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Instrumental Valuation Indicators for Natural Resources and Ecosystems

F. Gregory Hayden

Beldon Daniels, in the early draft of his latest book, which has a working title of *Rediscovering America, 1992*,[1] has written that there have been four major eras in human history. The fourth, into which we are now evolving, according to Daniels, is the age of intelligence. Although the intelligence activity of the modern age both uses and directs the development of large quantities of data, information, and knowledge; a measurement concept, or unit for valuation has yet to be developed. The industrial age from which we are evolving, consistent with the technology of that era, has used industrial production (or a proxy for production such as money value) as the basic measurement unit for valuation. This article is intended as a step toward the realization of a measurement concept consistent with Daniels's ideas.

The purpose of this article is to present a general instrumental methodology for determining value indicators with an application to natural resources and ecosystems. The article is guided by the work of four instrumentalists; John Dewey, Fagg Foster, James Swaney, and Richard Mattessich, who reject the possibility of valuation via a market price criterion and who support transactional valuation. All four have offered overarching criteria and principles for valuation. In addition the article uses the knowledge base of the Social Fabric Matrix (SFM) and the principles of General System Analysis (GSA).

The author is Professor of Economics, University of Nebraska, Lincoln. *This article was delivered at the annual Association For Institutional Thought Meeting, Portland, Oregon, April 1990.*

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Valuation Measurement as Indicator Creation

Because this research is being completed to develop a set of methods for determining valuation measures, this section will be devoted to the conceptualization of measurement in a public policy context. It is important to structure valuation indicators so they will serve as a relevant instrument for the public purpose intended.

As we know, research should be context-specific. This rule should especially be heeded in policy research, and the research and measurement should be consistent with the relevant context. The context is defined by the problem. "An essential question to ask of any piece of policy research is: whose 'problem' is being investigated? A 'problem' in social science can mean one of various things" [Blumer 1982, p. 51]. What we identify as policy problems are determined by our cultural values and societal beliefs. Thus, the values and beliefs should be consistently applied in all aspects of the design and construction of policy research and measurement. As was emphasized in the social indicator movement that began in the 1960s, all useful measures are ultimately social. They are recognized as social indicators to indicate that they are relevant to some social context, rather than as ultimate "measures" having universal applicability.

Kenneth Land stated that "a social indicator may be defined as a statistic of direct normative interest which facilitates concise, comprehensive, and balanced judgments" [Land 1970, p. 323]. Therefore, "the criterion for classifying a social statistic as a social indicator is its *informative value* which derives from its empirically verified nexus in a conceptualization of a social process" [Land 1970, p. 323]. "Social process" should be defined broadly as was conveyed, at about the same time that Land developed his criterion, by the interdisciplinary research group, the Technical Committee of the Water Resource Centers of the Thirteen Western States. The committee wrote that for social indicators to be completed in the area of water resources, it was necessary to have "an interdisciplinary team representing political science, geography philosophy, ecology, economics and engineering" [Technical Committee 1971, p. 1]. The committee's concept of "social" indicators was also broadly defined when they wrote "a social indicator is not necessarily defined according to the connotation of the word 'social.' . . . Consider the case of a commonly used measure of water quality: dissolved oxygen or DO" [Technical Committee 1971, p. 15]. The elements and components in a "social" system, which require the breadth of expertise envisioned by the Technical Committee in order to design and complete indicators, have been articulated in the SFM and GSA

literature. For now, it is important to recognize that policy indicators should be developed consistent with the problem, the relevant system, and the social belief criteria.

Indicator Design Standards

Therefore, to design relevant indicators, the following measurement standards, which were summarized from John Dewey in an earlier article by the author [Hayden 1983] should be applied.

