The revealed preferences of a government bureaucracy: theory

Daniel McFadden

Professor of Economics
University of California, Berkeley

> "The advance of the bureaucratic structure rests upon 'technical' superiority."
> —Max Weber, *Wirtschaft und Gesellschaft*

A method is developed for inferring, from the consequences or outcomes of organizational decisions, an implicit choice criterion such that the organization behaves as if it were following this decision rule. The method is quantified for the case of a public bureaucracy facing discrete alternatives, and is applied in a study of the decision rules underlying freeway route selection by a state division of highways. Tests are carried out on the form of the benefit-cost calculus utilized by the bureaucracy, on the implicit evaluation of indirect benefits and costs, and on the influence of political factors on routing decisions.

1. Introduction

■ Government bureaucracies responsible for regulating utilities or designing investment projects are often given the general mandate to maximize "public welfare" and left with considerable freedom in translating this goal into concrete decision rules. The result is often an ambiguity within the organization about the weight to be given to various factors in making choices, leading to decisions which are vulnerable to criticism on grounds of inconsistency or of lack of fidelity to the mandate. Because the quality of the decisions of a public agency, unlike those of a business firm, cannot be put to the market test of profitability, it

---

Daniel McFadden received the B.S. in physics and the Ph.D. in economics from the University of Minnesota. Currently, he is studying the problems of measuring supply and demand in transportation and in regulated industries.

This research was motivated by the work of Phoebe Cottingham, and draws heavily on her detailed investigations of the administration of the California Division of Highways, both for data and suggested hypotheses. I have benefited from discussions of the statistical procedure with H. Theil, Y. Mundlak, and Z. Griliches. Credit for programming assistance and data analysis goes to C. Liew, T. Ratcliffe, H. Wills, and G. Duguay. This research has received support from the Ford Foundation, the University of Chicago, the National Science Foundation, and the Institute of International Studies of the University of California, Berkeley; however, the opinions expressed herein do not necessarily reflect the positions of these agencies. The econometric methods developed in this research first appeared in an unpublished working paper, "The Measurement of Public Investment Criteria," in 1967. An extensive revision with empirical results appeared as an unpublished technical report, with the current title, in 1968. The detailed econometric procedures and other applications have been published separately in [3] and [4].

This is the first of a two-part study. The second part, which will appear in the Spring 1976 issue of *The Bell Journal of Economics*, will develop the evidence.

is necessary to examine the organization's decision processes and outcomes directly to evaluate its performance.

One approach to the assessment of organizational performance is the study of the *process* of decisionmaking, concentrating on the command and information structure within the organization. This is the "Carnegie" method pioneered by Cyert, March, and others. A drawback to this method is that it requires a degree of access and candor that is rarely attainable, particularly from outside the bureaucracy.[1]

A second approach to the study of bureaucratic performance is to examine the *consequences* or *outcomes* of the organization's decisions, and to pose the *revealed preference* question of whether there exists an implicit choice criterion such that the bureaucracy behaves *as if* it is attempting to follow this choice rule. Since bureaucracies are usually complex organizations in which information loss and scrambling of directives are common, it is unrealistic to seek a single choice criterion which rationalizes all outcomes. Rather, it is reasonable to look for a statistical distribution of decision rules which can explain observed patterns of choice. The "location" of this distribution provides information on the average weighting of factors in decisions, while its "dispersion" gives a measure of the internal consistency of the bureaucracy's decision structure.

This paper provides an econometric framework for the revealed preference analysis outlined above, and uses it to examine the criteria used for freeway route selection by the State of California Division of Highways between 1958 and 1966. We seek answers to the following questions:

(1) To what extent is freeway route selection controlled by simple investment criteria, such as maximization of net benefits or of the benefit-cost ratio?
(2) How do capital budget constraints on right-of-way and construction costs affect the relative weights given to benefits and costs?
(3) What is the implicit evaluation of net indirect benefits implied by the weights given to variables indicating alternative uses of highway corridors, including the number of parks and schools affected, etc.?
(4) What weight is given to the route preferences of affected individuals and groups, including local governments, community leaders, etc.?

The following section of the paper, based on the work of Cottingham,[2] describes briefly the California Division of Highways, and its planning procedures, in the period from 1958 to 1966. Section 3 describes the data collected by the Division as part of the route selection process, and the relation of their measures to common economic variables. Section 4 outlines a theoretical foundation for the measurement of a distribution of

---

[1] As Weber observes, a successful bureaucrat will protect himself from the scrutiny of superiors or outsiders by utilizing formal decision processes and regulations, secrecy, and the obscuration of relevant facts in volumes of irrelevant data, to shield discretionary behavior from view.

[2] In [1], chapters 2–3.

decision rules, and provides an econometric procedure for implementing the theory. The second part of this study tests the theory by applying it to route selection data for the California Division of Highways.[3]

2. Freeway planning procedures in the California Division of Highways

■ During the period from 1958 to 1966, the California Division of Highways was a government bureaucracy charged with planning, constructing, and maintaining the State's highway system. The activities of the Division were partly constrained by State legislative provisions and Federal guidelines for the interstate highway system. Nevertheless, because the Division's budget was funded by statutory provision from gas tax revenues and was therefore exempt from direct budgetary review and appropriation by the State legislature, the organization enjoyed unusual autonomy.

