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Socioeconomic Environmental Studies Series

A Review of Environmental Impact Assessment Methodologies

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A REVIEW OF ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGIES

by

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FOREWORD

The wide spread use of environmental impact analysis as a means of making Federal agency decisions responsive to environmental concerns was initiated by the passage of the National Environmental Policy Act of 1969 (NEPA). The Act required that Federal Agencies prepare statements assessing the environmental impact of their major actions which significantly affect the quality of the human environment. In subsequent years Federal agencies developed procedures for the preparation of environmental impact statements, often requiring similar analysis and statements from local governments and the private sector as a requirement for the award of a Federal permit or grant. The Council on Environmental Quality recently developed guidelines to define uniform procedures and approaches in the preparation of impact statements. While these guidelines specify what is desired in Federal impact statements, technical approaches to meeting these objectives are not always available and universally acceptable.

Among the several obstacles to the meaningful review of environmental impacts of proposed major Federal actions has been the general lack of adequate methodological tools. Under the pressures of an immediate backlog of projects already "in the pipeline" and a gradually unfolding judicial interpretation of the law, it is not surprising that agencies have, to date, paid far greater attention to procedural rather than content aspects of environmental impact statements. Recently, attention has begun to shift to the quality of impact statements as decision input and public information documents. Similarly, the proliferation of impact analysis methodological tools has been a recent phenomenon.

As part of a series of socioeconomic environmental studies, the Environmental Protection Agency, Office of Research and Development, is conducting research designed to

- Improve the technical quality of environmental impact analyses in areas of agency responsibility
- Improve the ability of the agency to provide substantive technical review of environmental impact statements prepared by other agencies, and

- Improve the effectiveness of the use of environmental impact analyses in influencing decision-making at all government levels.

This report reviews 17 currently available methodological approaches to impact analysis to highlight their strengths, weaknesses, and range of applicability. In assembling this review, only content-oriented methodological tools, as distinct from procedure-oriented guidelines for impact statement preparation produced by individual Federal agencies and the Council on Environmental Quality, have been included.

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ABSTRACT

Seventeen tools or methodologies designed for or applicable to the preparation of environmental impact statements are reviewed to identify their strengths, weaknesses, and potential range of use. Specific criteria are suggested for evaluating the adequacy of an impact assessment methodology in terms of:

- Impact Identification
- Impact Measurement
- Impact Interpretation
- Impact Communication
- Resource Requirements
- Replicability
- Flexibility.

The reviews presented serve as an introduction to the range of tools available and demonstrate that no single approach to impact assessment is superior in all circumstances.

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A REVIEW OF ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGIES

Environmental impact analysis, as required by the National Environmental Policy Act of 1969 (NEPA), is more art than science. There are no universally applicable procedures for conducting an adequate analysis. There are, however, a wide variety of assessment tools and even comprehensive methodologies that may make preparation of an environmental statement a less formidable and more meaningful task. This report describes and critically analyzes 17 of these tools and offers suggestions on choosing those tools or methodologies which may apply to the specifics of a particular environmental assessment situation.

In only a few cases are the tools discussed full-blown methodologies developed specifically for impact statement preparation. More commonly, they are more limited ideas borrowed from other fields with potential application to NEPA environmental assessments. None of these tools has been widely applied as yet in actual impact statements; indeed, many have never been so used.

This discussion is not intended as a step-by-step "cookbook" to the use of these tools; very rarely would any of them be directly applicable to any specific situation without modification. Instead, key ideas that one may find useful are discussed and the tools are described in sufficient detail to help the reader identify those which he or she might wish to examine more fully.

Choosing a Methodology

There is no single "best" methodology for environmental impact assessment. Characteristics of a methodology such as types of impacts or projects covered and resources required may be virtues in one instance, vices in another. Only the user can determine which tools may best fit a specific task. In selecting the most appropriate tools the following key considerations may be useful:

1. Use. Is the analysis primarily a decision or an information document? (A decison document is vital to determining the best course of action, an information document functions primarily to reveal the implications of a single, clearly best choice.) A decision document analysis will generally require greater emphasis on the identification of key issues, on quantification, and on direct comparison of alternatives. An information document requires a more comprehensive analysis concentrating on interpreting the significance of a broader spectrum of possible impacts.

2. Alternatives. Are alternatives fundamentally or incrementally different? If differences are fundamental, such as preventing flood damage by levee construction as opposed to flood plain zoning, for example, then impact significance can better be measured against some absolute standard than by direct comparison of alternatives since impacts will differ in kind as well as size. Fundamentally and incrementally different alternative sets require different levels of analysis to discriminate between alternatives, in that incrementally different alternatives require a greater degree of quantification.

3. Public Involvement. Does the anticipated role of the public in the analysis involve substantive preparation, token review, or vital review? The first two roles allow use of more complex techniques such as computer or statistical analysis that might be difficult to explain to a previously uninvolved but highly concerned public. A substantive preparation role will also allow a greater degree of quantification or weighting of impact significance through the direct incorporation of public values.