1. *Consistent with Problem*: Indicators must be consistent with the needs of the socioecological problem being pursued. Indicators should not be recycled data collected for other purposes.
2. *Not Necessarily Numerical Form*: Indicators are not all in numerical form.
3. *System Quantification*: Mere separation of discrete objects is not the basis of numerical identity. Quantification should be designed to express a system.
4. *Aggregation*: Aggregation of discrete objects is not a case of measuring, but mere counting. Until a system is defined, quantification leads to indeterminate or incommensurable aggregates.
5. *Limiting*: Social measurement must be relative and limiting—relative to the system and expressing the limits required by all systems.
6. *Systems Characteristics*: Systems principles of arrangement and order should guide numerical expression. Thus, the data system should be designed to articulate patterns, sequences, ordering, and linkages.
7. *Integrated*: It is important to remember that, in reality, systems are not disintegrated. Environmental conditions, institutions, and organisms exist only as a synthetic whole.
8. *Non-social Entities*: System specification must include physical and biological laws and their interactions along with technology.
9. *Site-specific Ecology*: System specification must also include conditions like soil, sea, mountains and climate—the environment in general. Thus, a social indicator system should be a geobased data system.

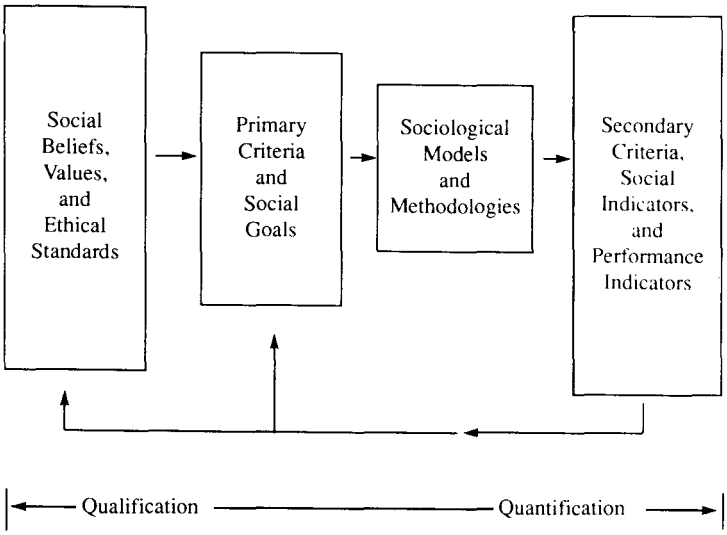
Policy Analysis Paradigm

Figure 1 is a schematic representation of a policy analysis paradigm consistent with the work of Thorstein Veblen, which follows the lead of the policy scientist, Yehezkel Dror [Dror 1968 and 1986], for designing indicators intended to serve the purposes of public policy.[2] Figure 1 demonstrates that social indicators are designed as the secondary cri-

teria for the more primary criteria. The primary criteria are the social policy goals that follow from the societal beliefs, values, and ethical standards. Fact finding cannot be separated from beliefs and values. Dan McGill has emphasized this point in this book, *Social Investing.* He says that "the realm of fact can be neither defined nor specified without using certain values, that it is impossible to stand firmly on the fact side of the fact-value distinction, while treating the other as vaporous, and finally, that the same processes which carve facts out of undifferentiated unconceptualized stuff also carve out the values" [McGill 1984, pp. 3–4]. Figure 1 reflects the concept of measurement as a spectrum from qualification to quantification as explained by John Dewey. For example, a society with a cultural value that stresses dynamic individual action will have policy goals for good health. Thus, to assess public health programs, it is necessary to design operational measures (secondary criteria) such as the number of hospital beds per thousand of population, the change in the disease level, and so forth.

It is important, as Roland McKean clarified long ago, that the indicator be consistent with the primary goal, because *operationally* the indicator becomes the public policy decision criterion [McKean 1967]. It is possible conceptually to distinguish between primary and secondary criteria, but operationally it is not. The secondary criteria become *the*

Figure 1. Policy Analysis Paradigm



action criteria. A primary goal of, let us say, an efficient engine, differs greatly in reality depending on whether one uses a horsepower or pollution indicator, and educational quality differs greatly depending on whether one uses an expenditure per student or a standardized test score as the indicator. In reality the policy indicators, if applied, determine the final goal. Therefore, it is important to understand that valuation indicators for assessing the various impacts on natural resources be consistent with the July 1989 opinion of the U.S. Court of Appeals, District of Columbia, which stated " 'efficiency', standing alone, simply means that the chosen policy will dictate the result that achieves the greatest value to society. Whether a particular choice is efficient depends on *how the various alternatives are valued*" *[State of Ohio v. Department of the Interior* 1989, p. 456].

