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198

A
METHOD FOR ESTIMATING THE VALUE
OF
TRANSPORT SERVICE ATTRIBUTES

By

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Abstract

This paper evaluates a method based on a conjoint measurement technique for estimation of value of transport service attributes. The technique uses ordinal rankings of shipper preferences to estimate each shipper's utility or preference function which, in turn, is used to estimate the change in consumer's surplus attributable to a change in service attribute. The method is applied to measure the value of increased sailing frequency in inter-island transportation.

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The value shippers attach to transport service characteristics such as transit time, variance of transit time, frequency of service, probability of loss or damage, etc., has been rather difficult to estimate. The knowledge of these values, however, is needed for management purposes as well as policy decisions.

In situations where two or more transport modes with different attributes are currently supplying transport services, a method based on the theory of "revealed preference" could be used. Conceptually, the method involves two steps: (1) Shippers' choices among the available transport modes are observed; (2) The values that shippers place on various attributes is inferred from this information.

This method, however, cannot be applied if currently the service is being supplied by only one transport mode. In these situtations responses to survey questions (either direct interview or mail) have been used to estimate the maximum willingness to pay or receive payment. This approach, known as the hypothetical valuation method (HV), has been applied to measure the value of outdoor recreation and other environmental amenities. Doubts, however, have been expressed whether this method can provide unbiased results. The main expected source of bias is the gamesmanship. Bishop and Heberlein (1979) describe it as follows:

> "...People who are asked hypothetically what they would be willing to pay for extramarket goods may recognize two different incentives to distort their responses. Perceiving that they will not actually have to pay and that their responses may influence the supply of an extramarket good or bad, people may respond in ways that are more indicative of what they would like to see done than how they would behave in an actual market.
>
> On the other hand, if people believe (correctly or incorrectly) that their responses will influence actual fees they may be more concerned about keeping their fees low than revealing their true values to the investigator..."

Although empirical results of several studies tended to indicate that the fear related to gamesmanship may have been exaggerated, the findings of Bishop and Heberlein (1979) rather clearly point to gamesmanship as a source of bias. In their study of goose hunting permits they have estimated consumers' surplus using data collected in an experiment and compared it to estimates based on hypothetical valuation and travel cost method. They found that the consumers' surplus estimates based on willingness to sell and willingness to buy responses were respectively 60 percent larger and 67 percent smaller than the estimate based on the experimental data. Their results suggest that an estimation method which minimizes the possible bias due to gamesmanship is needed.

The purpose of this paper is to suggest a method based on what is known as a conjoint measurement, a technique developed in the fields of mathematical psychology and psychometrics which has been applied in a number of marketing studies. The technique, as used in these studies, starts with consumers' overall judgments about a set of alternatives. It then decomposes the original evaluations into separate and compatible utility scales.

A more detailed description of the technique is presented in the next section. In the section that follows the proposed technique is applied to determination of the desirability of increasing the frequency of inter-island transport services in Hawaii. The final section presents an evaluation of the technique and suggests future research needs.

Description of the Estimation Method

The proposed technique requires three steps. The first step involves the collection of information from individuals regarding their ordinal preferences. This is accomplished by a survey in which each combination of attributes and their levels is described on a separate card and each respondent is asked to rank all cards in order of his preference. Surveys of this type are quite common in marketing and psychology.

One possible problem that may be encountered in this step is the large number of possible combinations. For example, if three attributes and five levels of each are to be considered the total number of possible combinations is 125. This would clearly present an unmanageable problem. It is possible, however, to reduce the number of combinations to be considered by using either orthogonal array or incomplete block experimental designs.[1]

The second step is to estimate ordinal utility functions for each individual surveyed on the basis of his reported preference rankings. The theoretical background of this step is as follows. In general it is assumed that the utility or preference function is of the form

$$U = U(q_1, q_2, \ldots\ldots, q_n) \qquad (1)$$

where U is the ordinal utility level and q_i, $i = 1,\ldots,n$ are variables indicating the level of each of the attributes. If the ranks (R) are also a function of attributes

$$R = R(q_1, \ldots, q_n) \qquad (2)$$

and $R_i < R_j$ implies $U_i < U_j$, then (2) is an equivalent function to (1) in that both imply the same ordinal ranks. Further, if the contribution of the attributes to rank are additive (under suitable transformation) (2) can be expressed as

$$R = \Sigma W_i f(q_i) \qquad i = 1, \ldots, n \qquad (3)$$

and the W_i can be readily interpreted as utility weights.

