ANALYSIS OF FREIGHT-FACILITY LOCATION CHOICE USING AN ELIMINATION-BY-ASPECTS MODEL

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ABSTRACT: *This paper presents an analysis of the factors affecting freight-facility location choice. These factors are determined by using an Elimination-by-Aspects model. Correlation between the characteristics in the model is minimised prior to model development. The modelling approach is then shown to be a suitable and potentially valuable approach for analysing freight-facility location. Using data collected in Melbourne, the model calibration shows that the decision of facility location can be modelled using five characteristics. Three of these characteristics are related to accessibility (accessibility to arterial roads, customers and labour) while the remaining two are fleet operating cost and the availability of suitable sites. Of these, accessibility to arterial roads is the most influential. This result is of value in a transport planning context because it means that transport system variables have an effect on the choice of freight facility location.*

INTRODUCTION

Both passenger and freight transport systems have important spatial ramifications. Transport effects, for instance, often influence the location decisions and viability of industry (Weber, 1929; McMillan, 1965; Rimmer, 1970). However, the extent of this influence and the nature of the relationship are as yet generally not fully understood.

Although the amount of urban land occupied by freight distribution facilities is relatively small, such land uses are amongst the most volatile from the community viewpoint (especially where large, heavy trucks are involved). Data from the United Kingdom (Wigan, 1979) has shown that freight depots and warehouses in London are highly footloose. If this is so in other cities (and Australian cities in particular), it may be possible to influence the location of such freight-generating land uses throughout the planning process to reduce transport costs and broader community costs associated with environmental and social impacts. In previous work Ogden (1979) has suggested that control of the location of freight generating activities is one of the main influences that the planner can exert on the urban freight system.

However, although a large body of theoretical and empirical work on the location of manufacturing industry already exists (Beard, 1973), comparatively little has been reported on the location of freight-distribution activities, which mostly fall within the service industry sector. Consequently, the level of understanding of the location behaviour of firms that operate such facilities, and the extent to which their choice processes might be common, is quite limited. Thus, before predictions about the spatial impact of policy initiatives on urban goods movement can be attempted, it is necessary to investigate further the location characteristics of such freight firms. The successful derivation of an explanatory capability for the location preference of individual freight firms could ultimately lead to the development of disaggregate behavioural models of freight-facility location for use in transport and land use planning of urban systems (Watson, 1975).

This paper reports on an extension to a previous study of the locational preferences of firms which operate freight facilities in Melbourne, Australia (Young, Ritchie and Ogden, 1980). The study included a range of firms whose main function was the distribution of goods, including freight forwarders, truck firms, wholesalers and distributors. Some firms whose main function is not transport and distribution but which had a significant distribution function were also included (e.g. oil companies and major retailers). Freight terminals, depots, storage facilities, distribution centres, warehouses, and similar facilities were included in the study.

AN ELIMINATION BY ASPECTS MODEL

In order to analyse the effects of transport and land use policy decisions on the location of freight facilities, a model sensitive to the influence of such policy decisions was used. Previous work (Young, Ritchie and Ogden, 1980) used a logit model to perform this task, but the present study reports on an extension to this work using an Elimination-by-Aspects (EBA) approach, first discussed by Tversky (1972). A comparison of the results of the EBA and logit model will be presented later in this paper.

Two features of the EBA model are of fundamental importance. First, the model states that, rather than an individual considering all the characteristics of all possible locations simultaneously in order to generate an overall composite evaluation for all locations, the individual conducts a mental search of the characteristics in a sequential fashion proceeding from the characteristic which is considered most important to that characteristic which is considered least important. It may well occur, therefore, that many locations are eliminated after only a few characteristics have been considered and that a decision can be made before all the characteristics describing all the locations are examined.

The method by which this characteristic-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 characteristic is considered), the level of the characteristic for each location is compared to a minimally acceptable level of that characteristic. If a location fails this test (i.e. the characteristic level is less than the minimally acceptable level) then that location is eliminated from further consideration. If it passes the test, it continues in the characteristic-search to be compared with other remaining locations with respect to the next most important characteristic. The search continues until all except one of the possible locations have been eliminated. The remaining location is then considered to be the chosen one.

