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ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGIES: A CRITIQUE

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The National Environmental Policy Act of 1969[1] is stimulating the growth and development of the environmental technology professions. Stimulation, however, is no substitute for expertise, and environmental professionals are often hard put to develop meaningful techniques to apply to the guidelines of Section 102 of NEPA, the environmental impact assessment clause.[2]

This section of the federal legislation requires that environmental impact statements be filed prior to the implementation of any project which is funded, directly or indirectly, by federal monies or which requires a federal certificate, license or lease. According to the law, such impact statements must be developed through a "systematic, interdisciplinary approach" and must do the following: describe environmental impacts of the proposed project; describe any adverse effects which could not be avoided if the project was implemented; evaluate all alternatives to the project; discuss the long-term and short-term impacts; and fully describe any "irreversible and irretrievable commitments of resources." Ideally, NEPA should bring environmental quality considerations into the decision-making process without forced recourse to federal legal intervention. "102 statements" are designed to assess environmental consequences and effects before actual policy and project decisions are made.

The Council on Environmental Quality (CEQ), also established by NEPA,[3] is the federal agency charged with the responsibility of creating guidelines for such assessments. President Nixon, who initially opposed the creation of the CEQ, clarified the agency's responsibilities in Executive Order 11514 (March 5, 1970). The CEQ then developed the necessary guidelines for all other federal agencies. These were refined again in April of 1971, when the CEQ revised its initial comments by integrating Section 102 with Section

309 of the Clean Air Act.[4] Yet, jurisdiction over the exact content of a 102 statement still rested with the "lead" agency charged with the responsibility of preparing the initial draft environmental impact statement.[5] Hence, while the CEQ's guidelines stressed administrative and jurisdictional issues, the lack of content directives from that agency or any other has resulted in a proliferation of agency guidelines on the subject of what constitutes an impact analysis. The lack of unified, concrete objectives and specified guidelines is perhaps one of the greatest weaknesses of the 102 program. As one critic has put it, "the quality of environmental impact statements has been hampered by a lack of technical knowledge on such questions as what is environmental quality? What should be included in a good environmental impact statement? What is the present condition of the environment?"[6]

These structural dificiencies in the implementation of NEPA are also methodological ones. As various agencies grapple with these problems, we see the emergence of various methods of analysis used in preparing a 102 statement. Perhaps at this point it is essential to begin to classify these various approaches, and to assess the relative merits and weaknesses of each.

There are essentially three types of approaches to the measurement of environmental impact: the associated matrix method, the index value approach, and computer program models. A fourth technique, the descriptive resource analysis model, has been utilized and will be discussed at the conclusion of this article, though it does not presently meet the objectives of NEPA guidelines, such as they are.

I. Associated Matrix Model

The associated matrix model attempts to describe potential impacts of a project through a comparative approach which utilizes a cause-and-effect matrix system. The various development alternatives under consideration, for example, the alternative ways in which the flow of water may be structurally regulated, are laid out on one axis, and the various environmental components of the study area which will be affected by these actions on the other. A number is then assigned to each cell in the matrix to represent the relative significance of each action with respect to each environmental characteristic. This "significance rating" will be given a positive or negative sign, depending on whether the impact is felt to be beneficial or detrimental as regards that characteristic.

Once these impacts are described, another matrix is usually developed to indicate all negative impacts of any particular development alternative. Emphasis in this second matrix is almost exclusively of a negative nature, since it can be assumed that the benefits of the project have been developed in a proposal or in engineering documents. Though the Sorenson[7] and Toth[8] models of the matrix approach are important, the United States Geological Survey method,[9] developed by Leopold, Clarke, Hanshaw, and Balsey, is the best known and will be more extensively discussed.

In this associated matrix, one hundred types of development actions (*e.g.*, alteration of ground cover, resource extraction, river/stream flow modification) are laid out on a horizontal axis, while eighty-eight environmental characteristics of the study area (*e.g.*, fauna, earth resources, water resources)[10] are put on a vertical axis. Each of the resulting 8,800 cells is assigned two numbers, the first representing the impact of that action on a particular component of an environmental system, and the second representing the effect of the action on the broader environmental subsystem of which that characteristic is a part. For instance, the cell representing the effect of an action on one species of wildlife would show one number for the impact on that species, and a second number for the overall impact of the action on wildlife in general. The second number would thus be the same for several different cells. Impacts are rated on a scale of 1 to 10; a minus or plus sign is added to the rating to indicate a generally negative or positive environmental effect.

