mechanisms to monitor the incremental use of unused capacity. Carrying capacity in the ecological context is defined as the threshold of stress below which populations and ecosystem functions can be sustained. In the social context, the carrying capacity of a region is measured by the level of services (including ecological services) desired by the populace.	• True measure of cumulative effects against threshold • Addresses impact in system context • Addresses time factors	• Rarely can measure capacity • May be multiple thresholds • Requisite regional data are often absent
9. Ecosystem Analysis	Ecosystem analysis explicitly addresses biodiversity and ecosystem sustainability. The ecosystem approach uses natural boundaries (such as watersheds and ecoregions) and applies new ecological indicators (such as indices of biotic integrity and landscape pattern). Ecosystem analysis entails the broad regional perspective and holistic thinking that are required for successful cumulative effects analysis.	• Uses regional scale and full range of components and interactions • Addresses space and time • Addresses ecosystem sustainability	• Limited to natural systems • Often requires species surrogates for system • Data intensive • Landscape indicators still under development
10. Economic Impact Analysis	Economic impact analysis is an important component of analyzing cumulative effects, because the economic well-being of a local community depends on many different actions. The three primary steps in conducting an economic impact analysis are (1) establishing the region of influence, (2) modeling the economic impacts, and (3) determining the significance of the impacts. Economic models play an important role in these impact assessments and range from simple to sophisticated.	• Addresses economic issues • Models provide definitive, quantified results	• Utility and accuracy of results dependent on data quality and model assumptions • Usually do not address nonmarket values
11. Social impact Analysis	Social impact analysis addresses cumulative effects related to the sustainability of human communities by (1) focusing on key social variables such as population characteristics, community and institutional structures, political and social resources, individual and family changes, and community resources; and (2) projecting future effects using social analysis techniques such as linear trend projections, population multiplier methods, scenarios, expert testimony, and simulation modeling.	• Addresses social issues • Models provide definitive, quantified results	• Utility and accuracy of results dependent on data quality and model assumptions • Social values are highly variable

Table 36: Summary Comments on Nine Methods for Addressing Cumulative Impacts (Sadler and Verheem, 1996)

GIS: Spatial analysis with the help of digital mapping. Strength: powerful and useful tool for carrying out spatial analysis of cumulative environmental change; applicable to mapping sources of cumulative environmental change and cumulative effects, with limited application for the analysis of pathways of cumulative change. Weakness: data requirements and variation in availability of data among different locales; inability to incorporate processes of accumulation.
Network analysis: e.g., "Loop analysis;" a qualitative, network technique that is based on feedback relationships. Strength: scores positive on most criteria; recommended for analysis of cumulative effects. Weakness: its application in CEA remains largely untested.
Biogeographic analysis (e.g., Landscape analysis): Landscape analysis emphasizes the spatial pattern of ecological components and processes within a defined land unit, usually a watershed or other naturally bounded region. Specific indicators that relate to structural and functional attributes at the landscape level are used to measure cumulative environmental change. For example, cumulative effects in bottom land hardwood forests: three indices for structural aspects (forest loss, forest contiguity, forest pattern), five indices for functional aspects (change in stream discharge, change in water residence time, trends in stream nutrient concentration, nutrient loading rates, native biotic diversity). Strength and weaknesses: see GIS.
Interactive matrices (e.g., Argonne multiple matrix): The Argonne multiple matrix was developed to analyze the additive and interactive effects of various configurations of multiple projects. The total cumulative effect of any configuration is assumed to be the sum of project specific effects adjusted for interactions among projects and their effects. Expert opinion is used to establish three types of data: scores that define the level of effect of each project on selected environmental components, weighting coefficients that reflect the relative value of each component, and interaction coefficients that measure the effect of each pair of projects on each component. These data sets are entered into matrices that are manipulated to calculate a total score indicating the cumulative effect for each project configuration. Strength: consideration of the cumulative effect of multiple sources of environmental change. Weakness: cumulative effects are not differentiated by type, and parameter values rely extensively on expert judgment.
Ecological modeling: (computer) modeling of ecosystems. Strength: theoretically, method scores very positive on a number of criteria. Weakness: application is dependent on reliable data, model validation and resources (time, money, expertise); models usually analyze the effect of multiple sources on only one environmental component; only applicable to environmental systems for which the system organization and behavior are reasonably well understood.
Expert opinion: Use of experts (e.g., in "cause and effect diagramming" in flow diagrams). Strength: provides an organizing framework for more empirical analyses. Weakness: scores negative on a number of CEA criteria.
Programming models (e.g., Linear programming): Linear programming is a tool that identifies resource allocations (solutions) which are feasible given specified environmental and other conditions (constraints), and then selects some "optional" allocation based on a specified decision rule (objective function). Strength: offers a potential planning approach to investigate and manage cumulative environmental problems. Weakness: application in CEA would be a novel departure from typical socioeconomic applications.

Table 36 (continued):

Land suitability evaluation (e.g., "Land disturbance target"): The essence of this method is to select an indicator of environmental quality and to establish an allowable target or threshold for this indicator, which is then used as a decision criteria to evaluate the cumulative effects of existing and future developments within an area. Strength: particularly suitable as a planning tool to evaluate and manage cumulative effects at the local and regional levels. Weakness: only a single activity or sole indicator of environmental change (e.g., erodibility); data-requirements dependent on a time limited historical record; an assumption that past land use trends and environmental responses are continued into the future.
Process guidelines: One approach consists of three main steps: Step one involves a decision tree diagram beginning with a series of directional questions to establish whether a CEA is needed for a particular problem. Major considerations include the type, size and number of projects, and spatial and temporal scales of anticipated effects. Step two requires a decision between two possible approaches to the analysis of cumulative effects, depending on the type identified in step one. Ex ante analysis is applied to identify and analyze cumulative environmental change in the future. Post analysis is implemented when cumulative effects are currently observable, but causality and origin are not known. Step three involves evaluation of development scenarios, assessment of the acceptability of future states of the environment, and appraisal of management options. Interdisciplinary expertise, "affected publics" and workshops are an inherent part of this step. Strength: satisfactorily meets most relevant CEA criteria; suited as an organizing framework within which to carry out a comprehensive CEA, including the selection and application of more rigorous methods and techniques. Weakness: lacks specificity.

Table 37: Features of Ten Types of Methods for Cumulative Impact Assessment (Smit and Spaling, 1995)

Category[a]	Main Feature	Mode of Analysis	Representative Method(s)
Spatial analysis	map spatial changes over time	sequential geographical analysis	Geographic information systems (GIS)
Network analysis	identify core structure and interactions of a system	flow diagrams; network analysis	Loop analysis Sorenson's network
Biogeographic analysis	analyze structure and function of landscape unit	regional pattern analysis	Landscape analysis
Interactive matrices	sum additive and interactive effects; identify higher order effects	matrix multiplication and aggregation techniques	Argonne multiple matrix; synoptic matrix; extended CIM[b]; modified CIAP[c]
Ecological modeling	model behavior of an environmental system or system component	mathematical simulation modeling	Hypothetical modeling of forest harvesting
Expert opinion	problem-solving using professional expertise	group process techniques (e.g., Delphi, nominal group technique)	Cause-and-effect diagramming
Multi-criteria evaluation	use of a priori criteria to evaluate alternatives	weighing of parameters and computational ranking of scenarios	Multi-attribute tradeoff analysis
Programming models	optimize alternative objective functions subject to specified constraints	mass-balance equations	Linear programming
Land suitability evaluation	use ecological criteria to specify location and intensity of potential land uses	define acceptable levels of ecosystem health and target thresholds utilizing ecological indicators	Land disturbance target Ecosystem-based planning
Process guidelines	logic framework to conduct CEA	systematic sequence of procedural steps	Snohomish guidelines CEA[d] decision tree

[a]: the first six categories include analytical methods; the last four are planning methods
[b]: CIM = cumulative impact matrix
[c]: CIAP = cumulative impact analysis process
[d]: CEA = cumulative effects assessment

Table 38: Six Evaluation Criteria for Types of Methods (Smit and Spaling, 1995)

Name	Description
Temporal Accumulation	Temporal accumulation occurs when the interval between one perturbation and succeeding perturbations is too small for an environmental system, or system component or process, to assimilate or recover from the perturbation. Temporal accumulation requires that a method consider time scale and frequency of a perturbation. A method should incorporate an extended time horizon to detect long-term, incremental environmental change, and also account for time lags.
Spatial Accumulation	Spatial accumulation occurs where the spatial proximity between perturbations is smaller than the distance required to remove or disperse the perturbations. A method should recognize the geographic scale of perturbations and set spatial boundaries accordingly. It should also account for cross-boundary movements at the same scale (e.g., intraregional) and movements between different scales (e.g., local to regional to global). A method should acknowledge variation in spatial density because perturbations and effects are differentiated over space. Configuration is a significant characteristic because some methods may be oriented toward a certain pattern (point, linear, areal) more than others. The ability to consider an areal pattern is particularly important because cumulative impact assessment is often conducted in a regional context.
Type of Perturbation	Perturbation type refers to a method's ability to account for perturbations that are single or multiple in kind. For a method to fulfill this criterion, it should recognize perturbations that originate from multiple sources, or the same source repeated over time or across space. A method should also consider whether an action stimulates or propagates additional developments that trigger further sources of perturbation.
Process of Accumulation	Processes of accumulation emphasize pathways or relationships that link cause and effect. A method should have the ability to trace and account for specific processes of environmental change. It should differentiate between additive and interactive processes, and incorporate a technique that aggregates the effect of each.
Functional Change	Functional effects refer to alterations to processes (e.g., energy flows, nutrient cycling, succession), or modifications to controlling properties (e.g., assimilation capacity, carrying capacity, thresholds). A method should be able to identify, analyze, and assess functional change in an environmental system, or a system component or process, after perturbation. The criterion of functional effects generally implies time-oriented changes and includes time-crowding, time lags, and triggers and thresholds.
Structural Change	Structural effects include population shifts, habitat modification, and alterations to geophysical resources (e.g., air, water, soil). Analogous to functional effects, a method should be able to identify, analyze, and assess structural change in an environmental system, or a system component or process, after perturbation. Structural change is viewed as essentially spatial and includes space-crowding, cross-boundary flows, and fragmentation effects.

Table 39: Summary Evaluation of Selected Methods (Smit and Spaling, 1995)

Method	Evaluation Criteria					
	Temporal Accumulation	Spatial Accumulation	Type of Perturbation	Process of Accumulation	Functional Change	Structural Change
Geographic information system	S	S	S	X	P	S
Loop analysis[a]	X	X	S	S	X	X
Landscape analysis	S	S	S	S	P	S
Argonne multiple matrix	X	P	S	S	X	X
Simulation modeling	S	S	S	S	S	S
Cause-effect diagramming	X	X	S	S	X	X
Multi-attribute tradeoff analysis	X	P	S	X	X	X
Linear programming	P	S	S	P	P	S
Land disturbance target	S	S	P	P	S	S
CEA Reference Guide[b]	S	S	S	P	S	S

Abbreviations: S, satisfactorily meets criterion; X, does not meet criterion.
[a]Also called network analysis.
[b]Refers to a reference guide consisting of 3 main steps as follows:

(1) Step one involves a decision tree diagram beginning with a series of directional questions to establish whether a cumulative impact assessment is needed for a particular problem. Major considerations include the type, size and number of projects, and spatial and temporal scales of anticipated impacts.

(2) Step two requires a decision between two possible approaches to the analysis of cumulative impacts, depending on the type identified in step one. Ex ante analysis is applied to identify and analyze cumulative environmental change in the future. Post analysis is implemented when cumulative impacts are currently observable, but causality and origin are not known.