Figure 1 also demonstrates that the kind of indicators compiled depends on the socioecological model or methodology utilized. As Kenneth Land's quote above stipulated, an indicator derives its legitimacy as an informative tool from being empirically verified in a model. It would therefore be necessary, as indicated in Figure 1, for the models and methodologies to be consistent with the primary social criteria and goals. "The social scientist's choice of problem is given exact form when he or she comes to define and specify the concepts to be used in a particular study" [Blumer 1982, p. 52]. As Richard B. Norgaard and John A. Dixon explain, ecological models should include both social and ecological systems [Norgaard and Dixon 1986]. Figure 1 includes a "feedback loop" from the secondary indicators back to beliefs, legal authority, and primary criteria in order to reflect that in public policy-making, the secondary indicators will provide negative or positive information feedback to those entities.

Indicator concerns today are, therefore, system measures instead of just inputs and outputs. Thus, model methodologies need to be measured against the system criteria to determine their adequacy. The methodologies need to be combined in such a way as to allow for the determination of system attributes such as structure, linkages, deliveries, and control mechanisms. If there is a concern for restoration of a damaged ecosystem, for example, the functioning of those system attributes is valuable for restoration and therefore needs to be ferreted out through the methodologies. Indicators can, from a system point of view, be catergorized as follows:

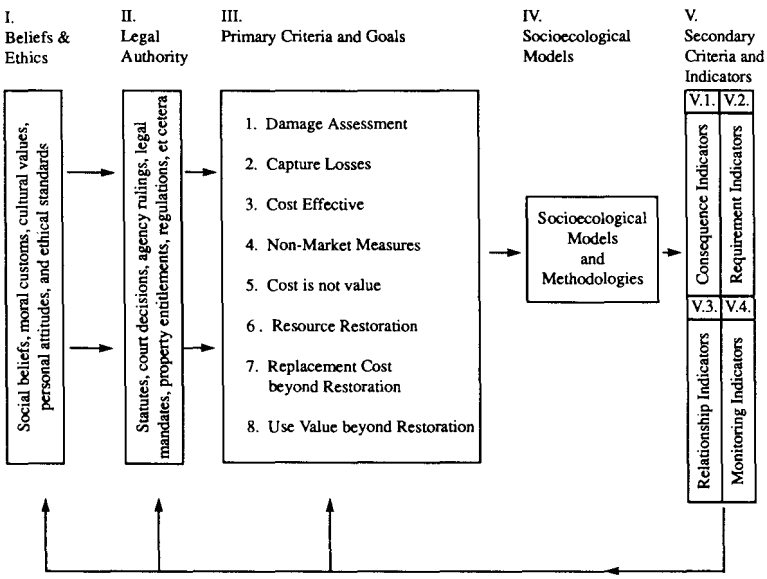
1) *Consequence*, or impact indicators, which are designed to measure the results of policies, or damages, or ongoing system processes;

2) *Requirement* indicators, which measure the contributions to the system of the required system elements;
3) *Relationship*, or linkage, indicators which measure the relationships and congruency among system elements and components;
4) *Monitoring* indicators, which are selected to provide information on some part of a system, especially after policy initiatives, to determine if system value has been maintained; for example, after ecosystem restoration actions.

Figure 2 is an elaboration of Figure 1 for an application to natural resource impacts. In Figure 2, the Social Beliefs section of Figure 1 is divided into two parts. Part I is the Beliefs and Ethics section, and Part II is the Legal Authority. Legal Authority concerns have been developed consistent with social beliefs, especially as expressed by Congress, and in turn, the primary social criteria have been developed consistent with Legal Authority. A listing of primary indicators is contained in Part III of Figure 2. The valuation indicators resulting from applied methodologies are indicated in Part V. The categories of secondary indicators in Part V will depend on the problem and the methodology being used to generate the data.