An essential problem with the matrix approach, the USGS model included, is its heavy reliance on the value judgments assigned to characteristics and actions by the investigators. Though it can be argued that nearly all methods of impact assessment ultimately require a degree of value judgment somewhere in the process, this approach relies most heavily on the investigator's abilities, almost to the exclusion of any other analytical approaches and techniques. Beyond this, the method tends to be something of an inventory approach, more akin to descriptive models than to some more rigorous techniques. Furthermore, the method presents a static rather than a dynamic picture of man-environment relations, since it implies a one-directional sequence of cause and effect, in which each action is directly responsible for environmental impact. This limitation often leads to a situation wherein impacts are noted only when a direct cause-and-effect relationship can be suggested. It is inherent in any understanding of ecosystem dynamics that impacts are rarely, if ever, the products of such a simple chain of causation. Rather, they tend to be the results, often transitory at that, of interrelated, cumulative, synergistic secondary- and tertiary-level processes.[11] As a result, such associated matrix approaches fail to confront the reality and dynamic nature of environmental systems.

II. Index Value Model

Like the associated matrix method, the index value method is designed to compare the consequences of several different courses of action. In addition, like the previous method, it is built on a set of quantified quality indicators applied to a set of development alternatives. Each individual environmental characteristic is assigned several weight factors, representing the different impacts of the various development alternatives. The index value method, however, differs substantially from the one-dimensional cause-and-effect approach of the associated matrix methods in that it can demonstrate linkages and feedbacks on several levels and orders. Through the use of statement of error analysis the whole system is quantified. Impacts can not only be added, as with the associated matrix model, but multiplied. The model is thus capable of showing the interactions of the different impacts, and their cumulative effect upon the environmental characteristics. To the degree that this method is effective it tends to provide a systems perspective to environmental impacts, a factor of critical importance, since environmental dynamics can best be described in a systems framework.

Index value models generally make use of the same listings of environmental characteristics and development actions as are used in associated matrix models, though in the index value technique these are not ordered on different axes but appear side by side on the same axis. This arrangement aids in the illustration of potential alterations in the whole ecosystem. In addition, there is usually a mathematical component added to the process so that distinctions between various action alternatives can be demonstrated by using error factors and statistical runs to flesh them out.

There are several outstanding examples of this approach, though here again, as throughout this article, only one will be discussed. The Battelle-Columbus Environmental Evaluation System[12] suffers from a degree of inflexibility. It was developed for a particular water resources project and as yet has not been generalized to other and different areas and/or problems. The Stover Index Value Matrix Method[13] has not been applied to a practical or "real world" problem and thus remains untested. The Georgia Ecology/Optimum Pathway approach[14] is of questionable applicability to problems which do not involve transportation systems. This is also the case with Douglas Lacate's method developed at Cornell.[15] The Georgia model, moreover, is committed to a "build" policy without a "no action" alternative being part of the system. The Bureau of Outdoor Recreation approach[16] is neither applicable for computer use at the present time, nor is it applicable for environmental characteristics analysis; it is very heavily weighted toward cultural and man-made environmental imperatives and inputs.

Perhaps the most representative of the index value approaches, both in terms of its strengths and weaknesses, is the U.S. Army Corps of Engineers' Tulsa District model.[17] Though initially developed for a reservoir project, this method can be applied to other projects. In this approach three basic standards are set up: environmental quality, human life quality and economic impact. These standards become "critical horizons" against which the sum of all negative impacts of an action alternative will be judged. Like other types of analysis in this catgeory, the Tulsa method attempts to point out differences between the various alternatives under study by introducing the technique of error factor analysis through computerization.

The magnitude of an impact in this approach is described in relative terms, not physical ones. The greatest positive impact receives a +5 quality rating, while those impacts which are generally negative receive a -5 rating. All other intermediate actions or impacts receive grades between these extremes. These raw scores, which are termed "equivalency factors," are summed and then multiplied by weighting factors which represent the investigators' subjective estimate of the importance of the particular environmental characteristics under consideration. At this point a standard deviation statistical process is performed on a set of randomly selected variables to determine significant differences among the net impacts.

Aside from the complexity of the process, a major problem with this method is that it tends to oversimplify alternatives, environmental parameters and net impacts. Moreover, the entire system is riddled by subjective ratings and interpretations. Its essential justification is that it can handle a significantly larger number of impact interactions than the associated matrix models, and that it readily suggests the tradeoffs which the planning process must seek to isolate. Unlike the Georgia model of this category, the Tulsa District technique uses a "no action" alternative as a baseline and thus meets one of the important requirements of Section 102—that all alternatives must be examined, not just those which will bring a proposed project into being.