The major investment decisions of the Division were the selection of freeway projects and the selection of routes within projects. There were several factors in the project selection decision which must be considered in our examination of route choices. First, a legislatively established system of "minimums" constrained the geographical distribution and timing of highway fund allocations.[4] Investment programs meeting these constraints were likely to show considerable variation between projects in terms of conventional economic measures of desirability such as the benefit-cost ratio. Second, the major determinant of project choice in a given geographical area was the "deficiency" of existing road systems, measured primarily by the number of vehicular trips per day and by accident fatality rates. Only crude projections of right-of-way and construction costs were available to the Division at the time of project selection, and appeared to be much less important than the deficiency measures in determining the choice of project. Information on net indirect benefits seems to have been almost entirely absent at the time of the project decision. Thus, there was usually substantial variation in costs and indirect benefits among projects. An implication of these two factors is that project selection was effectively independent of factors influencing the process of route selection within a project. As a consequence, the route decision conditioned on choice of project was a function of the attributes of the alternative routes available on the project rather than of Division concerns extending across projects.

Following the selection of a project, the Division initiated studies of alternative routes for the freeway segment. The timing of these studies was influenced by the budget of the district in which the project was located, and by the possibility of speculative activity in the expected freeway corridor which would increase right-of-way acquisition cost. The selection of alternative route locations to be studied was carried out by the District office. The number of alternatives considered seemed to be a function of the physical constraints present in the basic freeway corridor, the expected cost of the project, particularly right-of-

---

[3] This will appear in the Spring 1976 issue of this *Journal*.

[4] See Cottingham [2], p. II-5, for a detailed description.

way cost, and the extent of community distributional effects (externalities). The District office normally chose several alternatives which minimized right-of-way cost or distributional effects; others were suggested by private citizen groups and public agencies.

On each alternative route studied on a project, the District collected data on user benefits, construction and right-of-way costs, distribution impacts, and route preferences of business, political, and citizen groups. These data were assembled by the Division. After a series of meetings with local officials and public hearings, the record was reviewed by the State Highway Engineer, who made a recommendation to the California Highway Commission. Following further public hearings, the Commission adopted a freeway route. The Commission normally approved the State Engineer's recommendation, with the exception of a few cases where local governments were strongly opposed.

3. Decision criteria of the California Division of Highways

■ The empirical analysis of this paper is based on data collected by Cottingham for sixty-five route adoption cases of the California Division of Highways. The projects are located in the Los Angeles or San Francisco metropolitan areas (Districts 4 and 17), and were actually accepted and constructed by the Division between 1958 and 1966. The principal documentary sources for these data were the *Reports of Route Studies* compiled by the State Highway Engineer for each project in the sample. The categorization and definition of variables follows that in the Division's reports. These documents summarize all the data available to the Division on alternative routes, including the results of public hearings and negotiations with other public agencies, local governments, and citizen groups. Hence, it is reasonable to assume that the data contain the bulk of the quantitative information on which decisions are based. The properties of this set of data and the method of collection are discussed further by Cottingham.[5] Table 1 lists the collected variables.

The Division of Highway's definition of some of these variables requires comment. User benefits are a direct estimate of driver and vehicle cost saving, and are measured as follows. First, by using traffic counts and "origin and destination" surveys of travelers, the number of vehicular trips through the traffic corridor of a proposed project is estimated. These estimates are classified by zone of origin and destination. For each zone, an estimate is made of the percentage of traffic which will be diverted to a new freeway, for each alternative route.[6] These estimates are transformed into dollar benefit measures at a rate of 4.8¢ to 5.8¢ per mile saved for automobiles and 16¢ to 18¢ per mile saved for trucks, and $1.80 per passenger vehicle hour saved and $4.80 per truck hour saved, with some variation depending on the type of highway. Projections of future traffic

---

[5] In [1], chapter 3.

[6] See Cottingham [1], chapter II, for a discussion of the formula.

demands are made for a twenty-year period by employing local and statewide growth trends and by analyzing zonal growth with estimates made by planning bodies, mortgage agencies, and public utilities. The final user benefit measure is obtained by summing the dollar value of the net mileage and time savings estimated for a particular route for twenty years, *without* discounting. This calculation ignores maintenance costs and potential net congestion costs, as well as any impact on the demand for alternative transportation modes.

Right-of-way costs are estimated on the basis of appraisals by the Division of property in the traffic corridor, and are relatively precise, although speculation or delay in acquisition may introduce variations. Construction costs are estimated less precisely on the basis of past cost experience and preliminary engineering studies of the alternative routes. Because construction does not begin until four to eight years after the route adoption, there is considerable uncertainty in the projection of these costs. In this period, the Division did not attempt to attach dollar values to indirect net benefits.