(3) Step three involves evaluation of development scenarios, assessment of the acceptability of future states of the environment, and appraisal of management options. Interdisciplinary expertise, "affected publics," and workshops are an inherent part of this step.

Table 40: Examples of Cumulative Impact Prediction Methods Used in Three EISs by U.S. Army Corps of Engineers (Cooper, 1995)

Proposed Project	Illustrations of Methods
River channel and flood plain development near Dallas, Texas	Several quantitative models were used, including: (a) QUAL-TX Model The QUAL-TX model was used to quantify future water quality conditions of the river. The heart of the model is the Streeter-Phelps equation for the dissolved oxygen (DO) sag curve, which can be used to calculate DO based on biological oxygen demand and ammonia oxidation. The DO levels were predicted based on low flow conditions and stormwater runoff flows. (b) Habitat Evaluation Procedure (HEP) A cumulative impact analysis on wildlife was conducted using HEP. Habitat units for each alternative scenario were estimated based on three habitat types which were considered to have wildlife value. Baseline Habitat Suitability Indices (HSI) were developed for each selected species. The HSI for each species, in each cover type, was then averaged to develop a composite HSI. (c) Earth Resources Data Analysis System (ERDAS) and Geographic Information System (GIS) ERDAS consists of an integrated image processing system. GIS was used to identify and classify various types of geographic data (type of vegetation and land use, soil type, slope, political boundaries, etc.) and record into an overall data base. (d) HEC-1 Computer Program The HEC-1 computer program, developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center at Davis, California, was used to simulate surface water runoff responses of the river basin (from precipitation) by representing the basin as an interconnected system of hydrologic and hydraulic components.
Hurricane and flood protection near New Orleans, Louisiana	The HEP and the HES were both used to quantitatively predict habitat losses. The loss in habitat acres directly correlates to the cumulative loss of bottomland hardwoods, marsh, wooded swamp, and wetlands predicted for the proposed project. These methods are briefly described as follows: (a) Habitat Evaluation Procedure (HEP) The HEP was used to predict impacts on fish and wildlife resources. These impacts were determined by estimating the loss of habitat acres (i.e., bottomland hardwood, wooded swamp, marsh, and wetlands) in the project area. Habitat losses were measured in Annual Average Habitat Units (AAHUs). This analysis showed that implementation of the project would result in the loss of 1,990 AAHUs to seven evaluation species. (b) Habitat Evaluation System (HES) The HES was also used to predict impacts on fish and wildlife resources. These impacts were determined by estimating the loss of habitat acres (i.e., bottomland hardwood, wooded swamp, marsh, and wetlands) in the project area. Habitat losses were measured in Annualized Habitat Unit Values (AHUVs). Unlike HEP, HES does not examine individual species, but instead evaluates general habitat characteristics that support fish and wildlife populations within an ecosystem.

Table 40 (continued):

Proposed Project	Illustrations of Methods
Third dam and reservoir project in a river basin in Oregon	Quantitative methods were used to predict potential cumulative impacts on environmental resources; they are listed as follows: (a) WRE Model (Water Temperature) The WRE model, developed by Water Resources Engineers, Inc., Walnut Creek, California, was used to simulate reservoir water temperatures. (b) WESTEX Model (Water Turbidity) The WESTEX model, developed by the U.S. Army Corps of Engineers Waterways Experiment Station and the University of Texas was used to simulate reservoir water turbidity. (c) CE-THERM (Reservoir Process) CE-THERM model was used to verify the reservoir processes in Westex. (d) QUAL II Model (River Flow/Process) The QUAL II model was used to simulate the Rogue River to determine cumulative effects from all three dam projects. (e) Remote Sensing and Geographic Information Systems (GIS) Remote sensing and GIS technology was used to forecast daily suspended sediment levels in tributaries of the Rogue and Applegate Rivers, where observed data was unavailable, with the results used in the QUAL II model. (f) Habitat Evaluation Procedure (HEP) A cumulative impact analysis on wildlife was conducted using HEP. (g) HEC-5 Program The HEC-5 (Hydrologic Engineering Center) computer program, developed in 1986 by the U.S. Army Corps of Engineers, Davis, California, was used to simulate flood control and conservation systems.

SUMMARY OF ISSUE

In summary, six following observations are made:

(1) Numerous methods or tools are available for addressing direct, indirect, and cumulative effects of projects and of strategic plans. Although often it is used as an excuse, lack of methods should not constrain cumulative impact analysis. However, specific research is still needed. For example, Clark (1993) noted that research on methods of assessment of cumulative impacts is needed, especially as it relates to ecosystem analysis.

(2) In order to address cumulative impacts, it is necessary for the study managers and analysts to adopt an holistic perspective on the environment. Holistic perspectives might be limited in traditional academic backgrounds, thus suggesting the need for broader training for practitioners in EIA.

(3) There is great value in reviewing environmental impact statements prepared by others to glean useful information and approaches that could be used on specific studies. Many environmental impact studies represent excellent technical documents and resulting approaches and methods can be identified through the review of such documents.

(4) Similar benefits can be obtained through the systematic review of environmental impact statements in the context of selected case studies. Based upon such systematic reviews, lessons learned can be identified; and this information can then be communicated to EIA practitioners using a variety of technology transfer approaches.

(5) Planning and conduction of cumulative impact studies can be scientifically as well as institutionally complicated. Accordingly, it is necessary for practitioners to be creative in their consideration of methods and tools and to select approaches which are appropriate to individual study requirements.

(6) Synoptic assessments provide a broad overview of ecological functions and a context for understanding cumulative impacts. The approach is not intended to provide a preuse, quantitative cumulative impact analysis; rather, it can be used to consider the conditions of a natural area or regarded as a benchmark against which to judge resource loss and deterioration associated with proposed activities or development plans.

CHAPTER VI

STRATEGIC ENVIRONMENTAL ASSESSMENT -- A SPECIAL ISSUE

SEA refers to a systematic process for evaluating the environmental consequences of proposed policy, plan or program initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision making on par with economic and social considerations (Sadler and Verheem, 1996). Several recent publications have focused on the principles and practice of SEA; examples include Lee and Walsh (1992), Therivel, et al. (1992), De Boer and Sadler (1996), Sadler and Verheem (1996), and Therivel and Partidario (1996). A bibliography of SEA references has been prepared by the Canadian Environmental Assessment Agency (Partidario, 1996).

In this context, policy refers to a general course of action or proposed overall direction that a government is, or will be, pursuing and which guides ongoing decision making. A plan is defined as a purposeful, forward-looking strategy or design, often with coordinated priorities, options and measures, that elaborates and implements policy. Finally, a program denotes a coherent, organized agenda or schedule of commitments, proposals, instruments and/or activities that elaborates and implements policy (Sadler and Verheem, 1996). Other definitions emphasize evaluating the environmental impacts of a policy, plan or program and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision-making (Therivel, et al., 1992). In summary, SEA refers to the application of the EIA process to plans, programs, and policies, often referred to as PPPs or the 3 Ps.

Many types of PPPs could be subjected to SEAs. Various typologies of SEA have been proposed. For example, Therivel, et al. (1992) suggested that SEAs could be divided into three types: (1) sectoral; (2) regional; and (3) indirect. In some classifications, policy-related SEAs are delineated as a fourth type. Examples of sectoral SEAs include those for waste disposal, water supply, agriculture, forestry, energy, recreation, and transport. In the United States, for example, a SEA typically leads to the preparation of a programmatic environmental impact statement (EIS) (Bass and Herson, 1996). Regional SEA examples include those for regional plans, metropolitan/city plans, community plans, redevelopment plans, and rural plans. Examples of indirect SEAs include those for such "indirect" PPPs as science and technology, financial/fiscal policies, and justice/enforcement. Illustrations of specific concerns and case studies related to these types of SEAs are included in a subsequent section of this chapter.

METHODS FOR SEA

The planning and implementation of a SEA involves the consideration of a number of issues. Sadler and Verheem (1996) have suggested that "good practice" regarding SEA should incorporate the following framework of steps:

(1) Apply a simple screening procedure to initiate SEA or exempt proposals from further consideration, depending on their consequentiality. Several methods can be used: categorical lists, case-by-case test for significance, some combination,

or, where no formal guidance is available, prescreening questions.

(2) Use scoping to identify important issues, draft terms of reference where necessary for SEA, determine the approach to be followed, and establish other alternatives for consideration.

(3) Specify, evaluate and compare alternatives, including the no action option. The aim is to clarify the trade-offs at stake, showing what is gained or lost, and point, where possible, to the best practicable environmental option (or equivalent designation).

(4) Conduct a policy appraisal or impact analysis to the extent necessary to examine environmental issues and cumulative effects, compare the alternatives, and identify any necessary mitigation or offset measures for residual concerns.

(5) Report the findings of the SEA, with supporting advice and recommendations, to decision makers in clear and concise language. Depending on the proposal, the documentation may range from a few pages to an EIS; longer reports should have an executive summary.

(6) Review the quality of the SEA to ensure the information is sufficient, and relevant to requirements of decision making. Depending on the process, this activity can range from a quick check to an independent review.

(7) Establish necessary follow up provisions for monitoring effects, checking that environmental conditionalities are being implemented, and, where necessary, tracking arrangements for project EIAs. For policies, plans and programs that initiate projects, tiering EIA to the SEA can significantly improve process effectiveness and efficiency.

Applicable methods for SEA include the types of methods listed in Table 1 for project-focused impact studies, as well as methods typically used for policy analysis/plan evaluation (Wood and Djeddour, 1992). Examples of the latter group of methods include scenarios, planning balance sheets, and cost-benefit analysis. Depending upon the particular characteristics of the plan, program, or policy subjected to SEA, modifications may be necessary in selected methods from both groups. Table 41 lists some specific methods which can be used for impact identification in SEA; the methods are displayed in four categories (Sadler and Verheem, 1996). Examples of methods which can be used for impact analysis in SEA are shown in Table 42 (Sadler and Verheem, 1996).

Table 43 delineates examples of methods associated with different steps in planning and conducting a SEA (Sadler and Verheem, 1996). As noted earlier in conjunction with applying the EIA process to project-level actions, no single method can be used to fulfill all the steps in a SEA.

As a final note in conjunction with SEA, information on environmental standards, carrying capacity, and thresholds can be used for impact interpretation. These three topics are not addressed herein.

Table 41: Some Methods for Impact Identification in SEA (Sadler and Verheem, 1996)

Category	Specific Methods Within Category
Literature search	State of knowledge - survey to identify linkages between policy actions and environmental impacts. "State of the Environment" reports and environmental policy plans will be useful documents to start with. Case comparison - of examples from other policy domains or jurisdictions. Analysis of similar actions in other countries can provide insight into the possible impacts of policy options.
Expert judgment	Delphi survey - iterative canvass of opinions and perspectives from recognized "experts" in pertinent fields. Workshops - structured meeting with a problem-solving focus, e.g., to develop alternatives or map possible impacts.
Analytical techniques	Scenario development - projections, based on reasoned assumptions, to outline and compare the means by which, or conditions under which, a proposed action may be implemented; e.g., "best" vs. "worst" case scenario of risks and impacts. Model mapping - identification of cause-effect networks to qualitatively illustrate linkages; e.g., policies will influence plans and programs, which will subsequently initiate projects. Checklists - those developed for project EIA have proven useful at the strategic level too, in original or modified form. Indicators - often, it will not be appropriate, possible or necessary to predict all environmental impacts of a proposed policy; instead, screening against relevant indicators may be sufficient for the purposes of a SEA. In many cases, indicators can be used to establish networks focusing on emissions and paths rather than actual effects on flora and fauna. Because indicators, by definition, need little aggregation, this may reduce the workload considerably. Note, however, the possible distortion that may occur in the simplification process implied by aggregating environmental variables into one single indicator.
Consultative tools	Interviews - with experts, opinion leaders, political representatives, etc. Selective consultation - with key interest groups and/or communities and sectors directly affected by a proposed policy, plan or program. Policy dialogue - round table or other multi-stakeholder process to clarify issues, determine consequences and identify options that meet the concerns and interests represented.