III. Computer Approaches

This final type of impact analysis requires a large and costly information base. Large numbers of variables are integrated in this system, together with a variety of potential actions. Unlike the two previous methods, the computer-based methods are not comparative, but are designed to take the consequences of one particular action all the way through to their conclusion. The analysis must then be rerun for each alternative action. Computer technology provides the possibility of running simulations through combinations of these parameters, and hence a broad range of planning alternatives can be assessed within a short period of time.

Two of the most important computer approaches are the RECSYS[18] model developed at Michigan State University and various state-level agencies in Michigan, and the PARIS[19] approach developed by state agencies in California. Though both were developed to handle outdoor recreation problems, they are useful in other impact assessment situations. For the purposes of this essay, however, the Harvard Grid[20] technique will be discussed because of its widespread use and its recent application by the author.

The Grid system entails an analysis of a resource inventory and its interface with planning and programming alternatives through a computer grid mapping program. It provides a graphic display of large amounts of data collected to fit a rectangular coordinate grid. To run such a program requires two basic data inputs: values which have been assigned to environmental variables and instructions delineating the procedures and forms that are to be used for analysis and display. Each data value is associated with a specific cell on the grid, the nature of which is specified by the investigator.[21]

At the outset, a study area must be defined and data variables determined, usually on a subjective basis. A resource inventory is then developed to determine the qualities and properties of the study area. Then the alternatives or actions under consideration must be isolated and defined. These steps are really concerned with problem definition. The variables are then grouped to identify areas or sites of different character. Activities are then evaluated by the level of impact each will have on a particular variable group. A simulation model is then prepared for all of the previous data which includes information on demand for the various activity alternatives, the costs and benefits of the activities, and, of course, the impacts upon particular site variable groups.

The success of such modeling techniques is only as good as the data base—as computer specialists say, "Garbage in, Garbage out." The cost of this process is considerable, and may prove prohibitive in certain contexts. It is also highly subjective in that values are assigned to characteristics of the environment and to impacts by an investigator without a "control" process. Nonetheless, its graphic nature makes it a potentially important tool in generating citizen participation in the process. This is important since NEPA, through the CEQ directives, seeks to stimulate a high level of citizen input into the process, though this level is very rarely achieved, except in those situations where highly motivated citizens' groups do have a profound impact upon the process.

IV. Descriptive Methods

Most descriptive methods of assessment were developed prior to NEPA. Though useful in aiding in the inventorying process, these descriptive techniques fail to meet the requirements of a methodology which could meet the needs of Section 102. In essence, descriptive methods simply define and describe a site; they do not have a "predictive edge" to them. Because NEPA requires that a "systematic, interdisciplinary approach" be utilized which can tell, prior to an action's implementation, what its effects on the environment will be, descriptive techniques fail to meet this criteria by their own definitions.

Most descriptive methods are really graphic mapping systems which produce the all-important environmental inventory. They can aid tremendously in the process of resource and land use evaluation, as exemplified in Ian McHarg's[22] famous methodology. Since these techniques have been with us for some time we are fortunate in having some very good critiques of their relative merits and drawbacks. Carl Steinitz's[23] study is perhaps the most important of these and covers the most widely used approaches, including those developed by Hills,[24] McHarg,[25] Lewis[26] and the Harvard Landscape Architecture Group.[27] Because these approaches do not appraise impact, they have often been ignored. As part of a more dynamic process, descriptive techniques can be of immense utility since they can easily illustrate the natural resource base of any site under consideration.

V. Other Methodologies

The need to develop more satisfactory methodologies continues. The Environmental Protection Agency developed its own approach, known as the Strategic Environmental Assessment System,[28] but it has long since been scrapped. Some techniques have been developed for specific projects and have been quite successful. Though several have already been mentioned, Leonard Ortolono's Analyzing the Environmental Impact of Water Projects[29] is quite comprehensive and adds a great deal of clarity to the problem of assessing projects often conducted by the U.S. Corps of Engineers.

VI. Conclusion

Ultimately, full compliance with NEPA's Section 102 may be impossible. The ability to measure impact implies the ability to describe an environmental system. It is inherent in the understanding of ecosystem dynamics that change is the most basic and significant quality of real-world ecosystem behavior. To seek a precise description of an environmental impact forces us to deny the most important quality of the environment. To seek a description of something which cannot be described—such is the essence of Section 102.