The primary criteria listed in Figure 2, and explained below, have been developed after studying sources such as statutes, court opinions,

Figure 2. Policy Analysis Paradigm: Socioecological Indicators



policy statements, and scientific literature. (See for example the Comprehensive Environmental Response, Compensation and Liability Act [CERCLA], Superfund Amendments and Reauthorization Act [SARA], and *State of Ohio v. U.S. Department of the Interior 1989.*) Under the overarching goal to protect natural resources, the following primary criteria are available for defining the costs in the case of hazardous waste damage to natural resources.

1. *Damage Assessment*: To develop standardized techniques for assessing both the biological and economic damages from releases of hazardous substances.
2. *Capture Losses*: To capture fully all aspects of loss in determining damages, including both direct and indirect injury, destruction, or loss, and taking into consideration factors including, but not limited to, replacement, use value, and the ability of the ecosystem or resource to recover.
3. *Cost-Effective*: To select remedial actions that provide for cost-effective actions. The required costs include the total short- and long-term costs of such actions, including the costs of operation and maintenance for the entire period during which such remedial activities are necessary.
4. *Non-Market Measures*: To employ non-market measures for the value of natural resources because natural resources have value not measured by traditional means.
5. *Cost is Not Value*: To not view market (or cost-benefit) value and restoration cost as being equal or as having equal presumptive legitimacy. Traditional means of value is not consistent with the measurement of restoration costs.
6. *Resource Restoration*: To recover all costs necessary to restore the habitat and its inhabitants to the condition they were in before the release of the hazardous substance. For example, if the spill of a hazardous substance kills a rookery of seals and destroys a habitat for seabirds at a sealife reserve, then complete restoration is the intent; to make whole the natural resources that suffered injury from release of the hazardous substance. Such damages are to include both direct and indirect injury, destruction, or loss, and are to take into consideration factors including but not limited to replacement value, use value, and the ability of the ecosystem or resource to recover.
7. *Replacement Cost*: To recover replacement costs beyond restoration costs if applicable. The excess over restoration costs must be used to acquire the equivalent of the damaged resource—even though the original resource will eventually be restored. This cost

is to cover whatever must stand in for the injured resource while restoration is under way. Flows of services provided to the public by the resource may be curtailed long after the physical, chemical, or biological injury has abated. If a damaged forest is replanted with small trees, many years will pass before a mature forest emerges.

8. *Use Value*: To recover interim use values beyond restoration if applicable. The measures of damages must not only be sufficient to cover the intended restoration or replacement uses in the usual case, but may in some cases exceed that level by incorporating interim lost use values of the damaged resources from the time of the release up to the time of restoration. Use value is to be limited to "committed use," which means a current public use or a planned public use. This avoids the need for unreliable, and likely self-serving, speculation regarding future possible uses. Option and existence values are included as use values.

To accomplish the goals elucidated by the primary criteria, numerous measures must be developed. Several aspects of wildlife habitat defy market valuation, and information regarding the value of habitats is necessary to take full account of the impact of regulations and policies on the environment. Neither one measure nor one category of measures is sufficient to express or value system goals, nor can any one measure or concept serve as a common denominator for all the diverse indicators required.

Over the years, various groups have proposed various indicators to serve as the single measure or the common denominator function. These have included monetary prices, BTUs, protein ratios of the food chain, hours of leisure time, and so forth. Each of these failed to meet such an impossible standard. The failure of BTUs, as even a measure of an energy system, can serve as an example.

> Not all forms of energy are the same. Some forms of energy such as nuclear fission, electricity, or gasoline are quite concentrated or of high quality. These forms can perform a lot of useful work per pound or cubic foot of material. Other forms, such as sunshine, tides, wind, low temperature heat, are somewhat dilute and spread out over a large surface or volume. These forms do not have much useful work to offer, even though the total amount of energy might be the same as for a more concentrated form. Thus, in combining and evaluating the contributions of various systems, it is important that equivalent forms of energy be used. This is analogous to the old saying that we cannot add apples and pears. Likewise, we cannot add sunshine BTUs or kilocalories to gasoline BTUs or kilocalories and expect the total to accurately reflect the amount of work that can be done by that energy [Rohrlich 1976, p. 274].

Like BTUs, all dollars are not of the same value, so they cannot necessarily be added. Thus, it is important for policy scientists to develop methodologies that will allow for the generation of the indicators consistent with social goals.

