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The Analysis of Decision Making: Alternative Applications in Archaeology

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Anthropologists should study Economics and vice versa. I do agree with Gluckman that this should be done not to make the anthropologist an economist, but a better anthropologist. Given economic tools, he will improve anthropology. Give an economist the anthropological tools of sensitivity to what people say and of readiness to try to see order in different conceptual systems, and he may improve economics.

Richard Salisbury

Do I contradict myself? Very well then, I contradict myself. I am large, and I contain multitudes.

Walt Whitman

Much archaeological investigation focuses on the discovery of patterning in archaeological evidence, and the explanation of such patterning as the result of human actions and site formation processes. Ultimately, however, this level of analysis serves only as an intermediary to larger, theoretical questions of the nature of the human actions that gave rise to the patterns.

The diversity of theories explaining human actions define a continuum with respect to the impact of human decisions on behavioral patterning. At one end are largely traditional theories, stressing the constraints placed on human action by social, cultural, or biological processes. In archaeology these have their most forceful expression in various classificatory or typological ap-

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proaches, to both archaeological materials and the behavior that generated them. At the other end are theories that focus on individual and group choice making.

In this chapter regularities in choice making are seen as the fundamental process underlying the regularities of human behavior, and thus, much of archaeological patterning. Unlike previous archaeological applications of economic theory, however, the approach taken here is more general, emphasizing a diversity of theoretical and methodological frameworks to be used in varying contexts, yet integrated within a single general theory of rational choice.

Many theories of human decision making, which previously have been applied in archaeology, derive largely from economic geography and/or marginalist economic literature. These theories often require major assumptions to be made about the information-processing ability and calculation capability of the prehistoric peoples being studied. Methodologies based on these theories commonly require data not obviously consistent with "non-market" economies. At the other extreme, many archaeologists, rightly dissatisfied with the magnitude and implications of these assumptions and data requirements, have proposed alternatives, such as the "satisficer" approach.

In this chapter an intermediate view is proposed: that previous problems in the application of economic theory to prehistoric (or nonwestern) situations result largely from the attempt to apply not a general theory of "rational economic man" but a specific theory of "marginal economic man." From this perspective, this chapter has four purposes:

1) The basic concepts and axioms of a truly general theory of rational choice will be introduced. It will be shown that this theory, with the variation of certain of its parameters, is capable of being transformed into a continuum of more specific economic theories: the marginalist stance, applicable to market economies at one end, and other approaches more appropriate to "non-market" economies at the other. The different theories posit different structures of the rational choice process, dependent on the information access and measurement capabilities of the decision units.

2) The concepts of marginalism, satisficing man, and least effort will be placed in a historic perspective within the literature of economics and anthropology. This will clarify where arguments for and against these frameworks currently being made by archaeologists—many of whom are apparently unaware of the history of these ideas—are misguided, too narrow, or out of date.

3) It will be shown that the inclusiveness and flexibility of general choice theory can be operationalized through a variety of analytical methods consistent with various structures of rational choice. This is one of the most powerful aspects of the economic approach.

4) Recent economic studies in archaeology illustrating the various analytical methods will be discussed and then evaluated for the logical consis-

tency between the methods used, the specific manifestation of rational choice theory assumed, and the nature of their data.

In viewing the history of development of economic theory and its adoption first in social and cultural anthropology and then in archaeology, the simple sequence of events clearly indicates the excellent future potential of rational choice theories in archaeology. In the same way that the precepts of logical positivism swept first through chemistry and physics, then through the social sciences, and inevitably led to the "new archaeology," a similar ordering pertains to rational choice. In the case of logical positivism, it is clear that archaeologists rushed to the polemic ramparts even as the physicists were realizing its weaknesses and attempting to develop a new synthesis, integrating positivist rigor and order with an almost metaphysical humility in the face of the awesome complexity of atomic particles. We as archaeologists should be particularly skilled at learning from hindsight and be cautious not to again grasp a falling standard of the intellectual battlefield. Rather, we can hope, as we view the potential of rational choice theories, that our desire for precision and rigor does not blind us to the even more troubling complexities of human behavior. It is in this context that the following is presented.

A PHILOSOPHICAL PERSPECTIVE: FUNDAMENTAL CHARACTERISTICS OF ANY THEORY RELEVANT TO ARCHAEOLOGY

To be parsimonious and testable with archaeological data, a theory of rational choice, like any theory, must have characteristics that are more restrictive than those of the theories of other scientific disciplines. This restriction results from certain limitations inherent in archaeological data. First, the archaeological context provides few, if any, possibilities for controlled experimentation to be used in testing the propositions deduced from a theory. It is difficult enough to isolate and estimate behavioral variables and parameters from archaeological measures, let alone hold them constant. For example, in most archaeological data sets, the variable, time, cannot be controlled well. Chronometric control sufficient to isolate data suitable for time-series or cross sectional analysis is rarely feasible (cf. Wolfman, 1983; Braun, chapter 16). Thus, an archaeologically relevant theory must be of a form that allows its testing in a manner different from controlled experimentation.

Second, because archaeological materials at a particular location may have derived from different activities at different times, yet cannot easily be assigned after the fact to different times, a few processes can generate a great diversity of site forms in various combinations. For example, from the two kinds of processes, settlement by nut processors and settlement by deer hunters, three kinds of sites can be produced: those indicating only nut processing, those indicating only deer hunting, and those indicating both as a result of alternate settlement of the same locations by nut processors and then deer hunters. The complexity increases exponentially with the number of disjoint activities considered. Thus, theories dealing with the *form* of archaeological remains are apt to be less parsimonious than those dealing with the *processes* by which archaeological remains are generated. An archaeologically relevant theory, then, should focus on behavioral process rather than archaeological form.

These two characteristics of an archaeologically relevant theory are met by the characteristics of Fredric Barth's "generative" theory:

> . . . form in social life is constituted by a series of regularities in a large body of individual items of behavior. Much effort in social anthropology has been concentrated on the necessary step of constructing models or patterns descriptive of such forms, whereby structural features of the society are exhibited. The kinds of models which I discuss here are of a different kind. They are not designed to be homologous with observed social regularities; instead they are designed so that they, by specific operations, can *generate* such regularities or forms. They should be constituted of a limited number of clearly abstracted parts, the magnitude or constellations of which can be varied, so that one model can be made to produce a *number of different forms*. Thus by a series of logical operations, forms can be generated, these forms may be compared to empirical forms of social systems, and where there is correspondence in formal feature between the two, the empirical form may be characterized as a particular constellation of the variables in the model (Barth, 1966, p. v).

Barth goes on to note that "the logical operations should mirror actual, empirical processes which can be identified in the reality being analyzed" (1966, p. v). Such theories permit explanation of forms because they deal with the generative processes underlying forms.

Moreover, a generative theory, in generating forms and thus implying what forms are "possible" and "impossible," defines a set of hypotheses that may be used to falsify the theory (or portions of it) with comparative data (1966, pp. v-vi). This process has the methodological equivalent of controlled experimentation, which is necessary for theory testing and modification.

Generative theories have additional assets. In generating multiple forms, the evaluation process can be based on the comparison of the degree of contradiction of two or more alternative hypotheses with the data, rather than a situation in which one either accepts or rejects the single alternative (Dean, 1978, p. 113). The existence of two or more alternatives can serve to remove the possibility of fixation on one approach which the researcher feels bound to support.

In addition to the properties proposed by Barth, an essential feature of an effective generative theory should include the ability to structure an axiomatic or algorithmic form (model). As von Bertalanffy has so cogently noted:

> . . . an algorithm . . . wins a life of its own as it were. It becomes a thinking machine, and once the proper instructions are fed in, the machine runs by itself, yielding unexpected results that surpass the initial amount of facts and given rules, and are thus unforeseeable by the limited intellect who originally has created the machine. (1955, p. 259).

The structuring of the generative theory as an axiom or algorithm has a number of significant implications, including precise stipulation of the parameters, variables, and relationships even when the solution generated lacks such precisions (Clarke, 1972, p. 35; Keene, chapter 10).

Like all theories, a generative theory should have several additional characteristics. First, it should produce "unpredictable" predictions. Second, the predictions should be capable of refutation. If the generative theory predicts circumstances which either must always exist by definition, or alternately, have no operationalizable means of refutation, then the theory is inappropriate. As Friedman (1953) has stressed, this refutability or capability of contradiction is essential. Third, the theory should be "explanatory" rather than "descriptive." As Clarke has cogently pointed out (though perhaps with another goal in mind) it would be possible to formulate a theory which, based on prior knowledge of the factors to be considered, "predicts" what is known (1972, p. 2). As a practical example, an archaeologist finding that sites in an area are often close to water sources might "predict" that all sites are close to water. Finally, the axiomatic or algorithmic representation of a generative theory must be a simplified analogy of reality, following Occam's Razor. Belief that the algorithmic representation of a generative theory is identical with the processual details of reality is "a methodological fallacy" (Machlup, 1967, p. 11). In the case of rational choice theory, it would be a mistake to equate a mathematical model of the decision-making process with the mental processes or group dynamics involved in such behavior (Arrow, 1951).

A GENERAL THEORY OF RATIONAL CHOICE

In this section, a general theory of rational choice, concordant with the characteristics of an effective generative theory as just described, will be introduced. The theory is essentially that derived by Arrow (1951) and discussed by Walsh (1970). The theory does not imply the constraints of the marginalist approach, though its parameters may be defined so as to generate this approach. To illustrate the concepts to be introduced, the process of settlement location selection will be used. Any decision area, however, could have been considered.

Preference, Ordering, and Selection

The basic proposition of a general theory of rational choice is that individuals and groups order or rank alternative courses of action into sets, termed *preference* *sets*. Selection of an alternative then is made from the highest ordered preference set that is *attainable*. This simple statement defines the essential features of "rational" choice: preference, ordering, and selection.

Sets

The set of all alternatives is termed the *global choice set*. Using the settlement selection process as an example, the global choice set would simply include all locations in the area of study.

All alternatives in the global set can be *partitioned* or divided into *attainable* and *unattainable* sets. These two sets are subsets of the global set, and membership in either is based on the *givens* or structural parameters of the situation. For example, consider the partitioning of a group of locations into attainable and unattainable sets on the basis of the attainability of the nut resources that they support. For a particular processing technique (e.g., hand cracking of nuts using nutting stones), we can propose that the time/effort involved in processing nuts, as well as transportation costs, cause only locations within 8 km of the nut groves to be within our example's attainable set. Clearly what is attainable is potentially alterable, as the givens change. If a new technology allowing more rapid processing of nuts or more rapid transportation became available, then our previous attainable set of locations would be substantially increased. This seemingly obvious idea has great potential for archaeology because, at any particular point in time, one of the primary elements in defining at least material attainable sets is available technology.

Because of this relationship between attainability and parameters such as technology, rational choice theory has the necessary concurrent aspects of synchrony and diachrony needed in an archaeologically relevant theory. When the parameters are held constant, the theory is primarily synchronic. As the parameters are permitted or caused to vary, the approach can become dischronic. For archaeology, which deals with both temporal and spatial variation, it is desirable to avoid theoretical frameworks in which a different theory is required in different situations—a diachronic theory versus a synchronic one. Rational choice theory subsumes both.