Table 42: Examples of Some Methods for Impact Analysis in SEA (Sadler and Verheem, 1996)

Extended use of identification methods - In most SEAs, relatively simple and straightforward methods will be sufficient. Examples include: literature survey, case comparison, expert judgment, scenario development and model mapping. This last technique is reported to have been effective for SEA. Often, it has proven possible to sufficiently quantify environmental indicators by filling in each parameter of an impact network, based on data from literature, indicative calculations or expert judgment.
Use of matrices - Grid diagrams can be used to cross-reference a list of (sub)actions to a list of environmental impact parameters. Most SEAs make use of matrices in some form. The UK Guide on SEA for Structure Plans recommends them as the main tool, including their use for consistency analysis to identify potential conflicts between objectives in different policy sectors.
Computer modeling - In some countries, computer models are used to calculate the impact of strategic options on environmental indicators. For example, these have been applied to habitat supply analysis in Canada and the US, and to simulate the impact of tax policy on (national) energy use, and vehicle mileage and use of public transport in the UK.
Geographic Information Systems - These are especially useful in land use planning, routing studies and assessing cumulative impacts o several projects in the same area. Also, they may be used to support impact analysis, e.g., calculation of land occupation or measuring environmental impacts as function of distance to pollution sources.
Cost effectiveness analysis - Used to select the option which achieves a target or goal at least cost (environmental or financial). This is a useful technique in cases where actions are clearly constrained by existing (environmental) targets or objectives, for example, ambient air and water quality standards, emission limits under or resource harvesting allocations.
Cost-benefit analysis (CBA) - Technique in which as many impacts as possible are expressed in a unified value; the benefit-cost ratio is a basis for choice between the options reviewed.
Multi-criteria analysis (MCA) - This is an advanced form of CBA in which separate scores on a number of key evaluation criteria are given, rather than using one, unified value to express the significance of all impacts (as is the case in CBA). Using mathematical operations, combinations of weights and criteria scores provide a ranking of options. The advantage of MCA over CBA is that it allows for the joint analysis of both environmental costs and financial costs, even when the environmental costs cannot be valued in monetary terms. MCA does not necessarily lead to one, unambiguous solution; it generally leaves some freedom to decision makers. A specific form of MCA is the "goals achievement matrix" which helps in identifying how an action may potentially contribute to a se of specified (environmental) objectives.
Aggregation methods - Used to translate "groups of indicators" into one, composite indicator. The aim is to make the total amount of environmental information more manageable. In this process, results are often weighed against each other and "trade-off" choices are made. In principle, these are political decisions, and therefore, care should be taken in using aggregation methods for SEA. Usually however, some aggregation is needed and possible without generating controversy. Some methods are: • index methods - aggregation by valuation and weighted summation; • monetary methods - all impacts are translated into one unit; as yet,they are insufficiently developed for use in EA; • source methods - aggregation on an impact basis, for example, energy sources according to their contribution to the emissions of CO_2, air pollution sources according to their contribution to acidification.
Life Cycle Analysis - A standardized method taking into account the total "life cycle" of goods or services from use of natural resources, via production of goods to the treatment of waste. A standardized method is "scored" on ten environmental issues: human toxicity, aquatic ecotoxicity, soil ecotoxicity, greenhouse effect, ozone production, acidification, eutrophication, smell, use of space and use of natural resources. Scores are weighed against existing environmental problems in the area.

Table 43: Application of Methods to Steps in SEA (Sadler and Verheem, 1996)

Step	Examples of Methods
Baseline Study:	• SOE reports and similar documents • environmental stock/setting • "points of reference"
Screening/Scoping:	• formal/informal checklists • survey, case comparison • effects networks • public or expert consultation
Defining Options:	(by reference to): • environmental policy, standards, strategies • previous commitment precedents • regional/local plans • public values and preferences
Impact Analysis:	• scenario development • risk assessment • environmental indicators and criteria • policy impact matrix • predictive and simulation models • GISs capacity/habitat analysis • benefit/cost analysis and other economic valuation techniques • multi-criteria analysis
Documentation for Decision Making:	• cross-impact matrices • consistency analysis • sensitivity analysis • decision "trees"

MULTIPLE USES OF METHODS

Table 44 summarizes, on a relative basis, the usage of several types of EIA methods for project-specific and cumulative impacts, and for strategic-specific and cumulative impacts. A number of specialists consider that methods for use in SEAs need not be substantially different from those used in project-level EIAs (Sheate, 1996). However, it is important also to adopt a discriminating approach recognizing the concerns related to SEA noted below. To specifically illustrate methods application, Table 45 delineates methods which could be used for air impacts prediction at both project and SEA levels. Similar compilations could be presented for other impact categories. Finally, Table 46 illustrates types of EIA methods in terms of whether they are focused on impacts to specific media or resources, or whether they can be used for an integrative consideration of impacts. Table 46 has applicability for project-level, cumulative, and strategic impact issues.

CONCERNS RELATED TO SEAs

There are numerous concerns related to planning and implementing SEA studies. Pragmatically, such concerns include:

(1) lack of PPP specificity may limit specific considerations, thus an "impact footprint" approach is needed;

(2) nonavailability of regional/national plans for reference; or the availability of limited plans which are out-of-date;

(3) the larger scale of SEAs multiplies the effort needed for data gathering on other projects, environmental resources, laws, etc.;

(4) the environmental carrying capacity needs to be considered, and there may be a lack of information on this subject;

(5) the correlation of the activity-effect relationship is typically more tenuous in SEA than in project level EIA;

(6) the uncertainties may be greater than for project-level EIA;

(7) there is typically a greater need to address transboundary impacts; and

(8) the possible confusion as to whether certain topics should be addressed in a SEA or a subsequent project-level EIA, or both.

Finally, due to the relative newness of SEAs, there is a critical need for case studies from which lessons can be learned and articulated. This information could be used in guidance and training programs related to SEA. This would be helpful to substantive area professionals who may be poorly trained to think holistically and on broader scales.

Table 44: Methods for Usage in Studies

Types of Methods	Relative Usage			
	Project	Cumulative	Strategic	Cumulative
Analogs	H	M	L	L
Checklists	H	M	M	L
Decision-focused Checklists	M	L	L	L
ECBA*	L	O	O	O
Expert Opinion	H	M	M	L
Expert System	L	O	O	O
Indices or Indicators	M	L	M	L
Laboratory Testing	M	L	NA	NA
Landscape Evaluation	M	L	L	O
Literature Reviews	M	L	L	O
Mass Balances	H	L	L	O
Matrices	H	L	M	L
Monitoring (baseline)	L	O	O	O
Monitoring (field)	L	O	O	O
Networks	M	O	O	O
Overlay Mapping	M	L	L	L
Photographs/Photomontages	M	L	L	L
Qualitative Models	H	L	L	O
Quantitative Models	M	L	L	O
Risk Assessment	L	L	L	O
Scenario Building	L	O	L	O
Trend Extrapolation	L	L	L	O

H = relatively extensive (high) usage
M = relatively moderate (intermediate) usage
L = relatively low usage
O = limited usage, if at all
NA = not applicable
*ECBA = environmental cost benefit analysis

Table 45: Air Impacts Prediction at Project and Strategic Levels

Project:	Analogs
	ECBA· (C)[a]
	Expert Opinion (C)
	Indices or Indicators (C)
	Laboratory Testing
	Landscape Evaluation (C)
	Literature Reviews
	Mass Balances (C)
	Monitoring (field)
	Overlay Mapping (C)
	Quantitative Modeling[*](C)[**]
	Risk Assessment (C)
	Scenario Building (C)
	Trend Extrapolation (C)
Strategic:	Expert Opinion (C)
	Indices or Indicators (C)
	Literature Reviews
	Mass Balances (C)
	Matrices (C)
	Qualitative Modeling
	Quantitative Modeling (C)[***]
	Risk Assessment
	Scenario Building
	Trend Extrapolation

[a]C denotes can also be used for cumulative impacts
[*]SCREEN2 and ISC2 (single or multiple sources) models are examples (ISC = industrial source complex)
[**]ISC2 plus others
[***]Multisource regional models and atmospheric chemistry models are examples

Table 46: Specific Versus Integrative Focus of Methods

Types of Methods in EIA	Focused on Impacts Related to Specific Media/Resources	Focused on Integrative Consideration of Impacts
Analogs	+	+
Checklists		+
Decision-focused Checklists		+
ECBA		+
Expert Opinion	+	+
Expert Systems	+	+
Indices or Indicators	+	
Laboratory Testing	+	
Landscape Evaluation	+	
Literature Reviews	+	+
Mass Balances	+	
Matrices		+
Monitoring (baseline)	+	
Monitoring (field)	+	
Networks		+
Overlay Mapping		+
Photographs/Photomontages	+	
Qualitative Models	+	
Quantitative Models	+	
Risk Assessment	+	+
Scenario Building	+	
Trend Extrapolation	+	

CHAPTER VII

OTHER METHODS RELATED TO EIA PROCESS

Other methods are associated with different facets or components of the EIA process. Examples of such methods can be identified relative to public participation, EIS review, and follow-on auditing. These were identified as key areas for EIA process strengthening in the recently completed effectiveness study (Sadler, 1996). In the case of public participation, the component has particular application at the scoping stage (another key function for EIA process strengthening). EIS review and follow on auditing are crucial for building quality control and continuity into the EIA process, and accordingly, methods that apply to these phases are given particular reference.

METHODS FOR PUBLIC PARTICIPATION

Public participation occurs throughout the EIA process. It begins early during the scoping process, on a continuing basis during the actual conduction of the impact study, and as a final component during the review of a draft environmental impact statement (EIS). Numerous techniques have been developed to facilitate the communication process with a variety of interested publics, including personnel from several pertinent governmental agencies. Formalized public hearings or informal public meetings are two frequently utilized techniques. Additional examples of techniques include the use of letters, questionnaires, and telephone calls; hotlines; drop-in centers; workshops; citizens' advisory committees; and many others.

Recent reviews of these techniques and others is in Federal Environmental Assessment Review Office (1988) and Canter (1996a). A still relevant comparison of their capabilities in the context of EIA was made by Bishop (1975). Table 47 summarizes the communication characteristics of 24 public participation techniques and identifies their utility for meeting EIA objectives. A specific example of the application of involvement tools include a videotape of proposed sites for a project. This is an excellent aid for explaining site differences and limitations during the lecture-format portion of a scoping meeting (Council on Environmental Quality, 1981 and 1986). Workshops can also be useful. Their success, in large part, depends on the degree of advance preparation; therefore, this should be as comprehensive as possible. Advance preparation for workshops might include distribution of various types of brochures, planning visits, coverage by the media, and direct contacts with interested parties.

Special efforts are needed to facilitate public involvement of native peoples and others who pursue traditional lifestyles, constitute identifiable minorities, or live in remote communities. In these cases, public meetings, workshops and other widely used techniques may be an inappropriate means of gaining input and involvement. Community-based processes, including storefront operators maintained by local residents and "walk and talk" procedures may serve as more effective mechanisms (Sadler, 1990). Methods for documenting traditional ecological knowledge (TEK) held by native peoples (or rural communities) comprise a distinct and separate component that is being recognized as particularly important in Australia, Canada, New Zealand, the USA and other countries where aboriginal systems of resource use and management are retained. Guidance for consulting on and incorporating TEK into modern EIA can be found in Sadler and Boothroyd (1994).