Valuation

James Swaney's idea of *coevolutionary sustainability* means that development paths or technological applications that pose serious threats to long-run compatibility and sustainability of sociosystem and ecosystem evolution should be avoided. [Swaney 1987, p. 1750]. "Coevolutionary sustainability explicitly recognizes that environmental systems evolve interdependently along development paths that may or may not be sustainable" [Swaney 1987, p. 1750]. Thus when valuing alternative development programs, or ecological restoration projects, or technology applications, the higher the level of coevolutionary sustainability, the greater the value of the program project, or application. Such valuation can only be accomplished within a socioecological framework.

As outlined above in Figures 1 and 2, before indicators can be found, models of the real world must be used. The valuation methods designed below employ the Social Fabric Matrix (SFM) [Hayden 1982] because it can be used to detail the entities that contribute to a system. That contribution is a basis for valuing a system and its parts. As has been clarified, there is no common denominator that provides one measuring mechanism for a system. The relationships and entities of a system, for example, an agroecosystem, call for an array of different kinds of measures in order to define and evaluate the system. With such an array, it will be possible to focus on the evaluation of alternative policy concerns. The idea behind the current U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) project (on which the author has been a consultant) is to establish indicators to evaluate an agroecosystem. EMAP is currently considering an array of indicators to be used for evaluating agreoecosystems, including the integration of human agricultural systems and the natural environment to which they are connected. Currently under consideration in that array of indicators are the following: agricultural exports such as pesticides, sediments, and food contaminants; resource modification such as changes in species diversity, and changes in land use patterns; sustainability indicators like indications on tillage practices and soil organic matter content; contamination indicators like pesticide residues (in soil, water, and animals), biomarkers, and heavy metal concentrations; and socioeconomic

indicators such as farm income and population shifts. Dollar income is included, but not as *the* measure; rather, as one of many indicators.

A SFM analysis provides a wealth of information for the valuation process. The purpose of valuation is to determine what is better and worse, what is improvement, and what is degradation. As systems philosopher Richard Mattessich has stated, "to answer the question of how to improve the system, one needs criteria for and measures of effectiveness" [Mattessich 1978, p. 290]. A number of socioecosystem criteria concerns and norms, such as biodiversity and restoration, will be discussed next. First we consider the norms and control mechanisms of the system.

Norms and Control Valuation

Richard Mattessich has explained that *"a system has a goal or purpose either* (1) *because the inner or mentalistic aspect of the system is developed highly enough so that norms emerge out of this system . . . or* (2) *because some norms are imposed, in one form or the other, from outside upon the system"* [Mattessich 1978, p. 289]. The SFM can be used to document and demonstrate the importance of both kinds of norms. As social and ecological systems develop, entities with control properties develop to normalize relations and deliveries in the system—for example, social belief criteria and natural control mechanisms. In addition, policy control mechanisms are included as part of the system and in the SFM description. Mattessich and others have stated that these norms and criteria are the most important entities in the system. Thus, *their condition and ability to guide* must be evaluated.

If these norms and criteria are unable to work because of a paucity or abundance of deliveries, they are of less value. For example, the control mechanisms of an oceanic system may be misfiring because they are overwhelmed with an excess delivery of urban sewage. As another example, recent evidence indicates that farmers in Iowa have strong belief criteria to protect the ground water, yet they are polluting it through the use of farm chemicals because their ability to deliver consistent with their beliefs is hampered by the inadequacy of financial, educational, and institutional flows. The condition and welfare of the norms and control mechanisms are important, and their effectiveness can be evaluated through the SFM.

The SFM can be used to determine the effectiveness of the normalization controls by measuring the system flows that result from those norms. The relative value of the controls is determined by the degree

to which the system is functioning according to a normalized flow. Standard techniques can be used to determine the "goodness of fit" or deviation from the norm.

Biodiversity Valuation

There is a concern for biodiversity in ecosystems—the number of different kinds of species, the inventory of the species, and the redundancy through equifinality. The SFM approach provides information on all three. Species would be an element in the matrix in some cases, and in other cases a cell delivery—as, for example, a river delivering fish. In order to know either how much the species delivers to another element, or how much of the species is being delivered, it would be necessary to have information on the kind and number of species. Once the basic SFM and digraph are constructed, the computer can be instructed to list the species and sum their inventory. It will therefore be possible to value ecosystems with regard to biodiversity and to determine whether there are too many or too few of a species, consistent with the carrying capacity of the ecosystem.