The W's can be estimated using monotonic regression applied to the ranks obtained in step one and the attributes of each of the alternatives. Most monotonic regression procedures choose $\hat{W}$ to minimize a loss function of the following form

$$L = \sum_{i<j}^{N} \sum^{N} \delta_{ij} (\hat{R}_i - \hat{R}_j)^k$$

where

$$\delta_{ij} = \begin{cases} 1 \text{ if } (R_i - R_j)(\hat{R}_i - \hat{R}_j) < 0 \text{ for } i < j \\ 0 \text{ otherwise.} \end{cases}$$

and N = number of alternatives.

When $k = 0$ this can be accomplished by integer programming (Pekelman and Sen, 1974), or non-linear programming (Garrod, 1980), when $k = 1$ by linear programming (Srinivasan and Shocker 1973a, 1973b and Pekelman and Sen, 1974) and when $k = 2$ by iterative procedures (Johnson, 1975) or the minimization of stress (Kruskal, 1965).

Once the parameters of equation (3) are estimated it is possible to find the relative value the respondent attaches to each attribute and to determine trade-offs among attributes. The available studies in marketing stop at this point. However, utilization of the full potential of the technique requires further extension. This leads us to the third step.

Following Baumol and Vinod (1970) let us suppose that a transport mode can be characterized entirely in terms of two attributes, speed and economy, where speed may be defined as the reciprocal of the average time required to transport an item (1/T) and economy as the reciprocal of the rate charged for transportation between the two points under consideration (1/R). Estimates of coefficients of equation (3) allows mapping of estimated indifference curves for each respondent. An illustration of such a mapping for an individual shipper is given in Figure 1 where the current level of attributes is shown by point $r^o t^o$.

Now, consider another point on his indifference curve such as $r^* t^*$. This bundle of attributes represents an increase in speed (decrease in transit time) which is offset by a decrease in economy (increase in freight rate charged) in order to make the shipper indifferent between the two bundles.

Thus, the difference of the reciprocals of r^* and r^o (which is equal to the difference in freight rates) is the maximum this shipper would be willing to pay per unit shipped for the increase in speed of transport service (reduction of transit time).

If this shipper is currently shipping some quantity Q_x the point corresponding to $r^o t^o$ must lie on his demand curve for the transport services. A decrease in transit time would cause this demand curve to shift upwards. This is illustrated in Figure 2 which shows two (unknown) demand functions for two difference levels of t. The area R^oR^*ST must be equal to $(1/r^* - 1/r^o)Q_x$. But, furthermore, since this area represents a change in the area under the derived demand curves, it approximates the change in consumer surplus attributable to a change in one service attribute.

<u>Benefit/Cost Analysis of Improvement in Transport Services</u>

In this section, the proposed technique is used to estimate the gain in consumer surplus attributable to an increase in the frequency of inter-island surface transport service in Hawaii. This service is currently being supplied by one common carrier engaged in carriage of freight by means of barges towed by tugboats. Frequency of service between the Port of Honolulu and major ports on the other islands ranges from once a week to Port Allen on Kauai to three times a week to Hilo on Hawaii and Kahului on Maui.

Some shippers have claimed that the existing inter-island transportation system does not adequately meet their needs, especially the needs of shippers of agricultural commodities. It has been argued that in view of the highly perishable nature of most agricultural commodities, sailings are not sufficiently frequent, transit time is too long, and freight rates are too high.

Given the current technology (i.e., barges towed by tugboats) there is not much that can be done about transit times. The tugboat speed can be