4. Resources. How much time, skill, money, data, and computer facilities are available? Generally, more quantitative analyses require more of everything.

5. Familiarity. How familiar is the analyst with both the type of action contemplated and the physical site? Greater familiarity will improve the validity of a more subjective analysis of impact significance.

6. Issue Significance. How big is the issue in terms of controversy and scope? All other things being equal, the bigger the issue the greater the need for explicitness, quantification, and identification of key issues and the less appropriate become arbitrary significance weights or specific formulas for trading off one type of impact (e.g., environmental) against another type (e.g., economic).

7. Administrative Constraints. Are choices limited by agency procedural or format requirements? Specific agency policy or guidelines may rule out some tools by specifying the range of impacts to be addressed, the need for analysing trade-offs, or the time frame of analysis.

Categorizing Methodologies

The various methodologies examined can be divided into five types, based on the way impacts are identified:

(1) Ad hoc: These methodologies provide minimal guidance to impact assessment beyond suggesting broad areas of possible impacts (e.g., impacts on flora and fauna, impacts on lakes, forests, etc), rather than defining specific parameters to be investigated.

(2) Overlays: These methodologies rely on a set of maps of environmental characteristics (physical, social, ecological, aesthetic) for a project area. These maps are overlaid to produce a composite characterization of the regional environment. Impacts are identified by noting the impacted environmental characteristics lying within the project boundaries.

(3) Checklists: These methodologies present a specific list of environmental parameters to be investigated for possible impacts but do not require the establishment of direct cause-effect links to project activities. They may or may not include guidelines on how parameter data are to be measured and interpreted

(4) Matrices: These methodologies incorporate a list of project activities in addition to a checklist of potentially impacted environmental characteristics. These two lists are related in a matrix which identifies cause-effect relationships between specific activities and impacts. Matrix methodologies may specify which actions impact which environmental characteristics or may simply list the range of possible actions and characteristics in an open matrix to be completed by the analyst.

(5) Networks: These methodologies work from a list of project activities to establish cause-condition-effect networks. They are an attempt to recognize that a series of impacts may be triggered by a project action. These approaches generally define a set of possible networks and allow the user to identify impacts by selecting and tracing out the appropriate project actions.

Review Criteria

To serve the purposes of the National Environmental Policy Act of 1969 (NEPA), an environmental impact assessment must effectively deal with four key problems:

- Impact identification
- Impact measurement
- Impact interpretation
- Impact communication to information users.

Based upon experience with impact assessments to date, a set of 20 criteria for methodology evaluation can be defined covering these four key problems. These are:

- Impact Identification
  1. Comprehensiveness. An impact methodology should address a full range of impacts including: ecological, physical-chemical pollution, social-cultural, aesthetic, resource supplies, induced growth, induced population or wealth redistributions, and induced energy or land use patterns.
  2. Specificity. A methodology should identify specific parameters (subcategories of impact types) to be examined.
  3. Isolate Project Impacts. A methodology should require and suggest methods for identifying project impacts as distinct from future environmental changes produced by other causes.
  4. Timing and Duration. A methodology should require and suggest methods for identifying the timing (construction phase vs. short-term operation vs. long-term operation phase) and the duration of impacts.
  5. Data Sources. A methodology should require identification of the sources of data used to identify impacts.(Data sources should also be listed for impact measurement and interpretation.)
- Impact Measurement
  6. Explicit Indicators. A methodology should suggest specific measurable indicators to be used to quantify impacts on parameters.
  7. Magnitude. A methodology should require and provide for the measurement of impact magnitude as distinct from impact significance.
  8. Objectivity. A methodology should emphasize objective rather than subjective impact measurements.

- Impact Interpretation

  9. Significance. A methodology should require explicit assessment of the significance of measured impacts on a local, regional, and national scale.
  10. Explicit Criteria. A methodology should require that the criteria and assumptions employed to determine impact significance be stated.
  11. Uncertainty. A methodology should require an assessment of the uncertainty or degree of confidence in impact projections made.
  12. Risk. A methodology should require identification of any impacts of low probability but high potential damage or loss.
  13. Alternatives Comparison. A methodology should provide a specific method for the comparison of alternatives, including the no-project alternative.
  14. Aggregation. A methodology may provide a mechanism for aggregating impacts into a net total or composite estimate. If aggregation is provided for, specific weighting criteria or processes to be used should be identified. The appropriate degree of aggregation is a hotly debated issue on which no judgment has been made in this review.
  15. Public Involvement. A methodology should require and suggest a mechanism for public involvement in the interpretation of impact significance.

- Impact Communication

  16. Affected Parties. A methodology should require and suggest a mechanism for linking impacts to the specific affected geographical or social groups.
  17. Setting Description. A methodology should require a description of the project setting to aid statement users in developing an adequate overall perspective.

18. Summary Format. A methodology should provide a format for presenting in summary form, the results of the analysis.
19. Key Issues. A methodology should provide a format for highlighting key issues and impacts identified in the analysis.
20. NEPA Compliance. A methodology should provide guidelines for summarizing results in terms of the specific points required by NEPA and subsequent CEQ guidelines.