It will also be possible to determine the degree of equifinality redundancy (how many paths are available to fulfill system goals). If there are more paths for maintaining species, the *system* is more valuable from a biodiversity valuation criterion point of view.

Stability Valuation

Two types of stability valuation are of interest—the stability of the system as indicated by the vulnerability of the components and elements within, and the vulnerability of the system as a whole.

With regard to the first, the SFM digraph can be used to rank the most important relationships and "nerve" centers within a system. By valuing the importance of the centers within the system, system vulnerability can be ascertained. If the system becomes more vulnerable through the destruction of one node over another, then that one is more valuable than the others. The SFM can be used to measure the relative importance of the elements and nodes (elements and component) within a system by adding all the 1's in the rows and columns in the boolean matrix (Figure 3). The greater the number of 1's in a row, the more deliveries that element is making to other elements. Or, stated differently, the more 1's in the row, the more other elements depend on that element. The greater the number of 1's in a column, the more

Figure 3. *Boolean Matrix*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0
4	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0
5	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
6	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0
8	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0
9	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0
10	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0
11	1	1	1	1	1	0	1	1	1	0	1	0	0	0	0
12	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0
13	1	1	0	1	1	0	0	0	1	0	0	0	1	0	0
14	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0
15	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0

that element is receiving from other elements. Others cannot continue to function (process deliveries) if that element cannot continue to receive.

While the greater centricity of a system gives the central node in a system more value, the greater centricity makes the system more vulnerable. There is literature to suggest that more diversified ecosystems are more stable. Following from that, it is possible to compare the stability of systems by comparing their degree of centricity in the SFM digraph. If a system is more centrally organized, it is more vulnerable, and therefore less valuable. This can be determined by counting the number of elements and nodes. If two systems are the same except that one has a few large nodes upon which the system is dependent, then it is less valuable.

Ecodevelopment Valuation

Ecodevelopment is the coevolutionary approach committed to economic development consistent with ecological sustainability; to an "integrated coevolution of conscious civilization and nature" [Colby 1989, p. 22]. It "connotes an explicit reorientation and upgrading of the level

of integration of social, ecological and economic concerns in planning" [Colby 1989, p. 22].

The valuation guide for ecodevelopment is found by combining the concepts of *earmarking* presented by Karl Polanyi, and *minimal dislocation* presented by Fagg Foster; and designing an application to the socioecological system. Polanyi said sufficiency "is determined with the help of the simple operation of 'earmarking', which demonstrates whether there is or is not enough to go round" [Polanyi 1957, p. 246]. Foster's principle of minimal dislocation can be modified as indicated below to be consistent with the ecodevelopment context. Minimal dislocation "connotes the relationship between the current institutional [and ecological] pattern and proposed adjustments. The relationship is one of limitations. . . . Typically, among alternative choices, the one chosen is the one that least dislocates the institutional [and ecological] structures which are not . . . " part of the economic or technological development alternative being evaluated [Foster 1981b, p. 941]. "Modifications can not stand alone; they must be incorporated into the institutional [and environmental] structure of which they are parts. And this circumstance sets certain limitations on the rapidity and extent of institutional [and environmental] adjustments" [Foster 1981a, p. 934].

From the SFM data base, a normalized flow that must be maintained can be determined, and that normalized value can be used to evaluate alternative economic production projects that are being introduced to transform a socioecosystem. No new production project can be introduced without disrupting an ecosystem; thus, some of the normalized flows will have to change. However, by normalizing the flows in the SFM digraph and establishing a spectrum around that norm to establish how far it is safe for the system to deviate, different projects can be judged according to their "goodness of fit." The less the new project deviates from the normalized system, the greater its value. It may, of course, be decided that changes can be made in the original ecosystem, thereby establishing a new norm. Making judgments based on deviations from a normalized flow is consistent with Karl Polanyi's earmarking.