Given this basic framework, the generalised mathematical form of the EBA model is as follows (See Young (1983) in these proceedings for a more detailed derivation and Young (1982) for the full derivation).

$$P(x/J) = \frac{C_x + \sum_{\text{All } o} I(\bar{o}) \quad P(x/o)}{\sum_{\text{All } J} C_j + \sum_{\text{All } r} I(r)} \qquad (1)$$

where $P(x/J)$ = probability of selecting x from total set of location J

$\bar{o}$ = any subset of characteristics that are satisfactory for at least x

$I(\bar{o})$ = sum of importance for characteristics in set $\bar{o}$

$\bar{r}$ = all subsets of total locations set J except the subset that includes all location in J

C_j = constant for location j

Another problem to be addressed is the method by which minimally acceptable satisfaction levels are to be set. The present study uses a "minimum regret" criterion whereby characteristic satisfaction levels are considered to be acceptable if they lie within a specific fractional tolerance of the maximum satisfaction level for that characteristic over all locations for that individual. Thus,

$$\text{Acceptable } S_{kjq} \geq (1 - T_k) \max_j S_{kjq} \qquad (2)$$

where S_{kjq} = satisfaction with the k^{th} characteristic of the j^{th} location for the the individual q.

T_k = tolerance for the k^{th} characteristic

$\max_j S_{kjq}$ = the maximum satisfaction with the k^{th} characteristic for the q^{th} individual over all j locations

However, an individuals perception of his tolerance may be affected by a multitude of chance errors, and there may also be a distribution of tolerances across the individuals in the study population. Therefore the EBA model should be generalised to incorporate a distribution of the most appropriate set of mean tolerances (T_k). The task of the calibration program is to determine the distribution and mean of these tolerances such that a specified objective function is maximised. Because the output of the EBA model described above is a probability of selection (see eqn (1)) maximum likelihood is used to estimate these parameters. This procedure is explained later, when the results of the analysis are presented.

EMPIRICAL STUDY

Although the choice model outlined above has been applied to residential location choice (Young, 1982), it has not previously been applied to the location preference of firms and, more particularly, to firms involved in the distribution of freight.

Sample Selection

In selecting a sample from which to obtain data for the building of location choice models, two criteria should be met. The first is that the sample should be homogeneous with respect to location choice. This criterion was partly met in this study by selecting only firms that were (a) involved in the distribution of freight and (b) located in Melbourne. However, since the distribution sector is large, different firms have different market and location characteristics and therefore the sample could not be said to be truly homogeneous.

The second criterion is that the firms should be in equilibrium so that the factors which affect the decision to locate will be the same for all firms in the study. It is unlikely that this criterion will be satisfied, since different firms in the sample had been at their present location for different lengths of time and each firm was probably faced with a unique set of characteristics when it made its latest location decision. However, after that decision was made, changes in the firm's circumstances, or in the urban and economic environment, may have resulted in another location being more appropriate. To overcome this problem of lack of equilibrium, respondents to the survey were asked to compare their existing location with one other possible location, as of the time of the study and not as of the time when their last location decision was made. They were also asked which of these two locations they would select if they were making their location decision now. This preferred location, rather than the firm's actual current location, was used in the development of the models presented in this paper.

It is important at this point to note the distinction between the preferences of a decision-making unit and its final decision since, even if it is assumed that a firm's location behaviour is rational and that the choice set for the firm is completely specified, a firm's preference for a location other than its current one need not necessarily lead to a relocation. The preferences of individual firms for alternative locations can be viewed as a measure of the demand for alternative locations, but before a choice decision will result, an interaction of demand and supply must be considered. Moreover, unless the perceived "benefit" to the firm in moving to an alternative location exceeds the cost of that move, perhaps by some threshold amount, the firm is unlikely to relocate regardless of its stated preferences.

Questionnaire

To apply the model outlined earlier in this paper, data on importances and satisfactions are required. In this study, these data were obtained by using a questionnaire completed during interviews with senior management personnel of a sample of firms in Melbourne (Ritchie and Ogden, 1979). These firms covered a range of activities in the transport and distribution sector. A total of 71 questionnaires were completed satisfactorily.