In addition to the above "content" criteria, methodological tools should be evaluated in terms of their resource requirements, replicability, and flexibility. The following considerations, used in arriving at the generalized ratings for these characteristics (shown in Table 1), may be useful in considering the appropriateness of tools. Important specific requirements and limitations are discussed for each tool reviewed in the methodology descriptions below.

- Resource Requirements
  1. Data Requirements. Does the methodology require data that is presently available at low retrieval costs?
  2. Manpower Requirements. What special skills are required?
  3. Time. How much time is required to learn to use and/or actually apply the methodology?
  4. Costs. How do costs of using a methodology compare to costs using other tools?
  5. Technologies. Are any specific technologies (e.g., computerization) required to use a methodology?
- Replicability
  1. Ambiguity. What is the relative degree of ambiguity in the methodology?

TABLE 1. SUMMARY OF METHODOLOGY EVALUATIONS

	Type[1]	Comprehensiveness	Specificity	Isolate Project Impacts	Timing and Duration	Data Sources	Explicit Indicators	Magnitude	Objectivity	Significance	Explicit Criteria	Uncertainty	Risk	Alternatives Comparison	Aggregation	Public Involvement	Affected Parties	Setting Description	Summary Format	Key Issues	NEPA Compliance	Resource Requirements	Replicability	Flexibility
1. Adkins	C	◐[2]	●	○	○	○	○	○	○	○	○	○	○	●	●	○	○	○	●	○	○	●	○	●
2. Dee (1972)	C	◐	●	●	●	○	●	●	●	◐	●	○	○	●	●	○	○	◐	●	●	◐	○	●	◐
3. Dee (1973)	C-M	◐	●	●	●	◐	●	●	◐	○	●	○	○	●	●	◐	◐	●	●	●	●	○	●	○
4. Georgia	C	◐	●	◐	●	●	●	●	●	◐	●	●	○	◐	●	○	○	○	◐	○	○	○	◐	◐
5. Krauskopf	O	◐	●	○	○	○	●	●	◐	○	○	○	○	●	◐	○	○	○	●	●	○	○	◐	○
6. Leopold	M	◐	●	○	◐	○	○	●	○	◐	◐	○	○	●	–	○	○	●	●	●	◐	●	○	●
7. Little	C	●	●	○	○	○	◐	●	◐	◐	○	○	○	○	◐	◐	○	●	○	●	○	◐	◐	◐
8. McHarg	O	◐	●	○	○	○	◐	○	◐	○	◐	○	○	●	●	○	○	●	●	◐	○	◐	◐	○
9. Moore	M	◐	●	○	◐	○	●	●	○	◐	○	○	○	●	–	○	◐	○	●	◐	○	●	○	●
10. New York	M	◐	●	●	○	○	○	◐	○	◐	○	○	○	○	–	○	○	●	◐	◐	◐	●	○	◐
11. Smith	C	◐	●	○	○	○	◐	◐	◐	○	○	●	○	●	◐	○	○	○	●	○	○	○	○	◐
12. Sorensen	N	●	○	○	◐	◐	○	○	○	○	◐	◐	○	○	–	○	○	○	○	○	○	◐	◐	○
13. Stover	C	●	●	●	●	○	◐	●	◐	◐	○	◐	○	●	●	○	◐	●	●	○	◐	○	○	●
14. Task Force	C	◐	○	●	●	○	◐	●	◐	◐	○	○	○	●	–	◐	○	●	●	◐	◐	●	○	●
15. Tulsa	C	◐	●	◐	○	○	◐	◐	○	◐	◐	◐	○	●	●	○	○	○	●	○	○	●	◐	◐
16. Walton	C	◐	●	○	○	○	◐	●	◐	○	◐	○	○	●	◐	●	◐	○	●	◐	○	○	○	◐
17. WSCC	A	◐	○	○	○	○	◐	○	○	○	○	○	○	○	–	◐	○	◐	○	○	○	●	○	○

[1]Key to types: A = ad hoc
O = overlay
C = checklist
M = matrix
N = network

[2]Key to evaluation symbols:
● = substantial compliance, low resource needs, or few replicability-flexibility limitations
◐ = partial compliance, moderate resource needs, or moderate limitations
○ = no or minimal compliance, high resource needs, or major limitations
– = aggregation not attempted.

2. Analyst Bias. To what degree will different impact analysts using the methodology tend to produce widely different results?

- Flexibility
  1. Scale Flexibility. How applicable is the methodology to projects of widely different scale?
  2. Range. For how broad a range of project or impact types is the methodology useful in its present form?
  3. Adaptability. How readily can the methodology be modified to fit project situations other than those for which it was designed?

Methodologies were rated for their degree of compliance with the 20 content criteria, their level of resource requirements, and their replicability-flexibility limitations as follows:

- ● = Substantial compliance, low resource needs, or few replicability-flexibility limitations
- ◐ = Partial compliance, moderate resource needs, or moderate limitations
- ○ = No or minimal compliance, high resource needs, or major limitations.