The formal notation of set theory can be used to organize these intuitive ideas. First, the set of all x in the choice set that are attainable can be indicated by

$$(x \in C \,/\, Ax)$$

where C is the global choice set. A is the property of attainability. Conversely, the unattainable x comprise the set

$$(x \in C \,/\, -Ax)$$

Using set notation, preference and indifference relationships can also be proposed. These are:

$$(1)\ x_0\ P\ x_1$$
$$(2)\ x_0\ I\ x_2$$

In the first case we state that x_0 is *preferred* to x_1. If given the choice between x_0 and x_1, the chooser always will take x_0. In the second case, the chooser is *indifferent* to either x_0 or x_2. He sees no differences between x_0 and x_2 or finds the differences between the two of no merit. Thus, he will take either x_0 or x_2, and does not care which one. Over a series of choices, he might choose either x_0, or x_2 randomly. Note that the indifference relationship does not imply that x_0 and x_2 are *identical* (though they may be), only that the chooser is *indifferent* to whatever differences may exist.

A further concept that should be introduced at this point is *transitivity*:

$$\text{If } x_1\ P\ x_2 \text{ and } x_2\ P\ x_3$$
$$\text{then } x_1\ P\ x_3$$

In short this concept indicates a logical consistency.

Much more elegant and extensive discussions of the properties of rational choice are available in Walsh (1970, pp. 77-87) and Newman (1965, pp. 10-45). However, the fundamental, essential ones are illustrated above. The remainder of the theory can logically be derived largely from such simple axioms.

With these primitive relationships we can return to the original concept of the attainable set. This set can now be subdivided—partitioned—into a series of subsets, which can be placed in a preference order. In our example, we could define subset N_1 as all locations within close proximity to the nut source (e.g., 1-3 km), N_2 as those intermediate (e.g., 3-6 km), and N_3 as those distant (e.g., more than 6 km). This partitioning is based on the physical properties of the locations.

The next step is to *induce an ordering* based on the relative preference of the sets of locations. One obvious order would be

$$N_1\ P\ N_2 \text{ and } N_2\ P\ N_3$$

If this were the ordering, then any member of the subset N_1 would be selected, at random.

Physical Properties and Conditional Preference Aspects

Ordering of partitioned sets is based on the *conditional preference aspects* of the items in each set. A conditional preference aspect is a relevant choice-making characteristic of some physical property of an item; it is not isomorphic with the physical property. As an example, we can consider some potential, conditional preference aspects of the physical property, proximity to a permanent stream, for a location.

Physical Property	*Potential Conditional Preference Aspects*
Proximity to permanent stream	1) Access to domestic water 2) Access to transportation

3) Access to extensive aquatic food resources
4) Increased exposure to raiding parties

In short, a person does not prefer a location simply because of its physical properties. Rather a person prefers a location because of any single or combination of the conditional preference aspects of its physical properties.

A brief, intentionally simple example will illustrate the relevance of this distinction. If for a specific group of locations a significant preference aspect is access to transportation, then a number of physical properties might have the same choice-making aspects: nearness to a major overland trail, as well as proximity to a permanent stream. Conversely, locations near cut-off lakes with no outlets would be avoided. If we focus on only the physical property, nearness to permanent water, rather than the conditional preference aspect, access of transportation, then the fundamental choice-making *regularity* would be obscured. The apparently similar physical properties, proximity to a permanent stream and proximity to a cut-off lake with no outlet, have quite different conditional preference aspects. Again, we would be misled to focus on the physical properties.

Distinguishing a physical property from its conditional preference aspects emphasizes a further critical feature of the approach used here. The determination of a location's physical properties is essentially based on readily observable, *reproducible* physical referents. A physical feature of a location, such as number of meters from a water source, can be determined with equal facility by any individual. On the other hand, the assessment that, say, a high preference ordering is given to the conditional preference aspect, ease of access to domestic water, is not subject to similar easy evaluation.

Thus, reviewing the choice process, particular physical features are selected for partitioning the global choice set into subsets on the basis of their conditional preference aspects. The subsets are then ordered into a preference order based on the aspects defining them, and an alternative is selected from the highest attainable subset.

Dimensional and Primary Physical Properties

Some physical properties can be termed *dimensional* physical properties. A dimensional physical property is one in which the physical property is itself a complex variable including a number of *primary* physical properties. An example of a dimensional physical property is soil type.

Primary properties can, at least conceptually, be treated as isolated variables. It is possible to define all locations within, e.g., 100 meters of a domestic water supply, while concurrently holding the other primary variables constant, that is, controlling them independently. Dimensional variables, on the other hand, cannot be treated as isolated variables. A dimensional property can conceptually be decomposed into a number of primary physical variables, but these may not be controlled independently. This division of dimensional and primary physical properties to some extent parallels Plog et al.'s proposals for the separation of "intervening" and "independent" variables (1978, p. 183).

Production Frontiers and Trade-Offs

In our nut example, it might be preferable to choose either a location at which it is possible to produce the maximum nut harvest or one from which it is possible to achieve a desired level of harvest in the minimum time. Both preference aspects would give the same initial ordering of locations:

$$N_1 \, P \, N_2 \text{ and } N_2 \, P \, N_3$$

To create a more interesting example, we can propose that two features of a location are relevant to the decision process by adding a second resource, access to fish. With these two elements, it now becomes possible to make *trade-offs* in the preference ordering. Many locations near nut sources may be far from fish, and the converse. From a group of locations, production of various mixes of fish and nuts is possible. The production frontier (PF_1) shown on Figure 1 illustrates one array of possible combinations. From a subset of one or a group of locations, it may be possible to produce a maximum of 10 units of nuts but no fish (A), or 5 units of fish but no nuts (B), or various combinations such as at point C on PF_1, where eight units of nuts and one of fish are possible. All of the subsets of locations corresponding to the various production mixes along PF_1 are equally preferred with respect to the total production of calories they offer. For this conditional preference aspect, the decision unit would be indifferent to these alternatives. If additional aspects were involved, such as the preferable flavor of fish or nuts, then a new ordering would be appropriate.

A second group of locations, possibly at greater distances from the resources, have a lower production frontier, PF_2. At these locations, which again vary in the mix of nuts and fish they offer, a lower total caloric yield of nuts and fish may be produced. All the locations represented by PF_2 are less preferable than those represented by PF_1 with regard to the total production of calories they offer, but not necessarily in regard to the individual amounts of nuts or fish they offer.

Production of the mix of nuts and fish at point C on the production frontier may be attainable from *one* location or a *group* of locations, depending on the physical distributions of the resources. Thus, a number of different physical locations may correspond to a particular point on a curve. All the locations which correspond to a given point have the same conditional preference aspect for that combination of nuts and fish, though they, in fact, may be widely distributed across the landscape.

It is now possible to propose that certain constraints may be placed in the problem. Let us suppose that a particular level of protein is needed. Since both nuts and fish produce protein, though in differing proportions, a line can be drawn, DD_1, representing the various mixes of fish and nuts which have this

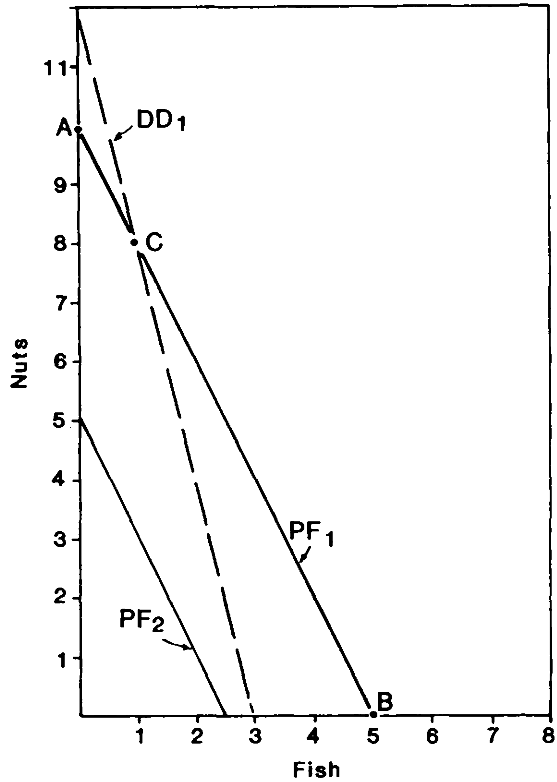

Fig. 7.1. Production frontiers and trade-offs for combinations of nuts and fish.

level of protein. All locations producing quantities to the left of the line have a lower preference order because they do not produce the appropriate level of protein. Locations represented by mix combinations to the right of the line are more preferred. Point *A*, for example, is on the higher production frontier for calories but falls lower in its preference ranking due to the reduced protein attainability.

Altering Production Parameters and Constraints

The attainability of any subset of locations depends on the *parameters of production*. In most archaeological problems, these parameters will include technology, environmental conditions, and the social organization of technology and labor. For example, continuing from the above illustration, suppose than an inefficient technology for nut gathering is used, requiring that a long time be spent in the gathering process. If a new technology improving the gathering time is then introduced, the production set frontier will be expanded. If the constraint on required protein remains the same, the attainable set will expand. Conversely, suppose a deterioration in the environment caused a reduction in the density of this food source. The attainable set would shrink. Similarly, changes in social organization, perhaps effecting the make-up of work groups and their productivity, could also alter the attainable set.

Alteration of system constraints, like alterations of production parameters, may change the attainability of subsets. For instance, a second constraint, such as group-spacing issues, might be added to the above case. This might have the effect of further reducing the attainable set.

Measurability and Marginality

In the most recent version of our example, we have suggested that very careful comparison between the units (locations) in terms of their productivity is possible. The ordering of *each* individual unit in relation to all others is possible, with the exception of exact ties, based on the exact same mix potential (e.g., exactly 5.0 units of nuts and 2.5 units of fish). In other words, it has been assumed that the *measurability* of the conditional preference aspects of items is great. For example, if there were 100 locations, then the chooser could distinguish among the conditional preference aspects of each of the 100 locations and rank them to form a preference order. If such an ordering were done, the theory would then predict that the highest ordered—optimal—location would be selected for a settlement.

In general, the degree to which any attainable subset of units may be partitioned into subsets of various preference is based on the measurability of the units' conditional preference aspects. If minor differences are measurable, then very subtle differences can be used to order the alternatives. As measurability decreases, the number of units that are "alike," i.e., to which the chooser is indifferent, increases. Detailed measurability is an assumption that typifies neoclassical, marginalist economic approaches.

As will be seen below, detailed measurability of the conditional preference aspects of a global set of units implies that great amounts of knowledge are accessible to the selector. Even in the very simple example just presented, we can see that complex and massive amounts of information would have to be examined to fully order the 100 locations. This circumstance would become even more overwhelming if we increased the number of conditional preference aspects considered for all locations. It is this type of information processing requirement, which is involved in the marginalist assumption of infinite measurability and in the assumptions behind the techniques used by marginalists, that has lead many to question the appropriateness of this approach in non-western situations.

Within the umbrella of general choice theory, however, it is not necessary to assume detailed measurability and ordering of *each* alternative. Rather, it is only necessary that each alternative be capable of being placed within an ordered *set*. These sets could simply be "good," "better," and "best" locations. *All* locations would have to be classifiable, but only into a subset; within the subset, no further ordering would be necessary. There might be ten locations in the "best" subset which are, in fact, *different*, but among which the differences are such that the chooser is indifferent.

When it is possible to order alternatives only among sets, not within them, the theory predicts that the alternative selected will be one from the most preferred set, the particular alternative chosen *at random* from those within it. In our settlement example, suppose that there are 100 locations, which can be ordered among three preference sets. The theory would predict that of the three subsets, a member of the highest ordered set will be selected. The *specific* location selected within that set cannot be predicted; this aspect of selection is a random process. The probability of any given member of the set being chosen is just the relative frequency of each location. If there were 10 locations within the most preferred set, then the theory would predict the probability of a given location being selected from it as $p = 0.1$, or one in ten. This compares to a probability of $p = .01$ of selecting a member of the global set without the ordering process. Thus, the theory allows the prediction of the alternative chosen with increasing probability as the choice process is better understood. Also, the theory specifies that as the chooser becomes more knowledgeable, choice may become more particular.