More specifically, each respondent was first asked to rate on a psychometric scale, whose end points were 1 and 100, how satisfactory two locations were with respect to 19 locational characteristics. The two locations were the firm's current location and one other possible location nominated by the respondent. (Note that not all areas in the urban region can be considered alternative locations. For example, land use planning regulations may prohibit freight activity in certain localities. Thus if all locations were considered in the estimation of model parameters a biased result may be obtained. This study only included one alternative, selected by the respondent, to ensure that the alternatives considered were valid for that firm).

The 19 location characteristics and their abbreviations (in parentheses) were as follows:

closeness to existing markets	(Customers)
closeness to expanding markets	(Expanding Markets)
closeness to other facilities operated by the firm	(Other Facilities)
closeness to firms providing services	(Other Firms)
closeness to arterial roads	(Arterial Roads)
closeness to freeways	(Freeways)
access to country highway	(Highway)
closeness to rail freight facilities	(Rail)
closeness to port facilities	(Ports)
closeness to public transport	(Public Transport)
traffic congestion and delay	(Congestion)
availability of suitable sites	(Sites)
investment potential	(Investment)
company prestige	(Prestige)
cost of land and buildings	(Land Costs)
cost of council rates	(Rates)
cost of operating the respondents vehicle fleet	(Operating Cost)
availability of labour	(Labour)
environmental impact of the facility	(Environment)

Respondents were then asked to rank, on a similar semantic scale, how important each of these characteristics would be in their selection of a location for their freight facility. Finally, they were asked to rate both location alternatives overall. It is interesting to note that, although most respondents ranked their existing site higher, many did not.

The result of this part of the questionnaire was a set of data on satisfactions and importances for each of the 19 characteristics given above. From these, it was possible to use the theory to build an EBA model of facility location preference.

CORRELATION OF CHARACTERISTICS

Before the formulation of the model of freight facility location preference is discussed, it is necessary to explain how the data obtained in the questionnaire survey were made suitable for analysis.

The characteristics introduced in the process of model calibration were in the form of separate importance and satisfaction ratings. However the characteristics described above are by no means unique or mutually exclusive and so may be interrelated. For example, several of the characteristics given above relate to closeness to transport, whereas perhaps only one relates to the availability of labour. Since correlation between independent variables can lead to a spurious model, it was necessary to determine which, if any, of the characteristics were correlated. To do this a factor-analysis technique which measures the latent dimensions in the data, was used. (Recker and Golob, 1976; Brown, 1977).

Factor analysis is a technique whereby characteristics which are correlated can be determined. In the factor analysis process the principal components are first determined from these correlations. The first component explains the maximum possible variance on the data. The second component is then the one that explains the second largest amount of variance and is also at right angles to (i.e. uncorrelated with) the first component. The process continues until all of the variance is explained. The amount of variance explained by each factor can be represented by the eigenvalue (Tarrant, 1973).

Since each of the components explains progressively less of the total variance, there comes a point at which factors explain less of the variance than a single characteristic. This point is reached when the eigenvalue of the factor is less than 1.0. Therefore, only components that had eigenvalues greater than 1.0 were used in this study.

To make the relationship between the characteristics and the factors clearer the principal components are "rotated". This rotation increases the correlation between some characteristics and particular factors towards 1.0 while it decreases the correlation between other characteristics and the factors towards 0.0.

Since the importance and satisfaction ratings are input into the EBA model calibration separately, factor analysis was carried out on both sets of data separately. Table I presents the results.

The factor analyses for importances and satisfactions show some differences. There are however several attributes that load onto the same factor for both importances and satisfactions. These are

Factor A	Customers and Expanding Markets
Factor B	Arterial Roads, Freeways and Highways
Factor C	Rail and Ports
Factor D	Land Costs and Rates

Given that each of the characteristics within the above factors are correlated it was decided to leave only one characteristic from each factor in the model building. The new attribute set, comprising 14 attributes (i.e. 19 minus the 5 incorporated in the above factors) is presented in Table II