The resulting ratings, shown in Table 1, should be regarded as subjective judgments only, but do provide a shorthand characterization of the important features of the methodological tools examined.

Methodology Descriptions

The 17 methodologies or tools discussed were examined via the above set of review criteria with results summarized in Table 1 on page 8. A brief description of each methodology follows, discussing the following points.

- The methodology type
- The general approach used
- The range of actions or project types for which the methodology may be applicable
- The comprehensiveness of the methodology in terms of the range of impacts addressed

- The resources required (data, manpower, time, etc).
- The limitations of the methodology (replicability, ambiguity, flexibility)
- Key ideas or particularly useful concepts offered
- Other major strengths and weaknesses as identified by the review criteria.

Because of the brevity and subjectivity of these characterizations, they should not be considered as adequate critiques of the tools examined. They may instead serve as a useful introduction to the range of techniques now evolving.

1. Adkins, William G. and Dock Burke Jr., Interim Report: Social, Economic, and Environmental Factors in Highway Decision Making, research conducted for the Texas Highway Department in cooperation with the U.S. Department of Transportation, Federal Highway Administration: College Station, Texas; Texas Transportation Institute, Texas A&M University (October 1971).

The Adkins methodology is a checklist using a +5 to -5 rating system for evaluating impacts but providing no guidelines for measuring impacts. The approach was developed to deal specifically with the evaluation of highway route alternatives. Because the bulk of parameters used relate directly to highway transportation, the approach is not readily adaptable to other types of projects.

The parameters used are broken down into categories of transportation, environmental, sociological, and economic impact. Environmental parameters are generally deficient in ecological considerations. Social parameters emphasize community facilities and services.

Route alternatives are scored +5 to -5 in comparison to the present state of the project area, not the expected future state without the project. Since the approach uses only subjective relative estimations of impacts, the data, manpower, and cost requirements are very flexible. Reliance on subjective ratings without guidelines for such ratings greatly reduces the replicability of analysis and generally limits the valid use of the approach to a case-by-case comparison of alternatives only.

The detailed listing of social and, to a lesser extent, economic parameters may be helpful for identifying and cataloging impacts in other types of projects. An interesting feature of possible value to other analyses using relative rating systems is the practice of summarizing the number as well as the magnitude of plus and minus ratings for each impact category. The number of pluses and minuses may be a more reliable indicator for alternative comparison since it is less subject to the arbitrariness of subjective weighting. These summarizations are additive and thus implicitly weigh all impacts equally.

2. Dee, Norbert, et al, Environmental Evaluation System For Water Resources Planning, report to the U.S. Bureau of Reclamation, Columbus, Ohio: Battelle Memorial Institute (January 1972).

This methodology is a checklist procedure emphasizing quantitative impact assessment. It was designed for major water resource projects but most parameters used are also appropriate for other types of projects. Seventy-eight specific environmental parameters are defined within the four categories of ecology, environmental pollution, aesthetics, and human interest. The approach does not deal with economic or secondary impacts and social impacts are only partially covered within the human interest category.

Impacts are measured via specific indicators and formulas defined for each parameter. Parameter measurements are converted to a common base of "environmental quality units" through specified graphs or value functions. Impacts can be aggregated using a set of preassigned weights.

The resource requirements are rather high, particularly data requirements. These requirements probably restrict the use of the approach to major project assessments.

The approach emphasizes explicit procedures for impact measurement and evaluation and should therefore produce highly replicable results. Both spatial and temporal aspects of impacts are noted and explicitly weighted in the assessment. Public participation, uncertainty, and risk concepts are not dealt with. An important idea of the approach is the highlighting of key impacts via a "red flag" system.

3. Dee, Norbert, et al., Planning Methodology for Water Quality Management: Environmental Evaluation System, Columbus, Ohio: Battelle Memorial Institute (July 1973).

This unique methodology of impact assessment defies ready classification since it contains elements of checklist, matrix, and network approaches. Areas of possible impacts are defined by a hierarchical system of four categories (ecology, physical/chemical, aesthetic, social), 19 components and 64 parameters. An interaction matrix is presented to indicate which activities associated with water quality treatment projects generally impact which parameters. The range of parameters used is comprehensive, excluding only economic variables.

Impact measurement incorporates two important elements. A set of "ranges" is specified for each parameter to express impact magnitude on a scale from zero to one. The ranges assigned to each parameter within a component are then combined by means of an "environmental assessment tree" into a summary environmental impact score for that component. The significance of impacts on each component is quantified by a set of assigned weights. A net impact can be obtained for any alternative by multiplying each component score by its weight factor and summing across components.

The key features of the methodology are its comprehensiveness, its explicitness in defining procedures for impact identification and scoring, and its flexibility in allowing use of best available data.

Sections of the report explain the several uses of the methodology in an overall planning effort and discuss means of public participation. The data, time, and cost requirements of the methodology when used for impact assessment are moderate, though a small amount of training would be required to familiarize users with the techniques used.

