□ 論　文 □

貨物輸送手段 選擇模型의 理論 및 適用側面에서의 考察

Mode Choice Models for Freight Transport : a Review of Theoretical and Applied Aspects

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국 문 요 약

본 연구는 화물수송수단 선택 모형이론과 그 적용측면을 개괄적으로 살펴봄으로써 관련 현황수준(state of the art)에 대한 이해를 높이고, 발전방향을 모색함에 그 목적이 있다.

이러한 관점에서 먼저, 모형구성 정황(context)과 집단화(aggregation)를 포함한 화물수송수요 모형화의 몇가지 기본과제를 고찰한다. 이어서 집단모형과 비연속선택 개별모형으로 대별되는 모형이론과 그 세부적 구조(specification)를 설명하고 각 모형들의 중요성(significance)에 관하여 언급하며, 비연속선택모형의 추정과 관련된 기존의 투입자료형태 및 표본추출방법들에 대하여 문헌조사를 통하여 고찰함으로써 그 장단점과 중요성을 검증한다.

마지막으로, 이러한 논의 및 검토결과를 토대로 화물수송수요예측을 위한 앞으로의 연구방향을 제시하여 본다.

I. Introduction

Over the last two decades a significant progress has been made in the field of demand analysis(Williams, 1987) particularly in these areas: i) understanding the relationship between studies of individual and group behaviour (the aggregation); ii) the specification of models relating to behavioral hypothesis(behavioral specification); iii) and new methods, both in sample and preference analysis. Compared to the study of passenger demand analysis, the literature of freight demand discloses several distinct features. First, the consideration of freight demand analysis is relatively under-developed with respect to the above areas(Kullman, 1973; Roberts, 1977; Gray,, 1982; Ortuzar and Willumsen, 1990). Second, studies of freight demand have been very diverse with respect to their scope of analysis, aggregation level, model specification, and the form of data used.

This paper provides an overview of the theoretical and applied aspects of econometric modelling of freight modal choice with respect to the above areas and clarifies certain related issues. The consideration here is confined to econometric models used mainly for predicting choice probabilities of freight transport mode and other types of demand models for freight transport, such as spatial price equilibrium models and network equilibrium models, are not included(see Smith, 1974; Harker, 1985 for the review of such models). In previous surveys of freight transportation research, Winstion(1983) reviewed econometric freight demand models and Zlatoper and Astrian (1989) surveyed econometric studies of freight transportation demand exclusively. Unlike these studies, this paper emphasises some issues not included in these studies such as some issues pertaining to freight demand modelling and estimation of models. This will facilitate an improved application of the theory and models of freight mode choice.

The paper consists of four sections. Following the introduction, Section 2 describes basic issues pertaining to the modelling of freight transport demand including context of modelling and aggregation issues. Section 3 presents the specification of the aggregate mode choice models and discrete choice micro models together with the underlying theories. A brief evaluation of the models is also provided with respect to their strengths and weaknesses. In Section 4 a summary and suggestions for further research are provided.

II. Issues Relevant to Freight Mode Choice Analysis

1. Context of Modelling

One of the most notable aspects concerning the literature of the demand for freight transportation is the wide range of freight demand models that have been developed (Winstion, 1983); this is attributable to the variety of contexts to which freight demand models have been applied as well as to the theoretical framework adopted. For example, with respect to the analytical procedures used, models primarily concerned with the investigation of modal competition are quite different from those concerned with forecasting the demand for a particular freight mode. The requirements for both the forms of the model and the data to support it might well be significantly different according to the needs of the models.

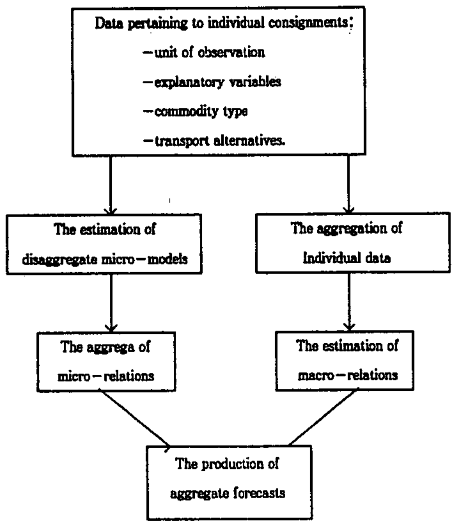
The context of model developments is various such as being "a projective, policy-testing, or plan-design context; short-term, medium-term, or long-term analyses; sketch planning or system evaluation; local or areawide studies; etc" (Williams, 1987). Each context appears to have a substantial bearing on the significance of different models. The purposes of modelling, such as forecasting freight traffic over time, policy analysis, and behavioral investigation at micro-level, are closely related to the degree of aggregation, specification of models and type of data desired. For instance, a macro-level model, based on one or two independent variables in a highly aggregate form, may be satisfactory for national studies but unacceptable for detailed policy analysis that requires important policy variables or micro-level analysis for which the determinants of demand themselves are required. Likewise, a micro model designed to analyse a particular commodity flow might be appropriate for certain types of study, but too detailed for large scale planning purposes. Other contexts, time and spatial dimensions, can be understood similarly.

