

Conjoint Analysis: A Preference-Based Approach for the Accounting of Multiple Benefits in Southern Forest Management

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ABSTRACT. *Conjoint analysis, which enables a manager to measure the relative importance of a forest's multidimensional attributes, is critically reviewed and assessed. Special attention is given to the feasibility of using conjoint analysis for measuring the utility of market and nonmarket outputs from southern forests. Also, an application to a case of designing a nature and recreational park within a pine forest of North Carolina is presented. The authors conclude that there are promising applications for conjoint analysis; however, traditional validity testing, especially of southern nonindustrial private forest owners, is needed. South. J. Appl. For. 21(4):180-186.*

Public and private southern forests produce multiple benefits from outputs that are both traded and not traded in the marketplace. Accurate accounting of both monetary and nonmonetary benefits is needed by forest resource managers and policy makers to evaluate the relative attractiveness of alternative forestry-related plans and decisions. Pearse and Holmes (1993) reviewed the theory of nonmarket valuation and alternative approaches for estimating the value of nonmarket benefits produced by southern forests. Conjoint analysis is critically reviewed and assessed in this paper as an approach for accounting for both the monetary and nonmonetary benefits provided by southern forests.

Conjoint analysis is a marketing research technique most commonly used for measuring individuals' preferences toward alternative new product or service designs containing multiple attributes (Wittink and Cattin 1989). Specifically, the technique involves the measurement of the joint effect of two or more product or service attributes on consumer preference. The technique has been used to value such natural resource-related opportunities as waterfowl hunting trips (Gan 1992, Gan and Luzar 1993), and nature and recreational

parks (Zinkhan et al. 1994). The approach presented here can measure nonmarket benefits in utility units from the perspective of either private landowners or users of forests. When applied to cases in which landowners are concerned with aesthetics, ecological integrity, and other nonmarket benefits in addition to timber production, the approach can generate, from the perspective of the landowner, utility measurements for each competing forest management plan. When administered to visitors of forests, the approach is capable of supplying visitor utility-level estimates for each management scenario under consideration.

There are three basic approaches for measuring the preferences of an individual or group: decompositional, compositional, and decompositional/compositional (Green and Srinivasan 1990). When applied to forestry, traditional conjoint analysis is a decompositional approach in which landowners or users rank or rate entire forest management scenarios relative to overall preference. It is assumed that each forest management scenario can be specified as an alternative bundle of attributes. Preference data are decomposed into marginal utility estimates (or part-worths, using the terminology of conjoint analysis) for each level of each attribute. One practical problem with this approach is that the number of forest management scenarios to rank or rate can become overwhelming, and thus mentally complex (see Green 1984), as the number of attributes increase.

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In contrast to the decompositional approach, the compositional approach relies on evaluations by the landowners or forest users of individual attributes and attribute levels—as opposed to having the respondents rate or rank full profiles of the forest alternatives. Lack of consideration of intercorrelation among attributes, however, is a significant problem with the compositional approach (Green and Srinivasan 1990). The decompositional/compositional approach combines elements of both methods; the combination eases the data collection process when the number of attributes is large, and yet intercorrelations between attributes are considered within the decompositional component of the survey. Adaptive conjoint analysis, which is one of the methods described in this paper, is an example of this hybrid approach.

After characterizing potential applications of conjoint analysis to southern forest management, we describe and then evaluate the alternative preference elicitation methods. Then, we review an application of adaptive conjoint analysis for estimating utility levels associated with alternative management plans from the perspective of potential visitors to a hypothetical private nature and recreational park within the longleaf pine (*Pinus palustris*) forests of North Carolina. Finally, we present our conclusions, with an emphasis on guidance for future research and empirical testing.

Potential Southern Forest Management Applications

Conjoint analysis is an example of a multi-attribute utility model, any of which holds potential for use in at least two basic categories of southern forest management problems:

- Managerial applications in which two or more competing forest management plans are evaluated from the perspective of one or more owners (or managers or planners) with respect to multiple attributes, at least one of which is a nonmarket benefit.
- Marketing applications in which utility or willingness-to-pay (WTP) levels for one or more nonmarket benefits need to be estimated.