Table 47: Capabilities of Public Participation Techniques (Bishop, 1975)

Communication characteristics[a]				Impact assessment objectives					
Level of public contact achieved	Ability to handle specific interest	Degree of two-way communication	Public participation techniques	Inform/ educate	Identify problems/ values	Get ideas/ solve problems	Feedback	Evaluate	Resolve conflict/ consensus
M	L	L	Public hearings		X		X		
M	L	M	Public meetings	X	X		X		
L	M	H	Informal small group meetings	X	X	X	X	X	X
M	L	M	General public information meetings	X					
L	M	M	Presentations to community organization	X	X		X		
L	H	H	Information coordination seminars	X			X		
L	M	L	Operating field offices		X	X	X	X	
L	H	H	Local planning visits		X		X	X	
L	H	L	Planning brochures and workbooks	X		X	X	X	
M	M	L	Information brochures and pamphlets	X					
L	H	H	Field trips and site visits	X	X				
H	L	M	Public displays	X		X	X		
M	L	M	Model demonstration projects	X			X	X	X
H	L	L	Material for mass media	X					
L	H	M	Response to public inquiries	X					
H	L	L	Press releases inviting comments	X			X		
L	H	L	Letter requests for comments			X	X		
L	H	H	Workshops		X	X	X	X	X
L	H	H	Charettes			X		X	X
L	H	H	Advisory committees		X	X	X	X	
L	H	H	Task forces		X	X		X	
L	H	H	Employment of community residents		X	X			X
L	H	H	Community interest advocates			X		X	X
L	H	H	Ombudsman or representative		X	X	X	X	X

[a] L = low; M = medium; H = high.

Public participation opportunities for some projects extend to settlement of conflicts and disputes related to specific impacts or the entire project. Accordingly, conflict resolution techniques may be useful in trying to avoid the use of litigation, legislation and/or regulation, administrative procedures, and arbitration. Newer techniques for the management and resolution of environmental conflicts involve mediation and negotiation between the parties in conflict (Crowfoot and Wondolleck, 1990). A variety of terms have been used for these techniques, including environmental mediation, environmental negotiation, environmental bargaining, environmental conciliation, conflict management, consensus building, alternative dispute resolution, alternative environmental conflict management, environmental dispute resolution (EDR), environmental dispute settlement, and others.

Such EDR techniques refer collectively to a variety of approaches that allow the parties to meet face to face to reach a mutually acceptable resolution of the issues in a dispute or potentially controversial situation (Bingham, 1986). This approach differs in kind rather than degree from conventional public participation. Advantages from using such conflict resolution, mediation, and collaborative problem-solving techniques include (Delli Priscoli, 1988): (1) expensive adversarial battles can be avoided; (2) durable agreements can be reached among seemingly irreconcilable adversaries; (3) productive relationships can be built out of conflict; and (4) mutual interests can be discovered among environmental, development, industrial, federal, private, and public interests. This approach is now formalized as a public review mechanism under the "Canadian Environmental Assessment Act" and offers an alternative to a public hearing-based panel review (Sadler, 1993).

EIS REVIEW

The quality of EIA is a subject of increasing concern and attention for process administrators and participants, as well as for decision-makers who rely on and use the information in development approvals and condition setting. Review of EISs provides an important mechanism for checking the quality of documentation and, by extension, the effectiveness of the approach taken in the impact study and the acceptability of methods applied. Experience gained in the United States, the Netherlands, and the United Kingdom at the Institute of Environmental Assessment, exemplify the methodological frameworks that are available and can be applied to EIS review.

In the United States, the U.S. Environmental Protection Agency (EPA) reviews EISs prepared by others, particularly with regard to water and air pollution, solid waste management, noise, radiation and pesticide use. Each statement reviewed is assigned a rating based on the nature of the proposed action. The EPA rating system is described in Table 48 (Canter, 1996a). When a project is rated environmentally unsatisfactory (EU) or an EIS is rated as inadequate (Category 3), the Council on Environmental Quality is notified so it can begin the necessary monitoring and oversight of the situation at an early stage in the EIA process.

In the Netherlands, all EISs and EIA reports are reviewed by an independent Commission as to their quality and adequacy for decision making. The Dutch EIA Commission has published formal criteria to assist their review of EIS/EIA reports (see Table 49) which include recommendations on how serious shortcomings in information should be addressed (Scholten, 1997b). Although the competent authority is not obligated to direct a proponent to follow the Commission's advice, this is commonly done in practice. The experience of the Dutch EIA Commission is

Table 48: EIS Rating System Used by U.S. Environmental Protection Agency (Canter, 1996a)

1. Rating the environmental impact of the action:

LO (lack of objections) The review has not identified any potential environmental impacts requiring substantive changes to the preferred alternative. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with not more than minor changes to the proposed action.

EC (environmental concerns) The review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require substantial changes to the preferred alternative or the application of mitigation measures that can reduce the environmental impact.

EO (environmental objections) The review has identified significant environmental impacts that should be avoided in order to adequately protect the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no-action alternative or a new alternative). The basis for environmental objections can include situations in which *(a)* an action might violate or be inconsistent with achievement or maintenance of a national environmental standard; *(b)* the federal agency violates its own substantive environmental requirements that relate to the EPA's areas of jurisdiction or expertise; *(c)* there is a violation of an EPA policy declaration; *(d)* there are no applicable standards, or applicable standards will not be violated but there is potential for significant environmental degradation that could be corrected by project modification or other feasible alternatives; or *(e)* proceeding with the proposed action would set a precedent for future actions that collectively could result in significant environmental impacts.

EU (environmentally unsatisfactory) The review has identified adverse environmental impacts that are of sufficient magnitude that the EPA believes the proposed action must not proceed as outlined. The basis for an "environmentally unsatisfactory" determination consists of identification of environmentally objectionable impacts as defined above and fulfillment of one or more of the following conditions: *(a)* the potential violation of or inconsistency with a national environmental standard is substantive and/or will occur on a long-term basis; *(b)* there are no applicable standards, but the severity, duration, or geographical scope of the impacts associated with the proposed action warrant special attention; or *(c)* the potential environmental impacts resulting from the proposed action are of national importance because of the threat to national environmental resources or policies.

2. Adequacy of the impact statement:

Category 1 (adequate) The draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2 (insufficient information) The draft EIS does not contain sufficient information to completely assess environmental impacts that should be avoided in order to fully protect the environment, or the reviewer has identified new reasonably available alternatives that are within the spectrum of those analyzed in the draft EIS and which could reduce the environmental impacts of the proposal. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3 (inadequate) The draft EIS does not adequately assess the potentially significant environmental impacts of the proposal, or the reviewer has identified new, reasonably available alternatives which are outside of the spectrum of those analyzed in the draft EIS and which should be analyzed in order to reduce the potentially significant environmental impacts. The identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. This rating indicates the EPA's belief that the draft EIS does not meet the purposes of the NEPA and/or the Clean Air Act Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or reworked draft EIS.

Table 49: Evaluation Form for EIS Review in The Netherlands (Scholten, 1997b)

		YES/NO
Does the Commission consider the EIS of sufficient quality for the decision making process?		
If not, on which of the following criteria does the Commission consider the EIS essentially lacking in substance? 1		
Operational criteria		
Criterion 1:	The quality of the description of the proposed activity and its environmental consequences	
Criterion 2:	The quality of the description of the alternative most favorable to the environment and its environmental consequences 2	
Criterion 3:	The quality of the description of other alternatives and their environmental consequences	
Criterion 4:	The quality of the comparison of alternatives 3	
Potential criteria		
Criterion 5:	The quality of the description of the goals and objectives of the proposed activity 4	
Criterion 6:	The quality of the information on gaps in knowledge and uncertainties in the environmental information	
Criterion 7:	(Only where applicable 5) The quality and usability for decision making of the EIS in light of the developments that have taken place since its publication	
	Any other criterion, i.e.	
Does the Commission present any recommendations for ongoing decision making? If yes, please highlight the most important ones.		

1 If applicable, present a short explanation in annex. 2 The description of this alternative is legally required in the Netherlands. 3 In this respect, quality includes both the extent to which subjectivity has been avoided and the clarity of the presentation: does the comparison enable decision makers and the public to come to an informed decision? 4 Meant here is the extent to which the defined goals and objectives enable to identify, develop and judge alternatives; objectives should not be defined in such a way that any realistic alternatives that could have environmental advantages are excluded beforehand. 5 i.e., in cases where during review it becomes evident that the project itself, or the conditions under which it will be operated, will be different from the description in the EIS.

described by Scholten (1997a) as part of a comprehensive comparative review of EIA practice which includes reference to methods used.

Specifically, the Dutch EIA Commission executes a three step EIS review (Scholten, 1997b):

Step 1 -- Strengths and deficiencies in the EIS/EIA report are listed on the basis of the specific guidelines and general criteria and checked against any experiences with reviews of available EISs/EIA reports on similar actions. Consideration is also given to any deficiencies and suggestions that are tabled in representations by the public and NGOs (nongovernmental organizations).

Step 2 -- The crucial shortcomings (if any) are specified and distinguished from the less important ones. This is done with the help of the operational criteria outlined in Table 49. Attention is also focused on those parts of the EIS/EIA report that are presented well and are in compliance with standards of good scientific practice.

Step 3 -- The review team recommends to the competent authority how and when any serious shortcomings should be remedied. For the shortcomings which are noted, four remedial options are available. (1) The shortcomings are so serious that they require immediate remedy in the form of a supplement to the EIS/EIA report. (2) The shortcomings can be rectified fairly easily by means of explanations and conditions attached to the decision. (3) The shortcomings cannot be remedied immediately -- either by adding additional information to the EIA or in the form of explanations and conditions attached to the decision -- because they require too much time and effort to collect. (4) The short-comings in the EIS/EIA report can be remedied immediately by the review team in its report.

In the United Kingdom (UK), there is no formal procedure for EIS review. However, the Institute of Environmental Assessment has reviewed over 250 EISs for 15 members. The Institute's review methodology adapts the checklist approach developed by Lee and Colley (1992). The adaptation applies a framework of criteria to make detailed comments on the merits or deficiencies of an EIS and to reach judgments as to the importance of particular aspects and issues. Review criteria focus on: comprehensiveness of information; adequacy of methodology; clarity and organization of information; transparency, objectivity, and impartiality; and compliance with regulations.

EISs are graded according to the completeness with which particular issues are addressed. Subsequently, an overall grade is assigned to the EIS as follows:

A - Excellent, no tasks left incomplete
B - Good, only minor omissions and inadequacies
C - Satisfactory despite omissions and inadequacies
D - Parts well attempted, but must as a whole be considered unsatisfactory because of omissions and/or inadequacies
E - Poor, significant omissions or inadequacies
F - Very poor, most tasks left incomplete

The final grade awarded to an EIS often will represent a subjective average of the grades awarded against the various component parts of the review criteria. However, on occasions, the overall grade may not reflect the average of the component grades. This will occur because important areas of the EIS are weighted differently. Specifically, these important areas are described in detail in Table 50 and comprise:

- a description of development, the environment and baseline conditions;
- identification and evaluation of key impacts;
- consideration of alternatives and mitigation; and
- communication of results.