A relation between the Division's measures of user benefits and costs and the accepted economic definition of these variables can be obtained provided simplifying assumptions can be made on utilization, the growth of benefits, the interest rate, and the proportions of right-of-way, construction, and maintenance costs. A typical freeway will open approximately four years after the acquisition of the right-of-way. Suppose that this freeway utilized at capacity provides an annual level of direct user benefits b, not considering congestion or maintenance costs. Suppose further that the freeway is initially utilized at a proportion u of capacity, and that utilization grows at a geometric rate g until capacity is reached. The Division's definition of benefits is then

$$B = b \sum_{t=0}^{19} \min\,[1, u(1 + g)^t]. \tag{1}$$

At a constant interest rate r and discount factor $d = 1/(1 + r)$, assuming an effective horizon of forty years, the present value of direct benefits as usually defined is

$$B^* = b \sum_{t=4}^{43} d^t \min\,[1, u(1 + g)^{t-4}]. \tag{2}$$

Table 2 relates the benefit measures B and B^* for various values of u, g, and r. One sees from these computations that the percent deviation of B from B^* is extremely sensitive to the rate of interest and relatively insensitive to the initial utilization and growth rates. For the period in question, where government bond rates were in the neighborhood of five percent, the Division benefit measure was approximately a thirty percent overestimate of the present value of net benefits. Note that neither of these measures deducts congestion costs, nor takes into account net benefits arising from changing patterns of use of other modes or externalities.

Assume that annual maintenance cost is a proportion μ of construction cost, and that construction cost (CC) is a propor-

TABLE 1

CHARACTERISTICS OF ROUTES COLLECTED BY THE CALIFORNIA DIVISION OF HIGHWAYS

SYMBOL	DESCRIPTION
LENGTH	LENGTH OF ROUTE (MILES)
B	USER BENEFITS OF ROUTE (MILLIONS)
CC	CONSTRUCTION COSTS (MILLIONS)
RWC	RIGHT OF WAY COSTS (MILLIONS)
TC	= CC + RWC, TOTAL COST (MILLIONS)
BDC	= B/TC, BENEFIT–COST RATIO
BMC	= B – TC, NET BENEFITS (MILLIONS)
BDL	= B/LENGTH, USER BENEFITS PER MILE (MILLIONS)
CCDL	= CC/LENGTH, CONSTRUCTION COSTS PER MILE (MILLIONS)
RWCDL	= RWC/LENGTH, RIGHT–OF–WAY COSTS PER MILE (MILLIONS)
TCDL	= TC/LENGTH, TOTAL COSTS PER MILE (MILLIONS)
TPAR	TOTAL PARCELS; THE NUMBER OF "PARCELS," "IMPROVEMENTS," OR "PROPERTIES" ESTIMATED TO BE REQUIRED BY A ROUTE FOR RIGHT–OF–WAY ACQUISITION
RESPAR	RESIDENTIAL PARCELS REQUIRED
NRPAR	NONRESIDENTIAL PARCELS REQUIRED
VACPAR	VACANT PARCELS REQUIRED
AGRIC	AGRICULTURAL ACRES REQUIRED
SCHL	THE NUMBER OF SCHOOLS EITHER ESTIMATED TO BE REQUIRED BY A ROUTE FOR RIGHT–OF–WAY ACQUISITION OR CITED BY THE DIVISION OR COMMUNITY REPRESENTATIVE AS "NEAR" THE FREEWAY RIGHT–OF–WAY, INCLUDING PLANS FOR NEW SCHOOLS
PARK	THE NUMBER OF PARKS REQUIRED OR AFFECTED
PUBLIC	THE NUMBER OF PUBLIC FACILITIES REQUIRED OR AFFECTED
UTIL	THE NUMBER OF PUBLIC UTILITIES OR PUBLIC TRANSPORTATION FACILITIES REQUIRED OR AFFECTED
HOSP	THE NUMBER OF HOSPITALS REQUIRED OR AFFECTED
CHURCH	THE NUMBER OF CHURCHES REQUIRED OR AFFECTED
FUTSUB	THE NUMBER OF PLANNED COMMUNITIES OR SHOPPING CENTERS ESTIMATED TO LOSE EITHER ALL OR PART OF THEIR LAND USE TO THE FREEWAY OR TO BE ADJACENT TO THE RIGHT–OF–WAY
OPBP	OFFICIAL POLITICAL BODIES PRO: THE NUMBER OF LOCAL GOVERNMENT UNITS OR THEIR REPRESENTATIVES (CITY COUNCILS, BOARDS OF SUPERVISORS) EXPRESSING APPROVAL OF A ROUTE