We can now see that a general theory of rational choice can have both deterministic and stochastic attributes. The theory predicts with $p = 1.0$ that a selection will be made from a specific partitioned set. Within that set, however, the probability of any specific unit being selected is a function of the number of units in the subset.

Implications of Variable Measurability

The measurability of the conditional preference aspects of a group of alternatives may be detailed or not, allowing their division and ordering into any number of subsets. In the example above, the number might range from 1 to 100. This fact may seem so obvious as to be trivial, but its implications on the process of ordering are of fundamental and overwhelming significance.

In particular, the measurability of conditional preference aspects and the degree to which a global set can thereby be partitioned has a behavioral or decision-making correlate. It represents the *information accessibility* and *processing capabilities* of the person(s) doing the ordering. Where much information about each alternative is available, and when the individual has the capability and desire to process this information, it becomes possible to make very subtle ranking variations.

This relationship between the measurability of conditional preference aspects and the nature of the decision-making process has methodological implications. Often, selection of an appropriate quantative methodology for analysis is seen as a function of the type of data available to the researcher. Certain methods, for example, are appropriate for interval data. What is perhaps not so obvious is that the selection of a methodology for the study of human decision making is inextricably interlinked to the nature of the emic choice process. As part of the decision process, the attainable choice set may have been partitioned into only a limited number of subsets. If this is the case, then, even though interval data may be available to the researcher, analysis using interval scale data and techniques may lead to spurious results. This circumstance has been demonstrated graphically in a study by H. Gladwin in his comparison of an additive vs. hierarchical decision rule (1975), as well as a number of other ethnographic studies (C. Gladwin, 1975, 1979, 1980; Johnson, 1978; Chibnik, 1980; H. Gladwin & Murtaugh, 1980).

Thus, the nature of the choice processes that generate an economic data set must be considered when assessing the methodologies appropriate for the analysis. When the measurability of conditional preference aspects is detailed and the global set can be partitioned minutely, methods requiring continuously divisible data, such as production function analysis, or linear programming are appropriate. As the selector's distinctions become more vague, techniques such as statistical decision analysis, decision trees, and hierarchical choice approaches become appropriate. This desirable relationship between choice process and analytic technique is one aspect of the concept of *emic symmetry*, to be discussed below.

K-fold Partitioning

It is possible to control the degree of measurability, information assessability, and processing capabilities assumed in a decision-making analyses by specifying the number of sets into which the global set is to be partitioned, that is, *k-fold partitioning* of the global set. The number of subsets *k* now becomes a measure of the continuity between the marginalist view of resources as factors having continuous, infinitely variable and perceptible properties, and that of binary choice. As the value of *k* approaches some small value, the character of choice moves from the marginalist position to a simple binary view.

We must be cautious in assuming for nonwestern contexts that detailed, k-fold decision processes do not occur because they are complex.

As Blumer has emphasized: "From the vantage point of the *particular human community*, living in a restricted geographical area, and over a restricted period of time there, there are very evident discontinuities in nature, that is, in living flora and fauna; and perception of certain of these is vital to human survival" (Blumer, 1970, p. 1083).

That the properties of any choice should be subject to a degree of discrimination greater than that resulting from a binary present/absent dichotomization is not, therefore, surprising. Even a cursory examination of the linguistic evidence illustrates this fact. In Byington's (1915) dictionary of the Choctaw language, for example, the following relative "frequency" terms may be noted:

ikshoka amohmi:	there is none at all
key uchohmi:	rare
ikchito:	scant; not great
achafoa:	a few and scattering, not many rare
apakna:	plenteous, abundant, copious
chitto:	less than chito
chito:	large, big, huge, immense, heavy, capacious, august, egregious, enormous, extensive

Thus, we should not automatically dismiss the emic capabilities of individuals to perform complex analysis.

In summary, by varying the number of sets into which the alternatives in the global set are classified, it is possible to generate, from the *general* theory of rational choice, more specific theories of the choice process. At the one end of the continuum (where k is large) stands neoclassical marginalist theory. At the other end (for small k) stands the set theoretic approach, or what will hereafter be termed axiomatic set theory.

Evaluation of the Relevance of the General Theory of Rational Choice to Archaeology

In the opening of this chapter, it was suggested that an archaeologically relevant theory should have the attributes of a generative theory, as well as additional features common to all theories. These characteristics include 1) being composed of a limited number of defined, measurable elements and interrelationships (e.g., axioms); 2) the ability to *generate* a diversity of possible archaeological forms and specify those that are possible and not possible under the theory, providing hypotheses that may be used to test the theory (as opposed to the experimental approach requiring the control of variables); 3) the ability to develop algorithms which are capable of modelling the theory, thus expediting the generation of alternative forms; 4) the prediction of "unpredictable" forms or relationships; 5) making refutable predictions; and 6) being explanatory, rather than redescriptive.

Each of these characteristics of an archaeologically relevant theory pertains to the general theory of rational choice outlined above. 1) The general theory of rational choice is well grounded and logically expanded from a limited number of axioms. Although only a limited number of axioms have been discussed here, readable and more complete discussions are provided by Walsh (1970) and Newman (1965). 2) The axiomatic formalizations focus on the process of decision making, as opposed to the forms generated by such processes. A variety of forms can be generated by adjusting the parameters of each empirical application of the theory (e.g., the number of partitions of the global set allowed). 3) Alternative algorithms allowing the generation of alternative forms are a natural outgrowth of the formal structure. As will be discussed below, a diversity of algorithmic formulations and analytical techniques may be used, implying differences in the information accessibility and processing capabilities of the selector, and other parameters of the decision-making process. 4) The unpredictability and 5) refutability of the predictions made by general choice theory will be illustrated in examples below. 6) The explicit, logical chain of derivations from axiom to prediction lends support to the explanatory power rather than rediscriptive nature of the approach, when the predictions concord with the evidence.

HISTORICAL PERSPECTIVE: DECISION ANALYSIS IN ARCHAEOLOGY, ANTHROPOLOGY, AND ECONOMICS

Since the mid 1970s there has been an increasing interest and application of a variety of economic theories and methodologies in archaeology. The increasing use of decision analysis models has engendered the beginnings of a lively debate. Unfortunately, the debate is largely a replay of those which arose in sociocultural anthropology in the 1960s, and/or in economics during the 1950s. There are two components to this debate: the formalist-substantivist arguments and the arguments for and against the view of "man, the satisficer."

The Formalist-Substantivist Debate

The essentials of the first argument will elicit a sense of *deja vu* among those familiar with the "formalist-substantivist" debates in anthropology in the 1960s and early 1970s (see Belshaw, 1965; Berliner, 1962; Bohannan & Dalton, 1962; Burling, 1962; Cancian, 1966; Dalton, 1961, 1963; LeClair, 1962; LeClair & Schneider, 1968; Sahlins, 1969; Schneider, 1970, 1974) because the arguments are essentially the same. The arguments of the 1960s fundamentally revolved around the appropriateness of a marginalist or formal approach applied in a "nonwestern" environment.

The essential point of origin for those arguing against the formalist view was the work of Polanyi (1957). As LeClair and Schneider have noted, Polanyi asserted that "in societies other than market-oriented societies, men in fact are not confronted with making choices in the sense of the formal meaning of economic" (1968, p. 10).

Substantivists pointed to the discrepancies between the powerful methodology of formal economics, requiring detailed measurability of conditional preference aspects, and the absence of easily evident nonwestern data sets consistent with those methods and assumptions. On this basis, they concluded, as they were philosophically inclined to do anyway, that use of choice theories was inappropriate in nonWestern situations. This conclusion, however, was erroneous; it was based on the false premise that formal applied economic theory is equivalent to economic theory in general. However, as has been repeatedly emphasized, marginalist theory can be seen as only one particular expression of general choice theory—that which is appropriate when preference partitioning is most subtle. When this circumstance is not true and when the attainable set cannot be minutely partitioned, it is still possible to employ axiomatic set approaches to choice. Thus, although in many nonwestern situations detailed measurability is not readily apparent, this does not imply, as the substantivist might, that theories of choice are not appropriate. Rather it indicates that care must be taken to apply the appropriate specific theory of choice and the methodologies consistent with it.

From a historical perspective it is not surprising that anthropologists of the 1960s drew upon marginalist concepts. Awareness of the different variations of economic theory and their subsumption under a general theory of choice is a relatively current one, even within economics. "Only recently have economists begun to understand consciously that the (general) theory of choice is the core of the pure science (as distinct from the engineering) in economics" (Walsh, 1970, p. 13). Within economics, it was only with the work of Arrow in the 1950s that the axiomatic formulations of the general theory of choice became influential and the proper role for marginalist approaches became clear. This position, however, was anticipated some 50 years earlier by Lionel Robbins (1935, p. 14), who has given perhaps the clearest definition of economics. Also, axiomatic choice concepts were proposed as early as 1926 by Frisch and later by Georgescu-Roegen (1935-36) and Wold (1943).

Malchup (1967) has emphasized that marginalism dominated economics perhaps as late as the early 1950s. This period saw a number of seminal articles and books, largely by Arrow and Debreu (see Newman, 1965, pp. 45-49 and Walsh 1970, pp. 14-60 for more details). Koopmans has described the impact of the then-newer axiomatic approaches to economics in his very influential *Three Essays* (1957):

> In recent years [these] mathematical tools of a more basic character have been introduced into economics, which permit us to perceive with greater clarity and express in simpler terms the logical structure of important parts of economic theory. Parallel with this change in tools, there has been a change in emphasis as between various aspects of the theories in which the tools are applied. Traditionally, mathematical economics has emphasized models that describe the formation of prices and quantities in competitive markets through unique, or at least locally determinate, solutions of equation systems. Such models have also been used to study how these solutions respond to changes in technological knowledge, in consumers' preferences, in governmental policies, or in "external conditions" such as weather or foreign demand. Calculus and the theory of implicit functions have formed the main mathematical tools for this type of analysis. The new tools allow us to shed new light on older and perhaps also more fundamental problems. The emphasis is shifted to the specification of conditions under which decentralization of economic decisions through a price system is compatible with efficient utilization of resources. It is not suggested that these classical problems were at any time lost out of sight. The "new

> welfare economics" has made them its special concern. However, the tools referred to were inadequate for the purpose in question. In the first place, they did not permit recognition of restraints on choice that require expression by inequalities rather than by equations. Owing to this limitation of the tools in use, the literature of an entire period almost completely ignored such simple facts as the impossibility of consuming negative quantities of goods or of rendering negative quantities of labor, or the impossibility of running production processes in reverse. Secondly, the calculus, used in the way it was used to scan the (restricted) domain of the target function for a maximum position, is a myopic instrument. It served only to compare the would-be-maximum position with alternative positions in its immediate neighborhood. For this reason, the problem of formulating conditions under which a position could stand comparison with more distant rivals was not faced. (1957, pp. 5-6)

In anthropology, a well-developed application of concepts fundamentally similar to axiomatic set theory can be associated first with H. Gladwin (1975), C. Gladwin (1975, 1979), and Quinn (1975). The conceptual framework and methodologies used by these researchers are generally consistent with Arrow's axiomatic choice theory, though they do not emphasize the works of Arrow (1951), Debreu (1959), or others (e.g., Walsh, 1970; Newman, 1965) who had developed accessible axiomatic methodologies in economics.

