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Mode choice modelling

A literature review on

the role of Quality of Service attributes

and

their monetary valuation

in freight demand models.

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Abstract - *This research paper was written in the framework of an OSTC*[1] *project entitled "Assessment of quality differences between freight transport modes". It was financed by the 'Sustainable production and consumption patterns SPSD 2' program, initiated by the Belgian State (contract CP/04/362). Therefore the Quality of Service (Q-o-S) aspects will be granted much attention in the present study. The review will start from an introduction to the frequently used demand models in freight transport. It is our intention to elaborate and further develop the idea of admitting Quality of Service attributes in these models. After presenting currently used demand-models, the identification of the determining attributes in the mode choice and the methods to compute their monetary valuation are the main subjects of the study..*[2]

1. Introduction

Mode choice modelling is probably the most important element of transportation planning as it affects the general efficiency of travel and the allocation of resources (Ortuzar and Willumsen, 1995, p. 187). That is why various methodologies have been explored to define the determinants of freight transport demand, which resulted in a very extensive literature. The main goal of all the articles and research papers devoted to this subject is to gather insight in the choice process of decision makers[3]. This knowledge helps to evaluate and predict the impact of certain measures on the modal split.

In earlier studies (60's - 70's) product characteristics, freight rates and distance for a transport performance were mostly used to explain the choice of a mode. Later on, Quality of Service (Q-o-S), if represented in the model, was roughly estimated by the mean and variance of time in transit. As from the 80's – see Winston (1983) and Zlatoper & Austrian (1989) – authors stressed the importance of Q-o-S in transport as a determining factor in mode choice. A review of recent literature confirms this trend of a growing importance of Q-o-S in freight demand. Especially for shippers of highly valued goods, the monetary value of the Q-o-S can be more important than the transport cost in the narrow sense when deciding over modes.

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[1] OSTC : Federal Office for Scientific, Technical and Cultural Affairs in Belgium

[2] We would like to thank Professors G. Blauwens, H. Meersman, E. Van de Voorde and F. Witlox for their highly valued input.

[3] Instead of referring to shippers, receivers and senders of goods, we will use the term 'decision maker'. In the logistic chain, others than the shipper can determine the way of transporting goods.

Therefore one might prefer the presence of additional quality attributes in mode choice models alongside the more traditional parameters cost, time and distance. After all, these variables are said to lead the behaviour of the decision-makers in the choice process.

The paper at hand is organised in two parts. The introduction is followed by a first part that gives an overview of the models currently used in freight transport demand. It focuses on the different types of data sets these models use and on various methodologies applied in this field of research. Volume demand models and preference- or market share models are given most attention.

The second part is concerned with the identification and the valuation of influential Q-o-S attributes. A monetary valuation facilitates to determine the attributes important in the choice of mode. Various methodologies that were developed for this purpose are examined and compared. It will turn out to be important to compute an annual value for all attributes in order to attain a footing for comparison. Many methodologies focus on a valuation with a different unit for each attribute rather than a uniform measure for comparison. We finalise with some remarks on this matter and point to some avenues for further research.

2. Overview of demand models

An overview of the different models is necessary if we want to analyse the role of Q-o-S attributes. In the following paragraphs two concepts are explained which permits to identify the models. These are *the data sets used* and the *applied methodologies* or *functional forms*.

2.1 The data sets used

A. The level of aggregation

When developing a model, one first determines the level of aggregation for the data that will be used. By making this choice one has to realize that different types of data and demand models will lead to different types of output or empirical results (elasticities) of the models (Oum, 1989, p. 163). In general, disaggregate data can be represented by a pool of individual observations, each of them valued on a certain number of variables. Aggregate data consists of sums or volumes which on their turn are characterised by certain variables.

In freight transport, disaggregate data is limited to information on individual shipments (Zlatoper en Austrian, 1989, p. 28). Models based on disaggregate data are more of a behavioural kind and satisfy the need of evaluating particular policies or plans (Shmueli, 1998, p. 145). These kind of models offer more easiliy the possibility to add additional variables such as elements on Q-o-S – e.g. delivery time, reliability and frequency of service.

The high level of detail that characterizes disaggregate data will lead to an increasing degree of accuracy. The downside is that also the costs of data collection and analysis will be considerable (Ortúzar and Willumsen, 1995, p. 20). Moreover, Meersman (1998) points out that disaggregate data often are of a confidential nature and therefore hard to obtain. In addition, to construct time series on a company level data can be insufficient due to a lack of quality in gathering the information or the limited period of time that can be studied.