Consequently, the context of a particular model development often dictates the specification of models, the form of data to be used, the degree of aggregation and so on. Therefore, any consideration on the relative significance of different model approaches needs to take place in the context of model developments.

2. Aggregate' and Disaggregate' Modelling Approaches

Broadly, modelling procedure is classified as aggregate and disaggregate approach (Figure 1) based on aggregating individual data either before of after model estimation. If data is aggregated prior to the estimation of the model we have the classical 'aggregate' approach, which observes the total, or average, demand for transport in an area such as a city, a state or the nation as a whole, and relates this aggregate demand to various explanatory variables, such as average freight rate in the area and average transit time. This approach involves aggregation of variables over space, over commodity type and over transport mode that can cause aggregation bias. In practice, this approach has been popular in freight mode choice analysis due to the practical needs for certain level of aggregation and the easy availability of data. Most real-world uses of models are related to the forecast of some aggregate demand which prefers data in aggregate form. In general such aggregate data are collected by a government agency on an annual basis. However, there has been continuous debate on the drawbacks of using such aggregation and aggregate data. That is, this approach is inefficient in the use of data and tends to obscure much of the information with respect

Figure 1 Aggregate and Disaggregate Modelling Procedure



to commodities and the supply characteristics of transport modes.

Another method is the 'disaggregate' approach which estimates models at the level of the individual consignments and then involves aggregating micro—relations. Theoretically, the disaggregate approach takes account of information pertaining to individual consignments. Thus, this approach is considered free from the aggregation problems noted above. In the context of behavioral mode choice analysis, this can more accurately represent the behavioral response of shippers to changes in fare and service characteristics and the degree of intermodal competition. In addition, this can make much more efficient use of the available data; fewer observations are needed for model estimations, resulting in substantial reductions in data collection and analysis costs. However such approach is subject to additional aggregation procedures (see Ben—Akiva and Lerman, 1989, for various methods of aggregation) for practical uses, and this is likely to introduce a certain amount of errors and loss of information.

The aggregation problem has been a long—time debate and the optimal level of aggregation is not an easy question to answer as there have been a few studies to compare such aggregate and disaggregate approaches. In practice, most application of disaggregate micro models has been to forecasting short—term effects (Daughety, 1979; Winston, 1981; Benabi, 1982; Prins and Schultheis, 1987), while that of aggregate models has been to long—term forecasting and equilibrium state. Thus the question of an appropriate level of aggregation and/or disaggregation, and the superiority of one over the other appears to depend heavily upon the context of the analysis and constraints upon it, such as data limitation, time and cost.

Ⅲ. Theory and Specification of Freight Modal Choice Models

This section examines several freight models which have been mainly used to analyse the mode choice decisions made by a shipper. For these models a shipper is assumed to make a choice of a particular freight mode for a given shipment based on the rate and level of service provided by carriers. These models can be classified in various ways, for instance, according to theories underpinning models, type of data employed, statistical techniques used, purpose of modelling and so on. Majority of previous studies have classified models broadly into aggregate and disaggregate ones. Such classification often seems to be ambiguous considering the complex nature of freight transport, and the terms are sometimes misused. Some studies use the term 'disaggregate' for their detailed commodity classification even though they rely on average measures for the unit of observation, explanatory variables and transport alternatives. In this light, Winston's (1983) classification of studies into aggregate and disaggregate based on the unit of observation, seems appropriate. Thus, in this section, the models are considered with respect to both aggregate specifications, including direct demand models(abstract mode model) and aggregate share models, and disaggregate specification which comprises discrete choice micro models.