Where then are we left? If the "letter" of the law commands an impossibility, we must at least seek to give meaning to its "spirit." This can best be done within a systems perspective, for such a perspective will make analysis as precise and relevant as possible. This observation was made by Davis Aggerholm of the Corps of Engineers' Institute for Water Resources:

> The overriding problem, in my opinion, is that impact assessment is not accomplished in a systems context. Those who do the assessments (even ecologists) do not think about or approach the problem with a truly holistic, ecological point of view; i.e., proposed actions are not viewed as perturbations of dynamic environmental and social systems, and impacts are not treated as *systems* changes. Rather, impacts are treated as discrete, separable, generally unrelated events. Likewise, to the extent they are recognized, whole systems are treated discretely. This is just not how the real world works.[30]

At the same time we must be wary of those systems approaches which are "generally linear and unidirectional in their analysis, treating causes and effects as simply one-to-one relationships and ignoring feedback relationships."[31] This criticism has particular relevance to the first two methods described in this paper, but can also apply to the computer grid technique, if that technique is not used properly.

Aggerholm has argued for a predictive process. This is largely possible, though we must recognize the limitations imposed by natural processes. Relating back to Section 102, what is necessary is a predictive model developed within a systems perspective, which will compare the various alternatives, describing their general and net impacts. It is also most important to stress secondary and tertiary level impacts as well as significant primary level ecological and social consequences. As a hypothetical illustration, let us suppose that massive annual flooding of the Lamoille River in northern Vermont has created a situation where the Corps of Engineers is evaluating various structural and non-structural remedies. One of the structural alternatives, building a dam at Cambridge, will create a large lake which will provide a new water resource opportunity for the largely rural and undeveloped community. The primary level impacts will be relatively easy to suggest. We need to see, however, that other impacts, those of a secondary or tertiary nature, may also occur. Once the lake is created land uses in the area may be significantly altered. A secondary level impact might be the development of a new set of shoreline housing units. Once this land is developed a tertiary level of impacts may be imagined. This third level might include the need to develop an all-weather road system, the need to build a new school for the children of year-round residents, an extention of the village water and sewage system, so forth and so on. The point is that the impact of a dam on the Lamoille at Cambridge certainly moves beyond the immediate impacts of dam construction, water flow regulation and the like on local ecosystems and social structure. We must recognize in our assessments that timing is a critical element, and that one impact can become the cataylst for an entirely new set of adjustments and reactions. This is the nature of real world systems.

At bottom, then, we may never be able to develop a single approach for all problems which will guarantee the results NEPA seeks to achieve.[32] This is a limition imposed upon us, and the tools we can develop must relate intimately with a set of realities dictated by the very nature of environmental systems.

FOOTNOTES

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[1] 42 U.S.C. § 4321 *et seq.* (1970).

[2] 42 U.S.C. § 4332(2)(c) (1970).

[3] 42 U.S.C. § 4342 (1970).

[4] 42 U.S.C. §§ 1857-58a (1970), *amending* 42 U.S.C. §§ 1857-57e (1964).

[5] 40 C.F.R. § 1500.7(b) (1974).

[6] L. Sumek, *Environmental Impact Statements: More Myth Than Reality,* in ENVIRONMENT: AN ANTHOLOGY OF SELECTED READINGS FOR THE NATIONAL CONFERENCE ON MANAGING THE ENVIRONMENT, Section IV, at 39-52 (International City Management Association and the Environmental Protection Agency, n.d.).

[7] J. Sorenson, 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 Architecture, 1971).

[8] R. Toth, CRITERIA FOR EVALUATING THE VALUABLE NATURAL RESOURCES OF THE TIRAC REGION, at 1-37 (Stroudsburg, Pa.: Tocks Island Regional Advisory Council, 1968).

[9] Leopold, *et al.*, A PROCEDURE FOR EVALUATING ENVIRONMENTAL IMPACT: GEOLOGICAL SURVEY CIRCULAR 645, at 1-13 (Washington, D.C.: United States Geological Survey, 1971).

[10] These examples are classes or types. Hence, "modification of fauna regime" would include such variables as destruction of certain types of browsing vegetation, etc. Likewise, an environmental characteristic like earth is divided into mineral resource, soils, etc. on the matrix.

[11] *See* R. Andrews, *Approaches to Impact Assessment: Comparison and Critique* (a paper presented at the Short Course on Impact Assessment sponsored by the Corps of Engineers, Ann Arbor, June 9, 1973).

[12] N. Dee *et al.*, ENVIRONMENTAL EVALUATION SYSTEM FOR WATER RESOURCES PLANNING (Columbus: Battelle-Columbus Laboratories, 1972).