The Institute of Environmental Assessment (IEA) has been criticized for the high expectations of EISs which its review criteria demand. However, an analysis of a sample of 167 reviews showed that 36.5% of EISs were graded A or B (Excellent/Good). This indicates that even with the limitations of cost and practicality, good practice EISs are readily achievable. Also, in many cases, the IEA's criticisms of EISs relate to transparent issues; for example, they are frequently applied when information which is omitted from EISs is available, easily obtainable, or is contained in another document. Minor changes in approach can therefore lead to significant improvements in the quality of EISs in the United Kingdom (Brown and Slater, 1997).

METHODS FOR AUDITING

Environmental auditing refers to the systematic, documented, periodic and objective review of facility operations and practices related to meeting environmental requirements (U.S. Environmental Protection Agency, 1986). The World Bank (1995a) has defined environmental audit as involving a methodological examination of environmental information about an organization, a facility, or a site to verify whether, or to what extent, they conform to specified audit criteria. Such auditing is a vital component in environmental management systems (EMSs) such as those addressed by the ISO (International Standards Organization) 14000 series, and particularly by ISO 14001 (Cascio, 1996; and Willig, 1995). The mandatory elements of EMSs are delineated in ISO 14001.

Specifically, three ISO standards address environmental auditing as follows (von Zharen, 1996):

ISO 14010 -- Guidelines for Environmental Auditing (General Principles of Environmental Auditing)

ISO 14011 -- Guidelines for Environmental Auditing (Audit Procedures -- Auditing of Environmental Management Systems)

ISO 14012 -- Guidelines for Environmental Auditing (Qualification Criteria for Environmental Auditors)

In addition to the increased emphasis on environmental auditing and EMSs in the United States, there is considerable interest in and implementation of such studies and concepts in developed countries in Europe and other parts of the world. Complete information on EMSs is considered beyond the scope of this chapter.

Table 50: Institute of Environmental Assessment -- Review Framework for EISs

1.0 DESCRIPTION OF THE DEVELOPMENT, THE LOCAL ENVIRONMENT, AND THE BASELINE CONDITIONS

1.1 Description of the development - The purpose and objectives of the development should be explained. The description of the development should include the physical characteristics, scale and design as well as quantities of material needed during construction and operation. The operating experience of the operator and the process, and examples of appropriate existing plant, should also be given.

1.2 Site description - The area of land affected by the development should be clearly shown on a map and the different land uses of this area clearly demarcated. The affected site should be defined broadly enough to include any potential effects occurring away from the construction site (e.g., dispersal of pollutants, traffic, changes in channel capacity of water courses as a result of increased surface runoff, etc.).

1.3 Residuals - The types and quantities of waste matter, energy and residual materials and the rate at which these will be produced should be estimated. The methods used to make these estimations should be clearly described, and the proposed methods of treatment for the waste and residual materials should be identified. Waste should be quantified wherever possible.

1.4 Baseline conditions - A description of the environment as it is currently and as it could be expected to develop if the project were not to proceed. Some baseline data can be gathered from existing data sources, but some will need gathering and the methods used to obtain the information should be clearly identified. Baseline data should be gathered in such a way that the importance of the particular area to be affected can be placed into the context of the region or surroundings and that the effect of the proposed changes can be predicted.

2.0 IDENTIFICATION AND EVALUATION OF KEY IMPACTS

2.1 Identification of impacts and method statement - The methodology used to define the project specification should be clearly outlined in a "method statement." This statement should include details of consultation for the preparation of the scoping report, discussions with expert bodies and the public, and reference to panels of experts, guidelines, checklists, matrices, and previous best practice examples of environmental assessments on similar projects (whichever are appropriate). Consideration should be given to impacts which may be positive or negative, cumulative, short or long term, permanent or temporary, direct or indirect. The logic used to identify the key impacts for investigation and for the rejection of others should be clearly explained. The impacts of the development on human beings, flora and fauna, soil, water, air, climate, landscape, material assets, cultural heritage, or their interaction, should be considered. The method statement should also describe the relationships between the promoter, the planning, engineering and design teams, and those responsible for the EIS.

Table 50 (continued):

2.2 Prediction of impact magnitude - The size of each impact should be determined as the predicted deviation from the baseline conditions, during the construction phase and during normal operating conditions and in the event of an accident when the proposed development involves materials that could be harmful to the environment (including people). The information and data used to estimate the magnitude of the main impacts should be clearly described and any gaps in the required data identified. The methods used to predict impact magnitude should be described and should be appropriate to the size and importance of the projected disturbance. Estimates of impacts should be recorded in measurable quantities with ranges and/or confidence limits as appropriate. Qualitative descriptions where necessary should be as fully defined as possible (e.g., "insignificant means not perceptible from more than 100m distance").

2.3 Assessment of impact significance - The significance of all those impacts which remain after mitigation should be assessed using the appropriate national and international quality standards where available. Where no such standards exist, the assumptions and value systems used to assess significance should be justified and the existence of opposing or contrary opinions acknowledged.

3.0 ALTERNATIVES AND MITIGATION

3.1 Alternatives - Alternative sites should have been considered where these are practicable and available to be developed. The main environmental advantages and disadvantages of these should be discussed in outline, and the reasons for the final choice given. Where available, alternative processes, designs and operating conditions should have been considered at an early stage of project planning and the environmental implications of these outlined.

3.2 Mitigation - All significant adverse impacts should be considered for mitigation and specific mitigation measures put forward where practicable. Mitigation methods considered should include modification of the project, compensation, and the provision of alternative facilities as well as pollution control. It should be clear to what extent the mitigation methods will be effective. Where the effectiveness is uncertain or depends on assumptions about operating procedures, climatic conditions, etc., data should be introduced to justify the acceptance of these assumptions.

3.3 Commitment to mitigation - Clear details of when and how the mitigation measures will be carried out should be given. When uncertainty over impact magnitude and/or effectiveness of mitigation over time exists, monitoring programs should be proposed to enable subsequent adjustment of mitigation measures as necessary.

4.0 COMMUNICATION OF RESULTS

4.1 Presentation - The report should be laid out clearly with the minimum amount of technical terms. An index, glossary, and full references should be given and the information presented so as to be comprehensible to the non-specialist.

Table 50 (continued):

4.2 Balance - The EIS should be an independent objective assessment of environmental impacts not a best case statement for the development. Negative impacts should be given equal prominence with positive impacts and adverse impacts should not be disguised by euphemisms or platitudes. Prominence and emphasis should be given to predict large negative or positive impacts.

4.3 Non-technical summary - There should be a non-technical summary outlining the main conclusions and how they were reached. The summary should be comprehensive, containing at least a brief description of the project and the environment, an account of the main mitigating measures to be undertaken by the developer, and a description of any remaining or residual impacts. A brief explanation of the methods by which these data were obtained and an indication of the confidence which can be placed in them should also be included.

The purposes for conducting an environmental audit can include one to all of the following (Newton, 1989): (1) to ensure regulatory compliance; (2) to define existing and potential liabilities; (3) to protect company officials; (4) to investigate an acquisition or merger; (5) to track compliance costs; (6) to transfer information among sites; (7) to provide for management accountability; (8) to provide information to insurance companies; and (9) for personnel training. Some of the positive results of an audit program include more cost-effective compliance with environmental regulations, reduced likelihood of fines and lawsuits, and a more positive public image. However, some potential negative aspects of an audit include (Newton, 1989): temporary disruptions of facility operations; increased potential for liability if recommendations are not followed; and provision of regulators with additional information.

Successful environmental audits do not occur by accident; rather, commitments and planning are necessary. For example, Newton (1989) identified the following nine key elements for a successful audit program: (1) top management support and commitment; (2) independent functioning of the program; (3) adequate team staffing and funding; (4) detailed program objectives; (5) outline of audit scope and resources; (6) a process to collect adequate information; (7) specific audit procedures; (8) a quality assurance program; and (9) management commitment to pursue recommendations.

Auditing in the context of the EIA process can include performance or regulatory audits (i.e., have stipulated conditions or mitigation measures included in EIA documentation been implemented, are they being utilized, and are they effective in minimizing undesirable impacts), and/or impact prediction audits. Comparative reviews of EIA products (i.e., EISs) prepared under the auspices of one agency or organization can be useful for EIA process improvement (World Bank, 1995a). Impact prediction audits are designed to identify and quantify environmental changes that occur as a consequence of a project. The objective of an audit of impact predictions is to assess the accuracy and utility of predictive techniques used in an impact study by comparing the actual consequences with the predicted environmental consequences of a project. Using this information should improve the accuracy of future impact predictions for similar projects (Canter, 1985; and Buckley, 1995).

Three key phases associated with an audit program include a preaudit questionnaire review, the conduction of the on-site visit, and the preparation of the audit report. The preaudit questionnaire should address an overview of the facility operations, all facility permits, all pertinent laws and regulations, and all pollution control equipment. It should be recognized that there is no common protocol in an environmental audit. For example, in contrast to three study phases, Figure 5 delineates five steps related to an on-site audit (Greeno, Hedstrom, and DiBerto, 1987). These steps represent a further complementary delineation of the three phases mentioned earlier. Also, professional groups such as the International Standards Organization and the American Society for Testing and Materials have developed or are developing more generic protocols which can be adapted to specific situations.

Guidelines for undertaking environmental monitoring and audit as part of a systematic approach to post-project analysis have been prepared for Environment Canada (Davies and Sadler, 1988). Their aim is to improve EIA methodology and process effectiveness by institutionalizing an adaptive (trial and learning) process of follow-up. A step-by-step approach to planning and implementing EIA audits is outlined using screening and scoping protocols to establish the monitoring and audit requirements at the onset; i.e., apply when uncertainty is relatively