Managerial Applications

As noted by Boucher and MacStrovic (1991, p. 3), the “robustness [of multi-attribute utility models] in dealing with judgment has made them a natural substitute for the limitations of the financial calculation.” For those managers desiring to integrate utility and financial considerations, a financial criterion such as net present value may serve as one of several attributes within the multi-attribute utility model.

There have been numerous applications of multi-attribute utility models to forest management problems. Some have been private-sector oriented [e.g., Hyberg’s (1987) comparison of forest management alternatives relative to the utility function of nonindustrial private forest owners] and some public-sector oriented [e.g., Teeter and Dyer’s (1986) adaptation to the comparison of strategies of forest fire management planners]. In a similar application, Zinkhan and Zinkhan (1994) adapted a form of conjoint analysis to elicit manager preference functions for an analysis of southern agroforestry alternatives.

Hyberg’s application suggests several important southern forest management problems to which conjoint analysis can be applied. Shelterwood, seed tree, and clearcut systems were evaluated for a loblolly pine (*Pinus taeda*) plantation in North Carolina. A “lottery” methodology, as opposed to conjoint analysis, was used to measure the owners’ utility as a function of such attributes as timber income and aesthetics (defined as a function of residual basal area). Whether adopting Hyberg’s or a conjoint analysis approach, the professional forester would need to accomplish two separate tasks:

- Estimate the owner’s utility function relative to a set of relevant attributes, in this case timber income and aesthetics.
- Assess each forest management alternative relative to the set of attributes.

Subject to any operating or regulatory constraints, the preferred forest management plan would be the one with the anticipated attributes that maximize an owner’s utility.

Estimating Users’ Utility for Nonmarket Benefits

As emphasized by Pearse and Holmes (1993), benefit/cost criteria for public forests with multiple outputs are not feasible without value estimates for the nonmarket benefits. Private forestland investors interested in capturing income from visitors’ use of the resources also need information about the visitors’ relative preferences for alternative mixes of forest conditions. Such data can be incorporated into the decision framework for both evaluating natural resource plan alternatives from the perspective of potential users and establishing pricing levels for a property’s outputs.

Given these needs, most of the previous applications of conjoint analysis to natural resource management problems have been oriented toward valuing nonmarket benefits or measuring users’ utility (e.g., Mackenzie 1990, 1993, Gan 1992, Gan and Luzar 1993, Johnson et al. 1995, Louviere and Timmermans 1992, Adamowicz et al. 1994, Holmes et al. 1996). Resource economists often adopt the contingent valuation method to value nonmarket benefits. The contingent valuation method is concerned with the use of surveys or simulated markets to reveal respondents’ maximum willingness to pay levels for nonmarket benefits. Although empirical testing of the relative merits of the two techniques is needed, Johnson et al. (1995, p. 23) hypothesized that “the comparative richness of conjoint data may make it possible to devise more satisfactory tests of theoretical validity for both use and nonuse values.”

Preference Elicitation Methods

In this section, we describe compositional, decompositional, and hybrid preference elicitation models in more detail.

The Compositional Method

To apply a hybrid preference elicitation method to a forestry application, at least three phases of data collection must be undertaken with each respondent (see Green et al. 1991). The first two phases represent the compositional

component of the hybrid method; the final phase consists of the decompositional component.

In Phase 1, each respondent rank orders the levels within each attribute. Consider the potential nature and recreational park in which one of the relevant attributes is entrance fee, with three levels under investigation: \$10, \$20, and \$30. Everything else the same, a rational respondent would rank-order this cost series as follows: 1 (for the \$10 level), 2 (for the \$20 level), and 3 (for the \$30 level).

