Road and Rail Freight Mode Choice: Application of an Elimination-by-Aspects Model

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The Australian Railway Research and Development Organization is conducting a study, and one of its objectives is to determine factors that affect freight modal use. Part of this has included the development and calibration of freight modal-choice models. The results obtained from the application of an elimination-by-aspects (EBA) model to this task are outlined. The theoretical background to the EBA model and the results of the model when applied to three samples of shippers involved in regional freight transport are described. For each sample, models are calibrated and, on the basis of attribute significance and correlations, these models are refined and recalibrated. Measures of elasticity are then calculated for each attribute in the refined model. The results of the model calibration are then discussed and are found to be plausible given the nature of the shippers in each sample. It is concluded that it is possible to use an EBA model for the analysis of freight modal choice. Areas of future research are identified, and implications of the research results for railways are discussed.

The Australian Railway Research and Development Organization (ARRDO) is a cooperative venture between the five government railway systems of Australia and the federal government. Its task is to conduct research related to rail. One of the current projects is concerned with freight modal competition; its goals are the identification of traffics in which rail can effectively compete with other modes (especially road) and the examination of factors that affect freight modal choice.

Most freight movements in Australia are not subject to regulation; interstate movements are unregulated under the Australian Constitution, and most states have recently removed (or started to remove) regulations on intrastate movement. All four major modes--rail, road, sea, and air--contribute to the national freight task and, while many traffics naturally fall to one or another of these modes, there are still substantial areas of competition. Perhaps the major area of competition is between road and rail for relatively long distance (especially interstate) movements of nonbulk commodities. The clients for these movements include both the shippers of the products who deal directly with a rail system or a trucking company and the freight forwarding industry. The latter is well-established in Australia and acts on behalf of shippers and provides complete door-to-door freight service, as well as warehousing, etc.; the industry is a major customer of both road and rail.

One of the aspects of the ARRDO project on modal competition was to develop and test freight modal-choice models. As part of this task, the Transport Group in the Department of Civil Engineering at Monash University was engaged to investigate the application of an elimination-by-aspects (EBA) model to the analysis of freight mode share.

To undertake this analysis, data were collected by ARRDO staff in two major corridors, namely, Sydney-Brisbane (approximately 700 km apart--a well-populated corridor with several important cities) and Adelaide-Perth (approximately 2500 km apart--very sparsely populated). Interviews were conducted with executives from a number of firms involved in either freight forwarding or in the shipment of goods associated with their own firm's operations. These interviews yielded data, inter alia, on the perceptions of importances and satisfactions (by using a 100-point semantic scale) with respect to nine modal attributes. The interviews were divided into two parts with each respondent. First, for both shippers and forwarders, there were a number of general information questions that sought details of the overall involvement of the respondent in the movement of freight. Second, forwarders were asked a number of more detailed questions about freight movements in specific corridors. Shippers were also asked about specific corridor movements and, in addition, were asked to respond for different commodities within each corridor.

More complete details of the study, including copies of the questionnaires, may be found in Young and Richardson (1) and ARRDO (2). This paper outlines some of the more important results from the study. In particular, it presents details of EBA models constructed to describe the choice behavior of freight shippers. The results of models constructed for freight forwarders were found to be inconclusive because of the small sample size for this group of respondents.

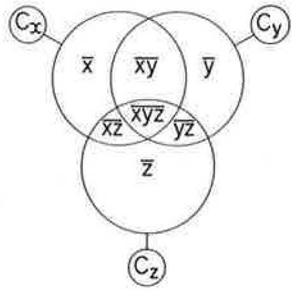
THEORETICAL FOUNDATIONS OF EBA MODEL

Most existing models of transportation choice implicitly assume that each individual considers all alternatives, and each attribute that describes these alternatives, before making a final choice. In behavioral terms, however, this assumption is perhaps unrealistic, especially in relatively complex choice situations where an individual may attempt to simplify the choice problem by eliminating many alternatives and/or attributes from active consideration. Models that allow for the elimination of attributes can be described as attribute-search models, and this class of models includes the EBA model, which is described in this paper.

Two features of such an EBA model are of fundamental importance. The first is that it is assumed that, rather than considering all attributes of an alternative simultaneously in order to generate an overall composite evaluation of the alternative, the individual conducts a mental search of the attributes in a sequential fashion, proceeding from those attributes that are considered most important through to those attributes that are considered least important. It may well occur, however, that this search is not completed and that the individual will make a choice before all attributes have been considered. The method by which this attribute search is terminated is the second feature of such a model. It is assumed that at each stage of the search (i.e., when each attribute is considered), the level of the attribute for each alternative is compared with a minimally acceptable level of that attribute. If an alternative fails this test (i.e., the attribute level is less than the minimally acceptable level), then that alternative is eliminated from further consideration. If it passes the test, it continues to be compared in the attribute search with other remaining alternatives with respect to the next most important attribute. The search continues until all except one of the alternatives have been eliminated. The remaining alternative is then considered to be the chosen alternative.