At first, it may seem surprising that after twenty years, Arrow's work has not had a greater impact on anthropological analysis. However, upon further study, we can see why this is so. Even though Arrow won the Nobel Prize and his ideas, as well as those of similar thinkers, have had a fundamental impact on basic theory, they have had little effect on the "engineering" side of economics. Popular undergraduate and graduate texts in economics (e.g., Mainsfield, 1970; Henderson & Quandt, 1971) include, at best, only a superficial treatment of axiomatic choice theory. Even today, the overwhelming focus in economic teaching is on theory and method involving continuously divisible data.

To conclude, the basic issue of the appropriateness of choice and its scholarly study in nonwestern, nonmarket economies has been considered. The fundamental issues have only been superficially examined, the magnitude of the debate only fleetingly glimpsed, and the significant questions have by no means been answered. It should be clear, however, that there is substantial support for a rational choice approach in nonwestern situations, including archaeological contexts. Considerable force is added to its use when it is recognized that many of the substantivist criticisms of "economics" were actually directed to only the marginalist expressions of the basic processes of choice. Careful marginal perception of alternatives in a nonmarket environment may not be a universal nor even typical phenomenon as the substantivists have argued (we are not prepared to argue either for or against the matter here). However, with their polemic insistence on misidentifying marginalism with choice, the substantivists have insisted on throwing the baby out with the bath water. Fortunately, both modern economic theory and anthropological study have shown that, in theory and practice, there is a productive middle ground in the study of nonwestern decision processes.

The Unsatisfactory Satisficer

Paralleling the replay of the formalist-substantivist debate in archaeology is another dichotomy concerned with the general nature of choice-making theories: that between "satisficers" and "maximizers." In this dichotomy, the satisficers propose more than the inapplicability of "western" economics to nonwestern environments. They propose that humans *everywhere* do not order their alternatives and select the most preferred; rather, individuals choose the first acceptable alternative. Humans, accordingly, are not maximizers; they are satisficers.

Serving to illustrate the position of an archaeological satisficer is Sullivan and Schiffer's (1978) evaluation of the theoretical basis underlying the SARG (Southwestern Archeological Research Group) research design. Sullivan and Schiffer note that a

> . . . more fundamental question exists regarding the basic utility of "maximizing" economic models. In order for the minimax principal and the PLE (Principle of Least Effort) to operate, a number of significant preconditions are assumed to have been satisfied. The preconditions are that players (individuals or groups) can 1) process the requisite information within the constraints of prevailing conceptual schemes (providing the information is available); 2) correctly calculate the success probabilities of alternative strategies; 3) evaluate potential outcomes based on the computed probabilities and rationally select the most attractive outcome and 4) do not err in any of the above and 5) act in terms of the particular strategy which in probabilistic terms is the most maximizing or constitutes the "least average rate of probable work" . . . . (1978, p. 171)

They go on to suggest that "rational economic men" should be replaced with "satisficing men" who satisfice "because they have not the wits to maximize" and who instead pursue "a course of action which is simply good enough" (Sullivan & Schiffer, 1978, p. 171, quoting from an unpublished paper by McGuire, n.d.).

Zimmerman also advocates the satisficing man view in his book *Prehistoric Locational Behavior: A computer simulation* (1977). He is perhaps more forceful in his rejection of other alternatives when he argues:

> Major criticisms of economic man models in location theory focus on the logical consistency of assumptions of the motives ascribed to economic man, and reject the high level of knowledge and abilities attributed to him. Man often operates in less than optimal ways but usually in ways that

> satisfy him in terms of needs. This satisficing behavior is both culturally and situationally defined. (p. 13)

Jochim (1976) also prefers the satisficer approach because

> . . . it represents an attempt to be descriptive rather than normative, it may reflect real-world decision processes more faithfully. Second, some hunter-gather decisions involve the procurement of nonedible material items such as hides, antler, and bone; the usual high mobility of these groups, however, militates against the maximization of material acquisitions. Third, the presence of conflicting goals or objectives guiding the decisions would dictate the acceptance of submaximal levels of attainment, which might lead to the development of submaximal levels of aspiration. (p. 7)

The basis for all of these satisficer views is a series of articles and books written largely in the late 1950s by another Nobel Laureate in economics, H.A. Simon (e.g., 1955, 1957a, 1957b, 1959). Simon's early work can be seen as a *response to marginal utility theory* and to the then recently introduced game theory approach (Von Neuman & Morgenstern, 1947). Simon (1959) refers to the new experiments on "realistic" choice situations stating:

> In the few extensions that have been made, it is not at all clear that the subjects behave in accordance with the utility axioms. There is some indication that when the situation is very simple and transparent, *so that the subject can easily see and remember when he is being consistent*, [italics added] he behaves like a utility maximizer. But as the choices become a little more complicated—choices, for example, among phonograph records instead of sums of money—he becomes much less consistent. (1959, p. 258)

Based on evidence of this type (and one can only wonder at his categorization of phonograph record comparisons as only "a little more complicated" than comparisons of sums of money), Simon concluded that, in the face of an incredibly complex environment, most real-life choices lie beyond the reach of a maximizing mentality—unless the situations are heroically simplified by drastic approximations (1959, p. 259). This occurs because, among other factors, optimization "requires, of course, a complete ordering of pay-offs" (1955, p. 108).

Some essential features of Simon's work, relevant to this discussion, can be summarized as follows: 1) Simon was responding to (a) the introduction to economics of game theory, which requires utility functions and careful evaluation of alternative outcome probabilities (Simon, 1959, p. 257), and (b) marginal analysis theory, which necessitated the development of a continuous utility function (Simon, 1959, p. 256; 1955, pp. 104-105). 2) For Simon, the single overwhelming factor militating against rational choice is the complexity of the world, although "in simple, slow moving situations, where the actor has a single operational goal, a maximization or optimization approach may be appropriate" (Simon, 1959, pp. 255 & 279; see also Winter 1971, pp. 238-239). 3) The inability of individuals to determine a complete (total) ordering of the preferences made satisficing the only viable alternative (Simon, 1955, p. 108). 4) Thus, while the substantivists focused their attention on the ability of some nonwesterners to *perceive* detailed differences among items in their conditional preference aspects (information accessibility), Simon focused his attention on the ability of all humans to *process* large amounts of information having complicated relationships among the conditional preference aspects of items (calculation capability).

Examining these points, it becomes clear, paradoxically, that Simon appears to argue that rational choice is inappropriate in many western economic situations but *would probably be appropriate in many nonwestern ("simple") ones.* The important variable is not the inherent behavioral processes of perception and decision, but the impact of *information overload* on the individual decision maker, leading to an inability of the decision maker to order his preferences *completely*. If this view is correct, then the use of the satisficer model for prehistoric situations is not supported by the originator of the ideas.

Empirically, it is unclear as to the degree to which a satisficing approach to economic analysis of nonwestern systems is appropriate. Ortiz (1967) has noted that

> Rationality of behavior does not imply that there is a constant conscious awareness of having made a choice or even the ability to express it verbally in terms of quantities or factors . . . When a (Columbian Indian) farmer answered me, rather impatiently, that he really could not tell me how many items of manioc he was going to plant, because he stopped planting when he could see he had enough, he was quite clear as to the amount required. (pp. 195-196)

Similarly, Jochim, though accepting Simon's satisficer approach, documents an impressive number of reports of careful analysis, evaluation, and preference ordering of properties of various resources by various hunter-gathering peoples. As only one example, the G/Wi rate food sources "in order of importance" by the "thirst and hunger-allaying properties of the plant food, the ease with which it may be exploited, and last its flavor" (Silverbauer, 1972, p. 283, quoted in Jochim, 1976, p. 17). On the other hand, there concurrently is evidence that explicit, detailed analysis of the probabilities of alternatives and their costs does not occur in many specific situations (Shepard, 1964; C. Gladwin, 1975).

Clearly, what is needed is a single theory which can move through the continuum of decision making, not one theory for one situation and a second theory for another. Game theory is strictly applicable only where the perfect actor knows all the outcomes and can order *all* the alternatives. Simon's satisficer theory, developed especially in response to game theory, however, is pertinent only where information load far exceeds the processing capabilities of individuals and alternatives are ordered into only two sets: acceptable and unacceptable. In contrast to these two approaches, the generalized theory of rational choice is applicable to each of these extreme circumstances and the continuum of situations between, fulfilling the need for a unified theory. It allows for variation in the number of conditional preference aspects and the complexity of their interrelationships which a person considers, and in the number of preference sets which a person recognizes.

In conclusion, it can be argued that the application of a satisficing man model to the prehistoric past is both unnecessary and may, in fact, be in contradiction to the initial proposals of Simon. There are a number of further detailed criticisms of Simon's approach, but in this short overview, it is not possible to discuss them at length. Briefly, these 1) examine the general question of a descriptive versus normative or predictive theory (Malchup, 1967), 2) present extensive evidence that a "rule of thumb" (apparent satisficer mechanisms) may in fact be an excellent optimality rule (Baumol & Quandt, 1964), and 3) integrate satisficing and maximizing into a rational strategizing which is related to the social situation and structural position of the individual (Prattis, 1973). What has been a major set of questions in economics and anthropology has not been presented in its full flavor, but the discussion should be sufficient to demonstrate the considerable caution that should be placed on application of a satisficing man view to prehistoric questions.

Additional Disagreements

Literature on economic analysis within anthropology and archaeology indicate disagreement, not only with regard to measurability, information accessibility, and information processings capability, but also, to a lesser degree, with respect to two other subjects: 1) the concept of effort minimization, or *Zipf's Law*—the Principle of Least Effort (Zipf, 1949)—and 2) the role of normative constraints on choice.

In this chapter, the Principle of Least Effort is rejected as an assumption basic to any general theory of rational choice. Even a superficial examination of the economic literature, or even everyday life, indicates that *no one* rather than everyone, is engaged in true least effort activities.

The ready archaeological acceptance of Zipf's work, described by Kluckholm as "fertile and suggestive, mad, irrelevant" (1950, p. 20), comes as somewhat of a surprise. To emphasize this point, it is useful to contrast many of the current archaeological uses of Zipf's law with the following comments by Burling:

> Zipf believed that all of our behavior is oriented toward the minimization of effort. Now, taken literally, as a principle with no leeway for ambiguity, this is nonsense. Athletic events and taking a walk to work up an appetite are hardly understandable within this framework. This among other flights of fancy has lead most people who have stumbled upon his book to reject its principles, even while recognizing the fertile mind which pro-

> duced them and the remarkable collection of data which he believed would support them . . . all this is rather neat, and it is reminiscent of the discussions of economists on how to maximize money income, except, of course, that it is so absurd to set up the minimization of effort as the overriding goal which guides all our behavior. . . . His lack of ambiguity, however, even though it may have led him to be rapidly rejected as a somewhat mad genius, allowed a more explicit formulation of the implications of a maximization theory. . . . Clearly the things we want are more complicated than expressed by any of these simple motivations. Certainly we are sometimes happy to avoid effort. . . . More significantly we often have to choose between these things. We must decide whether leisure (minimum effort) is more or less important to us at the moment than an increase in money income, or whether power is to be sought instead of either of these. (1968, pp. 181-182)

Regarding normative constraints on choice, it should be recognized that any application of rational choice theory to prehistoric peoples must address the criticism that such a theory is inappropriate in a nonwestern context because

> The individual (and/or group) is constrained by normative/institutional factors. Although Duesenberry's famous axiom is applied to sociology and economics it is an appropriate example of this type of thinking. He has stated that "economics is all about how people make choices. Sociology is all about why they don't have any choices to make" (1960, p. 233). If there are, in fact, no choices, then any theory which deals with optimum choices is clearly inappropriate. However, individuals or groups can, and do, choose to violate a norm. If we, therefore, recognize that the violation of a norm is a "high cost" social choice, then the normative and decision approaches are not in contradistinction. In the short run, norms will serve to limit the alternative choices by "adding" a high cost to some alternatives, but the *process* of decision making remains the same. In the long run, and perhaps of more significance to archeology, is the clear evidence that norms/institutions are, themselves, subject to change through time as the norm's relative preference ranking is modified by other external forces (Limp, 1983b, p. 19).