Because of its explicitness, the methodology possesses only minor ambiguities and should be highly replicable. Because the environmental assessment trees are developed specifically for water treatment facilities, the methodology cannot be adapted to other types of projects without reconstructing the trees though the parameters could be useful as a simple checklist.

One potentially significant obstacle to use of the approach is the difficulty of explaining the procedures to the public. Regardless of the validity of the "trees", they are unfamiliar devices developed by highly specialized multivariant analysis techniques and public acceptance of conclusions reached by their use may be low.

4. Institute of Ecology, University of Georgia, "Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process: Test case: Relative Impact of Proposed Highway Alternatives", Athens, Georgia: University of Georgia, Institute of Ecology (1971) (mimeographed).

The "Georgia"methodology incorporates a checklist of 56 environmental components. Measurable indicators are specified for each component. The actual values of alternative plan impacts on a component are normalized and expressed as a decimal of the largest impact (on that one component). These normalized values are multiplied by a subjectively determined weighting factor. This factor is the sum of one times a weight for "initial" effects plus ten times a weight for "long-term" effects.

The methodology is used to evaluate highway project alternatives and the components listed are not suitable for other types of projects. A wide range of impact types are analyzed including land use, social, aesthetics, and economic impacts.

The lower replicability of the analysis produced by using subjectively determined weighting factors is compensated for by conducting several passes at the analysis, and incorporating randomly generated error variation in both actual measurements and weights. This procedure provides a basis for testing the significance of differences in total impact scores between alternatives.

The procedures for normalizing or scaling measured impacts to obtain commensurability, and testing of significant differences between alternatives are notable features of potential value to other impact analyses and methodologies. These ideas may be useful whenever several project alternatives can be identified and compared.

The Georgia methodology places rather high resource demands on the user since computerization is necessary to generate random errors and make the large number of repetitive calculations.

5. Krauskopf, Thomas M., and Dennis C. Bunde, "Evaluation of Environmental Impact Through a Computer Modelling Process", Environmental Impact Analysis: Philosophy and Methods, (eds.) Robert Ditton and Thomas Goodale, Madison, Wisconsin: University of Wisconsin Sea Grant Program (1972), pp. 107-125.

This methodology employs an overlay technique via computer mapping. Data on a large number of environmental characteristics are collected and stored in the computer on a grid system of 1 km square cells. Highway route alternatives can either be evaluated by the computer (by noting the impacts on intersected cells) or new alternatives may be generated via a program identifying the route of least impact.

The environmental characteristics used are rather comprehensive, particularly as regards land use and physiographic characteristics. Though the methodology was developed and applied to a highway setting, it is adaptable, with relatively small changes in characteristics examined, to other project types with geographically well defined and concentrated impacts. Because the approach requires considerable amounts of data on the project region, it is not practical for the analysis of programs of broad geographical scope. The high manpower-skill, money, and computer technology requirements of the approach may also make it impractical at the present time for any but major projects, or in situations where a statewide, computerized data base exists (New York, Minnesota, Iowa, etc).

The estimation of impact importance is done through the specification of subjective weights. Because the approach is computerized, the effects of several alternative weighting schemes can be readily analyzed.

The methodology is attractive on several viewpoints. It allows a demonstration of which weighted characteristics are central to a particular alternative route; it presents a readily understandable graphic representation of impacts and alternatives; it easily handles several subjective weighting systems; the incremental costs of considering or generating additional alternatives is low; and it fits well with developing regional and statewide data bank systems.

The mechanics of the approach--how impacts are measured and combined--are not readily apparent from the reference cited. Considerable training beyond the information available in this reference would be required to use the approach.

6. Leopold, Luna B., et al., A Procedure for Evaluating Environmental Impact, Geological Survey Circular 645, Washington: Government Printing Office (1971).

This is an open-cell matrix approach identifying 100 project activities and 88 environmental characteristics or conditions. For each action involved in a project, the analyst evaluates the impact on every impacted environmental characteristic in terms of impact magnitude and significance. These evaluations are subjectively determined by the analyst. Ecological and physical-chemical impacts are treated comprehensively, social and indirect impacts are less well handled, and economic and secondary impacts are not addressed.

Because the assessments made are subjective, resource requirements of the approach are very flexible. The approach was not developed in reference to any specific type of project and may be broadly applied with some alterations.

Guidelines for use of the approach are minimal and several important ambiguities are likely in the definition and separation of impacts. The reliance on subjective judgment, again without guidelines, reduces the replicability of the approach.

The approach is chiefly valuable as a means of identifying project impacts and as a display format for communicating results of an analysis.

7. Arthur D. Little, Inc., Transportation and Environment: Synthesis for Action: Impact of National Environmental Policy Act of 1969 on the Department of Transportation, Vol. 3, Options for Environmental Management, prepared for Office of the Secretary, Department of Transportation (July 1971).