1. Aggregate Demand and Share Forms

1) Abstract-Mode Models

The abstract mode technique describes a mode by its characteristics rather than a physical mode. The abstract mode formulation proposed by Quandt and Baumol(1966) is consistent with Lancaster's(1966) new approach to consumer theory, which recognises that people have demands not so much for a single product, but for different combinations of attributes or characteristics. This demand model consists of the freight generation, distribution and modal split elements. The former two components are a function of "push and pull" variables, such as population, mean incomes and industrial character indices of the origin and destination, and impedance variables, such as travel time by the least time mode, cost by the least cost mode and so on. The modal split element is a function of the number of competing modes on the link, travel time and cost of using the mode. Thus, the general formulation of this model is:

$$Vijm = f(X1, X2,\cdots, Xm,\cdots, Xn, Dij)$$

Vijm = volume between regions i and j by mode m

Dij = demand needed between regions i and j, as a function of socioeconomic conditions at origin and destination

Xm = transport service characteristics of mode m

n = number of modes

Recently, Soliman et al. (1991) used this approach for analysis of the reform of trucking regulations in Canada. The selected model included socio-economic characteristics to represent supply and demand at origin and destination respectively. They are the product of population and industrial index and the product of per capita income and market index. In addition, it included two modal service attributes-travel time and transport cost. Thus, the model combines the aspects of gravity and mode choice models.

The abstract mode approach to freight modal split analysis offers several advantages compared with conventional modal choice models(Gray, 1982). The description of a mode by its characteristics allows for examination of new transport modes by specifying a few of the important modal attributes. This modal selection process can evaluate the sensitivity of the modal split with respect to price and transit time. The approach is, however, subject to certain shortcomings. As revealed in the general formulation of this model, no commodity attribute is taken into account. Thus, it may be necessary to calibrate separated models for different commodity groups. Another is that it depends on the best mode for modal split, neglecting the effects of changes in an other competing mode. In addition, "…it can be debated whether the models are sound enough and whether the resulting elasticities, since they correspond to an average of the travel market, are sufficiently representative of any individual mode" (Orituzar and Willumsen, 1990, p. 174). Consequently, it appears that the abstract mode model can be very effective for certain macro-level spatial interaction and mode choice analyses, but, for relatively detailed mode choice analysis its significance becomes weak.

2) Aggregate Share Models

An alternative approach to a joint demand model is a basic modalsplit model which applied to spatially grouped data, and often referred to as an aggregate share model. This type of model does not attempt to determine the total flow by a particular mode but rather the proportion of total traffic carred by all modes which is carried by a particular mode (Bayliss, 1988). The classic aggregate share models are characterised as explaining and predicting modal split at the level of aggregated areas such as city zones, cities, region zones, etc. Thus, the variables used in the aggregate share models are averages over the spatial units or totals of the corresponding individual variables. This is a popularly used technique for predicting the conditional probabilities of choosing various modes, particularly, for early studies on modal split. Linear regression analysis and linear logit analysis are the major techniques for estimating the modechoice probabilities.

Although there have been various forms of aggregate share models developed, the most common aggregate model used for predicting choice probabilities of freight transport mode is of logit form(for another type of demand model named neoclassical economic aggregate models, see Oum, 1979; Freidlaender and Spady, 1981). The logit model may be expressed as follows and estimated by linear regression:

$$\log \frac{S_i}{S_j} = \beta_0 + \sum_K \beta_K (X_{iK} - X_{jK})$$

where, S_iS_j = the ratio of the share of mode i to the share of mode j,

$X_{iK}-X_{jK}$ = the difference of explanatory variables K, between the modes.

Many previous studies on freight modal split analysis such as those of Morton(1969), Kullman(1973), Boyer(1977) and Levin (1978) have adopted this approach because of the simple structure of the model and the easy availability of the data required. The former makes it easy to estimate the models. The latter is one of the great advantages of this approach as the cost of data collection is a very significant consideration in modelling. As noted previous this type of data is easily available (i.e. data collected by a government agency on a yearly basis). Another significant advantage of such models asserted by Anas (1981) is that predictions performed by these models do not require intermediate steps of aggregation, and any specification and aggregation bias introduced in the estimation phase is not compounded further. However, the use of aggregate data for model estimation is often criticised as noted in Section 2.