The basic difference between attribute-search models and most existing models of transportation choice lies in the discontinuous or noncompensatory nature of the attribute-search model. Thus, whereas

Figure 1. Venn diagram representation of satisfactory attribute sets with alternative-specific constants.



in a typical transportation choice model (e.g., a logit model) an attribute that is unsatisfactory may be balanced or compensated for by another attribute that is more than satisfactory, such compensation is not possible in an attribute-search model. This is because at each stage of the search process all alternatives with an unsatisfactory attribute are immediately eliminated from further consideration.

The concept of sequential consideration of attributes has been used in many theories of information processing (3-5), while that of minimally acceptable levels of attributes is most notably postulated in the many works of Simon (6,7) in his expositions on the concept of satisficing. The application of attribute-search models to transportation modeling is, however, relatively limited with only a few examples evident in the transportation modeling literature (8-11).

The model developed in this study is based primarily on the EBA model described by Tversky (5). Thus, the EBA model described in this paper assumes that the more important attributes have a greater probability of being considered earlier in the attribute-search process. By allowing for individual differences, the probability of selection of each attribute for examination is in proportion to the importance of each attribute. Thus, the most important attributes are likely to be examined first, but not necessarily so for any one individual. Because of the probabilistic nature of the attribute-ordering procedure, repeated applications of the model for each individual will not result in the same choice every time but rather will result in a set of probabilities of selection of each alternative.

To avoid the necessity of actually simulating this decision process on repeated occasions to obtain choice probabilities, it is possible to express this model structure in the form of a general mathematical equation [as first shown by Tversky (5)]. The derivation starts with the representation of a three-alternative choice problem in the form of a Venn diagram, as shown in Figure 1. Each alternative is represented by a circle that encompasses those attributes for which the alternative provides a minimally acceptable level of satisfaction. The area that each attribute contributes to the circle is given by the importance of that attribute. Thus, the total area of each circle is given by the sum of the importances of those attributes for which the alternative provides a minimally acceptable satisfaction level.

Areas of overlap between the circles represent attributes that are satisfactory for two or more alternatives, while areas occupied by only one circle represent attributes that are satisfactory for only that alternative. The sets of satisfactory attributes may be represented by set notation; thus, $\bar{x}$ represents the set of attributes that are satisfactory for alternative x alone, $\overline{xy}$ represents the set of attributes that are satisfactory for alternatives x and y (but not others), and $\overline{xyz}$ represents the set of attributes that are satisfactory for all three alternatives. The area of each part of the circles is given by the sum of the importances over the relevant attributes and may be denoted by I(set). In addition to those satisfactory attributes actually specified for each of the alternatives, it is assumed that there also exists one set of unspecified satisfactory attributes for each of the alternatives. These alternative-specific attribute sets are mutually exclusive and non-zero. The size of these sets will be obtained through the calibration process in the form of alternative-specific constraints. These constraints (or attribute sets) are represented by C_x, C_y and C_z.

To enable standardization of the importances, define $K = \Sigma\, I(\text{set})$ over all sets except $\overline{xyz}$. Set $\overline{xyz}$ may be omitted from this summation, and from all later calculations, because it contains attributes that are satisfactory for all alternatives and that therefore cannot eliminate any alternatives and hence cannot affect the final choice probabilities. How, then, could alternative x be selected in this situation by using an EBA process? There are three possible methods. First, x could be chosen directly if any of the attributes in either set $\bar{x}$ or set C_x were selected as the first attribute for examination. Since neither y nor z have satisfactory performance with respect to any of the attributes in $\bar{x}$ or C_x, they would both be immediately eliminated from further consideration, thus leaving x as the only remaining, and hence selected, alternative.

Since the ordering of attributes for examination is a function of the importance of the attributes, the probability of the above event occurring is given by

$$P_1(x) = [C_x + I(\bar{x})]/K \quad (1)$$

where $P_1(x)$ is the probability of selecting x by the first method.