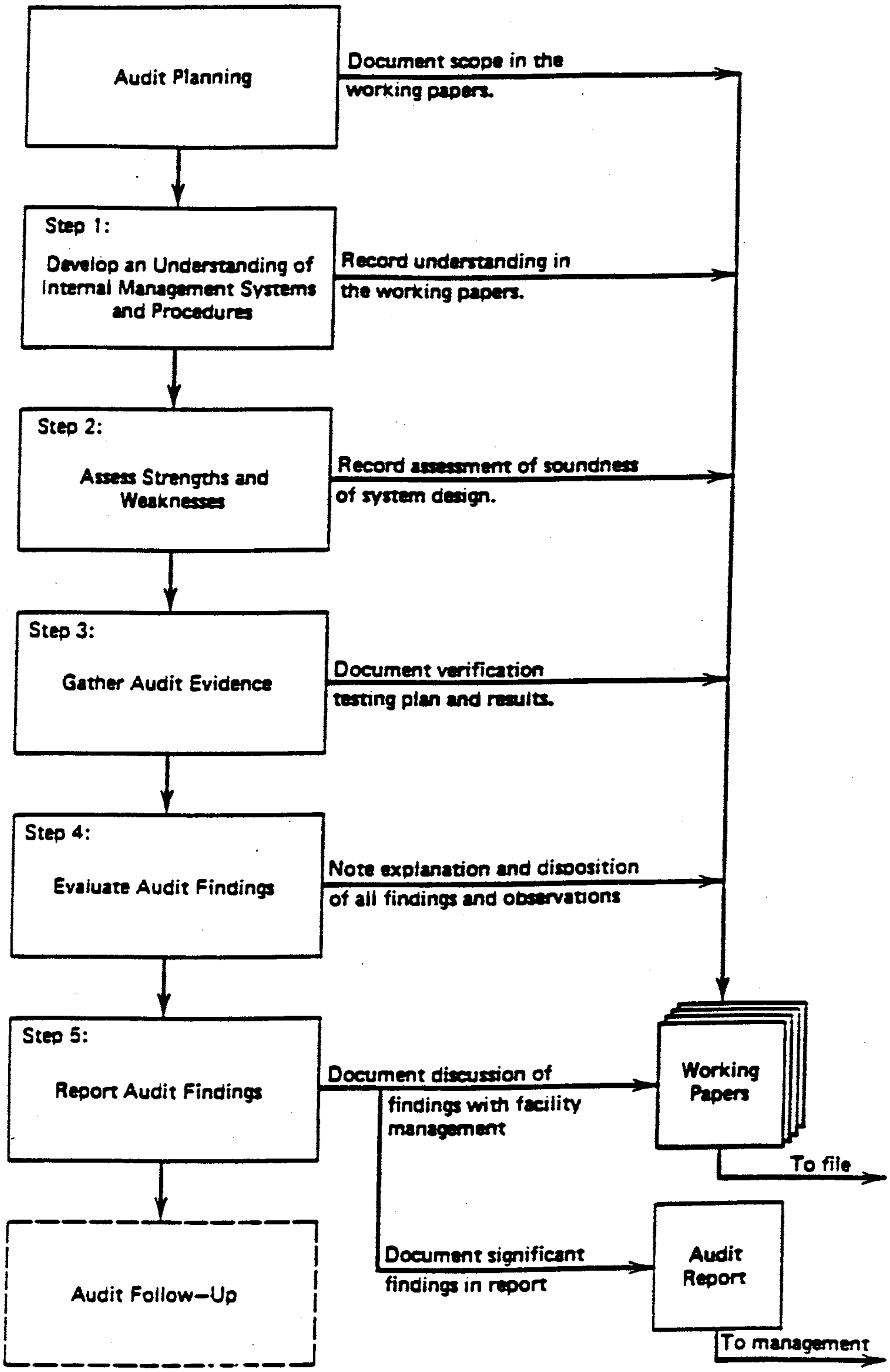

Figure 5: Basic Steps in the Typical Audit Process (Greeno, Hedstrom, and DiBerto, 1987)

high, and confidence levels in data and method reliability are relatively low. Under these conditions, an audit "trail" should be built into the EIA process via:

(1) baseline monitoring to establish natural variability, and understand cause-effect relationships (by using "reference" and "development" sites)

(2) formulating impact predictions as testable hypotheses of verifiable (quantified) estimates of expected change;

(3) effects monitoring to identify actual (versus "as predicted") impacts and to indicate the effectiveness of mitigation measures; and

(4) review and examination of the accuracy of prediction and success of mitigation, including reasons for variance.

Wilson (1995) suggested that there are three types of impact prediction audits: (1) a scientifically defined "ideal" audit; (2) a formal but "non-ideal" audit; or (3) an informal type of audit which involves feedback to specific impact studies on similar types of actions. The most feasible type of audit is the informal approach based on professional knowledge and judgment; which Wilson (1995) refers to as an "impacts-backwards method." This method has been applied to surface coal mines in Oklahoma and Texas by comparing observations of actual environmental effects to impact predictions, in order to reach qualitative judgments about whether the predictions foresaw what hindsight indicates has actually occurred. Impacts are documented in this method through professional networking, review of monitoring data, and simple field techniques.

Wilson (1995) noted that the most important lesson from the auditing case study was an appreciation that mitigation success is at the core of many predictions; thus audits should become a check on mitigation success. Therefore, there is a need for impact study documents to contain an expanded discussion of mitigation to allow for subsequent "mitigation tracking." A protocol for impact study-specific mitigation tracking could include the following (Wilson, 1995):

(1) Development of a "commitments list" to identify all mitigation proposals, and the organization responsible for each.

(2) Formal reporting requirements imposed on permitees to track and document mitigation success, using a standardized format.

(3) Some review of mitigation success as part of governmental permit renewal processes.

(4) Use of an inter-agency information network to improve coordination of mitigation tracking.

CHAPTER VIII

SELECTION OF METHODS FOR USAGE WITHIN A STUDY

Planning and management of impact studies will involve the consideration and selection of pertinent methods at several points in time. For example, the study manager, an appropriate interdisciplinary team, and/or individual specialists on the team may be involved in reviewing and recommending pertinent methods for different activities in the study; Table 51 summarizes potential methods which might be used for different study activities. Modifications in methods, or possible selection of replacement methods, may be necessary during the actual conduction of the study. While beyond the scope of this report, the study manager may utilize "team management methods" such as group meetings, the nominal group process, critical path methods, project evaluation and review techniques, and fiscal planning and control methods during the conduction of the study.

For some impact studies, the sponsoring agency (proponent) may specify the methods to be used. Depending upon the type of study, such methods may be dictated by proponent best practices or by statutory requirements. At the other extreme, and perhaps more typical of impact studies, the proponent does not specify any methods for usage. The presumption being that the professionals on the interdisciplinary team conducting the study will utilize appropriate methods depending upon the type of project, environmental setting, and study parameters such as time and funding. All impact studies require some methods selection, including those studies that have stipulations for the usage of particular methods to meet statutory requirements. For example, it may be necessary to select one or methods for impact identification related to a proposed coal-fired power plant, but then to utilize a specified air quality dispersion model for addressing the atmospheric dispersion of sulfur dioxide from the plant stacks.

Assume that selection of methods, either formally or informally, is a component of every impact study. The question then becomes what approaches might be used to accomplish such selections. Three such approaches are considered herein: (1) an approach based upon professional judgment only; (2) an approach based upon systematic but qualitative comparisons of different methods for usage for different purposes; and (3) an approach involving quantitative comparisons of different methods arrayed against a series of weighted decision criteria (factors).

USE OF PROFESSIONAL JUDGMENT APPROACH

Method selection based upon professional judgment is actually involved in all three approaches The distinction in this first approach is that methods are chosen based upon the professional knowledge and judgment of individuals on an interdisciplinary study team, or the collective judgment of the study team as a whole. Specific regard should be given to comparative features of available methods and their usage in the pertinent impact study. In this regard, specific decision criteria for comparing methods may not be delineated, with choices probably being related to the familiarity and possible previous usage of methods by individuals on the team. Note that professional judgment can relate to both substantive issues addressed by individual methods and their comparative ease of usage in terms of required data, time considerations, and budgetary limitations.

Table 51: Examples of Types of Methods Which Might be Used Within Various Study Activities

Study Activity*	Examples of Types of Methods Useful for Activity
PDN	Analogs Literature Reviews
PII	Literature Reviews Public Participation (for scoping)
IPI	Checklists Expert Opinion Literature Reviews Matrices Networks
DAE	Indices or Indicators Landscape Evaluation Monitoring (baseline) Overlay Mapping via GIS Photographs/Photomontages Trend Extrapolation
IP	Analogs Expert Systems Laboratory Testing and Scale Models Mass Balance Calculations Monitoring (field studies of receptors near analogs) Qualitative Modeling Quantitative Modeling Risk Assessment Scenario Building
IA	Expert Opinion Public Participation
IM	Analogs Literature Reviews
SPA	Decision-focused Checklists Environmental Cost-Benefit Analysis Public Participation
PWD	Matrices Photographs/Photomontages
EM	Monitoring (baseline) Monitoring (field studies of receptors near analogs)

*See Table 20 for definitions of coded activities.

USE OF QUALITATIVE COMPARISON APPROACH

Methods are also selected based on qualitative comparisons. These selections are typically made based on identifying decision criteria (or desirable attributes) and then comparing candidate methods, possibly on a relative basis, in conjunction with each of the listed criteria (or attributes). Several examples for this selection approach have been published, with the typical process involving:

(1) the identification of decision criteria (desirable attributes) for methods;

(2) the qualitative comparison of candidate methods relative to the desirable attributes; and

(3) the selection of the "best choice" for the situation based on the information in (2) coupled with professional judgment.

Four examples of desirable attributes (or decision criteria) will be cited; one is related to decision-focused checklists, one to methods in general, and the latter two to impact prediction methods. Multi-criteria decision-making methods, or decision-focused checklists, have been referred to as amalgamation methods by Hobbs (1985). Such amalgamation involves combining disparate impacts so that alternatives can be ranked. Hobbs (1985) suggested four criteria for consideration in choosing an amalgamation method: (1) the purpose to be served; (2) the ease of use (time, money, necessary computer resources, etc.); (3) the validity of the method; and (4) the anticipated results when compared to other methods.

Nichols and Hyman (1982) identified seven criteria for evaluating EIA methods in general. Table 52 summarizes these criteria. The first three reflect the complex attributes of real environmental responses to natural or man-induced changes. The remaining four represent the preferable attributes of a planning and decision-making process.

Based on an extensive review, decision factors related to the selection of impact prediction methods were enumerated by Environmental Resources, Ltd. (1982). Key decision factors expressed in the form of questions are included in Table 53 (after Environmental Resources, Ltd., 1982).

A second example of decision criteria for impact prediction methods includes eight criteria as shown in Table 54. These criteria include both practical and technical considerations. On the practical side, the method must first be credible, including: (1) substantive relevancy to the proposed action; (2) policy relevancy in terms of providing useful actionable information; (3) acceptability to affected publics; and (4) face validity to relevant experts or professionals. If the method is credible, additional desirable characteristics include how easily it can be used (applicability) and whether it can be used for different conditions and geographic areas (flexibility). Technical criteria include both accuracy and completeness. Methods should be able to provide results within acceptable error ranges, and they should provide a relatively comprehensive picture of impacts.

Impact prediction methods which could be compared relative to the questions in Tables 53 or 54 could be "off-the shelf" methods, or they could require modification to meet particular impact study needs. Depending upon the particular needs, it may be necessary to develop specific models or methods for impact prediction. The time and associated

Table 52: Criteria for Evaluating EIA Methodologies (Nichols and Hyman, 1982)

1. Assessment methods should recognize the probabilistic nature of effects. Environmental cause-effect chains are rarely deterministic because of many random factors and uncertain links between conditional human activities and states of nature.

2. Cumulative and indirect effects are important, although there are obviously limits on the extent to which they can be considered. Natural systems are highly interrelated, and a series of minor actions may have significant cumulative impact. Indirect effects may be cyclical due to positive or negative feedback.

3. A good methodology should reflect dynamic environmental effects through a capacity to distinguish between short-term and long-term effects. Impacts may vary over time in direction, magnitude, or rates of change. The larger system itself may be in ecological or social flux, and decisionmakers have time horizons of varying lengths.

4. Decision making necessarily encompasses multiple objectives (or multiple values). Assessment methods should include the diverse elements of environmental quality: maintenance of ecosystems and resource productivity; human health and safety; amenities and aesthetics; and historical and cultural resources. Environmental values can be divided into three types: social norms, functional values (environmental services, e.g., fisheries), and individual preferences. In addition, a good assessment method should recognize other societal objectives, such as economic efficiency, equity to individuals and regions, and social well-being.

5. Environmental assessment necessarily involves both facts and values. Values enter the process when deciding which effects to examine, whether an effect is good or bad, and how important it is relative to other effects. Methods should separate facts and values to the extent possible, and identify explicitly the source of values. Where the influence of values is obscure, the analysis itself may become a source of conflict. Under optimal conditions, results should be amenable to a sensitivity analysis where alternative value judgments are applied to a set of factors.

6. It is also important to consider whose values enter the analysis. Assessment techniques should encourage a participatory approach to incorporate the multiplicity of values provided by the public as well as by experts from varying disciplines and interest groups. Lack of participation by key actors can mitigate the usefulness of assessment results.

7. With all other things held constant, the best decision process is efficient in its requirements for time, money, and skilled labor. Increased complexity is justified only when there is a sufficient increase in the validity and decision-making utility of the analytical results.

Table 53: Questions Related to Evaluating and Selecting Impact Prediction Methods (after Environmental Resources, Ltd., 1982)

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(1) Can the method be used to produce the information needed? If not, can it be adapted to produce this information?