If one applies a disaggregate approach while developing a demand model, the study focuses on the company level. The decision maker has to choose one mode out of several alternatives (discrete choice). The outcome of these models tries to estimate the mode choice.

Aggregate data in transport studies consists of goods flows at the regional or national level. So rather than using absolute values which is the case for disaggregate data, aggregate data are more likely to made up of average values. As a result, company specific elements remain hidden and therefore a certain misrepresentation may occur. This is the major drawback of an aggregate analysis. Hence, it is generally accepted that estimates of important effects – such as market elasticities – out of models based on disaggregate data are more reliable (Winston, 1983, p. 421; Fischer, 1993, p. 10).

Nevertheless, the use of aggregate data is more appropriate if the object of the study focuses on political decision-making and policy-supporting predictions (Winston, 1983, p. 421; Oum, 1989, p.163; Ortúzar & Willumsen, 1995, p. 21). The goal of this kind of studies is not to measure the reaction of one specific decision maker when certain changes occur, it is to analyse how complete flows will react to these alterations. In such cases, the resulting estimates are to be interpret as directional rather than to value the estimates on their magnitude.

For freight transport studies on an aggregate level, the aim can be to allocate the total amount of goods to be transported over the different modes. In this framework the term modal split is appropriate.

It seems hard to pronounce an overall preference for either an aggregate or disaggregate approach. It is the practitioner's hard task to choose the most appropriate method (Ortúzar & Willumsen, 1995, p. 22). This choice depends on the goal of the study and the cost and availability of the data (Oum, 1989, p. 163). It is important to remark that the researcher's choice is not limited to use either disaggregate or aggregate data. The level of aggregation can gradually be adjusted over a continuous spectrum.

B. Revealed versus Stated Preference data

Subject to the availability of the data one needs to decide whether to opt for revealed or stated preferences. Revealed Preference (RP) data enables researchers to employ true observed behaviour into their studies. However, it seems difficult to observe or measure concepts such as Q-o-S. It is difficult to judge on non-existing elements as for example the construction of a new infrastructure. In addition, it is hard and costly to obtain the necessary variation in the collected data. RP data is used when one wants to grasp a more general impression of a certain situation.

A Stated Preference (SP) analysis bypasses the sensitivity of the necessary information because the technique makes use of hypothetical situations. Nevertheless, one needs to take into account possible discrepancies in what decision makers pretend to do and what they will do (Blauwens, 2002, p. 377; Fischer, 1993; Ortúzar & Willumsen, 1995).

Most of the research work done on the subject of mode choice modelling that incorporates Q-o-S attributes is based on Stated Preference data – see Maggi & Bolis (1999), Lobé (2000), Jovicic (1997 & 1998) and Bergkvist (2000). This is because the ultimate goal of modelling freight transport demand, is revealing the decision process that leads to the observed modal split. When using SP data the researcher can analyse the behavioural patterns of the transport/logistics decision maker for various hypothetical situations, in other words; choices are being made in a hypothetical market (Danielis, 1999, p. 2).

Some additional remarks on the use of SP and RP are in their place here. SP data offers a considerable freedom with respect to the formulation of hypothetical situations. A major benefit to the use of RP data is that it concerns actual decision-taking and therefore it is more realistic in nature. Relative to this, we state that when using SP data, the possibility and even the danger present itself of entering consciously some 'bias' in the answers in the advantage of the respondent (Blauwens, 2002, p. 377).

When discussing valuations of Q-o-S attributes it will become clear that the use of combined SP-RP data is a helpful option as well. This combination of data sources, also called *data enrichment*, can be motivated by different reasons but has implications for modelling choice behaviour. Amongst other views, the 'data enrichment paradigm' states that "*RP data are viewed as the standard of comparison, and SP data are seen as useful only to the extent that they ameliorate certain undesirable characteristics of RP data*" (Louvière J. J., D.A. Hensher & J.D. Swait, 2000, p. 227-231).

2.2 The methodology applied

The goal of modelling is to disclose, analyse and predict the behaviour of decision-makers so that possible future developments can be foreseen using the results and estimates of the model. When making transport decisions one needs to take into account many different variables. Furthermore, many of these variables are interrelated so that very complex issues can present themselves. That is why efficient models are developed which are able to estimate the input/output relationship while providing insight into the decision-making process (Sayed & Razavi, 2000, p. 23).