In Phase 2, the respondent is directed to rate the importance of receiving the most preferred level for each attribute (\$10 in this example) rather than the least preferred level (\$30). For example, the ACA (Adaptive Conjoint Analysis) System marketed by Sawtooth Software, Inc. (Ketchum, ID) directs the respondent to rate the importance of the difference on a 4-point scale: 1 ("not important at all"), 2 ("somewhat important"), 3 ("very important"), and 4 ("extremely important"). The output of Phase 2 consists of a preference measure, termed a part-worth, for each level of each attribute. The part-worth is estimated by rescaling the product of the importance rating and the rank order, so that the range of part-worths for a given attribute is equal to the attribute's importance rating while the sum of part-worths for a given attribute is set equal to zero (Huber et al. 1993). The part-worth (pal) contributed by level l of attribute a is (Green 1991):

$$pal = w_a[(r_{al} - 1)/(L_a - 1) - 0.5] \quad (1)$$

where

- w_a = the importance rating assigned to attribute a
- r_{al} = the converted form of the rank order assigned to level l of attribute a (rank orders of 1, 2, and 3 would be converted, for example, to 3, 2, and 1, respectively)
- L_a = number of levels associated with attribute a

For example, if a respondent provided the attribute entrance fee with an importance rating of "3," then the corresponding part-worths for levels \$10, \$20, and \$30 would be 1.5, 0, and -1.5, respectively. If another respondent provided an importance rating of "1," then the part-worths for entrance fee would be 0.5, 0, and -0.5.

Phases 1 and 2 are not intended to represent a stand-alone model (Huber et al. 1993). Rather, the compositional output serves as an input into the decompositional component (Phase 3). Prior to describing the ACA System's unique approach to Phase 3, we will present and discuss the general decompositional model.

The Decompositional Method (Traditional Conjoint Analysis)

The general form of the decompositional model assumes that the utility $U(X)$ for a given nature and recreational park design is the sum of the part-worths contributed by each level of all attributes being considered by a visitor (Jain et al. 1979):

$$U(X) = \sum_{a=1}^A \sum_{l=1}^{L_a} p_{al} x_{al} \quad (2)$$

where

- A = number of attributes
- x_{al} = dummy variable, equal to 1 if the park design being considered has attribute a at level l , or 0 otherwise

$L - 1$ independent variables are needed for each attribute to estimate the part-worths. Consider the task of designing the nature and recreational park, with two attributes under investigation: entrance fee (attribute 1) and the opportunity to visit a red-cockaded woodpecker (RCW) colony site in the company of a park ranger (attribute 2). Under investigation are three entrance-fee levels—\$10 (attribute 1, level 1), \$20 (attribute 1, level 2), and \$30 (attribute 1, level 3)—and two RCW visitation levels—prohibited (attribute 2, level 1) and permitted (attribute 2, level 2).

Given the six potential nature park design combinations, assume that a given visitor has rank ordered them as indicated in Table 1. Once the rank orders in Table 1 have been converted into $U(X)$ measures (simply, by using the converted form of the rank orders), the incremental contribution (B_{al}) of the l th level of the a th attribute can be estimated:

$$U(X) = B_{12}x_{12} + B_{13}x_{13} + B_{22}x_{22} \quad (3)$$

Using ordinary least squares regression, the estimated coefficients associated with the data in Table 1 are -1.5 (B_{12}), -3.00 (B_{13}), and 2.33 (B_{22}). Then, the part-worths can be estimated by solving a series of five simultaneous equations (Jain et al. 1979):

$$p_{11} + p_{12} + p_{13} = 0 \quad (4)$$

$$p_{21} + p_{22} = 0 \quad (5)$$

$$p_{12} - p_{11} = B_{12} = -1.50 \quad (6)$$

$$p_{13} - p_{11} = B_{13} = -3.00 \quad (7)$$

$$p_{22} - p_{21} = B_{22} = 2.33 \quad (8)$$

Table 1. Example of conjoint analysis where respondents rank-ordered six combinations of two attributes.

Combination	Entrance fee (\$)	RCW colony visit	Rank
A	10	No	3
B	10	Yes	1
C	20	No	5
D	20	Yes	2
E	30	No	6
F	30	Yes	4

The five estimated part-worths associated with the potential nature and recreational park are 1.5 (p_{11}), 0 (p_{12}), -1.5 (p_{13}), -1.17 (p_{21}), and 1.17 (p_{22}). Thus, using Equation (2), the highest ranked combination in Table 1 (combination B) has a total utility of 2.67 utils (1.5 + 1.17).