TABLE I FACTOR ANALYSIS RESULTS FOR IMPORTANCE AND SATISFACTION RATING

Characteristic	Satisfaction		Importance	
	Factor	% Variance Explained	Factor	% Variance Explained
Customers	1	45	3	71
Expanding Markets	1	37	3	57
Other facilities	-	-	4	20
Other firms	1	36	-	-
Arterial Roads	4	48	2	49
Freeways	4	44	2	58
Highways	4	25	2	35
Rail	2	55	4	43
Ports	2	62	4	43
Public transport	6	25	-	-
Congestion	-	-	1	42
Sites	3	42	-	-
Investment	-	-	5	34
Prestige	-	-	5	27
Land Cost	3	47	1	43
Rates	3	23	1	31
Operating Cost	1	29	1	39
Labour	5	23	1	50
Environment	3	20	-	-
Total		63		63

TABLE II INITIAL EBA MODEL

Characteristic	Tolerance	Significance of Parameters ($-2 \ln \lambda_k$)
Customers	0.45	4.33
Other Facilities	0.20 *	3.62
Other Firms	2.70 *	0.22
Arterial Roads	1.30 *	0.29
Port	0.90 *	0.75
Public Transport	2.80 *	0.17
Congestion	2.35 *	0.30
Sites	0.20	24.51
Investment	2.20 *	0.23
Prestige	0.25	12.93
Land Cost	2.30 *	0.30
Operating Cost	0.55	7.89
Labour	0.40	9.61
Environment	2.25 *	0.21
$-2 \ln \lambda_T$	47.07	
ρ^2	0.48	

* Not significant at 5% level

MODEL DEVELOPMENT

Initial Model

Table II also presents the parameter estimates for the EBA model developed using these 14 characteristics. A short description of the measures of significance of the model and parameters presented in Table II is given in Appendix A. A more detailed description can be found in Young (1982).

These tests of significance do however suggest that overall the model is highly significant ($\chi^2_{0.05,14} = 23.69 < 47.07 = -2 \ln \lambda_T$ and $\rho^2 = 0.49$). Hence the model is acceptable from the point of view of overall fit. However many of the parameter estimates for characteristics within the model have $-2\ \ell n\ \lambda_k$ values of less than 3.84 and are therefore not significant at the 5% level. The model was therefore refined by removing the characteristics with parameter estimates that were not significant. These characteristics were removed one at a time, the parameter with the lowest $-2\ \ell n\ \lambda_k$ value being removed at each step of the refinement.

Refined Model

Table III presents the tolerance estimates and the relevant statistical values for the refined model. Again the overall fit of the model is highly signficant ($\chi^2_{0.05,5} = 11.07 < 44.18 = -2\ \ell n\ \lambda_T$ and $\rho^2 = 0.45$). Furthermore all the parameter estimates have $-2\ \ell n\ \lambda_k$ values greater than 3.84 and are therefore significant at the 5% level.

The refined model includes only five characteristics. These are

closeness to existing customers
closeness to arterial roads [1]
availability of suitable sites
cost of operating the respondents fleet, and
closeness to labour

TABLE III REFINED EBA MODEL

Characteristic	Tolerance	Significance of Parameters ($-2\ \ell n\ \lambda_k$)
Customers	0.45	10.99
Arterial Roads	0.25	12.89
Sites	0.65	18.95
Operating Costs	0.65	6.64
Labour	0.50	9.21
$-2\ \ell n\ \lambda_T$	44.18	
ρ^2	0.45	

Several of these characteristics relate to the transport infrastructure. Some implications of this are discussed below.

The sensitivity of the characteristics to changes in the level of satisfaction has been shown to be related to the size of the tolerance

1. Correlated with closeness to freeways and closeness to country highways.

(Young, 1982). Characteristics with small tolerance estimates are more sensitive to changes in characteristic satisfaction than are characteristics with larger tolerances. Hence the characteristic which is most sensitive to a change in satisfaction level is closeness to arterial roads. This is followed by accessibility to customers and accessibility to labour. The availability of suitable sites and the operating cost of the fleet are the least sensitive. These results further reinforce the suggestion that the location of transport infrastructure has an influence on the location choice of freight facilities in Melbourne.