TABLE 1 CONTINUED

SYMBOL	DESCRIPTION
OPBC	OFFICIAL POLITICAL BODIES CON
PBP	PLANNING BODIES PRO: THE NUMBER OF PLANNING AGENCIES (FOR CITIES, COUNTIES) EXPRESSING APPROVAL OF A ROUTE
PBC	PLANNING BODIES CON
OSBP	OTHER STATE BUREAUCRACIES PRO: THE NUMBER OF OTHER STATE AGENCIES, DEPARTMENTS, COMMISSIONS (AND FEDERAL AND SPECIAL PURPOSE DISTRICTS) EXPRESSING APPROVAL OF A ROUTE
OSBC	OTHER STATE BUREAUCRACIES CON
POAP	PROPERTY OWNERS ASSOCIATIONS PRO: THE NUMBER OF ORGANIZATIONS REPRESENTING CITIZENS AS PROPERTY OWNERS EXPRESSING APPROVAL OF A ROUTE
POAC	PROPERTY OWNERS ASSOCIATIONS CON
BOP	BUSINESS ORGANIZATIONS PRO: THE NUMBER OF ORGANIZATIONS REPRESENTING CITIZENS AS OWNERS OF PRIVATE BUSINESS (INCLUDING CHAMBERS OF COMMERCE) EXPRESSING APPROVAL OF A ROUTE ALTERNATIVE
BOC	BUSINESS ORGANIZATIONS CON
COP	CONSERVATIONALIST ORGANIZATIONS PRO: THE NUMBER OF ORGANIZATIONS REPRESENTING CITIZENS CONCERNED WITH THE CONSERVATION OF NATURAL RESOURCES EXPRESSING APPROVAL OF A ROUTE
COC	CONSERVATIONALIST ORGANIZATIONS CON
SDP	SCHOOL DISTRICTS PRO: THE NUMBER OF SCHOOL BOARDS OR OTHER ORGANIZATIONS WHOSE MAJOR INTEREST IS SCHOOLS EXPRESSING APPROVAL OF A ROUTE
SDC	SCHOOL DISTRICTS CON
IPP	INDIVIDUAL POLITICIANS PRO: THE NUMBER OF ELECTED REPRESENTATIVES TO GOVERNMENTAL UNITS EXPRESSING APPROVAL OF A ROUTE
IPC	INDIVIDUAL POLITICIANS CON
IIMPP	IMPORTANT INDIVIDUALS PRO: THE NUMBER OF INDIVIDUAL CITIZENS NOT COVERED BY OTHER VARIABLE DEFINITIONS EXPRESSING APPROVAL OF A ROUTE (IDENTIFIED BY THE DIVISION UNDER THE HEADING "COMMUNITY LEADERS")
IIMPC	IMPORTANT INDIVIDUALS CON
PETP	PETITIONS PRO: THE NUMBER OF PETITIONS RECEIVED BY THE DIVISION OR COMMISSION EXPRESSING APPROVAL OF A ROUTE
PETC	PETITIONS CON
IIPOP	INDIVIDUAL LARGE PROPERTY OWNERS PRO: THE NUMBER OF CITIZENS IDENTIFIED AS OWNING LARGE TRACTS OF LAND EXPRESSING APPROVAL OF A ROUTE
ILPOC	INDIVIDUAL LARGE PROPERTY OWNERS CON

TABLE 2

COMPARISON OF DIVISION (B) AND ECONOMIC (B*) BENEFIT MEASURES

INITIAL UTILIZATION RATE, u	BENEFIT GROWTH RATE, g	INTEREST RATE, r	PERCENT DEVIATION 100 (B − B*)/B*
0.5	0.10	0.03	−7.98
0.5	0.10	0.05	34.90
0.5	0.10	0.07	88.96
0.5	0.10	0.10	191.85
0.5	0.05	0.05	31.29
0.5	0.05	0.10	192.04
0.3	0.10	0.05	30.35
0.3	0.05	0.05	12.49
0.7	0.10	0.05	35.24
0.7	0.05	0.05	34.94

tion α of total cost (TC), with right-of-way cost (RWC) constituting the remainder, $RWC = (1 - \alpha)\ TC$. Assume right-of-way acquisition is made in the initial year, and construction costs are spread evenly over the following three years. Then, the present value of costs is

$$TC^* = RWC + CC^*, \tag{3}$$

with

$$\begin{aligned} CC^* &= CC\left[\frac{1}{3}(d + d^2 + d^3) + \mu \sum_{t=4}^{43} d^t\right] \\ &= CC\left[\frac{1}{3}(d + d^2 + d^3) + \mu d^4(1 - d^{40})/(1 - d)\right]. \end{aligned} \tag{4}$$

In the absence of capital budget constraints, and ignoring indirect benefits and congestion costs, the accepted economic investment criterion is maximization of net benefits, $B^* - TC^*$, on each project (and, if project selection is unconstrained, across projects). Hence, if the Division followed the criterion of maximizing the present value of net direct benefits, we would expect selected routes to maximize $B^* - TC^*$, or if the District takes its own measures of benefits and costs as accurate, $B - TC$. In testing these hypotheses, we shall approximate the unobserved values B^* and CC^* by assuming an initial utilization rate of 0.5, a growth rate of utilization of ten percent, an interest rate of five percent, and a ratio of annual maintenance to construction cost of five percent. Then, from equations (1), (2), and (4), $B^* = 0.7413B$, $CC^* = 1.6498CC$, and $B^* - TC^* = 0.7413B - RWC - 1.6498CC = 0.7413\ (B - 1.3490RWC - 2.2255CC)$.