The second method of selecting x is to initially consider an attribute in set $\overline{xy}$ (hence eliminating z) and then choose x over y in subsequent comparisons. The probability of this event occurring is given by

$$P_2(x) = [I(\overline{xy}) \cdot P(x \mid xy)]/K \quad (2)$$

where $P_2(x)$ is the probability of choosing x by the second method and $P(x \mid xy)$ is the probability of choosing x in a comparison between x and y. This latter probability may be given by

$$P(x \mid xy) = [C_x + I(\bar{x}) + I(\overline{xz})]/[C_x + I(\bar{x}) + I(\overline{xz}) + C_y + I(\bar{y}) + I(\overline{yz})] \quad (3)$$

The third method of selecting x is to initially consider an attribute in set $\overline{xz}$ (hence eliminating y) and then choose x over z in subsequent comparisons. The probability of this event occurring is given by

$$P_3(x) = [I(\overline{xz}) \cdot P(x \mid xz)]/K \quad (4)$$

where

$$P(x \mid xz) = [C_x + I(\bar{x}) + I(\overline{xy})]/[C_x + I(\bar{x}) + I(\overline{xy}) + C_z + I(\bar{z}) + I(\overline{yz})] \quad (5)$$

The total probability of selecting x is given by the sum of the three probabilities in Equations 1, 2, and 4 and may be expressed as

$$P(x \mid xyz) = [C_x + I(\bar{x}) + I(\overline{xy}) \cdot P(x \mid xy) + I(\overline{xz}) \cdot P(x \mid xz)]/K \quad (6)$$

Similar equations may be derived to obtain expressions for the probabilities of selection of each

Table 1. Average importance and satisfaction ratings for shippers.

	Importance		Satisfaction			
			Rail		Road	
Attribute	Avg	SE	Avg	SE	Avg	SE
Door-to-door transit time	76.4	1.89	50.3	2.11	79.3	1.22
Reliability of meeting arrival time at destination	84.0	1.30	48.6	2.11	79.3	1.19
Availability of capacity when required	78.5	1.52	63.5	2.27	72.3	1.67
Frequency of service	76.7	1.56	62.7	2.29	75.3	1.67
Freight rates	86.2	1.36	58.8	2.14	62.8	1.82
Avoidance of damage or deterioration	82.0	1.77	56.8	2.21	72.8	1.57
Avoidance of loss or theft	76.7	2.02	66.9	2.25	78.7	1.38
Convenience of time of departure	66.0	2.10	63.4	2.15	78.2	1.39
Communication with respect to problems	85.0	1.13	55.5	2.34	75.4	1.53

of the other alternatives. Thus, for any individual for which attribute importance and satisfaction data are available, it is possible to calculate the probabilities of selection for each of the available alternatives.

The major problem remaining to be addressed is the method by which minimally acceptable satisfaction levels are to be set. This study uses a "minimum-regret" criterion whereby attribute satisfaction levels are considered to be acceptable if they lie within a specific percentage tolerance of the maximum satisfaction level for that attribute over all alternatives for that individual. Thus,

$$\text{Acceptable } S_{kjq} \geq (1 - T_k) \operatorname*{Max}_j \{S_{kjq}\} \tag{7}$$

where

S_{kjq} = satisfaction with the kth attribute of the jth alternative for the qth individual,

T_k = tolerance for the kth attribute, and

$\operatorname*{Max}_j\{S_{kjq}\}$ = maximum satisfaction with the kth attribute for the qth individual over all j alternatives.

Thus, if satisfactions are measured on a psychometric scale of 1 to 100 and the maximum satisfaction for an attribute over all alternatives is 80, then--assuming a tolerance of, say, 0.20--the remaining alternatives would be satisfactory if their satisfaction scores were greater than or equal to 64 [i.e., (1 - 0.20) x 80].

The determination of the most appropriate set of tolerances (T_k) is the task of the calibration program, where tolerances are selected such that a specified objective function is maximized. Because the output of the EBA model described above is a probability of selection (see Equation 6), maximum likelihood methods can be used to estimate (T_k).

MODEL RESULTS

Three of the models constructed in this study will be discussed in this section. Specifically, these models are for the choice between road and rail for (a) the total sample of shippers, (b) shippers of manufactured goods, and (c) shippers of nonmanufactured goods. The definition of manufactured goods was taken from the Australian Department of Transport's draft transportation freight commodity classification. By using this stratification, the total sample of 146 shippers was split into 92 responses from shippers of manufactured goods and 54 responses from shippers of nonmanufactured goods.