This is less a complete methodology than an overview discussion of the kinds of impacts that may be expected to occur from highway projects and the measurement techniques that may be available to handle some of them. A quite comprehensive list of impact types and the stages of project development at which each may occur are presented. As broad categories, the impact types identified are useful for other projects as well as for highways.

The approach suggests the separate consideration of an impact's amount, effect (public response), and value. Some suggestions are offered for measuring the amount of impact within each of seven general categories: noise, air quality, water quality, soil erosion, ecologic, economic, and sociopolitical impacts.

Five possible approaches to the handling of impact significance are presented. Three of these are "passive" (requiring no agency action) such as "reliance on the emergence of controversy". The other two involve the use of crude subjective weighting scales. No specific suggestions are made for the aggregation of impacts either within or between categories.

In general, the reference cited is a useful discussion of some of the important issues of impact analysis, particularly as they apply to transportation projects, but does not present a complete analytical technique.

8. McHarg, Ian., "A Comprehensive Highway Route-Selection Method", Highway Research Record, Number 246, 1968, pp. 1-15, or McHarg, Design With Nature, Garden City, New York: Natural History Press, 1969, pp. 31-41.

The McHarg approach is a system employing transparencies of environmental characteristics overlaid on a regional base map. Eleven to sixteen environmental and land use characteristics are mapped. The maps represent three levels of the characteristics, based upon "compatibility with the highway". These references do not indicate how this compatibility is to be determined but available documentation is cited.

This approach is basically an earlier, noncomputerized version of the ideas presented in the Krauskopf reference. Its basic value is as a method for screening alternative project sites or routes. Within this limited use, it is applicable to a variety of project types.

Limitations of the approach include its inability to quantify as well as identify possible impacts and its implicit weighting of all characteristics mapped.

Resource requirements of the McHarg approach are somewhat less demanding, in terms of data, than those of the Krauskopf approach because information is not directly quantified, only categorized into three levels. High degrees of skill and training are required, however, to prepare the map overlays.

The approach seems most useful as a "first cut method" of identifying and sifting out alternative project sites, preliminary to detailed impact analysis.

9. Moore, John L., et al., A Methodology for Evaluating Manufacturing Environmental Impact Statements for Delaware's Coastal Zone, Report to the State of Delaware, Columbus, Ohio: Battelle Memorial Institute (June 1973).

This approach was not designed as a method for impact analysis but its principles could be adapted for such use. It employs a network approach, linking a list of manufacturing-related activities-to potential environmental alterations-to major environmental effects, and finally-to human uses affected. The primary strength of the set of linked matrices is their utility in displaying cause-condition-effect networks and tracing out secondary impact chains.

Such networks are useful primarily for identifying impacts and the issues of impact magnitude and significance are addressed only in terms of high, moderate, low, or negligible damage. As a result of these subjective evaluations the approach would have low replicability as an assessment technique. For such a use, guidelines would likely need to be proposed to define the evaluation categories.

The approach incorporates indicators especially tailored to manufacturing facilities in a coastal zone though most indicators would also be pertinent to other types of projects.

The approach would perhaps be valuable as a visual summary of an impact analysis for communication to the public and decision makers.

10. Central New York Regional Planning and Development Board, Environmental Resources Management, prepared for Department of HUD (October 1972) (available through the National Technical Information Service PB 217-517).

This methodology employs a matrix approach to assess in simple terms the major and minor, direct and indirect impacts of certain water related construction activities. It is designed primarily to measure only the physical impacts of water resource projects in a watershed, and is based on an identification of the specific, small-scale component activities that are included in any project. Restricted to physical impacts on nine

different types of watershed areas (e.g., wetlands) and fourteen types of activities (e.g., tree removal), the procedure indicates four possible levels of impact-receptor interactions (major direct through minor indirect). Low to moderate resources in terms of time, money, or personnel are required for the methodology, due principally to its simple way of quantification (major versus minor impact). However, the procedure is severely limited in its ability to compare different projects or the magnitude of different impacts. There is no spatial or temporal differentiation, hence the full range of impacts cannot be assessed. Impact uncertainty and high damage-low probability impacts are also not considered. Only two levels of the magnitude of an impact are identified while the importance of the impacts are not assessed, resulting in moderate replicability. The lack of objective evaluation criteria may produce ambiguous results. NEPA requirements for impact assessments are not directly met by this procedure.

The value of this methodology is less in the actual assessment of the quantitative impacts of a potential project than in a "capability rating system" which determines recommended development policies based on existing land characteristics. Thus, guidelines on desirable and undesirable activities with respect to the nine types of watershed areas are used to map a region in terms of the optimum land use plan. The actual mapping procedure is not described, however, and hence that aspect of the impact assessment methodology cannot be evaluated here.

11. Smith, William L., "Quantifying the Environmental Impact of Transportation Systems", Van Doren-Hazard-Stallings-Schnacke, Topeka, Kansas (undated) (mimeographed).