The position proposed here as an appropriate and effective one for archaeology parallels that proposed by Barlett (1980, pp. 2-3) for the study of peasant farmer agricultural production:

> We seek to understand the production system of peasant farmers—how they change, and what forces influence and inhibit change. We begin from the point that small farmers are neither irrational nor tradition bound and we assume that their agricultural patterns are the consequence of long- and short-term adaptations based on observation and experimentation. Determining first what agricultural decisions have been made, we can then pursue the impacts of those decisions.

EMPIRICAL APPLICATIONS AND THE CONCORDANCE OF THEORY, METHOD, AND DATA STRUCTURE

Emic Symmetry, Etic Coherence, and Data Accessibility

In the following section, we examine two couplings of economic theory, methodology, and data. Two examples serve to illustrate some typical problems in economic analysis, including the information processing capabilities of the decision maker implied, cost estimation, and the conformity between the theory and analytical methodology applied. One example will illustrate the use of economic methods in subsistence analysis; the second in settlement analysis.

To aid us in revealing these problems, we can formulate three measures of the effectiveness of theory and method, and their conformity to each other and the data at hand. These are: *emic symmetry, etic coherence*, and *data accessibility*.

Emic symmetry can be defined as the degree of similarity between the decision process as modeled in theory and as effected in practice. It can also refer to the concordance between the theory *implied* by the assumptions that a technique makes about the structure of the data to be analyzed, and the decision process that generated that data. For example, if a series of alternatives were subjected by a person or group to only a simple ordering among larger sets, then a theory requiring careful measurement of potentially continuously divisible data, such as cost curve analysis, would not have good emic symmetry with this circumstance. In such a situation, H. Gladwin's (1975) hierarchical model would have greater emic symmetry. *Etic coherence* is a measurement of the degree of coherence between a theory and an analytical method regardless of their applicability to any particular data. For example, if a decision model involves conditional preference aspects of a continuously divisible character, then methods such as partial differentiation may have a high degree of etic coherence. In contrast, for a hierarchical decision model, methodologies involving evaluation of set membership would be coherent. Finally, a particular analytical technique may require more or less detailed information on costs or productivity to be applied. This necessary level of information can be termed *data accessibility*.

Cost Function Analysis: Alternative Resource Choice

The following example illustrates the characteristics of economic theory applied to the analysis of costs, and the methods of cost function evaluation, in the context of archaeological catchment analysis. At the same time, it suggests generally productive insights that may be provided by such an approach, when applied to conventional catchment studies.

Cost function analysis permits the mathematical comparison of the costs of a series of different alternative strategies to achieving a particular goal. For example, if there are four different production techniques by which a particular good can be produced, then cost analysis would permit evaluation of the optimal mix of the alternatives for each level of output. Methodologically, the approach requires the determination of a *cost function* for each alternative production method. A cost function is simply the mathematical representation of the costs of the production method for each level of output. Evaluation of the optimal mix for a specific level of output is determined by a series of partial differentiations of the functions to assess the relative marginal costs of the methods at that output level (see Henderson & Quandt, 1971, pp. 70-79). As generally applied, cost function analysis requires an accurate representation of the costs in the form of a continuously divisible function. Earle (1980) has a useful discussion of an archaeological application of cost analysis.

The term *catchment analysis* was popularized in archaeological circles by Vita-Finzi and Higgs (1970; Higgs & Vita-Finzi, 1972). Paralleling their work was a comparable early effort by Munson et al. (1971). More recently, there has been a considerable growth in studies using catchment analysis (see Roper, 1979; Reidhead, 1976; Flannery, 1976; Rossman, 1976; Zarky, 1976; Higgs & Vita-Finzi, 1972). The methods and properties of the approach are well described in Higgs (1975: Appendix A) and Flannery (1976) and need not be repeated here.

While there is some moderate disagreement among the practitioners of catchment analysis over the size of the catchment that should be used, they are in general agreement that a catchment should be of a relatively small diameter. For example, Higgs and Vita-Finzi (1972) propose a 5 km diameter for the catchment of agricultural groups and a 10 km diameter for hunting-gathering territories. Rossman (1976) used 5 km, as did Zarky (1976); Munson et al. (1971) used ca 2.9 km, as did Smith (1975). Reidhead (1976) invoked a catchment with a 3.5 km diameter.

The substantial diversity in the above distances calls attention to the necessity of considering the basic assumptions underlying catchment analysis, including the economic, choice-making structure assumed. Catchment analysis and its assumptions have their roots in the work of von Thunen during the 1820s. Von Thunen was concerned with developing a theory that would predict the nature of land-use around an "isolated city." Von Thunen's study served as a basis for Chisholm's (1962) work, which provided the direct rationale for the development of catchment analysis in archaeology, as did the other important works of Hoover (1948), Isard (1956), and Dunn (1954). Von Thunen's work, and the economic assumptions involved in it, have been summarized by Haggett (1960, pp. 161-182), as follows: 1) There exists a single, large city, which 2) occurs in an "isolated state," surrounded by waste on all sides; 3) the city is located in the center of a featureless plain over which both *production costs* and *transport costs* are the same everywhere; 4) farmers supply the city in return for manufactured goods; 5) transport costs are exactly proportional to distance; and 6) profit is maximized by all farmers by automatic adjustments in the crops planted.

Of these assumptions pertaining to the structure of choice making, three are integrally a part of catchment analysis as applied archaeologically, yet are clearly violated in some, if not most, contexts. These are the assumptions of an isolated condition, and the assumptions concerning the nature of production and transport costs.

Regarding the assumption of isolation, even a superficial evaluation of subsistence behavior indicates that there is a complex matrix of variable production costs which significantly influences resource selection beyond the limits of the typical catchment. In the eastern United States, for example, there is extensive evidence in the ethnographic literature that exceptional distances were traveled routinely in hunting activities. Tooker reports travel of "200-300 leagues" (1964, p. 65). For many groups in the southeast, Hudson indicates that hunting groups ". . . sometimes ranged as far as two or three hundred miles away from their towns. These hunts were conducted by the men accompanied by their able-bodied women and some of the children" (1976, p. 271).

Likewise, the assumptions about production and transportation costs can be shown to be very restrictive. This can be done by example through an empirical evaluation of the production and transport costs of food resources available to the aboriginal inhabitants of the midwestern area of the United States. In the process, the impact on analytic results of violating the two assumptions of concern, which are intertwined, will become clear.

In the empirical approach to be used, production and transport costs are summarized as the *caloric* productivity of a resource. The use of calories are presented here only for exemplary purposes. For a discussion of the problems with caloric reductionism, see Keene (1979) and Limp (1983a).

It is possible to evaluate the productivity of a food resource both at its point of origin and at varying distances from this location so as to allow the computation of a cost function for the resource. The method of computation involves consideration of technical productivity, speed and distance of travel, and the necessity for overnight camps when the distances to be traveled increase (see Limp, 1983a for details).

Figure 2 illustrates the application of Limp's computations for hickory nuts (processed by mortar and boiling). It shows the net caloric output of hickory nuts at varying distances, taking into consideration the total costs of production and travel, in the form of an output/input ratio. A transport unit of 40 kg of unshelled nuts has been assumed. This unit represents approximately 62,000 calories at the point of origin, with only the cost of production (not transport) subtracted. The cost of production, approximately 3,300 calories, is based on experiments reported in Reidhead (1976). The output/input ratios, are shown for one-way travel distances from 0 to 200 km. The steps in the curve represent the effect of the cost of each overnight camp. The curvilinear nature reflects the increasing impact of the transport costs as a component of the total costs.

From these calculations, we discover that it is feasible to exploit hickories up

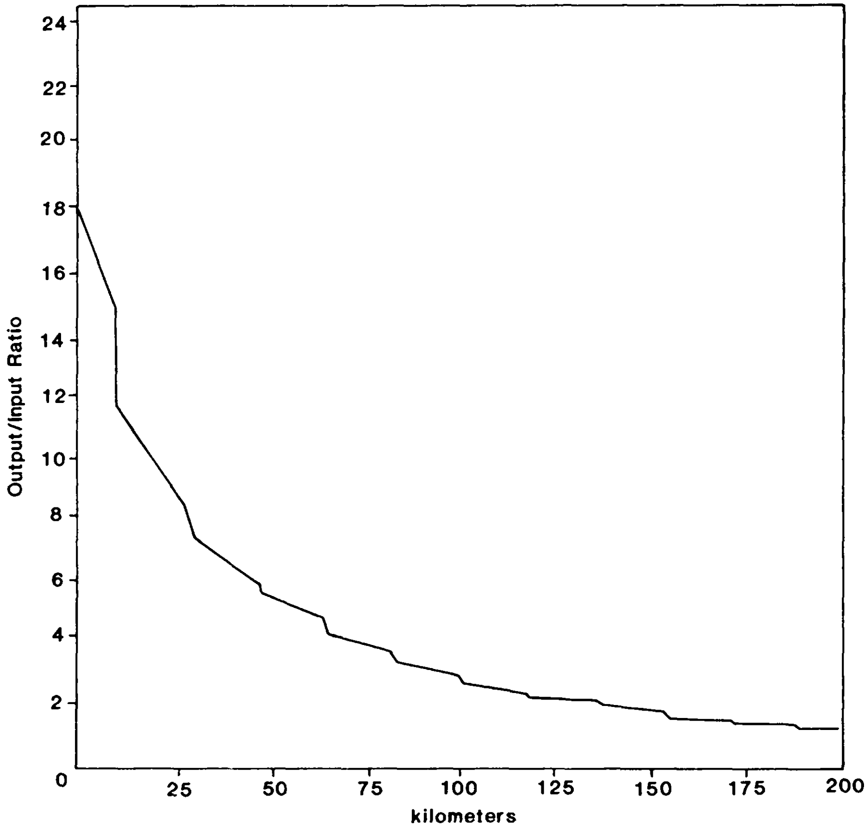

Fig. 7.2. Input/output ratios for various catchment distances for hickory nut production.

to 215 km away (one-way), with the calories produced still being greater than or equal to the calories required to obtain and process the resource. This "catchment" is considerably in excess of the 2 to 10 km circles often used in catchment studies. This is not to argue, however, that *any specific* catchment radius is correct or incorrect. Rather what is of significance is that a catchment basin is, in fact, a *variable* rather than a given, dependent on the cost analysis of a given resource and production technique. *To propose any single or even a limited number of catchment basins totally obscures the complex choice mechanisms and interrelationships which existed.*

Further suggestive of this circumstance are the data presented in Figure 3. In this figure, the distance dependent output/input ratios for four different resources are presented. Curve *A* illustrates the ratios for white-tailed deer using a stalking mode of hunting. Curve *B* indicates the relationship for hickory nut