Shippers Model

Importance and Satisfaction Ratings

Table 1 shows the nine modal attributes considered in the study. The average importance of each of the attributes as perceived by the total sample of 146 shippers is also presented in Table 1, together with the standard error of the estimate of average importance. It can be seen that most average importances are in the range of 75-85 (on a 100-point semantic scale), with only convenience of departure time being given the relatively low rating of 66. However, the total range of average importance is not great, which indicates that in the EBA model the order of examination of attributes will not, on average, be particularly biased toward or against any one attribute. For any one individual, however, the difference between maximum and minimum importance could be greater, which indicates that the importance scores could have a greater effect on the order of examination of attributes for that individual.

Also given in Table 1 is the average and standard error of the satisfactions for each of the modes. Without exception, the road mode has a higher average satisfaction for each of the attributes than the rail mode. This is most pronounced for transit time, reliability, and communication. Only with respect to freight rates does the rail mode approach the degree of satisfaction expressed with respect to the road mode. Although the importance and satisfaction ratings described above do not provide clear evidence as to the relative contributions of each attribute to the choice process, they do provide useful background information for the later interpretation of model results.

Initial Model Calibration

An EBA model was first calibrated for the sample of 146 shippers by using all nine modal attributes. The results of this calibration are shown in the table below (note: * = significant at 5 percent level):

Attribute	Tolerance	$-2\ln\lambda$
Transit time	0.34	2.66
Reliability	0.53	9.80*
Capacity	0.07	19.66*
Frequency	0.38	1.54
Freight rates	0.51	8.34*
Damage	0.37	17.72*
Loss	0.71	0.68
Convenience	0.37	4.60*
Communication	0.70	1.92

The associated statistics that describe attribute significance and model performance are as follows: rail constant = 6, road constant = 31, $L^*(\hat{T}) = -55.3$, $L^*(1.00) = -97.6$, $-2\ln\lambda = 84.6$ (significant at 5 percent level), and $\rho^2 = 0.43$. Since maximum-likelihood estimation techniques have been used in the calibration procedure, it is possible to use specific values of the likelihood function to test both the overall significance of the model and the significance of individual attribute tolerances. In particular, the generalized likelihood-ratio test can be used (12) to test whether the estimated tolerances are significantly different from 1.00. In this model, note that the hypothesis that tolerances are equal to 1.00 is equivalent to that in a logit model where coefficients are equal to zero; i.e., in each case, the null hypothesis is that the choice is independent of the values of the attribute satisfactions.

The generalized likelihood-ratio statistic is of the form $\lambda = \max L(\omega)/\max L(\Omega)$, where λ = likelihood ratio, $\max L(\omega)$ = maximum of the likelihood function where M tolerances have been constrained to 1.00, and $\max L(\Omega)$ = unconstrained maximum of the likelihood function.

Wilks (13) shows that $-2\ell n\lambda$ is approximately distributed like chi-square with M degrees of freedom when the null hypothesis is true. Therefore, if $-2\ell n\lambda$ is greater than the critical value of χ^2_M (for a preselected significance level) then the null hypothesis, in which the tolerances are equal to 1.00, may be rejected and the tolerances may be taken to be significant. In testing the overall model, all tolerances are constrained to zero (i.e., M = 9), whereas in testing individual attribute tolerances only that tolerance is constrained to zero (i.e., M = 1). Thus the critical value of χ^2 for the model (at the 5 percent level of significance) is 16.92, while the critical value of χ^2 for individual attribute tolerances is 3.84.

An alternative test of the overall model is the use of a pseudo-R^2 value termed the likelihood-ratio index (14). This measure is calculated as

$$\rho^2 = 1 - [L*(\hat{T})/L*(1.00)] \tag{8}$$

where $L^*(\hat{T}) = \ell n\,[\max L(\Omega)]$ and $L^*(1.00) = \ell n\,[\max L(\omega)]$. Since the unconstrained log-likelihood will always be greater than the constrained log-likelihood (both being negative numbers), the ratio $L^*(\hat{T})/L^*(1.00)$ will always be between 0 and 1. The smaller this ratio, the better the explanatory power of the model over the aggregate market-share-prediction model and, hence, the larger the value of ρ^2. However, although ρ^2 can theoretically vary between 0 and 1, it has been noted by Hensher and Johnson (12) that values of ρ^2 between 0.2 and 0.4 are considered extremely good fits. In light of this, the value of 0.43 obtained for the initial model (see the table above) for shippers suggests a significant overall model.