COMPARISION OF EBA AND LOGIT MODELS

As was stated earlier the EBA model is a relatively new addition to the tools available for analysing choice situations. It has however been applied to studying residential location choice (Young, 1982) and the transport mode used to move freight between capital cities of Australia (Young, Richardson, Ogden and Rattray, 1982). The more common model for studying choice situations is the logit model and a previous study of the freight facility data used for this study used this approach (Young, Ritchie and Ogden, 1980). It is therefore interesting to compare the EBA and logit models. Table IV presents such a comparison.

TABLE IV CHARACTERISTICS INCLUDED IN REFINED EBA AND LOGIT MODELS

Characteristic	EBA	LOGIT
Customers *	X	X
Expanding Markets *		X
Other Facilities *		X
Other Firms *		X
Arterial Roads †	X	X
Freeways †		X
Operating Costs †	X	X
Sites	X	X
Labour	X	X
$-2 \ell n \lambda_T$	44.18	40.42
ρ^2	0.45	0.41

* These characteristics were grouped into a factor called closeness to markets in logit model.

† These characteristics were grouped into a factor called truck transport in logit model

Table IV shows that the characteristics found to have significant parameters in the EBA model also had significant parameters in the logit model. The logit model does however contain more characteristics in the model that does the EBA. This is due to a slight difference in the formulation of the factors put into each model. (In the logit model characteristics were combined into factors using the factor analysis results, whereas in the EBA model one characteristic was used to represent all the characteristics included in the factor). Given these slight differences in model formulation and the marked similarity in the characteristics present in the final models it can be concluded that both models show the same characteristics influencing choice.

The second aspect of interest in Table IV is the overall fit of the models. It can be seen that the EBA model provided a better fit ($-2 \ln \lambda_T = 44.18$ and $\rho^2 = 0.45$) than did the logit model ($-2 \ln \lambda_T = 40.42$ and $\rho^2 = 0.41$). While these differences in overall fit are not very great, they do however suggest that the EBA model produced results which were at least as good as those produced by the logit model.

DATA LIMITATIONS AND IMPLICATIONS

The study outlined in this paper involves the application of a relatively new choice model to the location preferences of freight firms. Since the study is explanatory in nature, it is important to discuss some of the biases that may be present in the data so that these can be avoided in future. There appear to be two main areas of concern here.

One possible bias may result from the limitations put on a respondents' choice set. Each respondent was only asked to consider two locations. In reality, it is likely that a firm would consider several alternatives before making a final decision. If the two locations considered in this study are not representative of all these alternatives it is likely that there will be bias in the final model. One method of overcoming this problem is to incorporate a wider range of locations when collecting the data.

Secondly, it was pointed out earlier that there is a link between preference and the final decision which is not considered in this model. This link can be influenced by physical, social and institutional constraints or by the decision maker making a sub-optional location due to lack of knowledge of all the alternatives. More detailed knowledge of the processes linking preference and behaviour is required before the model can be applied with confidence.

Finally, before the models described in this paper can be made fully operational it is necessary that relationships between the measures of satisfaction used in this study and physical measures such as travel time and cost be developed. Some steps towards this goal have been described Young and Richardson (1978) and Young and Morris (1980)

CONCLUSIONS

Conclusions from this study fall into two areas, firstly, those related to the use of the EBA model in analysing freight facility location choice, and secondly those relating to the factors found to influence that choice.

Because of the relatively small sample size and the explanatory nature of the study, the results should be treated with caution. Nevertheless, the results are encouraging. With respect to the use of the EBA model in analysing freight facility location choice, the research showed that the EBA model not only provides a behaviourally acceptable theoretical foundation for this sort of analysis, but also that it provided a satisfactory fit to the data. Moreover, comparison between the EBA model and the commonly-used logit model showed that the EBA model provided a comparable (indeed slightly better) statistical fit.

It is concluded therefore that the EBA modelling approach is a suitable and potentially valuable method of analysing freight facility location choice.

With respect to the results of the analysis, the five factors found to be significant were not only reasonable, but consistent with those found using the logit model.

Closeness to arterial roads (which was correlated to closeness to freeways and closeness to country highways) reflects the importance of road access to freight facilities.

Closeness to existing customers is important, particularly for those firms with a small number of clients.