Cottingham[7] finds that capital budget constraints and restrictions impact on Division behavior. In particular, right-of-way costs tend to be constrained by the Division's budgets and allocation rules, are the most variable economic indicator across alterna-

---

[7] In [1], chapter II, p. 36.

tive routes in a project, and are the most closely examined indices in Division memoranda. These observations suggest a criterion of maximizing the present value of net benefits subject to capital budget constraints on right-of-way cost and total cost. Letting t index projects and j index routes within a project, and ignoring indivisibilities, this constrained optimization problem is

$$\max_{\theta_{tj}} \sum_t \sum_j (B^*_{tj} - RWC_{tj} - CC^*_{tj})\theta_{tj}, \tag{5}$$

subject to

$$\sum_t \sum_j RWC_{tj}\theta_{tj} \leqq \overline{RWC}; \tag{6}$$

$$\sum_t \sum_j (RWC_{tj} + CC^*_{tj})\theta_{tj} \leqq \overline{TC}^*; \tag{7}$$

$$\sum_j \theta_{tj} \leqq 1; \tag{8}$$

$$\theta_{tj} \geqq 0.$$

The solution to this problem can be characterized in several ways. First, one can attach a *penalty* λ to right-of-way cost and η to total cost such that the district maximizes

$$\sum_t \sum_j (B^*_{tj} - (1 + \lambda + \eta)RWC_{tj} - (1 + \eta)CC^*_{tj})\theta_{tj}, \tag{9}$$

subject to equation (8). Second, considering the maximization of

$$\sum_t \sum_j (B^*_{tj} - (1 + \lambda)RWC_{tj} - CC^*_{tj})\theta_{tj}, \tag{10}$$

subject to equations (7) and (8), where λ is the penalty above, one obtains the criterion that alternatives should be ranked by the modified benefit-cost ratio

$$MBDC^*_{tj} = \frac{B^*_{tj}}{TC^*_{tj}} - \lambda\frac{RWC_{tj}}{TC^*_{tj}}. \tag{11}$$

The first project and route are chosen for which this ratio is maximized. The remaining routes for this project are then eliminated, and the process is repeated for the remaining projects until the total capital budget is exhausted or the remaining $MBDC^*$ are less than one. For the last project selected, $MBDC^* = 1 + \eta$. Note that if the right-of-way budget constraint is not binding, then $\lambda = 0$ and $MBDC^*$ is the usual benefit-cost ratio.

A symmetric argument switching the roles of equations (6) and (7) leads to an alternative maximization of modified benefit-cost ratio criterion,

$$MBDR^*_{tj} = \frac{B^*_{tj}}{RWC_{tj}(1 + \eta)} - \frac{CC^*_{tj}}{RWC_{tj}}. \tag{12}$$

If the total budget constraint is not binding, then this criterion becomes

$$MBDR^*_{tj} = (B^*_{tj} - CC^*_{tj})/RWC_{tj}. \tag{13}$$

Our empirical analysis will test the hypothesis of simple present value of net direct benefits maximization criteria against the capital budgeting alternatives presented in equations (9), (11), (12), and (13).

In addition to the possibility of capital budgets' influencing the weighting of benefits and costs, there are additional factors which may have an important effect on the evaluation of right-of-way costs. First, the Division may use right-of-way costs as an index of net indirect costs. There is some justification for such a procedure, since right-of-way costs can be expected to correlate positively with social losses of dislocation and are unlikely to account fully for these losses. This would introduce a penalty on right-of-way costs beyond that arising from capital budgets. Current right-of-way costs are likely to be loosely linked with future social opportunity costs, or with the social costs associated with relocating or abandoning public services. Hence, one would expect that the introduction of explicit measures of indirect costs would modify the social cost premium attached to right-of-way cost. Conversely, stability of this weight would suggest the absence of a social cost penalty.[8]

Behavioral factors may also influence the evaluation of right-of-way costs. Construction activities involve substantial supervision by District personnel, with public participation limited by the technicality of decisions. By contrast, right-of-way acquisition involves limited participation by District personnel, and may expose the Division to public scrutiny and political pressure. The self-interests of a bureaucrat facing this environment suggest a preference for routes with relatively low right-of-way costs, or put another way, a penalty on right-of-way costs as a proportion of total costs. Combined with a total capital budget constraint, this effect would indicate the same modified benefit-cost ratio criterion as in equation (11), and would increase the magnitude of λ.

It does not appear feasible to distinguish empirically right-of-way budget constraints and behavioral penalties on right-of-way costs, in the absence of data either on total capital availability or on internal organization. A weak test which may confound social cost and behavioral penalties is to examine the relative weight given to right-of-way cost as a function of the degree of political pressure or public involvement in the route choice.

Throughout the preceding analysis, alternative choice criteria have been formulated in terms of the conventional economic measures of the present value of direct benefits B^* and of construction and maintenance costs CC^*. As alternatives to the hypotheses that the Division implicitly employed choice criteria using these measures, we wish to consider the possibility that the Division adopted one of the criteria described above, but substituted its own definitions of direct user benefits B and construction cost CC (the latter excludes discounting and maintenance). The consequences of this substitution may simply be a "rescaling" of the criterion, as in the case of the benefit-cost ratio condition in equation (11) when the right-of-way budget constraint is nonbinding. The critical value of B/TC corresponding to the criterion $B^*/TC^* = 1$ can be computed for alternative values of the initial utilization rate u, growth rate g, interest rate r, and construction and maintenance cost propor-

---

[8] This test is weakened by the possibility that our explicit measures of indirect costs are too crude, and the Division in fact ignores information other than right-of-way cost in assessing indirect costs.