The tolerances associated with each of the attributes are also shown in the table. These tolerances specify the percentage shortfall from the maximum satisfaction for an attribute before an alternative is considered to be unsatisfactory with respect to that attribute. Thus, it can be seen that if the satisfaction with transit time for an alternative is within 34 percent of the maximum satisfaction with transit time across all alternatives, then the lower satisfaction is still regarded as acceptable. Obviously, attributes with lower tolerances will, ceteris paribus, have more effect on the final choice because this lower tolerance will more readily classify the lower satisfaction as being unacceptable. Before attributing any meaning to the tolerances, however, it is necessary to ascertain whether the tolerances are statistically significant or whether they are merely the result of chance.

By using the generalized likelihood-ratio test described earlier, the values of $-2\ell n\lambda$ for each of the nine modal attributes were calculated and are shown in the above table. It can be seen that four of the attributes have insignificant tolerances in this model (namely transit time, frequency, loss, and communication), while the other five attributes appear to be significant.

The final aspect of the results in this table that needs explanation is the size of the alternative-specific constants estimated for the rail and road modes. It will be remembered that the alternative-specific constants have the function of accounting for attributes that have not been explicitly included in the specification of the choice model. The size of the constants estimated in the calibration procedure therefore indicates the bias toward each alternative due to unspecified attributes. By using this concept, it can be seen from the table that there is a large bias toward rail by shippers due to attributes as yet unidentified in the model, whereas there is only a small bias toward road in the same model.

Refined Model Calibration

To refine the model for shippers, the model was recalibrated by omitting attributes found to be insignificant. That is, transit time, frequency, loss, and communication were omitted from the model. The omission of these attributes is also supported on the basis of correlation between the attributes. Thus, both transit time and communication were correlated with reliability and hence their omission from the model should be in part compensated for by an increase in the significance of reliability. Similarly, frequency was correlated with capacity while loss was correlated with convenience and damage.

The results of the recalibration of the shippers model are given in the table below (note: * = significant at 5 percent level):

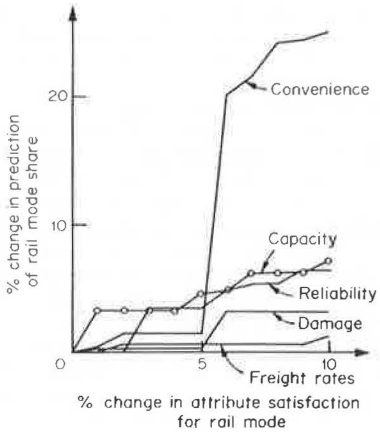
Attribute	Tolerance	$-2\ell n\lambda$
Reliability	0.46	20.84*
Capacity	0.11	20.54*
Freight rates	0.43	17.40*
Damage	0.37	21.48*
Convenience	0.05	28.76*

The associated statistics that describe attribute significance and model performance are as follows: rail constant = 26, road constant = 3, $L^*(\hat{T})$ = -56.53, $L^*(1.00)$ = -97.60, $-2\ell n\lambda$ = 82.14 (significant at 5 percent level), and ρ^2 = 0.42. With four attributes removed from the specification, it can be seen that the model is still highly significant, as demonstrated by the very high values of $-2\ell n\lambda$ (82.14) and ρ^2 (0.42). Moreover, the goodness-of-fit of the initial and refined models are not significantly different at the 5 percent level, as can be seen by using the values of $L^*(\hat{T})$ from the two tables shown above and by calculating the value of the likelihood-ratio statistic for the comparison between the two models; $-2\ell n\lambda$ is 2.46, which may be compared with the critical χ^2 value for 4 degrees of freedom of 9.49. The significance of the individual attribute tolerances is, however, greatly improved in the refined model with all tolerances being significant at greater than the 5 percent level. In all respects, then, the refined model can be seen as being highly significant.

Attribute Elasticities

Although the significance of the overall model and of individual attributes is a necessary statistical condition in model building, it is not the final

Figure 2. Attribute elasticities for total sample of shippers.



test of the model. Ideally, the model should be used to predict the results of a change in the system and to compare those predictions with observations of what actually occurs. This type of before-and-after study is, however, rare. It is informative, nonetheless, to use the model to predict what might occur if a system change was made. A convenient way of examining these model predictions is by the calculation of attribute elasticities--that is, to calculate the change in the proportion predicted to use an alternative mode consequent on a discrete percentage change in the satisfaction level of an attribute.

In this study, arc elasticities are calculated by complete enumeration, given increases of 1 to 10 percent in the satisfaction level of each attribute for the rail mode. The results of the elasticity calculations are shown in Figure 2 for the refined version of the shippers model. Several features of these elasticity curves are of importance. It is obvious from Figure 2 that the elasticity is not a smooth function of the change in attribute satisfaction. This is for two reasons. First, because the satisfaction ratings in the questionnaire were coded to the nearest multiple of five, the elasticity curve forms a step function as the increase in satisfaction level reaches a new multiple of five. Second, and more significant, the EBA model is inherently discontinuous in nature. Changes in prediction can only occur when the satisfaction level of an attribute crosses the minimally acceptable satisfaction level for that attribute. In such a situation, an alternative changes from unsatisfactory to satisfactory with respect to that attribute when satisfaction is rising and hence the probability of selection of that alternative increases in a discontinuous way.