Closeness to labour is interesting because, although much of the labour used in the freight and distribution sector is relatively unskilled or semi-skilled, firms apparently consider the availability of suitable labour as an important factor in their location choice.

Cost of fleet operation, although not statistically correlated with proximity to roads or clients, nevertheless reflects much the same sort of considerations, namely the importance of a good location on minimising costs and maximising market advantage.

Finally, the site-availability of attribute referred to the availability of a suitable site in the area concerned. Many firms nominated as their alternative location an inner-suburban or near-central locality (reasons for this, in the Melbourne context, included proximity to rail yards for firms that serve these markets, accessibility to radial freeways and arterial roads, and the cost advantages of having trucks running in the counter-peak direction). Since few suitable sites exist, this attribute figured quite prominently as a governing factor in location choice.

Except for the site-availability characteristic, all of the remaining four characteristics are transport-related. This result is important in a transport planning context because is suggests that the planner can have some influence on the location of freight facility location decisions, and thus on the level of truck traffic on roads in various parts of the urban area. This influence operates by changing the transport system, and thus changing the perceptions of the transport system attribute in such a way that freight facility location choices may be affected.

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APPENDIX A : Significance Tests

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 the overall significance of the model. In particular, the generalised likelihood-ratio test (Hensher and Johnson, 1981) can be used to test whether the probability of an individual choosing location is independent of the values of the parameter estimates. In this study the hypothesis that all tolerances are very large (say ∞) is equivalent to the null hypothesis that the choice is independent of the values of the parameter estimates.

The generalised likelihood-ratio criterion is of the form:

$$\lambda = \max L(\omega)/\max L(\Omega) \qquad \text{(A-1)}$$

where λ = the likelihood ratio
$\max L(\omega)$ = the maximum of the likelihood function where M tolerances have been set to ∞.
$\max L(\Omega)$ = the unconstrained maximum of the likelihood function.

Wilks (1962) shows that $-2\ln\lambda$ is approximately distributed like chi-square with M degrees of freedom when the null hypothesis is true. Therefore if $-2\ln\lambda$ is greater than the critical value of χ^2_M (for a preselected significance level) then the null hypothesis, that all tolerances are equal to ∞, may be rejected and the model, as a whole, may be taken to be significant.

The natural logarithm of the unconstrained maximum likelihood may be written as $L^*(T)$ (i.e. the log of the likelihood evaluated with the best estimates of the tolerances) whilst the log of the constrained maximum likelihood may be written as $L^*(\infty)$ (i.e. the log of the likelihood where all tolerances have been set equal to ∞). $-2\ln\lambda$ for the total model (T) may therefore be re-expressed as

$$-2\ln\lambda_T = -2(L^*(\infty) - L^*(\hat{T})) \qquad \text{(A-2)}$$

The above test is not a particularly strong test. An alternative test of the overall model is the use of a pseudo-R^2. This measure is calculated as:

$$\rho^2 = 1 - (L^*(\hat{T})/L^*(\infty)) \qquad \text{(A-3)}$$

Since the unconstrained log-likelihood will always be greater than the constrained log-likelihood (both being negative numbers), the ratio $L^*(\hat{T})/L^*(\infty)$ will always be between 0 and 1. The smaller this ratio, the better the explanatory power of the model over the aggregate constant-share prediction model, and hence the larger the value of ρ^2. However, whilst ρ^2 can theoretically vary between 0 and 1, it has been noted by Hensher and Johnson (1981) that a value of ρ^2 between 0.2 and 0.4 is considered to be a good fit.

The role of each characteristic in explaining variance in the data may be considered by examining the tolerances associated with each of the characteristics. A method of testing the significance of a tolerance estimate is based on the likelihood-ratio test (described above, as a test of overall model goodness-of-fit). Thus if two models, of the same form, are built from one data set where the first model uses M parameters whilst the second uses M' parameters (such that M > M'), then the significance of the second model with respect to the first is given by the likelihood-ratio test where:

$$-2\ell n\lambda = -2(L^*(\hat{T})_{M'},\ L^*(\hat{T})_{M}) \qquad \text{(A-4)}$$

where $L^*(\hat{T})_{M'}$ = the log-likelihood of the second model with M'parameters

$L^*(\hat{T})_{M}$ = the log-likelihood of the first model with M parameters

As for the overall model likelihood test, $-2\ell n\lambda$ is distributed like χ^2 but with (M - M') degrees of freedom. If $-2\ell n\lambda$ is less than the critical value of χ^2 then it may be assumed that the two models are not significantly different from each other. That is, the omission of the (M - M') parameters has had no significant effect on the explanatory power of the model.