What if the nature and recreational park was perceived to be a seven-attribute "product" (rather than a two-attribute one) and each attribute was composed of three levels? Then, a total of 2,187 alternatives (3^7) would have to be tested if all possible combinations were considered (see Green and Wind 1975). Clearly, this is not feasible. Instead, the researcher can use a test design based on an orthogonal main-effect plan in which, by definition, the independent contributions of all seven attributes are balanced (Green and Wind 1975). Using an orthogonal main-effect plan constructed by Addelman (1962), the 2,187 alternatives can be reduced to 18 combinations to be ranked by a respondent. Once the part-worth for each of the three levels for all seven attributes is estimated, the total utility of any of the 2,187 possible park combinations can be calculated using Equation (2).

Some debate has surrounded the relative merits of various techniques—ordinary least squares regression, monotone regression methods (such as MONANOVA), logit, and linear programming—for estimating the part-worths (Zinkhan 1982). The findings based on empirical research are mixed. Jain et al. (1979), for example, found that the logit and linear programming methods were superior in terms of overall predictive efficiency. However, for certain data collection procedures (such as when the designer of the study distinguishes data based on the ranking of an array of combinations versus a series of paired comparisons) and for selected validity criteria (such as predicting the single most preferred or least preferred combination), the other methods were found to be equal to or superior to the logit and linear programming methods. A survey of marketing researchers indicated that ordinary least squares regression was the most commonly used estimation method (Wittink and Cattin 1989).

The Hybrid Preference Elicitation Method (Adaptive Conjoint Analysis)

The hybrid method combines the output of Phases 1 and 2 (the compositional component) with a respondent's preference ratings toward a series of paired comparisons (Phase 3, the decompositional component). In our example, the respondent was directed to reveal her relative preference on a scale from 1 (strongly prefer the alternative presented on the left side of the screen) to 9 (strongly prefer the alternative presented on the right side of the screen) for each pair of nature and recreational park design alternatives presented. A rating of 5 indicates an indifference between the pair of alternatives. Prior to the updating of part-worths in this phase, the integer 5 is subtracted from the raw preference rating so that the potential range of adjusted preference scores is -4 to +4.

A procedure similar in concept to equations (3) – (8) is used after each paired comparison in Phase 3 to dynamically update the part-worths. However, the regression layout incorporates the adjusted preference scores, a design matrix containing dummy variables associated with each pairwise

comparison, and the previous series of updated part-worths (which initially is represented by the output from Phases 1 and 2). Details of the complex regression layout used in Phase 3 have been provided by Green et al. (1991) and Johnson (1991).

The attribute levels presented to the respondent in Phase 3 are selected by a heuristic so that the estimated difference in the utilities of the pairs is minimized, subject to the constraint that the array of levels is balanced in an "almost orthogonal" fashion (Green et al. 1991).

Advantages and Disadvantages for Forest Resource Managers

Over the last 2 decades, marketing managers have found conjoint analysis to be especially useful for improving their understanding of consumer behavior toward changes in one or more of a product's multiple attributes (Green and Wind 1975, Gan and Luzar 1993). As will be discussed in the next section, many forestry decisions are also multi-attribute in nature. Thus, conjoint analysis seems well suited to complement other forestry decision-making tools, especially when nonmarket attributes are considered relevant. Three major advantages of using conjoint analysis as a method for analyzing the preferences of forest owners and visitors include the following:

1. Conjoint analysis provides a measure of how sensitive a forest owner or visitor is to changes in forest attributes.
2. The technique is flexible in its ability to assess either the overall utility provided by an entire bundle of attributes or the marginal contribution of a single forestry attribute to an individual's or group's utility.
3. The trade-off aspect of the conjoint analysis process tends to deepen respondent introspection and generates a trail of responses for consistency checks (Johnson et al. 1995).