Two further points need to be made with respect to the general interpretation of elasticities. First, the elasticities are predicted changes in use with respect to changes in the satisfaction level of an attribute. The distinction must be drawn between changes in the satisfaction level and changes in the physical level of the attribute. For example, doubling the satisfaction level with respect to freight rates may not necessitate halving the freight rates in monetary terms. Similarly, doubling the satisfaction with capacity may not require the physical capacity to be doubled. It is therefore imperative that, before valid policy conclusions can be drawn, research be performed to obtain relations between the physical levels of attributes and the satisfaction associated with these physical levels.

Second, given that such relations could be found, it would then be possible to convert the elasticities with respect to satisfaction ratings to elasticities with respect to physical levels of attributes. This, however, still falls short of the policy objective to maximize the revenue increase with respect to the resources committed to changing the system. It is therefore necessary to determine the resource input required to increase the physical level of the different attributes by a specified amount. Only when the relations among resource input, physical level of attribute, and satisfaction rating are established, can the elasticities generated by the choice model be of analytical use in policy analysis.

Shippers-of-Manufactured-Goods Model

By using the same procedure as outlined above, an EBA model was calibrated on the sample of 92 shippers of manufactured goods. Thus, an initial model was calibrated by using all nine modal attributes. On the basis of the significance of each of these attributes in the initial model, and noting the correlation between attributes, a refined model was then constructed by using the attributes of reliability, freight rates, damage, and communication. The results of this calibration are given in the table below (note: * = significant at 5 percent level):

Attribute	Tolerance	$-2\ell n\lambda$
Reliability	0.53	21.80*
Freight rates	0.51	8.14*
Damage	0.37	6.62*
Convenience	0.70	9.54*

The associated statistics that describe attribute significance and model performance are as follows: rail constant = 7, road constant = 4, $L^*(\hat{T})$ = -28.23, $L^*(1.00)$ = -54.44, $-2\ell n\lambda$ = 62.42 (significant at 5 percent level), and ρ^2 = 0.53. The model is highly significant as shown by the high values of $-2\ell n\lambda$ (62.4) and ρ^2 (0.53). All four attributes in the refined model are significant at the 5 percent level of significance. Importantly, the size of the alternative-specific constants are both very small, which indicates that more of the variance in the data set is being explained by the specific attribute in the model, with less reliance being placed on unspecified attributes outside of the model. The elasticities for the four attributes in the refined model are shown in Figure 3 for changes in the satisfaction with the rail mode, which varies from 1 to 10 percent. It should be noted that for communication, no line appears on the graph (or at least it is not visible) because for all percentage changes in satisfaction (up to 10 percent), there is no increase in the rail modal share.

Shippers-of-Nonmanufactured-Goods Model

By using all nine modal attributes, an EBA model was calibrated for the sample of 54 shippers of nonmanufactured goods. In this initial model, only three attributes (capacity, freight rates, and loss) appeared to be significant. The refined model was calibrated by using these three attributes and the results are given in the table below (note: * = significant at 5 percent level):

Attribute	Tolerance	$-2\ell n\lambda$
Capacity	0.07	12.02*
Freight rates	0.07	24.14*
Loss	0.45	3.44

Figure 3. Attribute elasticities for shippers of manufactured goods.

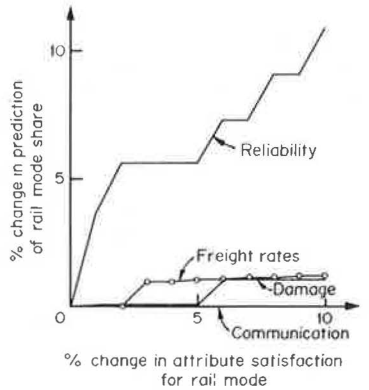
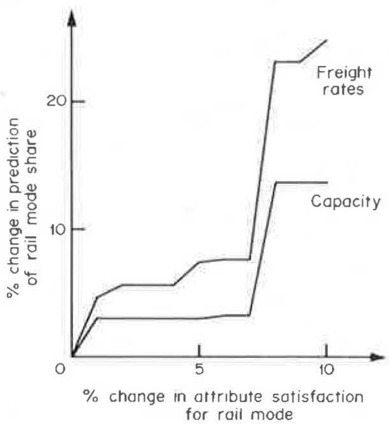


Figure 4. Attribute elasticities for shippers of nonmanufactured goods.