(2) Can the method be applied to the particular activity and environment under study (i.e., to the alternative activities and environments which must be compared)? Are the limitations of the method, and the assumptions made, applicable to the circumstances of the proposed alternatives and the affected environments?

(3) Are the data needed to use the method available? If not, can they be collected using the available resources of time, manpower, equipment, etc.?

(4) Are the resources available to use the method - computing time, laboratory work, field studies, expertise, etc.?

(5) Are the outputs from the method in a suitable form to serve as inputs into predictions of higher order effects if necessary?

(6) Can the outputs from the method be presented in a form which is understandable and useful for the decision maker and other users? What will be the costs of analyzing and interpreting the results for the end users?

(7) Can the method be satisfactorily explained to the non-specialist so that he/she can understand its use, and does it generate information in a form comprehensible to a broad range of people with different backgrounds?

(8) Does the method provide a sufficiently accurate or reliable prediction of the effect? What is the level of uncertainty associated with the prediction?

(9) If the method was repeated using the same data base would a second group obtain the same result as the first group?

Table 54: Criteria for Choosing Impact Prediction Methods

Criteria	Definition
I. Practicality	
1. Substantive relevancy	Appropriateness for the proposed action. Previous use to assess impacts of similar proposed actions is one indicator of relevancy.
2. Policy relevancy	Does the method provide information which can be useful, particularly with respect to avoiding or mitigating impacts? Methods would need to address actionable impact categories, be capable of producing timely predictions, etc.
3. Acceptability	Is the method acceptable to relevant publics likely to be impacted? Does it include the substantive areas of concern to local populations? These areas of concern can be determined by previous experience, public hearings, or survey techniques.
4. Face validity	Is the method credible in the professional research community or with others having experience in assessing similar types of impacts? This can be determined by the use of advisory groups or external review panels.
5. Applicability	Ease of using or implementing this method. Do the data exist; are analysis routines easy to use, etc.? Must be determined by professional judgment.
6. Flexibility	Can the method be used for different substantive impact areas, for different geographic areas, different environmental conditions, etc.?
II. Technical Quality	
7. Accuracy	Is the method likely to provide results within acceptable error ranges? Has it been subject to previous reliability and validity studies? Has it generated significant problems in previous uses?
8. Completeness	Does the method include a complete set of impacts? Can it be easily combined with other approaches to provide a comprehensive picture?

costs for modification or development should be considered in the selection process.

Finally, the following points related to selecting impact prediction methods using a qualitative comparison approach should be remembered (Environmental Resources, Ltd., 1982):

(1) The selection of appropriate methods for use in EIA is always a balance between the need for information and the availability of resources; to obtain a more accurate and complete description of an effect always requires the expenditure of more resources.

(2) The selection of methods for obtaining information about environmental effects involves: identifying methods which can provide the types of information needed; and examining whether they are applicable to the particular activity and environment in question, and with the resources available for the impact study.

(3) Many methods can be used at varying levels of sophistication. Their applicability in different circumstances and their resource requirements will vary accordingly, with a corresponding variation in the quality of information obtained.

(4) Where limited resources are available, decisions have to be made about information needs for different effects, and therefore about the allocation of these resources between the different effects.

(5) Each specialist will have his own "favorite" method for solving a problem, which is only natural for him/her to advocate. The overall impact study group (interdisciplinary team) needs to maintain a wider view of the needs and possibilities and thus advise the specialist accordingly.

(6) Occasionally a method specifically designed for the study area (but for some other purpose) is available for use, already calibrated and validated; if it can be adapted to serve the impact study needs it may provide an extensive predictive capacity with small use of resources.

(7) In certain cases only one method is available to predict a particular type of effect for a particular type of environment; information needs must then be conditioned to match the possible outputs from that method. But the problem should not be redefined solely to suit the method.

(8) Often there may be no one method which is suitable; the results of several may then be combined together to give the fullest possible picture of the environmental effect. Additional methods may also be used to test the results of a first method.

(9) The choice of methods is not immutable; adaption, evolution and shifting of approaches can be expected as an impact study proceeds and understanding is improved.

USE OF UNRANKED PAIRWISE COMPARISON APPROACH

The most comprehensive approach relative to selecting methods would involve utilizing a systematic comparison of methods relative to pre-selected decision criteria (factors), with consideration given to the relative importance of the decision criteria and to the comparative features of each method in conjunction with the stated criteria. In this regard, such approaches are analogous to multiple criteria decision making which has been used for comparison of alternatives in environmental impact studies. To illustrate the pragmatic nature of this approach for such decision making, the following steps can be identified:

(1) Specify the particular phase of the impact study for which a method should be selected, and then identify key decision factors or desirable attributes which should be considered in selecting the method.

(2) Give consideration to the relative importance of the decision factors and to the usage of importance weighting to indicate the differential importance of the decision factors in selecting the method.

(3) Compare each candidate method on a relative basis in association with each decision factor. The information related to each decision factor can be either qualitative or quantitative, with the resulting comparisons of the candidate methods being an approach which reduces the information to a common perspective or common scale.

(4) Develop a final decision matrix, using a mathematical approach, by multiplying the importance weight of each decision factor times the numerical score of each candidate method for the individual factor. When these are summed across the candidate method, the following selection score will result:

$$Score_j = \sum_{i=1}^{n} (FIC)_i \, (RCC)_{ij}$$

where

$Score_j$ = composite selection score for the jth candidate method

n = number of decision factors

$(FIC)_i$ = importance coefficient of the ith decision factor

$(RCC)_{ij}$ = relative choice coefficient of the ith decision factor for the jth candidate method

To illustrate this approach, an unranked pairwise comparison technique will be utilized to indicate how it could be applied in selecting a method for accomplishing a particular need within an impact study.

The first step in using the unranked pairwise comparison technique is to list the decision factors (criteria) and to assemble information on each considered method relative to each factor. Table 55 shows the results for this application. The decision factors in Table 55 can be prioritized based on their relative importance. This is called importance

Table 55: Example Information for Selecting an EIA Method

Decision Factor	Candidate EIA Methods			
	A	B	C	D (dummy)
Acceptability by EIA regulators	Acceptable	Not acceptable without modification	Some effort required to gain acceptability	Not acceptable
Data requirements for use of method	Moderate	Minimal	Moderate	Extensive
Uncertainty related to method	Some uncertainty	Some uncertainty	Minimal uncertainty	High uncertainty
Dummy	-	-	-	-

weighting; it consists of considering each decision factor relative to every other factor, and assigning to the one considered to be the most important of the pair a value of 1, and to the lesser important of the pair a value of 0. This unranked paired-comparison technique, which is shown in Table 56, does not mean that the factor assigned a 0 in each pair has no importance; it simply means that relative to the pair, the factor is least important. In addition to the basic decision factors, a dummy factor is included so as to preclude the net assignment of a value of 0 to any one basic factor in the process. The dummy factor is defined as the least important in every comparison. If two factors are considered to be of the same importance (one is not more important than the other), a value of 0.5 can be assigned to each factor in the pair.

Following assignment of the relative weights as shown in Table 56, this process is completed only after several iterations. This ensures that each factor is considered in a consistent manner to each other factor. Individual weight assignments are then summed, with the factor importance coefficient (FIC) being equal to the sum value for an individual factor divided by the sum for all factors. The total the FIC column should equal 1.00. The total of the sum column should equal to (N) (N-1)/2, where N is the number of factors included in the assignment of weights. In the example shown, four factors were included, hence the sum total should be 6.0. The assignment of importance weights can be done by an individual, or by a group of both technical and non-technical persons who are charged with the responsibility of identifying the most appropriate EIA method for a given need. The FIC column in Table 56 indicates that acceptability by EIA regulators is the most important followed by, in order, data requirements and uncertainty.

The next step in the decision process involves comparing each candidate method relative to each decision factor. Comparisons can be based on quantitative, qualitative, or relative information. Examples of qualitative information are included in Table 55. The systematic comparison of methods involves their prioritization relative to each decision factor. Table 57 illustrates the comparison of the methods relative to the first decision factor. Each method is compared to every other method through the use of a paired comparison approach. The basic decision for each pair of methods is to decide which one is best relative to that decision factor. For the method considered to be the best a value of 1 is assigned; to the method considered to be the least desirable of the pair a 0 is assigned. Note that a dummy method is included in Table 57 to preclude the net assignment of a value of zero to any basic method relative to the decision factor. If two methods are the same relative to their desirability in terms of a decision factor, a value of 0.5 can be assigned to each method. Following assignment of desirability numbers to each method, the individual assignments are summed, with the relative choice coefficient (RCC) being equal to the sum value for an individual method divided by the sum for all the methods. The total for the RCC column should equal to 1.00. The total of the sum column should equal to (M) (M-1)/2, where M is the number of methods included in the analysis. In this example four methods were included, hence the sum total should be equal to 6.0. Tables 58 and 59 display the RCC values for the other decision factors in the illustration.

The final step in the use of the unranked paired-comparison decision-making technique involves the development of a decision matrix. This matrix is derived by multiplying each FIC by each RCC. Summation of the products for each alternative will yield numerical scores which can be used in the final selection. Table 60 displays the decision matrix based on the illustration. Method A would represent the optimal choice in this instance. One numerical check in the decision matrix is that the summation of all products for all methods should equal to 1.0.

Table 56: Importance Weighting of Decision Factors

Decision Factor	Relative Importance Assignments	Sum	FIC
Acceptability by EIA regulators	1 1 1	3	0.50
Data requirements for use of method	0 1 1	2	0.33
Uncertainty related to method	0 0 1	1	0.17
Dummy	0 0 0	0	0
Totals		6.0	1.00

Table 57: Relative Choice Coefficients of Candidate Methods for "Acceptability by EIA Regulators" Factor

Candidate Method	Choice Assignments	Sum	RCC
A	1 1 1	3	0.50
B	0 0 1	1	0.17
C	0 1 1	2	0.33
D (dummy)	0 0 0	0	0
Totals		6.0	1.00

Table 58: Relative Choice Coefficients of Candidate Methods for "Data Requirements for Use of Method" Factor

Candidate Method	Choice Assignments	Sum	RCC
A	0 0.5 1	1.5	0.25
B	1 1 1	3.0	0.50
C	0.5 0 1	1.5	0.25
D (dummy)	0 0 0	0	0
Totals		6.0	1.00

Table 59: Relative Choice Coefficients of Candidate Methods for "Uncertainty Related to Method" Factor

Candidate Method	Choice Assignments						Sum	RCC
A	0.5	0	1				1.5	0.25
B	0.5			0	1		1.5	0.25
C		1		1		1	3.0	0.50
D (dummy)			0		0	0	0	0
Totals							6.0	1.00

Table 60: Decision Matrix for Selection of Method

Decision Factor	Method (FIC x RCC)			
	A	B	C	D (dummy)
Acceptability by EIA regulators	0.250	0.085	0.165	0
Data requirements for use of method	0.083	0.167	0.083	0
Uncertainty related to method	0.042	0.042	0.085	0
Dummy	0	0	0	0
SUM =	0.375	0.294	0.333	0

The unranked paired-comparison multiple criteria decision-making technique is illustrative of a number of approaches which can be used to systematically compare EIA methods and select a "best choice." The primary advantage of this technique is that it provides a systematic framework for making decisions. Most decisions are made, and will continue to be made, without using structured approaches; however, the use of these approaches assist decision-makers to make better choices considering all relevant selection factors. One note of caution is that careful consideration should be given to the interpretation of the FIC and RCC numerical values. These numerical values represent both quantitative information and the application of professional judgment.