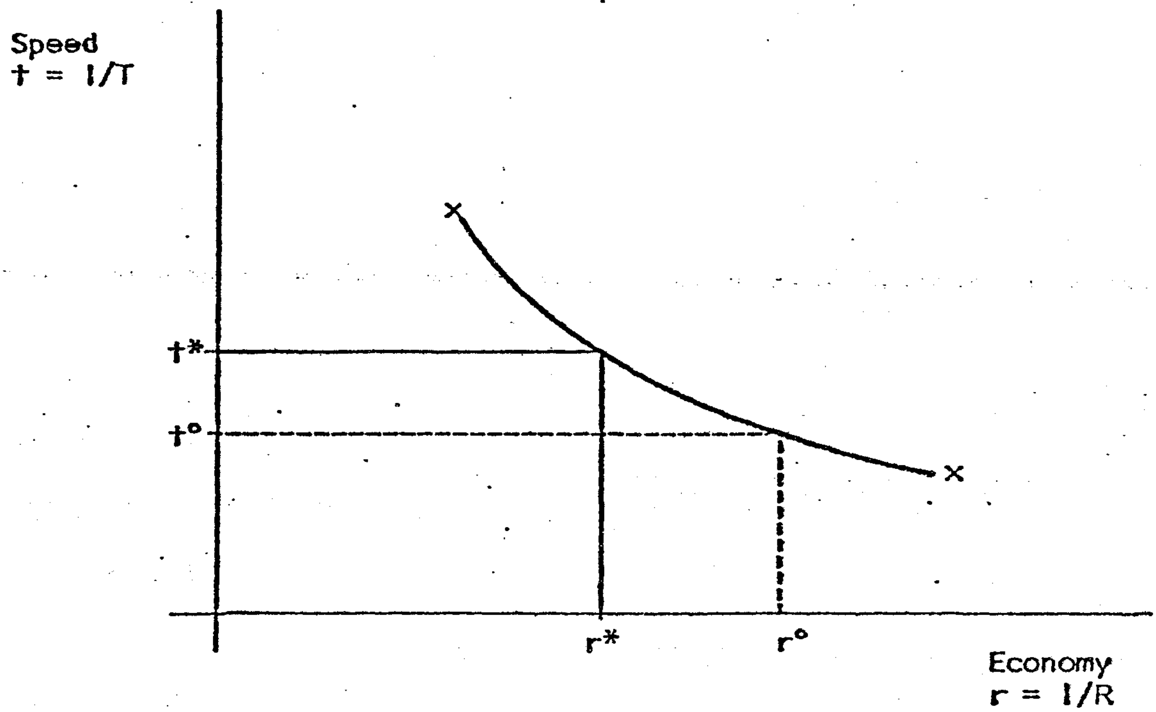

Figure 1

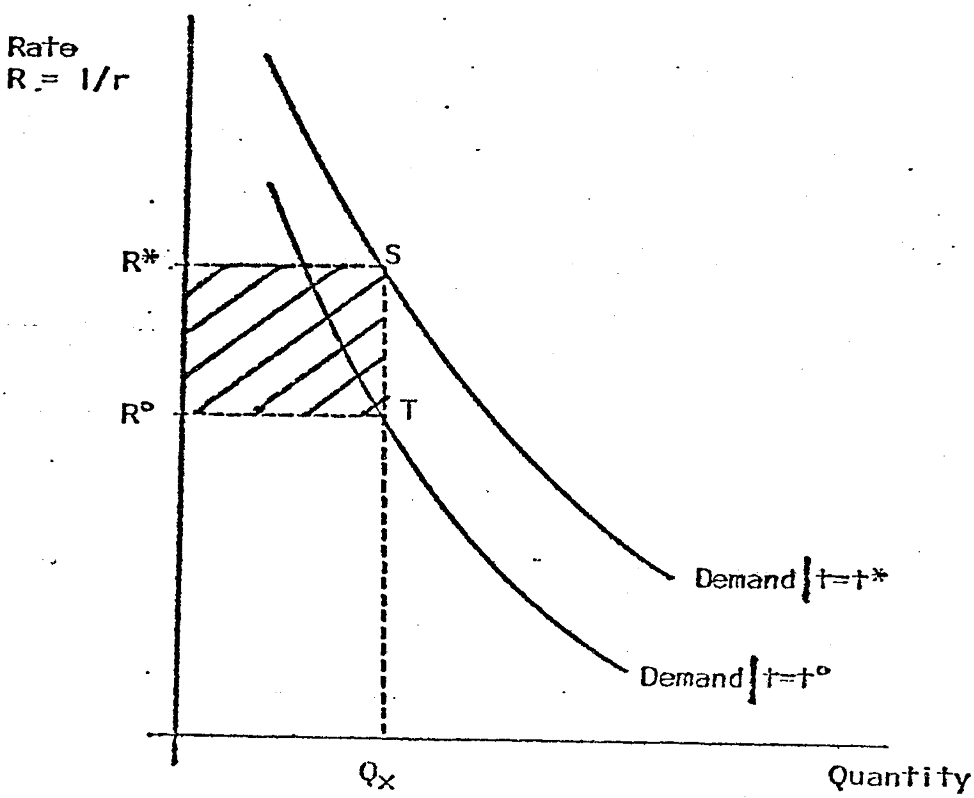

Figure 2

varied only within a relatively narrow range and even the maximum increase in speed will not have a significant effect on transit time because of the relatively short distances between ports (for ocean transportation).