Potential disadvantages to the technique include the following:

1. One of its core underlying assumptions is that all relevant attributes can be identified and described. Not only are individuals heterogeneous relative to their sets of relevant attributes, but also some forestry-related attributes such as aesthetics are difficult to describe.
2. Responding to trade-offs can be "cognitively challenging" to the respondents, especially when they include unfamiliar attributes and a large number of questions (Johnson et al. 1995).
3. The technique assumes that interaction effects between attributes are absent. With conjoint analysis software packages permitting as many as 30 attributes per study, inclusion of the maximum number would tend to increase the likelihood of introducing interaction effects. However, even simple studies can violate the assumption of independence of attribute effects. For example, if two

attributes being considered by a forest owner in his evaluation of harvesting plans are residual basal area and a form of aesthetics score for the alternatives, then double-counting would probably result. Since aesthetics is probably, at least in part, a function of residual basal area, it should not be considered as an additional, independent variable. In other cases, two attributes may be closely linked. If two attributes included in the previous example were immediate net cash inflow from a timber sale and residual basal area of timber (as a proxy for aesthetics), then the attributes' levels are clearly not independent. A high (low) net cash flow would suggest a heavy (light) harvest level and thus a relatively low (high) residual basal area.

To address the first two potential disadvantages, the manager or researcher should take great care in selecting and describing the attributes used in the exercise. A well-designed focus group or survey, for example, might be necessary to gain insights about the relevant attributes, how the targeted individuals make decisions, and the appropriate range of levels to be used in the study (Mercer et al. 1995). The range of levels incorporated within the study should be consistent with the range of possibilities associated with the forest resource (Metegrano 1991). For example, consider again the case in which near-term residual basal area of a given forest stand is an attribute. Also assume that the stand contains 100 ft²/ac of basal area and that "clearcutting" and "no harvest" are two of the management options being considered. Then, the appropriate range for this attribute is 0 – 100 ft²/ac.

With respect to the third disadvantage, selection of an appropriate data structure may enable the researcher to include two attributes in a study even though they are linked. For example, the ACA System enables the designer of the study to identify prohibited pairs of levels. Thus, the respondent would not be asked to consider a paired comparison in which one or both of the alternatives had infeasible combinations, such as a relatively high level of residual timber basal area linked with a relatively high level of net cash inflows from a timber sale.

The relative validity associated with the alternative preference elicitation methods (compositional, traditional conjoint analysis, and adaptive conjoint analysis) is an empirical issue. In the most comprehensive evaluation of the three methods, Huber et al. (1993), using a consumer product application, reported that adaptive conjoint analysis predicted choices better than the other two methods when warmup tasks were not administered to the respondents. With respect to a nature tourism application, Holmes et al. (1996) found that adaptive conjoint analysis and traditional conjoint analysis correctly predicted a similar percentage of most-preferred trip packages; for the entire sample, both of these methods outperformed the compositional model. In the next section, an application of adaptive conjoint analysis to the measurement of users' utility for alternative nature and recreational park designs within a southern pine forest is presented.

An Application

We tested adaptive conjoint analysis for forest management problems with a case study of 30 students in a graduate business administration class¹ in Rocky Mount, North Carolina. The students were directed to consider a prospective (and hypothetical) 5,000-acre private, nature and recreational park near Pinhurst/Southern Pines, North Carolina. The exercise was characterized as a marketing application tailored to the measurement of potential visitors' total utility for various design mixes. The park was described as follows:

This site, located in the sandhill region, is largely forested with natural stands of longleaf pine—including some that are over 120 years of age. A number of colonies of the endangered red-cockaded woodpecker, or RCW (*Picoides borealis*), are located on isolated portions of the tract. The prospective park includes a 300-acre, man-made lake stocked with bass. A small fishing pier, accessible to visitors, runs into the lake. A sandy beach surrounds the lake; part of the lake will be designated as a swimming area and will be patrolled by a lifeguard. Hiking trails will permit individuals to reach most parts of the park.

A nature center in the park will serve as the site for displays of local nature-oriented photographs, art, and literature. A video that describes and depicts the local ecology will be shown at the center. Also, the center will serve as the base for evening lectures.

Directed to assume the perspective of a prospective visitor, students were informed that five park designs were under investigation. Each alternative park design represented a unique mix of the four attributes described in Table 2.