In summary, the advantages of using a decision methodology in EIA methods selection include:

(1) it forces a systematic approach;

(2) it provides a rational framework;

(3) it can be used to document the selection process;

(4) it provides an "audit" trail for the selection; and

(5) it can be used to demonstrate trade-offs among the candidate methods.

CHAPTER IX

RESEARCH NEEDS RELATED TO EIA METHODS

No comprehensive programs exist for research on EIA methods. This reflects the fact that the EIA systems of many countries are primarily focused on procedures and implementation of specific guidelines, with minimal attention given to research. In the United States there is no single governmental agency that has a mission to conduct research related to the EIA process. While considerable research has been undertaken on specific impact prediction techniques and other phases of the EIA process (e.g., public participation and environmental mediation), it has been ad hoc and uncoordinated. Similar conditions apply in other countries, although the Canadian Environmental Assessment Research Council (1984-1992) had a mission to conduct research on the EIA process.

A current effort is underway to identify research needs for both EIA and SEA within the European Union (Colombo, Haq, and Melaki, 1997). Research topics have been identified via a literature survey and targeted questionnaire completed by 58 EIA/SEA experts. Methods-related priority research areas which have been proposed include: (1) environmental indicators for EIA; (2) prediction of impacts in EIA; (3) monitoring in EIA; (4) public participation in EIA; (5) integration of EIA and socio-economic appraisal in the overall appraisal of the project; (6) methods to predict the impacts of PPPs (SEA); and (7) integration of SEA and socio-economic appraisal in the overall appraisal of PPPs. Actual research efforts on these areas await initiation. As a final example, it is noted that South Africa has recently initiated a modest research effort on several facets of EIA/SEA (Weaver, 1996).

Despite the current efforts, the lack of historical emphasis in EIA research indicates a need for systematic delineation of research topics and factors for their prioritization. Five topical areas of need will be briefly described: (1) methods for emerging issues; (2) use of emerging technical tools; (3) adaptation of existing methods; (4) integration of information within the synthesis phase of the EIA process; and (5) necessary training for practitioners. These topical areas should not be considered as a comprehensive representation of research needs on EIA methods; rather, they are indicative of research which would strengthen EIA practice.

Numerous emerging issues would be facilitated by research on appropriate methods. Examples of such issues include: (1) prioritization of the results of the scoping process; (2) planning and conduction of cumulative impact assessments; (3) consideration of transboundary impacts; (4) conduction of strategic environmental assessments on broader plans, programs and policies; (5) integration of methods focused on the biophysical environment with those that address socioeconomic impacts; (6) use of risk assessment; and (7) recognition and documentation of uncertainty within the EIA process. There are many other emerging issues that could be enumerated and incorporated into an overall research strategy.

A second topical area for research involves the incorporation of new tools for information aggregation and decision making into the overall EIA process. Geographic information systems (GIS) have particular usefulness for larger scale projects and cases in which retrospective analysis can be useful to identify how environmental conditions have changed over time, with this information then being used to forecast further anticipated changes.

Numerous decision tools have been identified and utilized already in the EIA process. There continues to be interest in new tools that might remove some of the concerns related to placing values on different environmental resources or impacts. As noted earlier, the AHP is a tool which has been utilized in decision making in many fields, and its systematic exploration regarding potential usefulness in the EIA process would be appropriate.

Expert systems are a final example of a new tool being developed in numerous fields, including those related to environmental management and engineering. Several efforts are currently underway to develop an expert system for the EIA process. Particularly useful would be modules for addressing the impacts of either certain types of projects, or the impacts of a broad range of projects on particular environmental media or resources. These and other expert systems should be based upon the collective professional knowledge and judgment of experts in the topical field; hence, their development would require research that would entail considerable expenditures to develop appropriate heuristics.

Recognizing that an adequate number of types of methods exist; a primary research need is related to a better understanding of the fundamentals of such methods and how to adapt them for specific projects in unique locations. Accordingly, research could be conducted on the fundamental principles related to methods, and how these principles can be applied to a broad range of project types or categories of impacts. The adaptation of existing methods would, of necessity, need to be based upon the review of case studies and the documentation of lessons learned.

As described earlier, the EIA process can be viewed as consisting of an analysis phase and a synthesis phase. The analysis phase may involve the usage of a number of types of methods as shown earlier in Table 1; this phase can be seen as breaking the proposed action into appropriate impacts on the physical-chemical, biological, cultural, and socio-economic components of the environment. The synthesis phase should involve the aggregation (integration) of information from the various findings of the analysis phase. Accordingly, the synthesis phase should involve the integration of information from a variety of EIA methods; for example, from matrices, quality modeling, and risk assessment, coupled with expert opinion (professional judgment). In addition, synthesis involves the integrated consideration of impacts on the above-mentioned environmental components. Research is needed to develop effective methods for integration within the synthesis phase. One difficulty is that synthesis, of necessity, involves both facts and values (or science and policy), and EIA specialists and the general public. Decision-focused checklists have been used in the synthesis phase; however, their usage may be controversial, and more effective decision analysis methods appear to be needed for usage in the EIA process.

A final topical theme relates to training in the use and application of EIA methods. EIA training modules should be developed based on current knowledge relative to methods; and include specific illustrations and case studies to demonstrate the application of methods. Several efforts related to training modules or manuals have been conducted, including those at the Institute of Environmental Assessment, the University of Manchester, the University of Aberdeen, and the University of Wales in the United Kingdom. Such efforts of necessity have typically been limited in terms of scope or application and funding support; and, hence, a less-than-comprehensive approach has resulted. An EIA Training Resource Manual has been developed by the United Nations Environment Programme and the

Environment Protection Agency in Australia; this Manual incorporates the results of the effectiveness study (United Nations Environment Programme, 1996). This is new initiative for training for wide application in developing countries with support funding made available by the Netherlands Ministry of Foreign Affairs, and also an important vehicle for undertaking and incorporating research in EIA training. Needs and requirements for advanced training modules in EIA methods have also been identified by the authors of this report; however, these modules remain to be developed.

Few comprehensive research programs related to EIA practice and methods specifically can be identified. Accordingly, any completed research has tended to be reflective of the research interests and specific needs of a funding agency. That being the case, it is instructive to identify factors which could be used to prioritize research needs from an international perspective. Examples of such factors (questions) include:

(1) Will the resultant method be broad or limited in applicability relative to either types of projects or environmental impacts/affected resources?

(2) Is it possible to conduct field tests of the method and make appropriate modifications prior to its final dissemination?

(3) What are the budgetary requirements for the conduction of the research and can potential sponsors be identified?

Many additional factors could be enumerated relative to research on EIA methods. However, it is considered beyond the scope of this report to thoroughly address such factors given the absence of a clearly defined set of research needs or funding mechanisms. Possibly, this is a challenge for IAIA.

CHAPTER X

SUMMARY

A potentially confusing aspect of a review of EIA methods is related to the meaning of the term. The term "methods" is variously utilized, often interchangeably, but in some instances such terms are used to delineate distinctions. Examples of utilized terms include "methodology," "technique," "tool," and "prediction or forecasting technique or model." The EIA practitioner should recognize that a variety of terms may be used to describe the plethora of methods used in the EIA process. As the field matures, it is possible that a typology of terms will be developed to describe the variety of available methods.

Multiple types of methods are useful for one or more activities in EIA studies; no single method meets all study needs. Several types of methods are typically used in a given impact study. Simple interaction matrices, networks, and simple or questionnaire checklists can be very useful in identifying impacts at the beginning of the EIA process; these types of methods are also useful for summarizing the study results. Numerous specific impact prediction techniques are or can be applied, depending upon the topical issue being addressed and the type of project and location. Such prediction techniques are typically identified by the discipline-based professionals associated with a given impact study. They range from simple qualitative approaches to the application of environmental indices and quantitative mathematical models. Finally, decision-focused checklists or multiattribute decision methods can provide a useful basis for evaluating alternatives via a tradeoff analysis. Many other approaches also can be used to systematically consider a series of decision factors and the pros and cons of various alternatives relative to each decision factor. User friendly computerization of such decision methodologies is a current trend.

A total of 22 types of methods have been described herein for project-level studies; their application, along with several other policy-related methods, are also addressed with reference to cumulative impact assessment and strategic environmental assessment. The most-used types of methods tend to be simpler ones, including analogs, checklists, expert opinion (professional judgment), mass balance calculations, and matrices. Emerging types of methods include geographical information systems, expert systems, risk assessment, and economic valuation of environmental impacts. Irrespective of the methods used, uncertainty exists in various facets of the EIA process; such uncertainty should be described in impact study documentation.

EIA methods may not have uniform applicability in all countries. For example, developing countries may not have separate EIA legislation nor procedural frameworks (Ebisemiju, 1993). There may also be limited in-country environmental baseline data, quality standards, and natural resource protection programs (Ahmad and Sammy, 1985). Further, capacity-building related to professional careers in EIA and environmental management may not have received historical attention. Accordingly, simpler methods such as those mentioned above would have greatest applicability in developing countries.

Integration of results from the usage of a variety of methods is a key consideration in planning and conducting an efficient and effective impact study. Examples of numerous linkages between the outputs of methods applications can be noted:

(1) converting verbal information on impact issues of concern received during the scoping activity into a display based on a simple interaction matrix;

(2) assigning an appropriate impact rating to a calculated ambient air quality concentration based on a Gaussian dispersion model, with the rating to be used in a summary impact matrix;

(3) integrating qualitative ecological risk information resulting from a risk assessment with the results of habitat index methods based on habitat quality and quantity (for wildlife as a whole or for individual species);

(4) relating anticipated human population increases in a geographical study area (as determined by a population projection model) to potential changes in quality-of-life (QOL) based on a QOL index;

(5) matching generic mitigation measures as identified via a literature review to the specific impacts and mitigation needs of a proposed project;

(6) discerning relationships between technical impact information and "value judgments" associated with interpreting such information; and

(7) aggregation of impact information on several environmental factors or resources into a composite "picture" of the key impacts of concern relative to the proposed action.

The results of methods usage can be extended beyond the EIA process and into environmental management (and vice versa). Specific examples include the use of mass balances of water pollutant emissions for discharge trading, or air pollutant emissions for allowance or emissions trading. Such trading programs are already used in support of environmental management, and relevant aspects are expected to be incorporated within the EIA process. Another example is an outgrowth of the Habitat Evaluation Procedure (HEP) used by the U.S. Fish and Wildlife Service. Quantified impacts resulting from a HEP analysis are used as the basis for mitigation banking to offset adverse biological impacts of proposed actions. Mitigation banking efforts represent an emerging sustainability-based EIA (Sadler, 1996). HEP analysis also can be integrated with cost-effectiveness analysis to economically justify mitigation measures.

A range of specific research on EIA methods is needed; however, it must be recognized that no single country, institution, or agency has such a research program. Examples of topical areas in need of research include: (1) methods for emerging issues such as cumulative impact assessment and strategic environmental assessment; (2) use of emerging technical tools such as GIS and expert systems; (3) adaptation of existing methods; (4) integration of information within the synthesis phase of the EIA process; and (5) necessary training for practitioners. These topical areas are only indicative of research which would strengthen EIA practice.

The absence of an integrated research program on EIA would suggest that a professional organization, such as the IAIA, could provide leadership in the planning and development of a comprehensive program. Research needs could be identified through the membership of IAIA, and prioritization of these needs could also be facilitated through the membership or a subset of individuals with particular interests in the topical theme. Further, IAIA could facilitate the integrated consideration of research funding via contacts with various in-country and international organizations that could provide some research monies. In light of the EIA research situation in most countries, and as illustrated by the absence of specific in-country research organizations, the approach involving IAIA may be the only feasible option for facilitating necessary research on EIA methods.

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