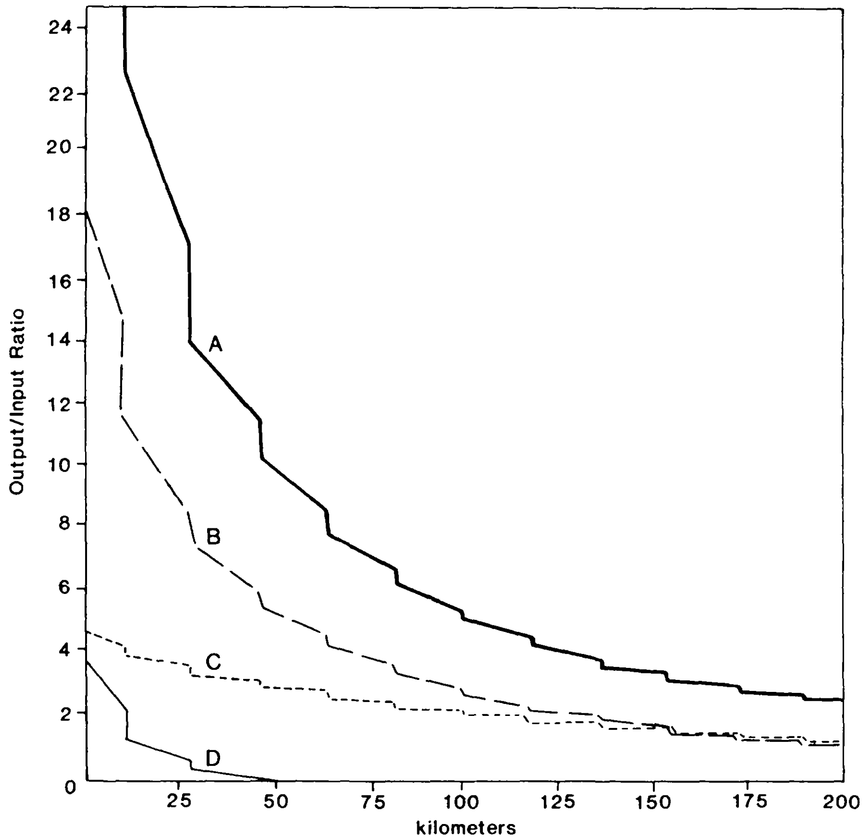

Fig. 7.3. Input/output ratios for various catchment distances for:(A) white-tailed deer, (B) hickory nuts, (C) white oak acorns, and (D) riverine mussels.

production discussed above. Curve *C* pertains to white oak acorns and *D* to riverine mussels. Again the original productive technique data were obtained from Reidhead (1976).

The figure shows that similar output/input ratios can be obtained for the several resources, but at varying one-way travel distances and for catchments of varying radii. Cost relationships are the same at 1 km for mussels, 20 km for white oak acorns, and 150 km for white-tailed deer. Again, this emphasizes that the catchment basins of different resources may vary in size, some being quite large, and that their size depends on the specific production and travel costs of the resources. It also emphasizes the fact that production and transportation costs need not be equal over all resources. Thus, we find that the two assumptions of isolation and uniform production and transportation costs involved in archaeological catchment analysis, as derived from von Thunen, are inappropriate to the example provided, and are probably inappropriate in most archaeological applications.

The impact of erroneously assuming a simple, restricted catchment basin and uniform production and transportation costs in a catchment analysis, as in traditional applications, has at least two facets. First, it may result in a decrease in the accuracy of the subsistence model-building process and associated predictions. Second, and perhaps more important, it may lead to a narrowing of the range of theoretical topics open for investigation. By making such assumptions, attention is drawn away from the choice-making process. If, instead, these assumptions are relaxed and the methods and theory of cost function evaluation are integrated into analysis, then the nature of decision process can be studied.

For example, in the case study presented above, we find that within a 25 km catchment basin, the unit productivity of deer is greater than any other resource (Fig. 3). Deer obtained at 26 km from a site are less productive, however, than hickories obtained in the immediate vicinity of the site. If these relationships are correct, then we might predict that a producer would choose to walk 20 km to obtain deer rather than produce hickory nuts at 5 km, if caloric productivity were the conditional preference aspect of primary importance. Of course, there may be a diversity of factors involved in any choice. It is by focusing on decisions of these kinds that cost function analysis can significantly augment and broaden the scope of traditional catchment analyses.

To take into consideration the diversity of factors involved in choices of the kind just discussed, and to evaluate when a producer should (optimally) shift from one resource to another, methodologically, cost function analysis employs a series of *normative decision rules*. The optimal mix of resources is determined by partially differentiating the cost functions of each resource in order to evaluate their marginal costs at each level of output, and then applying decision rules. The decision rules state that for any increase from a given output level, a producer should choose the alternative resource having the lowest marginal costs. Using our example, in behavioral terms, this would mean that a producer would evaluate the productive yield of *each* resource at *every* unit distance from the point of use. Considering the level of productive output desired to achieve compared to that already achieved, the producer would then ask at each such location, "Is it more productive to walk one more unit distance to obtain resource *x* (i.e., deer), or to remain within the current catchment and shift to some other resources, *y* or *z* (i.e., hickories). A series of decisions would be made accordingly. As long as the unit productivity of a particular resource is greater than any alternative resource, the producer will extend the catchment. At the point where the marginal cost of the first resource rises above that of an alternative for another unit extension of the catchment, the producer will hold the level of the first constant and shift his additional effort to the second.

Cost Function Analysis: Evaluation of the Concordance between Theory, Method, and Decision Process

Emic Symmetry

Emic symmetry for any specific case is, of course, impossible to determine confidently because it literally requires evaluation of the mental processes of the decision unit. As the above discussion intimates, however, complete cost function analysis does assume the *considerable* information processing capabilities of the decider and the decider's desire to make detailed evaluations. While it is impossible to say with assurance, it seems reasonable to conclude that this approach has a low emic symmetry in many applications, particularly those concerned with simpler societies. To avoid this problem of asymmetry between the structure of the phenomenon being examined and that assumed by the method and theory, others have proposed that the marginal evaluations be collapsed into a lower ordered ranking approach (see Hasdorf, 1980; Christenson, 1980). In these approaches it is assumed that the decision units simply rank order the alternatives. Such a solution would surely increase the emic symmetry, but it has significant consequences for the method, as we note below.

Etic Coherence

The type of data presented for the catchment problem is continuously divisible. It is possible to assume a theory of rational choice involving detailed measurability of conditional preference aspects and the ability of the decider to access and process continuously divisible information and calculate marginal costs in the manner described above. While we have not done so here, it would be correct and quite straightforward to actually compute the marginal costs as desired for the sample data, and the approach would have excellent etic coherence. Such an analysis would then yield optimal mixes of the resources for various desired levels of output.

As we have noted, however, in the discussion of emic symmetry, there is some potential question as to whether we should make the assumption of the necessary level of information processing capabilities. If, instead, we assume that these capabilities involved only rank ordering and that a set theoretic approach has emic symmetry, then the appropriate methodological equivalent would be found in either statistical decision analysis (Hillier & Liberman, 1974, p. 597ff) or the decision analysis methods proposed by C. Gladwin (1979).

Data Accessibility

Cost function analysis poses two problems in relation to data accessibility when applied in the context of catchment analysis of archaeological data. First, the methodology requires estimates of the production and transportation costs of particular resources on a *continuously divisible scale*. Estimates of this specificity are difficult and time-consuming to make. The production costs upon which the above discussions are based were derived only after extensive, replicative experimentation in prehistoric technology and/or extensive review of ethnohistoric literature (see Reidhead, 1976; Keene, 1981). These projects represented a major research commitment and expense. The value of any catchment analysis using a cost function approach must be considered in light of this expense.

A second, and related problem of using a cost function approach to catchment analysis is that it requires *accurate* estimates of production and transport costs. Cost function analysis is not a highly robust method. A small error in a particular cost estimate can have (though not always) a major effect on the optimal resources mix predicted, and its accuracy. The particular effect of an error on results depends on the shape of the cost functions. Unfortunately, the magnitude of the effect of any particular sets of errors on the accuracy of a solution is exceedingly difficult to estimate.

All archaeological studies are troubled to some degree by data accessibility. However, when the method employed requires continuously divisible data and the effects of errors on results may be substantial yet undeterminable, as in cost function analysis, then the appropriateness of the method must be carefully considered in relation to the nature of the data base.

Hierarchical Choice Models: An Application to Settlement Location Analysis

The second example of the use of economic methods in archaeology considers the subject of a decision maker selecting a locale for settlement. Axiomatic choice theory, operationalized within a hierarchical decision framework or methodology, will be employed.

Additive vs. Hierarchical Choice Models

Previously, we have considered the partitioning and the information processing capabilities of the decision unit. For choices involving more than one conditional preference aspect, yet another factor must be considered. Multiple conditional preference aspects may be evaluated either *simultaneously* or *sequentially* by the decision unit. For purposes of this discussion, a simultaneous decision can be modeled by the classical additive linear regression equation:

$$\text{choice}\, y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

As Gladwin and Murtaugh have emphasized (1980, p. 133) this model implies that low values on one aspect can be "balanced off" against high values on another. The approach further assumes that it is possible to simultaneously evaluate a wide diversity of combinations of the aspects to achieve the optimal mix.

In contrast, a sequential decision process can be modeled using a hierarchical "decision rule" approach. A model of this approach might have the form discussed by Gladwin and Murtaugh (1980, p. 133):

$$\text{choice}\, y\, (1\text{:accept, } 0\text{:reject}) = x_1 \cdot x_2 \cdot \,.\; .\; . \cdot x_n$$

This choice model

> . . . differs from the additive choice model ("trade off" model) commonly assumed in discussions of indifference curves (the marginalist approach) . . . . The model that is actually used in this paper is hierarchical, in that it assumes decision makers consider aspects, dimensions, or criteria of objects separately and often sequentially. The consideration of later aspects takes place in a sequential process only if prior aspects have been considered and found to have the correct value. (H. Gladwin, 1975, p. 160)

A representative of the specific manifestation of general choice theory proposed here, as applied to settlement location selection, is shown in Figure 4 in primitive form. Each conditional preference aspect is evaluated sequentially and is accepted or rejected based on an evaluation of the specifics of the aspect.

H. Gladwin (1975) has shown that use of the additive model to analyze what was, in fact, a hierarchical decision process can yield statistically valid but totally erroneous estimators. In his study Gladwin used conventional regression techniques to investigate a data set that had been derived from a series of known hierarchical choices. The regression equation yielded apparently valid estimators but when these results were compared to the known choices they were found to have significant errors.

The development and application of a hierarchical decision model to a question of archaeological settlement analysis is exemplified by recent work by Limp (1983b), a small part of which is summarized here. In this example a

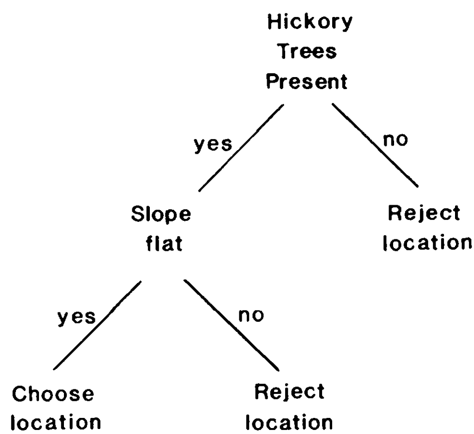

Fig. 7.4. A primitive hierarchical choice model of settlement location selection.

series of decision rules are evaluated for their capabilities in predicting site location.

The first step in applying the approach to archaeological data involved the selection of specific locational physical properties having potential importance in structuring the location choice process. Some 13 primary measurements were selected, based on an extensive review of archaeological and ethnographic literature (see Lafferty et al., 1982 for a further discussion).