The Smith approach, as developed for highway route selection, is a checklist system based on the concepts of probability and supply-demand. The approach attempts to identify the alternative with least social cost to environmental resources and maximum social benefit to system resources. Environmental resources elements are listed as: agriculture, wildlife conservation, interference, noise, physical features, and replacement. System resources elements are listed as: aesthetics, cost, mode interface, and travel desires. For each element, categories are defined and used to classify zones of the project area. Numerical probabilities of supply and of demand are then assigned to each zone for each element. These are multiplied to produce a "probability of least

social cost" (or maximum social benefit). These least social cost probabilities are then multiplied across the elements to produce a total for the route alternative under examination.

The approach is tailored and perhaps limited to project situations requiring comparison of siting alternatives. The range of environmental factors examined is very limited, but presumably could be expanded to cover more adequately ecological, pollution, and social considerations.

Since procedures for determining supply and demand probabilities are not described, it is difficult to anticipate the amounts of data, manpower and money required to use the approach. The primary limitations of this methodology are difficulties inherent in assigning probabilities, particularly demand probabilities, and the implicitly equal weightings assigned to each element analyzed when multiplying to yield an aggregate score for an alternative.

12. Sorensen, Jens, A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, Berkeley: University of California, Department of Landscape Agriculture (1971), and Sorensen and James E. Pepper, Procedures for Regional Clearinghouse Review of Environmental Impact Statements -- Phase Two, report to the Association of Bay Area Governments (April 1973).

These two publications present a network approach usable for environmental impact analysis. The approach is not a full methodology but rather a guide to the identification of impacts. Several potential uses of the California coastal zone are examined through networks relating uses-to causal factors (project activities)-to first order condition changes-to second and third order condition changes, and finally-to effects. The major strength of the approach is its ability to identify the pathways by which both primary and secondary environmental impacts are produced.

The second reference also indicates types of data relevant to each effect identified, though no specific measurable indicators are suggested. In this reference some general criteria for identifying projects of regional significance are suggested, based on project size and types of impacts generated, particularly land use impacts.

Because the preparation of the required detailed networks is a major undertaking, the approach is presently limited to some commercial, residential, and transportation uses of the California coastal zone for which networks have been prepared. An agency wishing to use the approach in other circumstances might develop the appropriate networks for reference in subsequent environmental impact assessments.

13. Stover, Lloyd V., Environmental Impact Assessment: A Procedure, Miami, Florida: Sanders and Thomas, Inc. (1972).

This methodology is a checklist procedure for a general quantitative evaluation of environmental impacts from development activities. The type and range of these activities is not specified, but is believed to be comprehensive. Fifty different impact parameters are sufficient to include most possible effects, and thereby allow much flexibility. Sub-parameters indicate specific impacts, but there is no indication of how the individual measures are aggregated into a single parameter value. While spatial differences in impacts are not indicated, both initial and future impacts are included and explicitly compared. Resource requirements are moderate to heavy, especially in terms of an interdisciplinary personnel team which grows as more subparameters are included, requiring additional expertise in specific areas. However, the actual measurements are not based on specific criteria and are only partially quantitative, with seven possible values ranging from an extremely beneficial impact to an extremely detrimental one. Therefore, there is potential for ambiguous and subjective results, with only moderate replicability. Impact areas are implicitly assumed to be of equal importance. A specific methodology is mentioned for choosing the optimum alternative in terms of benefits and adverse effects. The procedure for alternatives comparison may be the most interesting aspect of the procedure, with results given in terms of the proportional significance of an impact vis-a-vis other potential alternatives. There is no explicit mention of either public involvement in the process, or environmental risks.

The impact assessment procedure is presented as only one step in a total evaluation scheme which includes concepts of dynamic ecological stability and other ideas. An actual description of the entire process is not included, however.

14. Multiagency Task Force, "Guidelines for Implementing Principles and Standards for Multiobjective Planning of Water Resources", Review Draft, Washington: U.S. Bureau of Reclamation (1972).

The Task Force approach is an attempt to coordinate features of the Water Resources Council's Proposed Principles and Standards for Planning Water and Related Land Resources with requirements of NEPA. It develops a checklist of environmental components and categories organized in the same manner as the WEC Guidelines. The categories of potential impacts examined deal comprehensively with biological, physical, cultural, and historical resources, and pollution factors but do not treat social or economic impacts. Impacts are measured in quantitative terms where possible and also rated subjectively on "quality" and "human influence". In addition, uniqueness and irreversibility considerations are included where appropriate. Several suggestions for summary tables and bar graphs are offered as communications aids.

The approach is general enough to have wide applicability to various types of projects, though its impact categories are perhaps better tailored to rural than urban environments. No specific data or other resources are required to conduct an analysis, though an interdisciplinary project team is specified to assign the subjective weightings. Since quality, human influence, uniqueness, and irreversibilities are all subjectively rated using general considerations only, results produced by the approach may be highly variable. Significant ambiguities include a generally inadequate explanation of how human influence impacts are to be rated and interpreted.