To use this test to ascertain the significance of individual chacteristics within a model [illegible]'s necessary to first construct the model with M parameters and calcul[illegible] $L^*(T)_M$. The characteristic in question is then omitted from the model (i.e. its tolerance is set equal to ∞) and the value of $L^*(T)_{M-1}$ is calculated. The value of $-2\ell n\lambda_k$ (the measure of the significance of a parameter associated with characteristic k) is then calculated and compared to the critical value of χ^2 with 1 degree of freedom. Using a 5% level of significance the critical value of χ^2 is 3.84. If $-2\ell n\lambda_k$ is less than 3.84, the tolerance of the characteristic in question can be assumed to have no significant influence on the model and can be removed from the models characteristic set.

REFERENCES

BROWN, H.P. (1977). "Attitudinal measures in models of mode choice", Proc. of 3rd Australian Transport Research Forum, Melbourne, pp.445-466.

BEARD, C.L. (1973). "The location of Manufacturing Industry in Melbourne" Master of Engineering Science Thesis, Monash University.

HENSHER, D.A. and JOHNSON, L.W. (1981). Applied discrete choice modelling. (Croom Helm, London).

McMILLAN, T.E. (1965). "Why manufacturers choose plant locations", Land Economics, Vol.41, No.3, 1965.

OGDEN, K.W. (1979). "Goods movement processes and policies". Proc. Freight Symposium, University of Newcastle-upon-Tyne, England.

RECKER, W.W. and GOLOB, T.F. (1976). "An attitudinal model choice model", Transportation Research, Vol.10, pp.299-310.

RIMMER, P.J. (1970). "Manufacturing in Melbourne". Department of Human Geography, Australian National University, Canberra, Publ. GC/2.

RITCHIE, S.G. and OGDEN, K.W. (1979). "Analysis and Appraisal of Freight Generation Characteristics: Part 1 - Data Report", Australian Road Research Board, Melbourne.

TARRANT, J.R. (1973). "The identification and interpretation of Principal components". Publication of Geography, Monash Univeristy, Melbourne.

TVERSKY, A. (1972). "Elimination by aspects: A theory of choice", Psychological Review, Vol.79, pp.281-299.

WATSON, P. (1975). Urban Goods Movement, Lexington Books, Lexington, M.A., 1975.

WEBER, A. (1929). Theory of Location of industry, (University of Chicago Press).

WIGAN, M.R. (1979). "Indicators of urban commodity movements". In Behavioural Travel Modelling, D.A. HENSHER and P.R. STOPHER, eds., (Croom Helm London)

WILKS, S.S. (1962). Mathematical statistics (John Wiley and Sons, Inc.: New York).

YOUNG, W. (1982). "The development of an Elimination-by-Aspects model of residential location choice" Ph.D. dissertation Monash University. Melbourne, Australia (unpublished).

YOUNG, W. (1983). "Factors affecting residential location choice". Proc. of 8th Australian Transport Research Forum, Canberra.

YOUNG, W. and MORRIS, J.M. (1980). "Perception and evaluation of the journey to work". Proc. of <u>6th Australian Transport Research Forum</u> pp.509-630.

YOUNG, W. and RICHARDSON, A.J. (1978). "Residential preference: A perceptual view of Melbourne" Proc of <u>4th Australian Transport Research Forum</u> pp.591-622.

YOUNG W., RICHARDSON, A.J., OGDEN, K.W. and RATTRAY, A. (1982). "Road and rail freight modal choice: The application of an Elimination-by-Aspects Model". <u>Transportation Research Record</u> 838 pp.38-44.

YOUNG W., RITCHIE, S.G., and OGDEN K.W. (1980). "Factor that influence freight facility location preference", <u>Transportation Research Record</u> 747, pp.71-77.