[13] L. Stover, ENVIRONMENTAL IMPACT ASSESSMENT: A PROCEDURE, at 1-9 (Miami, Florida: Sanders and Thomas, Inc., 1972).

[14] J. Zieman *et al.*, OPTIMUM PATHWAY MATRIX ANALYSIS APPROACH TO THE ENVIRONMENTAL DECISION MAKING PROCESS—TESTCASE: RELATIVE IMPACT OF PROPOSED HIGHWAY ALTERNATIVES (Athens: Institute of Ecology, University of Georgia, 1971).

[15] D. Lacate, THE ROLE OF RESOURCE INVENTORIES AND LANDSCAPE

ECOLOGY IN THE HIGHWAY ROUTE SELECTION PROCESS: A CASE STUDY USING THE PROPOSED RELOCATION OF NEW YORK STATE ROUTE 13 (Ithaca: Office of Regional Resources and Development, Cornell University, 1970).

[16] Northeast Regional Staff, AN ENVIRONMENTAL QUALITY RATING SYSTEM (Philadelphia: Bureau of Outdoor Recreation, n.d.).

[17] United States Army Corps of Engineers, Tulsa District, *Matrix Analysis of Alternatives for Water Resources Development* (Draft Technical Paper, July 31, 1972).

[18] Department of Commerce, State Resources Planning Program, OUTDOOR RECREATION PLANNING IN MICHIGAN (Lansing: Technical Reports, n.d.).

[19] Department of Parks and Recreation, State of California, OUTDOOR RECREATION OUTLOOK TO 1980, Monograph Series (Sacramento: Dept. of Parks and Recreation, 1966).

[20] C. Steinitz, D. Sinton, GRID: A USER'S REFERENCE MANUAL (Cambridge: Laboratory for Computer Graphics and Spatial Analysis, Harvard Graduate School of Design, 1969).

[21] Information on the application of this approach to the problem of interpreting the meaning of "growth" and "non-growth" in the context of Fairfax County, Virginia, may be obtained by writing the author or Dr. Leonard Simutis, Environmental Systems and Planning, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

[22] *See* I. McHarg, DESIGN WITH NATURE (Garden City, N.Y.: The Natural History Press, 1969).

[23] Steinitz, *et al.*, A COMPARATIVE STUDY OF RESOURCE ANAYLSIS METHODS (Cambridge: Department of Landscape Architecture, Harvard Graduate School of Design, 1969).

[24] A. Hills, THE ECOLOGICAL BASIS FOR LAND-USE PLANNING (Toronto: Ontario Department of Land and Forests, 1961).

[25] I. McHarg, *supra* n. 22, and I. McHarg, TOWARDS A COMPREHENSIVE LANDSCAPE PLAN FOR WASHINGTON, D.C. (prepared by Wallace, McHart, Roberts and Todd for the National Capitol Planning Commission, April, 1966).

[26] P. Lewis, LANDSCAPE ANALYSIS I: LAKE SUPERIOR SOUTH SHORE AREA (Madison: Wisconsin Department of Resource Development, 1963) and P. Lewis, REGIONAL DESIGN FOR HUMAN IMPACT (Kaukauna, Wisconsin: Thomas Publishers, 1972).

[27] *See* Steinitz, *et al.*, *supra* n. 23.

[28] United States Environmental Protection Agency, STRATEGIC ENVIRONMENTAL ASSESSMENT SYSTEM (Washington, D.C.: Office of

Research and Monitoring, Environmental Studies Division, n.d.).

[29] L. Ortolono, ed., ANALYZING THE ENVIRONMENTAL IMPACTS OF WATER PROJECTS (U.S. Army Corps of Engineers, Institute for Water Resources, 1973). *See also* L. Ortolono, *Impact Assessment in the Water Resources Planning Process* (paper presented at the Short Course on Impact Assessment sponsored by the Corps of Engineers, Ann Arbor, June 9, 1973).

[30] D. Aggerholm, *Developing Systems for Impact Analysis* (a paper given at the Symposium on NEPA, American Association for the Advancement of Science, December 28, 1972).

[31] *Id.*

[32] Subsequent to the development of this paper two new studies have been published which likewise evaluate impact methods. *See* AN ASSESSMENT METHODOLOGY FOR THE ENVIRONMENTAL IMPACT OF WATER RESOURCES PROJECTS, at 196-210 (Washington, D.C.: EPA, Office of Research and Development, 1974) and M. Warner & D. Bromley, ENVIRONMENTAL IMPACT ANALYSIS: A REVIEW OF THREE METHODOLOGIES (Madison: Institute for Environmental Studies, University of Wisconsin, 1974).