TABLE 3

CRITICAL VALUES OF THE BENEFIT—COST RATIO DEFINED BY THE DIVISION TO GIVE $B^*/TC^* = 1$

INITIAL UTILIZATION RATE, u	BENEFIT GROWTH RATE, g	INTEREST RATE, r	CONSTRUCTION÷ TOTAL COST, α	ANNUAL MAINTENANCE÷ CONSTRUCTION COST, μ	CRITICAL BENEFIT—COST RATIO B/TC
0.5	0.05	0.05	0.57	0.01	1.438
0.5	0.05	0.05	0.57	0.05	2.217
0.3	0.05	0.05	0.57	0.01	1.232
0.7	0.05	0.05	0.57	0.01	1.478
0.5	0.10	0.05	0.57	0.01	1.478
0.5	0.05	0.10	0.57	0.01	2.850
0.5	0.10	0.05	0.57	0.05	2.278
0.5	0.10	0.05	0.90	0.05	2.237
0.5	0.10	0.05	0.20	0.05	2.324
0.5	0.10	0.03	0.57	0.05	1.864
0.5	0.10	0.07	0.57	0.05	2.783
0.5	0.10	0.10	0.57	0.05	3.706

tions. Typical values are given in Table 3. For our 65 adopted routes, the average benefit-cost ratio as measured by the Division was 3.59, and 46 of the 65 had a benefit-cost ratio above the critical value of 2.278, corresponding to plausible parameter values $\mu = 0.5$, $g = 0.10$, $r = 0.05$, $\alpha = 0.57$, $\mu = 0.05$, for the period of observation.

The third and fourth questions posed in the introduction to this paper concern the weight given by the Division to indices of indirect costs and to various private and political opinions on the desirability of the level and distribution of these costs. The data include both direct indices of the externalities, such as the number of schools and parks affected, and measures of the opinions of citizens and groups expressed in hearings and written communications. Indices of indirect costs may be weighted directly, and may interact with economic indicators; e.g., the weight on right-of-way cost may rise with the proportion of parcels taken from public service. One can anticipate difficulty in obtaining reliable weights for these factors for two reasons. First, the indirect cost indices are crude, counting number of parcels of each service use taken, rather than attempting to value each parcel and report total values. Second, the number of projects requiring the taking of public service parcels is limited; e.g., of the 65 projects, 11 select routes required the taking of a parcel containing a park, 11 projects involve schools, 5 involve hospitals, 3 involve churches, and 14 involve utilities.

The use of opinions of citizens and groups presents two difficulties. The first is that the volume and distribution of opinions is sensitive not only to the overall level of indirect costs, but also to their distribution. Our analysis will have difficulty distinguishing whether a high volume of negative opinions on a route is the result of high indirect costs, or of the distribution of low indirect costs to the disadvantage of an effective lobby.

The second difficulty arises because public response to alternative routes is affected by the leanings of the Division. Thus, a large number of petitions against a route may be forthcoming only if it becomes apparent in public hearings that the Division favors this alternative. The only satisfactory methods of dealing with these effects would be to obtain temporally disaggregated data in which the directions of causality are clear, or to construct a simultaneous equations model in which the behavior of petitioners and other groups is explained in terms of underlying exogenous variables and the endogenous influence of District recommendations.

4. A model of qualitative choice behavior

■ The starting point for our analysis of route selection is a general model of qualitative choice behavior. Consider a universe of conceivable objects of choice (routes), and let M be an arbitrary index set naming the elements of this universe. For each route, a vector of attributes x can be observed (e.g., the variables in Table 1). A *project* is defined by (1) a vector s of observable characteristics of the environment of the route choice (e.g., geographical area, year) and (2) a list of alternative routes, each with an observable vector of attributes. A possible project is assumed to have a finite number of alternative routes, identified by a vector of indices $N = \langle n_1, \ldots, n_J \rangle$ from M. The vector of observable route attributes for this project is denoted $B = \langle x_{n_1}, \ldots, x_{n_J} \rangle$. The vector of observable data for this project is then (B,s), or with subscripts identified, $(x_{n_1}, \ldots, x_{n_J}, s_N)$. The axiom below provides the basic structure of possible projects.

Axiom 1. The universe of possible projects is a class $\mathcal{M}$ of nonempty finite vectors of distinct elements from M. If N is a possible project and N' is a non-null subvector of N, then N' is a possible project and $s_{N'} = s_N$.

There are unobservable attributes of routes and characteristics of project environments which vary from project to project. Consequently, if one could obtain a sample of projects with the same observable data (B,s), one would expect to observe an empirical distribution of choices which could be interpreted as a sample from a multinomial distribution. The *selection probability* in this multinomial distribution for an alternative with observable attributes x^i, where $(B,s) = (x^1, \ldots, x^J, s)$, is denoted $P(x^i | B,s)$. Note that this probability does *not* depend on the indexing of routes.[9] However, when a project is identified by its index vector $N = \langle n_1, \ldots, n_J \rangle$, we shall use an abbreviated notation for selection probabilities,

$$P(x_{n_i} | (x_{n_1}, \ldots, x_{n_i}, \ldots, x_{n_J}, s_N)) \equiv P_n(n_i). \qquad (14)$$

---

[9] As a consequence, two routes in a project having the same observable attributes are equally probable. This is not fundamental, but an implication of the arbitrary indexing.