Key ideas incorporated in the approach include explicit identification of the without-project environment as distinct from present conditions, and use of uniqueness rating system for evaluating quality and human influence (worst known, average, best known, etc). The methodology is unique among those examined in not labeling impacts as environmental benefits or costs but only as impacts to be valued by others. The approach also argues against the aggregation of impacts.

15. Tulsa District, U.S. Army Corps of Engineers, Matrix Analysis of Alternatives for Water Resource Development, draft technical paper (July 31, 1972).

Despite the title, this methodology can be considered a checklist under the definitions used here since, though a display matrix is used to summarize and compare the impacts of project alternatives, impacts are not linked to specific project actions. The approach was developed to deal specifically with reservoir construction projects but could be readily adapted to other project types.

Potential impacts are identified within three broad objectives: environmental quality, human life quality, and economics. For each impact type identified, a series of factors are described, indicating possible measurable indicators. Impact magnitude is not measured in physical units but by a relative impact system. This system assigns the future state of an environmental characteristic without the project a score of zero; then assigns the project alternative possessing the greatest impact on that characteristic a score of +5 (for positive impact), or -5 (for negative impact). All other alternatives are assigned scores between 0 and 5 by comparison. The raw scores thus obtained are multiplied by weights determined subjectively by the impact analysis team.

Like the Georgia approach, the Tulsa methodology tests for the significance of differences between alternatives by introducing error factors and conducting repeated runs. The statistical manipulations are different from those used in the Georgia approach, however, and considered by the Corps' writers to be more valid.

Resource requirements of the Tulsa methodology are variable. Since specific types or levels of data are not required, data needs are quite flexible. The consideration of error, however, requires specific skills and computer facilities.

The major limitations of the approach, aside from the required computerization, are the lack of clear guidelines on exactly how to measure impacts and the lack of guidance on how the future no-project state is to be defined and described in the analysis. Without careful description of the assumptions made, replicability of analyses made using the approach may be low since only relative measures are used. Since all

measurements are relative, it may also be difficult in some cases to deal with impacts that are not clearly definable as gains or losses.

The key ideas of wider interest incorporated in the Tulsa approach include reliance on relative rather than absolute impact measurement, statistical tests of significance with error introduction, and specific use of the no-project condition, as a base line for impact evaluation.

16. Walton, L. Ellis, Jr., and James E. Lewis, A Manual for Conducting Environmental Impact Studies, Virginia Highway Research Council (January 1971) (available through the National Technical Information Service PB-210 222).

The Walton methodology is a checklist, unique in its almost total reliance on social impact categories and strong public participation. The approach was developed for the evaluation of highway alternatives and identifies different impact analysis procedures for the conceptual, corridor, and design states of highway planning. All impacts are measured by either their dollar value or a weighted function of the number of persons affected. (The weights used are to be determined subjectively by the study team.) The basis for most measurements is a personal interview with a representative of each facility or service impacted.

Resource requirements for such a technique are highly sensitive to project scale. The extensive interviewing required may make the approach impractical for many medium-size or large projects because agencies preparing impact statements seldom have the necessary manpower or the money to contract for such extensive interviewing.

Analyses produced by the approach may have very poor replicability due to the lack of specific data used and the criticality of the decision regarding boundaries of the analysis since many impacts are measured in numbers of people affected. There is also no means of systematically taking into account the extent to which these people are affected.

The key ideas of broader interest put forth by the approach are the use of only social impacts without direct consideration of other impacts (pollution, ecology, etc), the heavy dependence on public involvement and specific suggestions on how the public may be involved, and the recognition of the need for different analyses of different stages of project development.

17. Western Systems Coordinating Council, Environmental Committee, Environmental Guidelines (1971). (Mr. Robert Coe, Southern California Electric Company, Environmental Committee Chairman.)

The Environmental Guidelines are intended primarily as a planning tool for siting power generation and transmission facilities. However, they address many of the concerns of environmental impact analysis and have been used in the preparation of impact statements. Viewed as an impact assessment methodology, the approach is an ad hoc procedure, suggesting general areas and types of impacts but not listing specific parameters to examine.

The approach considers a range of pollution, ecological, economic (business economics), and social impacts but does not address secondary impacts such as induced growth, or energy use patterns. The format of the approach is an outline of considerations important to the selection of sites for each of several types of facilities -- e.g., thermal generating plants, transmission lines, hydroelectric and pumped storage, and substations. An additional section offers suggestions for a public information program.

Since the approach does not suggest specific means of measuring or evaluating impacts no particular types of data or resources are required. The application of this approach is limited to the siting of electric power facilities with little carry over to other types of projects.

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16. Abstract

Seventeen tools or methodologies designed for or applicable to the preparation of environmental impact statements are reviewed to identify their strengths, weaknesses, and potential range of use. Specific criteria are suggested for evaluating the adequacy of an impact assessment methodology in terms of:

- Impact Identification
- Impact Measurement
- Impact Interpretation
- Impact Communication
- Resource Requirements
- Replicability
- Flexibility

The reviews presented serve as an introduction to the range of tools available and demonstrate that no single approach to impact assessment is superior in all circumstances.

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