As discussed in previous section, the significance of aggregate models depends primarily on the context of analysis. For certain decisions of a wide ranging nature, aggregated models may be sufficient, the total volume transported being the determinant variable. For deatiled mode choice analysis, for example to study the effect of service quality and other supply side factors, and to quantify modifications in behaviour and the evaluation of changes in service quality, the models need some degree of disaggregation by region, sector, commodity type, transport mode and so on, since too global an approach hides the phenomena of substitutability and complementarity essential for a proper understanding of transport phenomena(ECMT, 1981). Practical limitations on budget, time and data availability should also be recognised in consideration of aggregate issue. Indeed, the literature discloses that the selection of an appropriate form of data for a particular study appears dependent upon heavily data availability as well as context of analysis.

2. Discrete Choice Micro Models

The most significant theoretical development in both passenger and freight modelling over the last 3 decades has been to formulation of models estimated with individual data which predict the probability that a particular mode will be selected. These are usually underpinned by economic theory of discrete choice in which the existence of discrete of qualitative alternatives generally presupposes a probabilistic behaviour, i.e. it is probabilistic behaviour which explains observations of different choices for the same set of independent variables (Bayliss, 1988). Within this category, models are distinguished according to the underlying theory of decision making process in which the alternatives are characterised by many attributes. The selection process involves different assumption of how these different attributes are combined in the decision process and two broad classes of models are usually defined such as compensatory and non-compensatory (Train, 1986). The description of models in this paper is confined to the former category which has been widely adopted and a special set of models, inventory based models, which have attempted to analyse freight demand from the perspective of an inventory manager, are also described.

1) The Logit Model and Economic Foundation

The extensive development and application of models of freight modal choices that have occurred over the last decade have been based primarily on random utility theories of choice. In this view the alternative is characterised by a set of attributes that contribute to an index of utility for the alternative. The attribute utilities are generally combined into a measure of total utility typically through the use of a linear additive function. This implies that the choice process is compensatory; that is, a high value of utility associated with one attribute can compensate for a low value of utility associated with another attribute.

The random utility for a shipper n of the ith alternative is expressed as the sum of two components, v_{in} and e_{in}. The former is a function of the observed characteristics and shared by all shippers, while the latter is a random component that accounts for the effects of unobserved characteristics and the amount of utility shared with no other shipper.

$U_i = V_{in} + e_{in}$

It is assumed that a shipper will select alternative i that yields the highest utility among a set of alternatives j, if:

$U_{in} > U_{jn}$, for all $j = 1, \cdots, N, j \neq i$

This completes the specification of how the decision maker behaves and is for any individual deterministic in nature; he chooses the althernative that provides the highest utility. From the analysis's point of view the probability that an individual, drawn from a population characterised by the same observable attributes, will select alternative i can now be written

$U(i \mid Cn) = \text{Prob}[(U_{in} > U_{jn}),\ \text{all } j \neq i,\ j \in Cn]$

which may be expressed as

$P(i \mid Cn) = \text{Prob}[(e_{jn} - e_{in} < V_{in} - V_{jn}),\ \text{all } j \neq i,\ j \in Cn]$

where, Pi=probability that alternative i will be chosen

Prob=denotes "probability"

Cn=Choice set for an individual decision maker n

The selection of different functional forms for the distribution of the random term e results in different functional specifications relating the probability of choice to the independent variables, for instance the logit and probit model.

In order to derive the logit model from the above equation, two assumptions must be made about the joint probability distribution of the full set of random variables (e_i, $i = 1 \cdots N$) (Ben-Akiva and Lerman, 1989).

Firstly, it is assumed that the terms are independent (uncorrelated) across the alternatives. Secondly, it is assumed that the e_{in} has a reciprocal exponential (Weibull) distribution. Accordingly, the choice probability of alternative i is only a function of the differences of observable components of the total utilities. The linear −in−attributes and/or linear in parameters utility function

$$V_i = \Sigma \beta_K X_{iK}$$

results in the standard linear logit form:

$$P_i = \frac{\exp V_i}{\sum_j \exp V_j}$$

Through different specification of the function, different choice models can be obtained within the random utility theory. Alternative distributional assumptions generate different probabilistic choice models − normal distribution generating probit models, while suitably selected distribution generated nested logit models(Ben−Akiva and Lerman, 1989).