Further, when N is a two-element set, $N = \{n,m\}$, we define

$$p_{nm} \equiv P(x_n|(x_n,x_m,s)) \equiv p_{\{n,m\}}(n). \tag{15}$$

By convention, we assume $p_{nn} = 1/2$; therefore $p_{nn} \neq p_{\{n\}}(n) = 1$.

A decision rule, or demand function, is a mapping h from projects, described by data (B,s), into selected routes; i.e., $h(B,s) = x$ states that a route with observable attributes x is selected in a project described by (B,s). In the presence of unobservable effects ω, the decision rule h will depend on ω; we write $h_\omega(B,s) = x$.[10] Associated with the class of projects having observable data (B,s) is a probability distribution π of the unobservable effects ω.[11] Then,

$$P(x^i|B,s) = \pi(\{\omega|h_\omega(B,s) = x^i\}). \tag{16}$$

It is often convenient to suppress ω and think of π as a probability distribution over the set of decision rules; with an abuse of notation, we write

$$P(x^i|B,s) = \pi(\{h|h(B,s) = x^i\}). \tag{17}$$

This relation provides two possible routes to the construction of econometric qualitative choice models. The first is to assume π to be a member of a parametric family of probability distributions over decision rules. The second is to work directly with the selection probabilities, imposing axioms which are consistent with a plausible distribution π and which lead to convenient parametric forms for estimation. Both approaches lead to a parametric family of multinomial distributions which can be analyzed using a variety of statistical procedures, such as maximum likelihood.

We take the approach of imposing conditions directly on the selection probabilities. It is convenient to use the abbreviated notation of equation (14) in stating these conditions.

Axiom 2. Selection probabilities are positive; i.e., $n \in N \in \mathcal{M}$ implies $p_N(n) > 0$.

Axiom 3. If $n,m \in N \in \mathcal{M}$, then

$$p_{nm}p_N(m) = p_{mn}p_N(n). \tag{18}$$

Since zero probability events are empirically indistinguishable from extremely unlikely events, Axiom 2 represents virtually no loss of generality. On the other hand, Axiom 3 is an extremely strong condition Luce terms *independence from irrelevant alter-*

---

[10] To the extent that the effect ω arises from the practical inability of the econometrician to measure attributes of routes that are observable, we can interpret choices as coming from a deterministic choice model with observation error. Alternately, if ω arises from factors such as loss of information by the decisionmaker, taste variations, or other "states of nature" that are unobservable, we can interpret the model as one of stochastic choice. In practice, it is difficult to distinguish these alternatives, particularly since "observability" varies with the application.

[11] The form of π will depend on the mechanism used to select projects. If a random mechanism is used, then π is the conditional probability for ω given (B,s).

natives. When $p_N(m)$ is positive, this axiom implies p_{mn} positive for any $n \in N$, which in turn implies that

$$\frac{p_{nm}}{p_{mn}} = \frac{p_N(n)}{p_N(m)}. \tag{19}$$

This condition states that the odds that n will be chosen over m in a project N containing both are independent of the presence of "irrelevant" third routes in N.

Under the independence from irrelevant alternatives axiom, the multiple choice selection probabilities can be written in terms of binary probabilities p_{nm}. For n, $m \in N \in \mathcal{M}$, Axioms 2 and 3 imply

$$p_N(m) = \frac{p_{mn}}{p_{nm}}\, p_N(n). \tag{20}$$

Summing over $m \in N$,

$$1 = \sum_{m \in N} p_N(m) = p_N(n) \sum_{m \in N} \frac{p_{mn}}{p_{nm}}, \tag{21}$$

or

$$p_N(n) = 1 \Big/ \sum_{m \in N} \frac{p_{mn}}{p_{nm}} \tag{22}$$

and

$$p_N(l) = \frac{p_{ln}}{p_{nl}} \Big/ \sum_{m \in N} \frac{p_{mn}}{p_{nm}}. \tag{23}$$

Equation (23) relates the probability that route l will be chosen on project N to the odds p_{mn}/p_{nm} that each route $m \in N$ is chosen over a "benchmark" route n. Using equation (14), the odds p_{mn}/p_{nm} can depend only on x_n, x_m and s_N; we write $\ln\,(p_{mn}/p_{nm}) = \nu\,(x_m,x_n,s)$. Consider equation (18) for indices $l,m,n \in N$. Permuting these indices and multiplying the resulting formulae yield the condition

$$p_{lm}\, p_{mn}\, p_{nl} = p_{ml}\, p_{ln}\, p_{nm}, \tag{24}$$

or

$$\nu\,(x_m,x_n,s) = \nu\,(x_m,x_l,s) - \nu\,(x_n,x_l,s) \tag{25}$$

for any $l \in N$. Since the left-hand side of this expression is independent of l, ν can depend only on components of its second argument which are uniform in the project. If we incorporate these uniform factors in the description of the environment s, then we can define $v(x_m,s) = \nu\,(x_m,x_l,s)$. Hence, binary odds can be written in the form

$$\ln p_{mn}/p_{nm} = v(x_m,s) - v(x_n,s), \tag{26}$$

and equation (23) becomes

$$p_N(l) = e^{v(x_l,s)} \Big/ \sum_{m \in N} e^{v(x_m,s)}. \tag{27}$$

Marschak calls this the *strict utility model* of stochastic choice.