Roughly three groups of methodologies can be distinguished. A first group of functional forms tries to model the demand for freight transport by calculating the number of tons or tonkms (volumes) that will be transported by the different modes, given the values for some explanatory variables. These are known as the volume demand models.

Preference models or market share models constitute a second group of methodologies. This approach models the *choice* or *market shares* for the available transport modes. The functional form is based on the utility maximising choice process of the decision maker. This methodology is of a behavioural kind.

A last group of models is represented under the common name of Artificial Intelligence models or more specifically Artificial Neural Networks (ANNs). This technique is developed to handle a multiplicity of interrelated variables and its estimation process of the relation between in- and output variables takes place naturally (Shmueli, 1998, p. 146). The use of ANN's is a fairly new approach in this field and due to the lack of substantial material this methodology will not be discussed any further. All these models link explanatory variables to a variable that in a certain way expresses the choice of mode.

A. Volume demand models

The *linear* demand model consists of a set of linear specifications relating the variables to the volumes transported by each mode. Here the elasticity of demand depends on the value of the independent variables. This means that when using this form, one assumes that the elasticities are not constant.

$Y_1 = \alpha + \beta X_1 + \delta X_2 + \gamma X_3 + \varepsilon$ Y_1 = demand for road transport

X_i = independent variables

$e_{y1} = (d\, Y_1 / d\, X_1). (X_1 / Y_1)$ elasticity depends of the value for the variables

The *log-linear* demand model plots the *logarithms* of transport volumes as linear specifications of the *logarithms* of independent variables such as prices and Q-o-S attributes. Regression methodologies (OLS, GLS, SURE or Likelihood) are used to estimate the variables' coefficients. For the log-linear model these estimated coefficients are the ordinary Marshallian demand elasticities for each variable. These are constant over time. The data and the researcher's insight should indicate which of both foregoing forms is most appropriate (Oum, 1989, p. 174-179).

if $Y_1 = e^{\alpha} X_1^{\beta} e^{\varepsilon}$ Y_1 = demand for road transport

then $\ln Y_1 = \alpha + \beta \ln X_1 + \varepsilon$ X_1 = independent variable

$\Rightarrow$ $d \ln Y_1 / d \ln X_1 = \beta = \text{constant}$

we know that $d \ln Y_1 / d \ln X_1 = d\, Y_1 / d\, X_1 \,.\, X_1 / Y_1$

$\Rightarrow$ $e_{y1} = d\, Y_1 / d\, X_1 \,.\, X_1 / Y_1 = \beta = \text{constant}$

The *translog* demand model[4] uses a different approach. The short term demand functions for the various transport modes are deduced from a cost function. To present this model, we will start from the following problem definition; after production goods need to be transported from shipper to recipient and the decision maker has to make a choice between available modes. It shows how transportation can be seen as a production factor next to labour and capital. To attain a certain output a combination of production factors (input) will be preferred that minimizes costs. The modes considered here are road, inland navigation and rail. The generalised cost of the transport operation C in our example is a function of quantities (tkm) and prices per tkm. This can be extended with hedonic characteristics.

Output	Input	Price	
x	x_1	p_1	Quantity transported by road at p_1
	x_2	p_2	Quantity transported by rail at p_2
	x_3	p_3	Quantity transported by inland navigation at p_3

$$C = \sum_{i=1}^{3} p_i x_i$$

$$Min_{x_1, x_2, x_3} \sum_{i=1}^{3} p_i x_i$$

$$constr.: f(x_1, x_2, x_3) = x$$

The cost minimising combination of transport modes can be found by using an underlying cost function deduced from a production function. Here we use the non-homothetic[5] translog cost function:

$$\ln C = \ln \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{j=1}^{3} \gamma_{ij} \ln p_i \ln p_j + \alpha_x \ln x + \frac{1}{2} \gamma_{xx} (\ln x)^2 + \sum_{i=1}^{3} \gamma_{ix} \ln p_i \ln x$$

[4] The presentation of the translog demand model is based on Friedlaender & Spady (1980), Hamermesh (1993), Oum (1989), Berndt (1991), Varian (1992) and Meersman & Van de Voorde (1997).