In order to record the physical property information in the study area, a grid of hexagons was laid over the area. Each unit was constructed to a uniform size that would probably accommodate only one archaeological site (radius of 50 m) and was conceptualized as an alternative location for settlement. Each of the 13 physical properties was measured for the more than 21,000 units in the research unit. A suite of computer programs was developed to process the more than ⅓ million observations that were generated. The software allowed the plotting of maps showing the distribution of selected properties. It further allowed the evaluation of each location as to whether it had been subjected to a modern intensive survey, whether a site was present, the type of site, and the characteristics of the artifact assemblage.

One hundred and forty-one combinations of the attribute states of the physical properties were evaluated for their potential in predicting site locations, the particular combinations having been chosen in relation to certain a priori hypotheses of interest (see below). This was done first by designating those units in the region having combinations of property states hypothesized to be preferable for settlement as *viable locales*. Then, for each combination of preferred states, the number and percentage of all viable locales having a site present in them was determined. This figure was taken as a measure of the ability of the combination of hypothetically preferable states to predict location choice, a higher value indicating greater predictive success.

Related combinations of attribute states can be combined into a *decision tree* (see C. Gladwin, 1979) on the basis of a priori considerations of the importance of the states as preference criteria so as to form an expected preference ordering of the items being considered for selection. This expected preference ordering can then be compared to that actually indicated by data in order to test the postulated relative importance of the attribute states.

The following discussion focuses on two decision trees dealing with the nature of location choice on the floodplain of the study area. Figure 5 graphically illustrates the first of these trees which involves the conditional preference aspects of soil permeability and flood risk for locations on the floodplain. The percentage of locations having each combination of the presence or absence of these preference aspects and also having sites in them is tabulated below the tree. As can be seen, the correspondence between the postulated preference ordering of locations and that indicated by the data is very good. Additionally, it can be noted that the postulated decision tree offered the best predictions of site

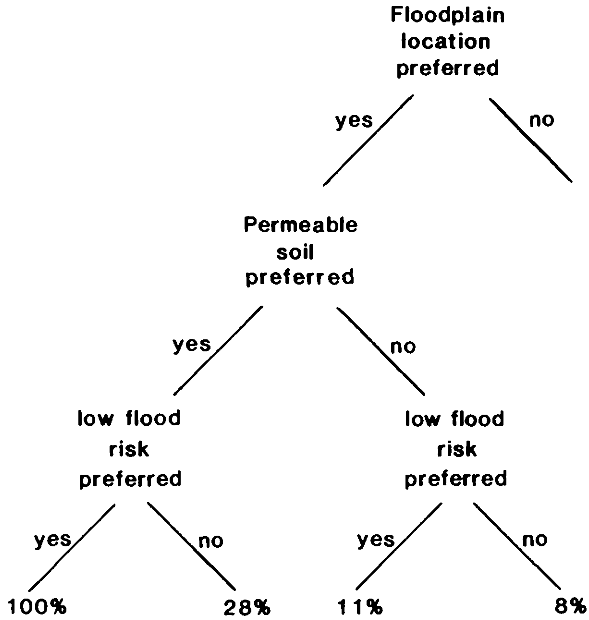

Fig. 7.5. Decision tree for floodplain locations including soil permeability and flood risk.

locations compared to others of the family of possible trees involving one or both of the floodplain locational attributes of concern. One alternative decision tree, which did not include low flood risk as a preferred aspect, was a good predictor of site location, but not as effective as the former. All decision trees which did not consider high soil permeability a preferred aspect were poorer predictors.

Figure 6 presents a second decision tree in which floodplain location, proximity to water, and low flood risk are the considered preference aspects. Again, the correspondence between the postulated preference ordering of locations and that indicated by site locational data is good. Compared to alternative decision trees within the same family, those trees that had proximity to water as a preferred locational aspect were uniformly superior to those which did not. Lower flood risk was also important but to a lesser degree.

In comparing Figure 5 and 6, it would appear that good soil permeability was a more preferred locational attribute than proximity to water. While this may be true, the situation cannot be assessed easily. Good soil permeability in the study area was associated with soil types which were only located near the largest stream. As a component of a dimensional physical property soil type, soil permeability does not yield itself to easy comparison to this other locational property for its importance.

Beyond the assessment of specific properties and location choice, it also is

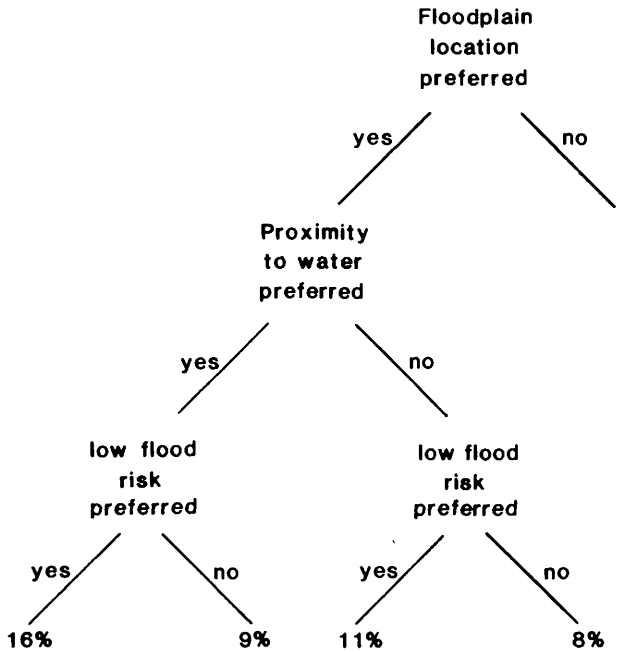

Fig. 7.6. Decision tree for floodplain locations including proximity to water and flood risk.

possible to apply this methodology to a more systematic evaluation of the differences of location decision processes among different cultural units. To illustrate the approach, evaluation of only two of the many hypotheses on cultural unit location choice that were considered will be summarized. These two hypotheses concerned four specific cultural units in the area: Early Archaic, Late Archaic, Early Woodland, and Late Woodland/Mississippian.

One area of interest was an evaluation of the differences in the decision process between Early and Late Archaic. Based on the characteristics of resource selection proposed for these periods (see Brown, 1977; Ford, 1974), it was posited, for example, that Late Archaic preferred locations could be more effectively predicted than Early Archaic preferred locations using the physical property, proximity to permanent water. To evaluate this prediction, decision trees in which variable distances to permanent water were included were constructed, and the observed results of these trees (e.g., the percentages in Figs. 5 & 6) were compared for locations with sites of the two cultural units. In ten of the decision trees involving units proximal to water, the relative density of Early Archaic sites was less than that for Late Archaic sites. In only six trees was the density of Early Archaic sites greater. Thus, the specific prediction that distance to water is a better predictor of Late Archaic sites than Early Archaic sites in the area of concern was evidently supported. Additionally, it was noted that Early Woodland and Late Woodland/Mississippian sites were distributed similar to the Late Archaic sites and unlike the Early Archaic sites. Thus, the Early Archaic occupations had a significantly less riverine focus than any of the other occupations.

There is at least one potential alternative explanation of this pattern, however, which would not require the hypothesis on decision making to be true. This is that the floodplain Early Archaic sites have been buried by alluviation. In at least two situations, deeply buried materials were observed eroding out of riverbank locations. As a result, even though the location choice modeling appeared to support the original prediction, it must remain unconfirmed.

A second prediction that was evaluated postulated that Late Woodland/ Mississippian groups should place a higher preference on high permeability soils than did earlier groups. The basis for this prediction lies in the assumption that the later prehistoric groups focused on agricultural products and would, therefore, prefer permeable soils (see Smith, 1978). Unexpectedly, it was found that all cultural units have a higher relative site density on the most permeable soil. This can be explained by the facts that soil permeability is strongly interlinked with a number of other soil and environmental variables as a dimensional physical property. Not only are permeable soils desirable for agriculture, but they also supported a vegetation type (cane) which, in turn, fostered a high faunal biomass. Such areas also could easily have been cleared to make way for any occupation. Furthermore, they were the highest locations on the floodplain yet relatively near the river course. They, therefore, were desirable for groups other than agriculturalists. In fact, considering sites of all time periods, the most permeable soil class was one of the best predictors of location choice.

Hierarchical Choice Analysis: Evaluation of the Concordance between Theory, Method, and Decision Process

Emic Symmetry

Within the original caveats about evaluation of emic symmetry, we can propose that the hierarchical choice theoretical approach and the decision tree methodology associated with it have a high degree of emic symmetry with the decision processes that probably occurred in the societies of the kinds examined. It would appear that the theory and the methodology do not place unreasonable requirements on the decision unit's information gathering or processing capabilities. In the example provided, all variables considered were simply ordered for their importance in the selection process, and locational units were ordered as sets rather than individually.

Although the hierarchical choice theoretical framework and the decision tree methodology employed in contexts of the kind illustrated here may have the greatest potential for symmetry between theory, methodology, and data structure, it is significantly constrained by the cumbersome methodology by which it is operationalized (see below). This problem characterizes not only the archaeological example presented here, but also ethnographic hierarchical decision studies (e.g., C. Gladwin, 1979). The archaeological application is limited further by the necessity of hypothesizing the potential decision trees without recourse to direct ethnographic data or observation.

Etic Coherence

There is a good degree of etic coherence in the approach presented here because the computer algorithm used to evaluate the permutations was designed specifically to mirror the decision trees under consideration, which in turn directly operationalize hierarchical choice theory. However, the methodology was limited by the absence of any simple statistical measurement for comparing the predictive strengths of alternative decision trees. This, compounded with the fact that the number of permutations of the 13 variables and the number of alternative decision trees was substantial, made evaluation of the importance of the chosen physical properties difficult. Even the 141 combinations studied were only a small fraction of the possible alternatives. Moreover, for this large number of variables and permutations, it was difficult to hold any single property constant while others varied. As a result of all of these problems, the potentially desirable goal of finding a single physical properties set predicting all site locales but only site locales (i.e., a site density of 100% and a site inclusiveness of 100%) was not feasible. It was not possible, therefore, to evaluate the success of a specific physical properties set in predicting location choice except on a series of competing, noncomplementary criteria.

Data Accessibility

The accessibility of the empirical data for each variable in this example was good. However, the massive task of gathering the mandated data must be noted as a restriction on feasibility. This task would have been necessary for any economic approach to locations prediction—hierarchical or nonhierarchical in design (see Parker, chapter 8). Fortunately, current remote sensing approaches indicate the potential for technological solution to the data-gathering encumbrance (see Kvamme, chapter 9).

Of greater concern, of course, is the conformity between the physical properties measured and the conditional preference aspects that operated prehistorically. This is not an issue of simple data accessibility, but clearly affects the structuring of observation and measurement. It is a problem that pertains not only to this example and the hierarchical framework used, but to any decision-making application in archaeology and sometimes ethnology.

There does not appear to be an easy solution for confidently assessing the conformity of the variables observed and the pertinent conditional preferences aspects in archaeological applications. It appears that only through careful ethnohistoric and ethnographic evaluations can we evaluate the first approximation of the conditional preference aspects. Further refinement must be derived from the consistency of the logic and degree of prediction support within the application.

A BRIEF INTRODUCTION TO AND ASSESSMENT OF OTHER SELECT METHODS OF ECONOMIC ANALYSIS FOR ARCHAEOLOGY

In this section we briefly consider a number of additional economic quantitative methods and associated theories which have or may have merit in application to archaeological data. Their potential in regard to their emic decision-making requirements and their data accessibility requirements is also mentioned. This discussion is meant only to suggest the diversity of economic literature on theory and method, rather than a systematic review.