The final step in obtaining a convenient parametric family of selection probabilities is to note that provided $v(x,s)$ is continuous, it can be approximated to any desired degree of accuracy on a closed bounded set by a finite expansion in terms of a "full rank" list of numerical functions $z^k = Z^k(x,s)$; i.e.,

$$v(x,s) = \sum_{k=1}^{K} \beta_k Z^k(x,s) + \text{residual}, \tag{28}$$

where the β_k are unknown parameters.[12] Ignoring the residual error, we then have a *multinomial logit* model

$$p_N(l) = e^{\beta' z_l} / \sum_{m \epsilon N} e^{\beta' z_m}, \tag{29}$$

with $\beta' = (\beta_1, \ldots, \beta_K)$, $z'_l = (z_l^1, \ldots, z_l^K)$, and $z_l^k = Z^k(x_l,s)$. We shall assume that the route selection behavior of the Division conforms to this model, and use equation (29) as a basis for our econometric analysis.

Axioms 1–3 are consistent with a distribution π over decision rules which has a traditional economic interpretation. Suppose the Division chooses routes to maximize a utility function $u(x,s)$ which can be written

$$u(x_n,s) = v(x_n,s) + \omega_n, \tag{30}$$

where v is a function of observed data and ω_n represents the contribution to utility of unobservable route attributes and environmental factors. If, for a project $N = \langle n_1, \ldots, n_J \rangle$, the vector $\omega = \langle \omega_{n_1}, \ldots, \omega_{n_J} \rangle$ is a drawing from a cumulative multivariate distribution $\Pi(\omega)$, then

$$\begin{aligned} p_N(n_1) &= \text{Prob}\,[u(x_{n_1},s) > u(x_{n_j},s) \text{ for } j = 2, \ldots, J] \\ &= \text{Prob}\,[\epsilon_{n_j} - \epsilon_{n_1} < v(x_{n_1},s) - v(x_{n_j},s) \text{ for } j = 2, \ldots, J] \\ &= \int_{w=-\infty}^{+\infty} \Pi_1(w, w + v_1 - v_2, \ldots, w + v_1 - v_J)\,dw, \end{aligned} \tag{31}$$

where Π_1 is the derivative of Π with respect to its first argument, and $v_j = v(x_{n_j},s)$.[13] The author has shown[14] that with a mild technical condition, a necessary and sufficient condition for selection probabilities to satisfy equation (31) and to have the strict utility form of equation (27) is that $\omega_{n_1}, \ldots, \omega_{n_J}$ be *independently,* identically distributed with the Weibull distribution

---

[12] A list of functions $Z^1, \ldots, Z^K$ is of "full rank" if for almost all selections of arguments $(x^1,s^1), \ldots, (x^K,s^K)$, the matrix

$$\begin{bmatrix} Z^1(x^1,s^1) & \cdots & Z^K(x^1,s^1) \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ Z^1(x^K,s^K) & \cdots & Z^K(x^K,s^K) \end{bmatrix}$$

is of rank K.

[13] Equation (31) can be used as a basis for specifying a variety of econometric qualitative choice models; see Domencich and McFadden [3], Chapter 4, and McFadden [4].

[14] In [4], p. 111.

$$\text{Prob}\,[\omega_{n_j} \leqq w] = e^{-e^{-w}}.$$

We conclude that the multinomial logit model of equation (29) is consistent with a theory of utility maximization by the Division, with unobservable factors entering the utility calculus. These factors may be due to "stochastic" choice by the Division, arising from information and control loss, or changes in decisionmaking personnel, or may be due to the inability of the econometrician to measure all the variables considered by the Division. The Weibull form of the distribution of the ω_{n_j} is not implausible; this distribution is bell-shaped and well-behaved, and differs little from a normal distribution in superficial appearance. However, the independence of the ω_{n_j} is a strong property which is not plausible if there are important unobserved attributes of routes which are not independent. The model provides a method of testing this assumption. If independence holds, then the same strict utility function $v(x,s)$ can be estimated either by considering the full set of available routes on each observed project, or by considering a randomly chosen subset of routes.

References

1. COTTINGHAM, P. *Decision Criteria in Freeway Planning.* Ph.D. dissertation, University of California, Berkeley, 1968.
2. ———. "Measurement of Nonuser Benefits." Center for Planning and Development Research, University of California, Berkeley, mimeographed, 1966.
3. DOMENCICH, T. AND MCFADDEN, D. *Urban Travel Demand: A Behavioral Analysis.* Amsterdam: North Holland, 1975.
4. MCFADDEN, D. "Conditional Logit Analysis of Qualitative Choice Behavior," in P. Zarembka, ed., *Frontiers in Econometrics,* New York: Academic Press, 1973.