where :

$$
\begin{aligned}
\ln C = {} & \ln \alpha_0 + \alpha_1 \ln p_1 + \alpha_2 \ln p_2 + \alpha_3 \ln p_3 + \frac{1}{2}\gamma_{11}(\ln p_1)^2 + \frac{1}{2}\gamma_{12} \ln p_1 \ln p_2 \\
& + \frac{1}{2}\gamma_{13} \ln p_1 \ln p_3 + \frac{1}{2}\gamma_{21} \ln p_2 \ln p_1 + \frac{1}{2}\gamma_{22}(\ln p_2)^2 + \frac{1}{2}\gamma_{23} \ln p_2 \ln p_3 \\
& + \frac{1}{2}\gamma_{31} \ln p_3 \ln p_1 + \frac{1}{2}\gamma_{32} \ln p_3 \ln p_2 + \frac{1}{2}\gamma_{33}(\ln p_3)^2 + \alpha_x \ln x + \frac{1}{2}\gamma_{xx}(\ln x)^2 \\
& + \gamma_{1x} \ln p_1 \ln x + \gamma_{2x} \ln p_2 \ln x + \gamma_{3x} \ln p_3 \ln x
\end{aligned} \tag{1}
$$

With following symmetry constraints:

$\gamma_{12} = \gamma_{21}$; $\gamma_{13} = \gamma_{31}$; $\gamma_{23} = \gamma_{32}$ (2)

Supposing that this cost function is homogeneous (of degree 1) in prices, than simultaneously it needs to hold that (conditions of homogeneity):

$\alpha_1 + \alpha_2 + \alpha_3 = 1$

$\gamma_{11} + \gamma_{21} + \gamma_{31} = 0$

$\gamma_{12} + \gamma_{22} + \gamma_{32} = 0$

$\gamma_{13} + \gamma_{23} + \gamma_{33} = 0$

$\gamma_{1x} + \gamma_{2x} + \gamma_{3x} = 0$ (3)

As in Berndt (1991, p. 469), we can extend this function by admitting some additional restrictions, concerning homotheticity of the cost function ($\gamma_{1x} = \gamma_{2x} = \gamma_{3x} = 0$), homogeneity of the cost function in the output ($\gamma_{1x} = \gamma_{2x} = \gamma_{3x} = 0$ and $\gamma_{xx} = 0$) and constant economies of scale of the production function ($\gamma_{1x} = \gamma_{2x} = \gamma_{3x} = 0$ and $\gamma_{xx} = 0$ en $\alpha_x = 1$).

If we take into account the constraints on symmetry expressed in (2) than equation (1) looks like this:

[5] Homotheticity: if $x_1,x_2,x_3 \sim x \Rightarrow \alpha x_1,\alpha x_2,\alpha x_3 \sim \alpha x$ for all $\alpha >= 0$

$$
\begin{aligned}
\ln C = {} & \ln \alpha_0 + \alpha_1 \ln p_1 + \alpha_2 \ln p_2 + \alpha_3 \ln p_3 + \frac{1}{2}\gamma_{11}(\ln p_1)^2 + \frac{1}{2}\gamma_{22}(\ln p_2)^2 \\
& + \frac{1}{2}\gamma_{33}(\ln p_3)^2 + \gamma_{12} \ln p_1 \ln p_2 + \gamma_{13} \ln p_1 \ln p_3 + \gamma_{23} \ln p_2 \ln p_3 \qquad (4) \\
& + \alpha_x \ln x + \frac{1}{2}\gamma_{xx}(\ln x)^2 + \gamma_{1x} \ln p_1 \ln x + \gamma_{2x} \ln p_2 \ln x + \gamma_{3x} \ln p_3 \ln x
\end{aligned}
$$

Starting from the hypotheses of constant economies of scale with regard to the production function, the result is an expression based on average costs:

$$
\begin{aligned}
\ln C - \ln x = {} & \ln \frac{C}{x} = \ln average\cos t = \ln \alpha_0 + \alpha_1 \ln p_1 + \alpha_2 \ln p_2 + \alpha_3 \ln p_3 \\
& + \frac{1}{2}\gamma_{11}(\ln p_1)^2 + \frac{1}{2}\gamma_{22}(\ln p_2)^2 + \frac{1}{2}\gamma_{33}(\ln p_3)^2 + \gamma_{12} \ln p_1 \ln p_2 + \gamma_{13} \ln p_1 \ln p_3 \qquad (5) \\
& + \gamma_{23} \ln p_2 \ln p_3
\end{aligned}
$$