Linear Programming

Linear programming is an exceptionally powerful methodology which has seen a wide diversity of applications in modern economic studies. Reidhead (1979) and Keene (1981; this volume, chapter 10) review the methodological and theoretical basis for the approach, as well as present specific archaeological applications (see Johnson, 1980 for a more pessimistic view).

Linear programming (LP), as normally applied, requires continuously divisible data; detailed linear cost functions based on analysis of a diversity of options; and a specifiable linear, algebraic, synchronic objective function which is the "targeted" relationship. Other variants of normal LP reduce some of these methodological limitations. Integer programming (Gaifinksel & Nemhauser, 1972) permits modeling with discrete, integer variables rather than requiring continuous variables. Separable programming, quadratic programming, and the sequential unconstrained minimization technique (Wagner, 1975, pp. 562-573; Hillier & Liberman, 1974, pp. 722-735) all reduce the necessity for linearity in the cost and/or objective functions, whereas dynamic linear programming (Throsby, 1962), in part, addresses the question of synchronic limitations. However, all these alternatives themselves have significant methodological constraints. For this reason, as well as the greater accessibility of computer algorithms for performing normal LP, we can anticipate that normal LP will be used for most archaeological studies.

Linear programming has a low potential for emic symmetry in most archaeological applications because it assumes major data gathering and processing capabilities for the modeled decision unit, including detailed measurability of conditional preference aspects and their simultaneous (as opposed to sequential) consideration. Also, etic coherence between LP and economic theory is troublesome because few cost functions actually are linear. The empirical data accessibility requirements of LP are massive, as both Keene (1981) and Reidhead (1976) demonstrate. Such data is primarily available through only modern experiment and/or inference from ethnographic or ethnohistoric accounts. In addition, in prehistoric situations, it is difficult to define the currency used to measure costs (see Keene, chapter 10).

The above assessment would seem to preclude LP from consideration by archaeologists, but there are aspects of LP which, while they do not eliminate these problems, certainly reduce them. These are parametric programming (or range analysis) and the analysis of the dual. Without giving technical details, it can be said that parametric programming can allow the researcher to determine the specific effect of changes or errors in the cost function and constraints on the optimal solution. The analysis gives precise values over which cost (or other variables) and constraints may range and not affect the solution. As a result, the researcher can assess the implications of potential inaccuracies in cost and constraint estimates, significantly reducing the impact of poor data accessibility and etic coherence.

The dual allows the researcher to evaluate the potential for emic asymmetry in his analysis. The dual quantitatively indicates the information accessibility and calculation capability that would have been needed by the decision unit if the modeled approach corresponds with the actual characteristics of the decision unit. This is done by stipulating the number of resources that constrain the solution (binding constraints). If the dual indicates that only one or a few resources constrained the solution, then this is clearly within the information gathering and processsing capabilities of the decision unit.

Thus, with the dual and parametric programming, LP may serve as an effective approach in a number of circumstances. Its actual emic symmetry, etic coherence, and data accessibility requirements are themselves a matter for case-by-case evaluation.

Statistical Decision Theory Using Decision Trees

This approach is similar in method to the hierarchical choice approach presented earlier, in that both employ decision trees. As commonly practiced, however, it differs from the hierarchial choice approach because it involves the assessment of numeric probabilities for various alternatives and a similar assessment of the "payoffs" (value) of each alternative.

Regarding the emic decision process assumed by the theory and the data accessibility requirement posed by the methods associated with it, statistical decision approaches may be restrictive. Statistical decision theory is characterized by the decision maker enumerating all the available courses of action, expressing the utilities, and quantifying his subjective probabilities. This approach also has limitations because the data required (the subjective probabilities, utilities, etc.) may be either impossible to obtain or heavily dependent upon the judgment of a single individual (Hillier & Liberman, 1974, p. 616).

However, when these data are available, decision analysis becomes a powerful tool in determining an optimal course of action.

Game Theory

Game theory concepts present an attractive structure from which to conduct analysis of prehistoric decision making. Such methods have been used, for example, in a number of anthropological studies (Barth, 1959; Davenport, 1960; Gould, 1963; Manch, 1971). The concepts underlying the initial SARG research design (Gummerman, 1971) used game theory nomenclature in presenting an analytical framework for the analysis of prehistoric site distributions.

Like statistical decision theory, game theory and its associated methodologies have a number of significant quantitative requirements for full application, increasing the likelihood of emic asymmetry when applied to prehistoric contexts. Objectively measurable and transferable "stakes of interest" (the expected gains) must be determined by the players. Alternative outcomes must be enumerated, as the probabilities for each alternative must be for each player.

The information accessibility requirements of game theory and its associated methodologies are high. In a specific empirical situation, it becomes quite difficult to obtain the level of information described above. Johnson (1980, p. 22) goes so far as to say that anthropologists "have had no success" with game theory. The economists, Dorfman, Samuelson, and Solow (1958), characterize the merits of the approach.

> What, in view of all these limitations, has game theory to contribute to economics? Oddly enough since game theory is an attempt to determine optimal strategies explicitly, the contribution seems to be qualitative rather than quantitative. The conceptual framework developed in game theory provides a useful set of constructs for the qualitative discussions of problems of opposing interest in economics (p. 445).

Appropriate Contexts of Use of the Diversity of Economic Theories and Methods

In our discussion of the formalist-substantivist debate it was proposed that the critical, theoretically relevant issue separating the two positions was the assessment of the amount of information that is *accessible* to a nonwestern decision unit. Methodologically, this degree of information accessibility can be modeled by the number of k-fold partitions into which the relevant decision information can be divided and whether the decider enumerates the probabilities of success and the payoffs offered by each set of alternatives. In the discussion of the satisficer-maximizer debate, it was further proposed that the key theoretical issue segregating these views was the information *processing* capabilities required of the decision unit. This requirement is represented methodologically by the sequential or simultaneous nature of information processing, the size of the matrix of variables simultaneously or sequentially considered, and the degrees to which the probabilities of success and the payoffs of alternatives are modeled into the decision process.

These two measures, information accessibility and information processing, can be used to display graphically (Fig. 7) the relationships between the various theoretical or methodological approaches discussed in this chapter, in regard to the nature of the decision-making process which they assume. In addition, a limited number of other approaches not discussed here are also displayed (see Bamoul, 1972 for discussions of these alternative approaches).

As Figure 7 clearly indicates, there is a diversity of economic approaches that are conceptually and methodologically appropriate across a wide range of combinations of circumstances. Previous applications of choice theory and method to archaeological problems have tended to focus on one or only a limited range of the alternatives, particularly at the more assuming end of the spectrum. This focusing has tended to obscure the range of choice analyses possible

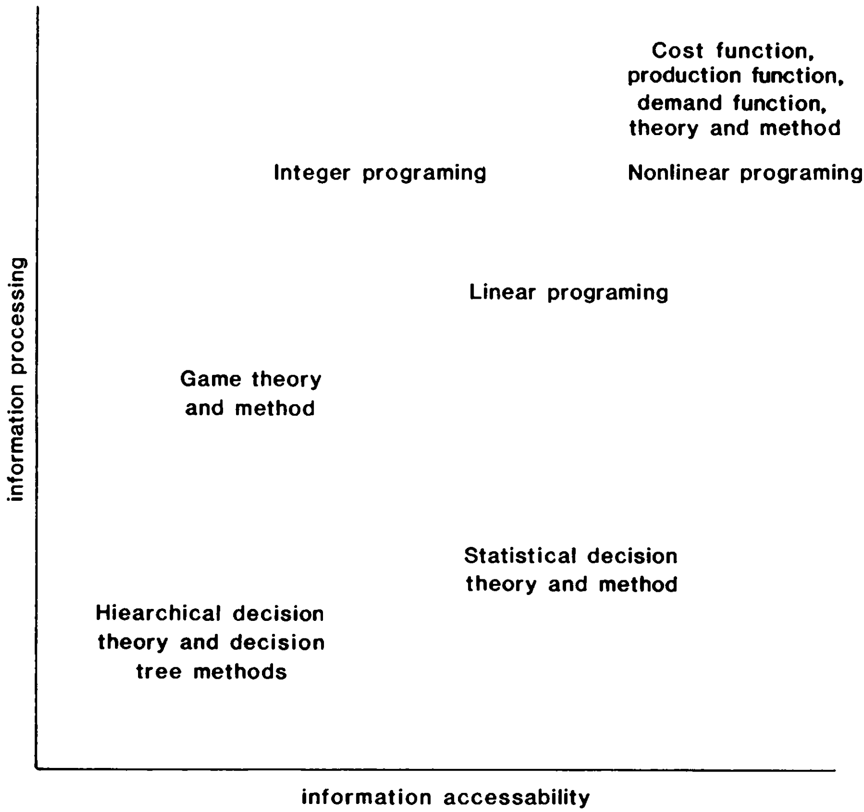

Fig. 7.7. Alternative economic approaches graphed along dimensions of information processing and accessibility.

and in many situations has led to an inappropriate rejection of choice analysis *generally*, when the correct conclusion to be drawn was that the *specific* pairing of theory and method was inappropriate. Additionally, the more focal view has not encouraged archaeologists to either consider the specific contexts in which one form of general choice theory might be more appropriate than another or to develop the proper bridging arguments between theory and data. It is hoped that this chapter has suggested the rich diversity of forms of choice analyses available, the work that still is necessary for us to be able to apply them appropriately, and the potential understanding of prehistoric behavior which may be gained by their appropriate application.

CONCLUSION

This chapter has only begun to present the complexity of the theoretical and methodological issues pertinent to the analysis of choice in an archaeological context. Furthermore, it should be emphasized that there is a wide diversity of theory-method couplings which have or could have merit in archaeological applications. It is appropriate, therefore, to close with two cautionary notes. First, it must be recognized that economics, perhaps more than any other social science, is ideological and intertwined with political implications. So, too, are any economic analyses, including those within archaeology.

> Every economic doctrine has a purpose. Economics is an ill developed branch of the biology of the human species; an economist is (presumably) a human being and cannot regard his fellowmen with the same detachment as his colleague in the laboratory regards a collection of fruit flies. Thus there is always an element of ideology in any discussion of social problems. (Robinson, 1980, p. 1x)

The presentation here has intentionally not addressed the subject of any of these ideological concerns, but an awareness of their existence and implications is critical to fully understanding and applying any economic theory. It is clear that neo-classical marginal analysis has, at least its roots in western "capitalist" economics, though this simple statement obscures a very real complexity. The ideological roots of axiomatic choice theory are more obscure. Axiomatic choice developed initialy out of fundamental disagreements between Arrow, who explicitly wished to include social factors generally and social welfare specifically in economic formulae, and neoclassical theoreticians, who were not so inclined.

It is far beyond the scope of this chapter to confidently place axiomatic choice within the diversity of economic ideology beyond these simple basic statements. Suffice it to say that the ideological and practical implications and assumptions of economic theories must be considered in any analysis, just as assumptions such as information processing capacity or the relation between physical properties and conditional preference aspects have been considered here.

A second consideration, only suggested here, is that economic models need not be restricted to the traditional arena of material provisioning. Blau (1964), Homans (1958), Heath (1976), Schneider (1974), and others have presented productive applications of choice theories to a diversity of processes, often collectively referred to as *social exchange*. Again, our discussion here has been restricted intentionally, in order to yield the clearest practical examples. However, we must emphasize that while, pragmatically, material provisioning may be initially the most productive area for economic theory in archaeology, it is by no means the only or the most important component.

Archaeologists have often been encouraged to consider the Indian behind the artifact. More recently the discipline has been invited to consider the system behind the Native American behind the artifact. The emphasis here has been on the decision process behind the system behind the Native American behind the artifact.

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