The associated statistics that describe attribute significance and model performance are as follows: rail constant = 15, road constant = 8, $L^*(\hat{T}) = -23.99$, $L^*(1.00) = -37.28$, $-2\ell n\lambda = 26.58$ (significant at 5 percent level), and $\rho^2 = 0.36$. The three-attribute model is significant as shown by the values of $-2\ell n\lambda$ (26.6) and ρ^2 (0.36). However, only two of the attributes (capacity and freight rates) remain significant at the 5 percent level. The elasticities for these two attributes are shown in Figure 4.

DISCUSSION OF RESULTS

Models have been calibrated for the total sample of shippers and for two subgroups of this sample. In the shippers model, five attributes were found to be significant: reliability, capacity, freight rates, damage, and convenience. In the two models for the subgroups, subsets of these five factors were found to be significant. Thus, for shippers of manufactured goods, reliability, freight rates, damage, and communication were found to be significant, although communication was later found to have zero elasticity. For shippers of nonmanufactured goods, capacity and freight rates were the only significant factors. Within each of these subgroups, the elasticities of each of the significant attributes have been shown in Figures 3 and 4. For shippers of manufactured goods, it appears that a change in satisfaction with reliability is by far the most effective way of increasing the rail modal share. Changes in satisfaction with freight rates and damage are much less effective while changes in communication are completely ineffective within the range of satisfaction changes investigated. For shippers of nonmanufactured goods, a change in freight rates is most effective in increasing the rail modal share although both freight rates and capacity have high elasticities.

In interpreting these elasticities, several limitations must be clearly understood. As noted earlier, the elasticities are with respect to changes in the satisfaction rating of the attribute and not with respect to the physical level of the attribute. Also, the resources involved in making such changes have not been considered. Therefore, the elasticities described in this paper should not be confused with cost-effectiveness measures for changes in each of the attributes. Note also that the elasticities produced in this study are for increases in the level of satisfaction with the rail mode. Elasticities that correspond to decreases in satisfaction with the rail mode may produce very different results.

Given these limitations, it is useful nonetheless to examine the modal attributes found to be important, particularly from the viewpoint of their implications for railways in improving their market share in competitive traffics.

The freight rates of rail relative to road are clearly an important determinant of freight modal choice. For some commodities or shippers it may be the dominant one but, for others, service factors are also important and may outweigh any price advantage that the rail mode may have over the road mode. The corollary is that if rail's level of service improves, higher rates will more likely be accepted by rail's customers.

The reliability of transit time is of importance to many customers. Delays or uncertainty cause costs to them in terms of delays to vehicles awaiting the arrival of goods for pickup, extra warehousing for buffer stock at the destination, managerial time taken up in seeking the whereabouts of late goods, and possibly lost sales. Improvement of reliability involves a series of initiatives on the part of railways and the incidence of these is likely to vary from place to place. For example, terminal throughput, mainline delays, shortage of suitable wagons, and industrial disputes are all likely to be relevant. Solutions of these problems include investment options (e.g., improvement of mainline capacity, extra wagons, and improvement to terminals), information options (e.g., wagon monitoring), and management options (e.g., fewer industrial disputes, consistency between systems in criteria for inspection, and red-carding of wagons).

Where damage or deterioration is of particular concern to shippers, it is obvious that extra costs may well be incurred by the user. Causes of loss in the railways include such elements as heavy shunting, mixing, or stocking of incompatible goods; inadequate cleaning of wagon interiors; missing or inadequate paperwork; pilferage; mishandling of goods; etc. Although railways are aware of these practices and seek to minimize them, improvements are possible through such avenues as staff training, improved management, or technological advances in packaging or shipment, which includes greater use of containers.

As with the reliability variable, the ability of a transportation system to have sufficient capacity to deliver goods when the consignee requires them is an important feature of the system. If suitable wagons are not available, either unsuitable wagons must be used, which possibly will increase the chance of damage or further delay, or the dispatch of the goods is held up. Causes of these problems may be an absolute shortage of particular wagons or unavailability of wagons due to poor use or poor information about wagon locations. Thus, solutions lie in investment, which includes private ownership of wagons and improved wagon-monitoring systems.