These type of models has been popular because of its underpinned random utility theory and presupposed probabilistic behaviour of choices. The applicability of these type of models to a wide range of policy analysis also seems to be attributable to the popularity of such models. In practice, disaggregate models are considered more effective than aggregate models to explore the extent and nature of intermodal competition and the impact of changes in transport policies related to pricing and service variables. As described briefly in previous section, however, disaggregate models are subject to additional aggregation procedures and this diminishes somewhat of such advantages. Compared to passenger studies, there has been a relatively small number of disaggregate studies on freight mode choice (Hartwig and Linton, 1974; Daughety, 1979; Daughety and Inaba, 1981; Winston, 1981; Benabi, 1982; Prins and Schultheis, 1987) due to the limited availability on suitable data. Majority of such disaggregate studies however relied upon average measures for certain explanatory variables which implies the practical limitations on data availability.

2) Extending the Range of Choices

The most common application of the logit model has been to modal context in which typically two modes form choice set. Other combinations of choices are modal choice and production decision by the firm. These formulate inventory−theoretic models which attempt to analyse freight demand from the perspective of an inventory manager. The underlying notion of this model is consistent with the neoclassical theory of the firm, in that firms are assumed to maximise profits, or to choose a least−cast mode of transport for a given transportation requirement (Smith, 1974). The model was first proposed by Baumol and Vinod based on the assumption that a shipper minimises the total cost of transportation and inventory management (TRB, 1977). Some early studies, however, such as Meyer et al. (1959) and Harbeson (1969), implemented the inventory concept to analyse modal split with very simple cost function, in which they considered a few variables in order to take account of inventory costs, such as shipment size, average transit time and average commodity value. These studies, which were frequently termed a comparative cost approach (Boyer, 1977; Levin, 1978), were criticised for their simplified cost function. Since the work of Baumol and Vinod(1970), Roberts(1977), Whiteing(1982) and McFadden et al(1985) have developed this approach to a micro, disaggregate approach.

This approach attempts to integrate the mode choice and production decisions made by a firm, in which production–related variables, such as shipment size and frequency of shipments are treated as endogenous decisions along with mode choice(Winston, 1983). The rationale of the model is that "freight in transit can be considered to be, in effect, an inventory on wheels, a working capital inventory perfectly analogous with goods in process in a factory" (Bayliss, 1988). The model derives the shipper's trade–offs between freight rate and service attributes through the determination of shippers' indifference curves (iso–cost curve) (TRB, 1977). The formulation of the model varies, but generally, the probability of a transport user's choice of a particular mode is derived from the function incorporation total costs, consisting of purchase costs plus logistics costs as (Roberts, 1977):

Total Costs = purchase cost + order and handling cost + transport cost + capital carrying and storage cost + stockout cost.

The model formulated by Roberts (1977) assigns probabilities of mode choice to combinations of shipper alternatives such as origin, shipment size and mode which enables one to characterise the mode choice decision in the context of other activities relevant to the freight transport decision. The form of model chosen was a multinomial logit function as :

$$P^{K}(i, mq : ALTS) = \frac{e^{U(T,C,M,R)}}{\sum e^{U(T,C,M,R)}}$$

where P = the probability of choosing a particular combination of mode, shipment size and supply point

U(T.C.M.R) = the utility function of the receiver based on four groups of attributes

k = commodity index

i = origin point

mq = mode/shipment size combination

ALTS = alternatives available to the receiver

T = transport attributes

C = commodity attributes

M = market attributes

R = receiver attributes

The model equations are generally derived by simple linear–in–parameters functional forms and the underlying parameters can be estimated by maximum likelihood methods (Winston, 1983). The major task for developing such model is the specification and estimation of the utility function which involves combining the four groups of variables through the selection of appropriate parameters. The utility function here assumes that the structural relationship between the variables is specified in advance, i.e. it is not embedded in the co–efficients (Bayliss, 1988). Using a logistics costs formulation, the parameters take values that reflect the transport users' cost structures.

The inventory theoretic approach has been given a considerable attention because of its merits such as trade−off between time and cost, and the consideration of simultaneous choices (origin, shipment size and mode) (Winston, 1983; Zlatoper and Austrian, 1989). This approach however has some practical drawbacks. The major one is the data requirements to calibrate the model. Specifically, the necessary inventory date required by the model can cause severe constraint on the development and application of this model. Another drawback is the issue of aggregation of data, which is whether the shipping behaviour of an individual firm can be applicable to all firms that exhibit similar characteristics(TRB, 1977).