The relatively high charges per ton/mile reflect high costs which, in turn, are attributable to small sizes of shipments and, again, short distances involved. The increase in frequency of sailings is not financially feasible from the carrier's point of view, i.e., expected MC exceed expected MR. It is possible, however, that the benefits of increased frequency would exceed the costs. It is also possible that it would be desirable to provide more alternatives to the current, first-in-first-out queuing arrangement. An increase in frequency of sailings, however, would require a subsidy and in order to evaluate the desirability of this subsidy it is necessary to estimate the change in consumer surplus and the cost of service with increased frequency of sailings. The method discussed in the preceding section was used to estimate the former.

For the empirical application of the method it was decided to concentrate on shippers of agricultural and agriculture-related items since it was expected that these shippers would be more sensitive to changes in the frequency of sailings. The survey of bills of lading indicated that there were only 42 shippers of these items that shipped quantities larger than those corresponding to the minimum charge. In 1978 these 42 shippers accounted for a total of 218,000 tons or approximately 20 percent of total inter-island cargo (both agricultural and non-agricultural).

Successful interviews were conducted with 19 shippers. In each firm an individual responsible for transport decisions was asked to rank in order of preference fifteen combinations of service attributes. These combinations included 1 to 5 sailings per week, fifteen levels of freight charges and the

Table 1
Utility Weights, Summary Statistics, and Type of Shipper

Shipper Number	Utility Weights a/ b_1	b_2	b_3	b_4	Summary Measures Spearman's Rho	Kendall's Tau	Percent of Concordant Pairs	Shipper of Perishable Products
	Utility = $b_4 R$							
1	0	0	0	-1.0	1.000	1.000	100.0	no
	Utility = $b_1 F + b_2 G + b_3 SA + b_4 R$							
2	0.1296	0.2199	-0.1812	-0.9497	0.911	0.790	89.5	no
3	0.1224	0.2107	-0.1741	-0.9541	0.768	0.695	84.8	no
4	0.1331	0.2210	-0.1735	-0.9505	0.954	0.867	93.3	yes
5	0.1305	0.1974	-0.1408	-0.9613	0.911	0.790	89.5	no
6	0.1009	0.1780	-0.1300	-0.9702	0.800	0.733	86.7	yes
	Utility = $b_1 \ln(F) + b_2 G + b_3 SA + b_4 \ln(R)$							
7	-0.3450	-0.1538	0.2826	0.8817	0.496	0.352	67.6	no
8	0.2581	0.2178	-0.2178	-0.9157	0.971	0.924	96.2	no
9	0.4085	0.1930	-0.1930	-0.8710	0.993	0.962	98.1	yes
10	0.4071	0.1928	-0.1974	-0.8707	0.986	0.924	96.2	yes
11	0.4185	0.1797	-0.1939	-0.8689	0.996	0.981	99.0	no
12	0.4613	0.2027	-0.2027	-0.8396	1.000	1.000	100.0	yes
13	0.4045	0.1743	-0.1916	-0.8771	0.954	0.861	92.4	yes
	Utility = $b_1 \sqrt{F} + b_2 G + b_3 SA + b_4 \sqrt{R}$							
14	0.2484	0.1534	-0.1636	-0.9423	0.995	0.981	99.0	yes
15	0.2751	0.1701	-0.1543	-0.9336	0.975	0.924	96.2	no
16	0.1695	0.0833	-0.0826	-0.9785	0.912	0.823	90.5	yes
17	0.2848	0.1104	-0.1309	-0.9432	0.954	0.861	92.4	no
18	0.3523	0.0884	-0.0784	-0.9284	0.864	0.752	87.6	yes
19	0.2075	0.0841	-0.0962	-0.9699	0.943	0.867	93.3	yes

F = Frequency in trips per week
G = A dummy variable for a guaranteed queueing system
SA = A dummy for a space available queueing system
R = The rate or cost-per-unit relative to the existing service
a/ = Standardized such that the vector of utility weights has a length of 1.

three following alternative queuing arrangements: (1) Guaranteed service on the first sailing; (2) First-in-first-out (the current arrangement); (3) Service on a space available basis. One of the fifteen combinations consisted of the current service attributes.

The ranks assigned to the different alternatives were then used to estimate an ordinal utility function for each shipper. The utility weights were obtained using a mathematical programming procedure for monotonic regression with a loss function designed to simultaneously minimize the number of discordant pairs and maximize the number of concordant pairs (Garrod, 1980). As there is no a priori reason to expect each individual's utility function to have the same form, three alternative functional relationships were tried for each shipper. The form that performed the best was then used in the analysis that follows where "best" was defined as producing the largest number of concordant pairs.