A simplified illustration is contained in Figure 4. Only a simplified digraph can be so illustrated in two dimensions. Assume a system as contained in Figure 4 with 2, 3, 5, 7, and 11 representing system elements and E representing the system environment (which is not under direct study). The digraph elements from Figure 4 can be placed on an axis as in Figure 5 with the normalized flow level for each node in-

dicated, including the environmental input and output necessary to keep the environment functioning. Each dot on the graph represents a different delivery level. The dots placed on the axis are not quantitative indicators; they represent qualitative indicators like criteria. The flow level in Figure 5 can be normalized along the axis in Figure 6, as indicated by the dots. That is, the dots in Figure 6 are equivalent and represent those in Figure 5.

Figure 4. *Simple SFM Digraph*

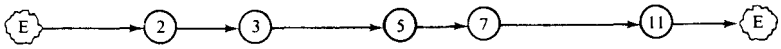
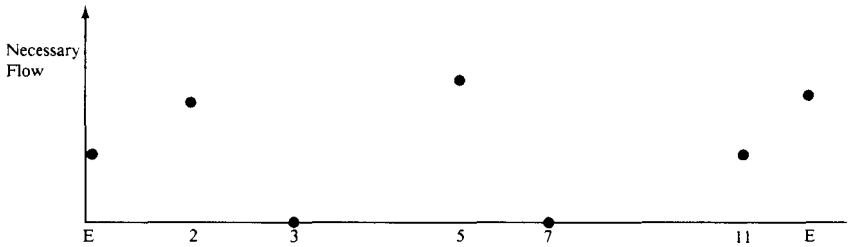


Figure 5. *Necessary Level for System Feasibility*



If there are two different characteristics or dimensions to be measured for each delivery, the axes above and below the normalized level are positive in order to determine how much a project's trajectory deviates from the normalized feasibility level. In all systems, there is a spectrum of permissible deviation from the norm. The critical threshold level is the extreme extent of deviation allowable. It is indicated by

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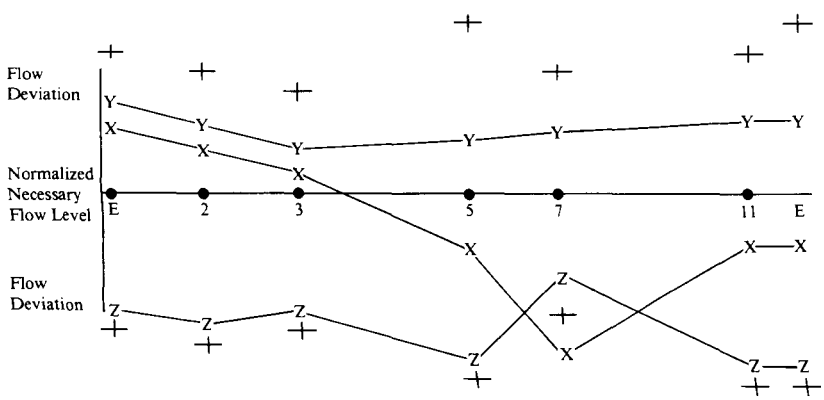
+ in Figure 6. Some of these will be quality indicators, for example, in the case of criteria and requirements, and others will be quantity indicators. This is not a maximization construct as insisted upon by neoclassicalists. The quantity flow can be too great a surplus, as with excess pollution from an industry or excess numbers in animal flocks when a predator is removed; or too small a flow, as when the flow of a species in a food chain is decreased. Alternatives *X*, *Y*, and *Z* in Figure 6 represent three different ecodevelopment projects. They can be ranked according to their deviation from the normalized flow. The deviation can be determined by the difference (distance) between the project trajectories and the system sequence axis, except in those cases where the trajectory penetrates the critical level represented by +. No project is acceptable that is outside the critical threshold. As Foster stated, "projections must do no violence to the factors not considered problematic" [Foster 1981a, p. 934]. This would eliminate *X*, even though generally it conforms most closely to the normalized system sequence axis. The idea is to fit a selected norm, represented by the horizontal axis, rather than to maximize a function from the axis. As is obvious, Project *Y* is the best fit, and therefore is evaluated to have the greatest value to the system.