3) Estimation of the Models

(1) Alternative Sampling Methods

Generally, for the estimation of logit models and other probabilistic discrete−choice models, either a simple random sample of the population concerned or a stratified random sample is used. For the former, individual observations of the population have an equal chance of being sampled, and similarly, for the latter, each observation of a stratum has an equal probability of being sampled; the proportion of the total sample drawn from each stratum being determined by the analyst. These samples that are unstratified or stratified on population characteristics other than choice set are termed "exogenous" in which a sequence of decision makers are drawn and their choice behaviours observed. Such sampling has been most widely used and the sampling procedure and estimation methods are well established. The estimation of the parameters of models for these sample designs can be carried out easily; classical maximum likelihood yields consistent, asymptotically efficient parameter esimators.

In the 1980s the use of alternative sampling designs has been adopted for both reasons of efficiency and ease of data acquisition. In particular, a choice based sampling has been given increasing attention as the sampling process can often be cost effective. This sample is termed "endogenous" sample; the stratification of the population into subsets to be sampled being based on the choice of a particular freight transport mode. In this sampling method, a sequence of chosen alternatives is drawn and the characteristics of the decision makers selecting these alternatives are observed. In the freight context, the large majority have used a random smaple method and to our knowledge there have been two applications of the choice based approach (Winstion, 1981; McFadden et al. 1985).

Choice−based sampling,which is less widely used, is said to be an easier and cheaper sampling method than exogenous sampling for a model of transport mode choice, particularly where some alternatives are so infrequently used that exogenous sampling is unlikely to obtain an adequate number of observations for that mode(Cosslett, 1981). In addition, when consideration is confined to a particular freight transport segment, choice–based sampling can obtain observations directly relevant to the selected market more easily (it first draws concerned modes and observes shipper characteristics selecting these modes). Random sampling, in that case, may comprise a number of observations which are not relevant to the selected transport market as generally shippers are concerned with several different freight transport segments. Thus, to obtain an appropriate number of observations, a substantial sample size may be necessary.

Consequently, it would appear that a properly designed choice–based sample can often provide more precise estimates than can a random sample of the same total size resulting in a reduction of the size and cost of the sample. However , a choice–based sample is generally drawn from transport suppliers, and thus it usually provides poorer information on mode choice decision · making than does shipper–based survey data.

(2) Type of Data

The type of data has commonly been considered into two broad categories, revealed preference and stated preference (Hensher et al., 1988). The revealed preference method emphasises the observed behaviour of transport users (Hensher et al., 1988). The data is obtained by direct observation of mode choice decisions or obtained in surveys asking for actual mode choice behaviour. Through the comparison of the chosen althernatives and those which are rejected, the preferences of the transport users are disclosed, and by the use of appropriate statistical techniques (i.e. maximum likelihood method) the implicit utility functions of the decision makers can be inferred. The revealed preference methods are a most appropriate tool for deriving utilities and estimation models of mode choice(Kroes and Sheldon, 1988). Most previous studies of freight mode choice analysis have relied on this method. Against this popularity, certain limitations of the revealed preference method have emerged which restrict its general suitability. One of the most frequently cited limitations is that this method is impractical for the evaluation of mode choice under transport supply conditions which are not available in current experience (Fowkes and Tweddle, 1988).

This is against the drawback of the revealed preference method that the use of stated preference methods became an attractive option in transport research. Stated preference experiments present respondents with various hypothetical mode choice situations and seek their preferences in the form of either a preference ranking/rating or a choice selection. An added advantage of the stated preference approach is its usefulness in helping to decide which is the most appropriate functional form to model a given choice situation and this allows the use of other choice models such as nested logit(Ortuzar and Willumsen, 1990). Thus, this method allows researchers to study situations where revealed preference analysis would not be practicable. The approach is becoming quite popular for passenger demand analysis(see Kroes and Sheldon, 1988; Hensher et al., 1988; Preston, 1991 for recent reviews).

For the study of freight transport demand, the stated preference method was considered to be effective particularly because of its ability to use hypothetical data. For instance Fowkes and Tweddle(1988) utilized stated preference techniques instead of revealed preference techniques for several reasons. Firstly, the freight rates actually paid were for the most part confidential. Secondly, a limited number of firms would perceive themselves as facing realistic alternatives for their shipments. Thirdly, the consideration was to investigate the role of new technologies not yet in common use. Compared to passenger transport, however, there have been few studies on freight transport demand analysis which relied on the stated preference approach. The works of Ortuzar and Palma (1988) and of Fowkes, Nash and Tweddle (1992) are among the few which appear in the literature.