Although communication with respect to problems did not emerge as being particularly significant in any of the calibrated models, this feature was often mentioned in the interviews conducted by ARRDO staff. Many shippers and forwarders reported that their treatment by railway staff was not on a businesslike basis; forwarders in particular contrasted rail attitudes toward them with forwarders' attitude toward their own customers, where they had learned the necessity of maintaining good relations with their customers. Other aspects include not being told when things went wrong (for example, when there was a delay), a lack of ability to supply requested information (for example, about the expected time or date of delivery of a particular shipment), and an inability to locate shipments in transit. Improvements in these areas are in part in the nature of delivery of information (e.g., through a comprehensive wagon-monitoring system) and in part in terms of changed management practices or staff training.

CONCLUSIONS

This paper has presented the results of the application of an EBA model to regional freight modal choice. Several conclusions may be drawn from the study. First, it has been shown that the calibration of an EBA model is possible and that the model yields significant results. Second, it shows that different factors appear to be influencing the mode choice of shippers of manufactured and nonmanufactured goods. Such factors appear plausible given the nature of the commodity movements for each group of shippers.

Although the results of this study are encouraging, in that significant models have been constructed and the significant attributes are plausible, there is still opportunity for further research in the area of freight modal-choice modeling. First, it may be possible to examine a different stratification of the shippers' population on the basis of various descriptions of the freight movement. Stratifications that spring readily to mind include the unit value of the consignment, whether the consignment is full carload/truckload or less than carload/truckload, and, perhaps, the trip length of the movement. A further area of research is the application of the EBA model to freight modal-choice situations in which the special features of the EBA model can be exploited. These include complex choice situations with a large number of attributes and multimodal situations where the ability of the EBA model to allow for nonequal similarity of alternatives can be of great benefit.

The final area of research, which has perhaps the most immediate relevance to the present study, is the establishment of relations between the physical and psychometric values of attribute levels. Until this is done, the elasticities derived in this study cannot be fully used to assist in the formulation of policy options for improved rail-freight services.

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REFERENCES

1. W. Young and A.J. Richardson. Regional Freight Mode Choice: An Application of the Elimination-by-Aspects Model. Report to Australian Railway Research and Development Organization, Melbourne, Australia, 1981.
2. Analysis of Modal Competition in Sydney-Brisbane and Adelaide-Perth Corridors. Australian Railway Research and Development Organization, ARRDO Rept. 81/25, Melbourne, Australia, 1981.
3. F.D. Luce. Semiorders and a Theory of Utility Discrimination. Econometrika, Vol. 24, 1956, pp. 171-178.
4. R.A.M. Gregson. Some Possible Forms of Lexicographic Evaluation. Psychometrika, Vol. 28, 1963, pp. 173-183.
5. A. Tversky. Elimination by Aspects: A Theory of Choice. Psychological Review, Vol. 79, No. 4, 1972, pp. 281-299.
6. H.A. Simon. Rational Choice and the Structure of the Environment. Psychological Review, Vol. 63, No. 2, 1956, p. 129.
7. H.A. Simon. Satisficing and the One Right Way. In Humanscapes: Environments for People (S. Kaplan and R. Kaplan, eds.), Duxbury Press, Belmont, CA, 1978, pp. 127-131.
8. W.W. Recker and T.F. Golob. A Non-Compensatory Model of Transportation Behavior Based on Sequential Consideration of Attributes. Transportation Research, Vol. 13B, No. 4, 1979, pp. 269-280.
9. J.F. Foerster. Mode Choice Decision Process Models: A Comparison of Compensatory and Non-Compensatory Structures. Transportation Research, Vol. 13A, No. 1, 1979, pp. 17-28.
10. J.F. Foerster. Non-Linear Perceptual and Choice Functions: Evidence and Implications for Analysis of Travel Behavior. In New Horizons in Travel Behavior Research (P.R. Stopher, A.H. Meyburg, and W. Brög, eds.), Lexington Books, Lexington, MA, 1981, pp. 335-352.
11. W. Young and A.J. Richardson. Residential Location Preference Models: Compensatory and Non-Compensatory Approaches. Presented at Planning and Transport Research and Computation Company, Ltd., Summer Annual Meeting, Univ. of Warwick, Coventry, England, 1980.
12. D.A. Hensher and L.W. Johnson. Applied Discrete Choice Modelling. Croom Helm, Ltd., London, 1981.
13. S.S. Wilks. Mathematical Statistics. Wiley, New York, 1962.
14. D. McFadden. Quantitative Methods for Analysing Travel Behaviour of Individuals: Some Recent Developments. In Behavioural Travel Modelling (D.A. Hensher and P.R. Stopher, eds.), Croom Helm, Ltd., London, 1979.

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