Part-worths, associated with each level of the four attributes, were estimated for the group using a customized routine prepared with the ACA System. The results are reported in Table 2. Notice that the part-worths are scaled to sum 400 utils (i.e., 100 × # attributes). As expected, these data suggest the following with respect to each of the four attributes:

Table 2. Part-worths associated with different levels of the 4 attributes of a prospective (and hypothetical) park used as a case study of adaptive conjoint analysis with 30 graduate students as respondents.

Attributes	Level	Part worth
Boat launch (for nonmotorized watercraft)	No	6
	Yes	81
Overnight accommodations	Tent	3
	Tent & cabin	86
RCW colony	No	11
	Yes	45
Entrance fee	\$10	110
	\$20	58
	\$30	0
Sum		400

¹ Graduate business students are frequently used as subjects for presenting and testing conjoint analysis approaches (e.g., Safizadeh 1989, Srinivasan 1988).

Table 3. Descriptions and estimated total utilities of 5 alternative park designs based on adaptive conjoint analysis with 30 graduate students as respondents.

Combination	Boat launch	Overnight accommodations	RCW colony visit	Entrance fee (\$)	Total utility
A	No	Tent only	No	30	20
B	Yes	Tent & cabin	Yes	20	270
C	No	Tent & cabin	Yes	10	247
D	Yes	Tent only	Yes	30	129
E	Yes	Tent & cabin	No	20	236

- A preference for the right to launch their non-motorized boats (versus a prohibition).
- A preference for the availability of small rustic cabins in addition to an area for tents.
- A preference for the provision of the opportunity to visit an RCW colony site with a park ranger.
- A preference for a relatively low entrance fee (per adult visitor) compared to a relatively high entrance fee. (Given the obvious nature of this outcome, the direction of this relationship is *a priori* ranked within the ACA System.)

Using the part-worth matrix in Table 2 in conjunction with the descriptions of the five park designs in Table 3, the sums (i.e., the total utility levels) for each alternative were tallied (and are shown in Table 3). For this sample of respondents, park design B provided the greatest utility. Estimated total utility levels for the park designs are quite sensitive to selection decisions for each of the four attributes. For example, if the manager of the park were to raise the entrance fee of design B from \$20 to \$30, then its estimated total utility level would decrease from 270 to 212 utils—less than park design C (247 utils).²

Without additional inputs, the estimated total utility levels simply provide the park manager with an indication of relative visitor preference for each design alternative. The ACA System, however, enables the analyst to feed such utility data along with assessments (relative to the same attributes) of competing visitation destinations into a market simulator component. This component estimates market shares for each competing visitation destination. Preliminary empirical evidence indicates that conjoint analysis can accurately predict market share estimates for consumer products and services (Green and Srinivasan 1990). Projected market share serves as one input for generating forecasts for revenues, net profits, net cash flows, and other relevant financial variables for each prospective park design. Thus adaptive conjoint analysis may be used to improve the accuracy of traditional financial criteria.

Conclusions

For some forestry applications, conjoint analysis may improve financial projections. In other cases, financial criteria may be inadequate for evaluating alternative forest management scenarios. When the latter is true, we recommend conjoint analysis to quantify nonmarket forest ben-

efits when complemented with professional judgment regarding forest management alternatives.

To date, only a few studies have applied conjoint analysis to forestry and other natural resource management and policy problems. Given the importance of nonindustrial private forest land owners in the South, empirical tests of conjoint analysis measures of nonmarket benefits produced by their forests should prove especially fruitful. Traditional validity testing (e.g., Green et al. 1981) of conjoint analysis applied to actual cases involving nonindustrial private forest owners is a logical first step.

In addition, methodological research in applying conjoint analysis and its extensions to forestry/natural resource problems is warranted. As the demand for recreation and other nontimber outputs from southern forests continues to increase, the need for accurate nonmarket benefit valuation approaches will intensify. In terms of applications to recreation and nature tourism, research examining the potential for combining conjoint analysis with traditional nonmarket valuation tools such as the contingent valuation method and travel cost analysis may prove especially beneficial (see Adamowicz et al. 1994).

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² Preliminary validity testing associated with this exercise is described by Zinkhan et al. (1994).

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