Figure 6. *Level of Deviations of Alternate Programs*



It may, of course, be decided to change the system flows from the original. If so, the same procedure could be followed with a new selected delivery level. The SFM data base could be used to indicate the impacts of the new flow levels throughout the system. A complex digraph system that conveys real world complexity is not displayed; however, the idea is the same as in the simple case displayed in Figure 6. For each delivery upon which an economic project will impact, whether quantitative or qualitative, the normal delivery needs to be established and the project's deviation from it determined. If the project falls within the critical threshold, it is acceptable; if it best fits the overall normalized flow levels, it is the most efficient. Every project has a multitude of impacts, and they should be considred in a systems approach to minimize transformation costs.

Restoration Costs

The establishment of restoration costs to restore a damaged ecosystem is not a case of valuation. It is an operational action to convert the damages into a budget sufficient for restoration. The July 1989 ruling in *State of Ohio v. U.S. Department of the Interior* on this subject is consistent with this view. The Court stated, "restoration is the proper remedy for injury to property where measurement of damages by some other method will fail to compensate fully for the injury. Congress's refusal to view use value and restoration value as having equal presumptive legitimacy merely recognizes that natural resources have value that is not readily measured by traditional means" [*State of Ohio v. U.S. Department of the Interior* 1989, pp. 456–57].

Restoration costs are not even necessarily market costs in the sense that the prices to be paid for the equipment, labor, and materials were established by a competitive private market system. Some prices are explicitly governmental through price regulation; others by indirect governmental impacts through subsidies and taxes; and others are charges by other government agencies to do the cleanup. In addition, many of the private sector prices are determined in an oligopolistic setting. Restoration costs are a matter of determining "shelf" prices to get the job done. A SFM digraph model of an ecosystem can be helpful in tracing the indirect impacts of a toxic or hazardous substance spill to help trace how the spill is delivered through the system, and therefore all the costs that must be undertaken for restoration.

Restoration Valuation

Restoration valuation is different from restoration cost. The valua-

tion aspects of system restoration can be completed with the SFM. First is the selection of the optimal restoration alternative (restoration ecodevelopment). Restoration projects themselves can also change an environment. Thus, they should be judged as outlined above in the section on *Ecodevelopment Valuation.* The optimal restoration alternative is the one that generates flows to return the ecosystem to its original purpose and structure without creating other adverse deliveries outside the threshold level for the system.

The second valuation aspect of restoration is to minimize the use of resources in the cleanup. The SFM offers digraphs to illustrate alternative paths that exist to accomplish the same purpose and maintain the ecosystem's capacity. Therefore, if one path is damaged, there is yet a redundancy of equifinality paths, it may be that the ecosystem will be able to fulfill its goal without using as many resources. The remaining paths will allow the system to function without repair. Secondly, the SFM provides means for boolean-generated hypothetical delivery paths. Some of those paths may appear feasible and viable, and therefore could be tested against other alternatives to determine if they are more valuable restoration alternatives.

If budgets are limited, ecological improvements can be ranked according to these valuation concepts. However, before they can be used, judgments will have to be made. For example, is the budget going to be divided among ecosystems or among important parts of ecosystems? SFM valuation methodologies provide helpful information, but basic decisions from policymakers are still necessary.

Ending Note

This article has designed valuation methods to fulfill instrumental criteria as they apply to the evaluation of socioecosystems and natural resources. As Charles W. Anderson wrote, "the *achievement* of reliable knowledge and performance implies prescriptive methodology, consensus on basic standards among practitioners" [Anderson 1990, p. 40]. The prescriptive methodology designed here includes the means to conduct valuation of: 1) norms and control properties, 2) biodiversity, 3) ecodevelopment, 4) restoration costs, and 5) system restoration. These valuation techniques have been designed so instrumentalists can develop inquiry procedures, skills, and workmanship to inform policymakers on issues of socioecosystem valuation.

Notes

1. Beldon Daniels has discussed the early draft of this work with the author.
2. This schematic representation was originally presented in: Hayden, F. Gregory. 1989. "Public Pension Power for Socioeconomic Investments." *Journal of Economic Investments* 23 (December): 1027–45.

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