Against the advantages cited above, there are certain well known theoretical and practical disadvantages (Brandley et al., 1988). First is the difficulty in providing reasonable realistic hypothetical alternatives for the particular situation in question. Second is that people may not necessarily behave in the way they say. Third is the difficulty faced by a respondent in evaluating a set of alternative options by expressing his preferences properly on the measurement scale being used. The final disadvantage is that the use of stated preference method in forecasting is still in its infancy (Preston, 1991).

Each method has advantages and disadvantages, which is mostly situation specific. The stated preference method is said to be easier to control, more flexible and cheaper to apply (Kroes and Sheldon, 1988), while the revealed preference is matured in various applications. The significance of each method, however, appears to depend on context, i.e. the stated preference method is appropriate for estimating relative utility weights while the revealed preference method is more appropriate for absolute values.

Ⅳ. Summary and Directions for further research

This paper has reviewed theoretical and methodological aspects of freight mode choice modelling. The basic issues of freight demand modelling were considered including context of modelling and aggregation issue. The context of model development dictates the type of analytical technique, form of data to be used, estimation method and so on. Thus, any consideration on relative significance of model developments needs to take place in its particular context. The question of optimal aggregation and/or disaggregation was found dependent heavily upon the context of analysis and the constraints on the analysis, such as data limitation and time and cost constraints.

The models, which have been commonly used for freight mode choice analysis, have been reviewed with respect to their specification, underlying theory and their relative significance. This draws a finding that each model has its own merits and drawbacks in both theoretical and empirical contexts. The significance of each model, however, is not absolute, but is situation specific, i.e. the purpose of analysis, form of data to be used, the required accuracy of estimation results and so on. For detailed behvioral investigation, discrete choice models are always preferable, while for large scale mode choice analysis, direct demand models and aggregate share models are appropriate. Thus this aspect needs to be clarified in advance for any attempt at mode choice modelling.

As to the estimation aspect in utility function the relative advantages and disadvantages of alternative sampling methods were discussed. Revealed and stated preferences have been also discussed. The former is found to b e an appropriate tool for estimating utility function and estimating models of mode choice. Conversely, the latter is preferable for hypothetical mode choice situations and is instrumental in helping to decide the most appropriate functional form to model a given choice situation. Thus, they can be used in a complementary way.

The review of this paper suggests a number of directions for further research. Firstly, the choice of appropriate model specification needs to be paid much attention. Each model has its own advantages and disadvantages depending on contexts. Furthermore, the choice of model is likely to affect the empirical results, such as the forecast of future traffic volume's elasticity of demand with respect to price and service quality variables (Oum, 1989). Thus, it seems desirable to attempt to compare the significance of different models, especially aggregate and disaggregate models, for a particular context.

Secondly, the selection of appropriate sample designs would be worth of paying attention. it has been argued that the advantages of the choice based approach relate to the ease with which commodity choice data may be obtained. This is significant as the cost of data collection is a very significant consideration in sample design. Howerver, literature discloses that this must be paid for in two respects, firstly the limited range of variables(often used as proxies), which can be incorporated, and secondly it is necessary to use the averages of certain level of service variables(although this is usually the case in practical application of disaggregate models). To some extent the problems can be overcome with the random sample approach in which relevant decision makers are surveyed. A few studies have been undertaken to evaluate the significance of each approach. Thus, the relative advantages and disadvantages of each approach needs to be further considered, and further research needs to be conducted on such related topics : (i) a comparison of choice based vs random sample methods: and (ii) hybrid approaches in which different sampling methods are combined; that is random samples are enriched by a choice based sample, as in the case of some passenger demand applications.

Finally, improved understanding of behavioral response needs to be obtained. Majority of studies has utilised revealed preference techniques, The use of stated preference techniques, which have been utilised in a few freight studies, for further freight mode choice analysis, is desirabel because of their ability to use hypothetical data. They allow a number of detailed observations on the shipper choice decision-making process. This will accommodate the analysis of shipper responses, a thorough analysis of heterogeneity, as they provide sufficient observations of preference for each individual and a detailed analysis of functional form. In addition, this can evaluate new transport system to be introduced. Further research therefore needs to be carried out with respect to the adoption and comparison of revealed and stated preference approaches which are now common in passenger demand analyses.

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