The first form postulated that the ordinal utility measure was a linear function of the attributes. This form proved to be the best for five individuals. The second assumed that the utility measure was a linear function of the logs of the attributes. This measure was best for seven individuals. The third assumed that the ordinal utility measure was a function of the square root of the attributes. The ordinal ranking of six individuals were described best by this function. One individual ranked the alternatives based on rates alone. The estimated utility weights along with three summary measures are presented in Table 1.

With one exception, the estimated utility weights are reasonable. An increase in frequency increases utility and an increase in rates decreases utility while a guaranteed queuing system is preferred over the current first-in-first-out system which, in turn, is preferred over a space available queuing system. The levels of Spearman's rho and Kendall's tau statistics as well as the percentage of concordant pairs relative to the total number of pairs are quite satisfactory. A hypothesis that rho ≤ 0 or tau ≤ 0 can be rejected at the 99 percent confidence level in all but one case.

The only exception is shipper number 7. In this case all the estimated utility weights have unexpected signs; the percentage of concordant pairs is quite low and a null hypothesis of no or negative association could not be rejected on the basis of the computed values of tau or rho. Given that the reported values represent the best fit of three attempts to fit a function to the reported rankings, and that the fit was still unsatisfactory, the seventh individual was dropped from the analysis.[2] The remaining 18 functions were used to define indifference surfaces corresponding to the current bundle of service attributes.

The estimated indifference surfaces were used to find the value of rate (R^*) that would make each shipper indifferent between the new service frequency F^* and the current service frequency F^o at current rate (R^o). Note that for shipper Number 1, $R^* = R^o$ since this shipper indicated that he is not willing to pay more for additional frequency.

The potential gain in consumer surplus of the i th shipper is then

$$\Delta\, CS_i = (R_i^* - R^o)Q_i$$

and the total change in consumer surplus is $\Sigma\Delta CS_i = \Sigma R_i^* Q_i - R^o Q_t$ where Q_t is the total quantity shipped and the percentage change in total consumer surplus relative to current costs is obtained by dividing by $R^o Q_t$ and multiplying by 100. Carrying out the calculations, the percentage increase in consumer surplus relative to current costs associated with an increase in frequency by one sailing per week is 12.37 and with an increase in frequency of two sailings per week is 23.31.

The change in consumer surplus can now be compared with the cost of providing the additional service. The carrier has estimated that an increase in frequency by one sailing per week would increase costs by 15 percent and an increase in frequency by two sailings would increase costs by 30 percent. Thus, if the eighteen shippers represented the entire population an increase in frequency of service would not be desirable since the percentage change in costs exceeds the percentage change in consumer surplus.

If the eighteen shippers represented a sample drawn randomly from a larger population it would have been possible to conclude whether the increased frequency is feasible if the underlying distribution of gain in consumer surplus can be specified. Using the estimates reported above as an example, the average gain in consumer surplus per ton shipped attributable to an increase in frequency by one sailing is 0.1237 with the standard deviation of 0.031. If the average gain in consumer surplus per ton shipped were distributed normally, there is an 80.2 percent chance that the additional service frequency is not feasible, i.e., costs exceed the benefits. For an increase in frequency by two sailings the average gain is 0.2331 and the associated standard deviation is 0.060. Again, assuming normality, the probability of the total gain being less than the increase in costs is 86.8 percent.

Evaluation

The proposed technique appears to be promising. One of it's major advantages is the ability to estimate the consumer surplus, needed in benefit-cost analysis as a measure of benefits, without estimating the demand functions. It's second major advantage lies in relatively low cost of data collection since small samples are sufficient. This is in sharp contrast to disaggregate mode approaches where the use of logit or probit requires very large samples.

Since the estimation is based on survey responses the gamesmanship bias may not be totally avoided. However, since responses are restricted to a preselected set of combinations trading-off different attributes, this source of bias is less likely to be as important.

The major disadvantage of the proposed technique is that the quantity shipped by each shipper is assumed not to vary with changes in rates or levels of other attributes. This may be a reasonable assumption in some situations but not in others. In the future work it may be possible to relax this assumption by incorporating quantity-related questions in the survey instrument.

In short, on the basis of the preliminary effort the results of which are reported in this paper, it appears that additional research on the proposed technique is warranted. Of course, the value of the proposed method can only be assessed after a number of validation tests have been performed.

FOOTNOTES

1. For further discussion, see Green (1979).

2. Several shippers who initially agreed to be interviewed refused when the procedure was explained to them or when they had a chance to examine the choices and found out that their favorite response -- some version of "we prefer better service at lower rates" -- was not among them. One possible explanation is that shipper number 7 should be classified as one of those who have refused to be interviewed. However, instead of simply refusing he may have ranked the cards at random.

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