Using Sheppard's lemma[6], we can compute share equations. These equations indicate the share of costs for using a particular mode:

$$
\begin{aligned}
& \frac{\partial \ln C}{\partial \ln p_1} \approx \frac{\partial C}{\partial p_1}\frac{p_1}{C} = \frac{x_1 p_1}{C} = \frac{\text{cost to use road}}{\text{total cost}} = S_1 \\
& \frac{\partial \ln C}{\partial \ln p_2} \approx \frac{\partial C}{\partial p_2}\frac{p_2}{C} = \frac{x_2 p_2}{C} = \frac{\text{cost to use rail}}{\text{total cost}} = S_2 \qquad (6) \\
& \frac{\partial \ln C}{\partial \ln p_3} \approx \frac{\partial C}{\partial p_3}\frac{p_3}{C} = \frac{x_3 p_3}{C} = \frac{\text{cost to use inland navigation}}{\text{total cost}} = S_3
\end{aligned}
$$

Based on the translog cost function (1) elasticities can be computed. Both substitution- and price-elasticities can be deduced. The so called 'Allen partial substitution-elasticities' of demand for mode i are (see Berndt, 1991, p. 475; Hamermesh, 1993, p. 24):

[6] Sheppard's lemma states that $dC/dp_i=x_i$ (see Varian, 1992, p. 74), where x_i indicates the cost minimising input to attain output x.

$$\sigma_{ij} = \frac{\partial \ln \frac{x_i}{x_j}}{\partial \ln \frac{p_j}{p_i}} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j} \qquad i, j = 1,2,3 \quad i \neq j \qquad (7)$$

When this expression results in a positive value, than modes i and j are substitutes. Inputs i and j are complements when the expression leads to a negative value.

Price-elasticities of demand for mode i are (see Berndt, 1991, p. 475):

$$\varepsilon_{ij} = \frac{\partial \ln x_i}{\partial \ln p_j} \approx \frac{\partial x_i}{\partial p_j}\frac{p_j}{x_i} = S_j \sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i} \qquad i, j = 1,2,3 \quad i \neq j$$

$$\varepsilon_{ii} = \frac{\partial \ln x_i}{\partial \ln p_i} \approx \frac{\partial x_i}{\partial p_i}\frac{p_i}{x_i} = S_i \sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i} \qquad i = 1,2,3 \qquad (8)$$

As mentioned above, the translog cost function (1) can be extended with hedonic characteristics. These features capture the Q-o-S aspects for transport performances. Elements such as distance and delivery time (proxy for speed), variation in delivery time (proxy for reliability) and frequency can be admitted in the model this way.

D_1 = covered distance on the roads to transport x_1
D_2 = covered distance on rail to transport x_2
D_3 = covered distance on waterways to transport x_3
T_1 = time on the roads to transport x_1
T_2 = time on rail to transport x_2
T_3 = time on waterways to transport x_3
V_1 = measure for variation in delivery time when transporting x_1 on the roads
V_2 = measure for variation in delivery time when transporting x_2 on rail
V_3 = measure for variation in delivery time when transporting x_3 on waterways

So the translog model turns into:

$$
\begin{aligned}
\ln C &= \ln \alpha_0 + \alpha_1 \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} + \alpha_2 \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} + \alpha_3 \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} \\
&+ \frac{1}{2}\gamma_{11}\left(\ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1}\right)^2 + \frac{1}{2}\gamma_{12} \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} \\
&+ \frac{1}{2}\gamma_{13} \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} + \frac{1}{2}\gamma_{21} \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} \\
&+ \frac{1}{2}\gamma_{22}\left(\ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2}\right)^2 + \frac{1}{2}\gamma_{23} \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} \\
&+ \frac{1}{2}\gamma_{31} \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} + \frac{1}{2}\gamma_{32} \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} \\
&+ \frac{1}{2}\gamma_{33}\left(\ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3}\right)^2 + \alpha_x \ln x + \frac{1}{2}\gamma_{xx}(\ln x)^2 + \gamma_{1x} \ln p_1 D_1^{\beta_1} T_1^{\chi_1} V_1^{\delta_1} \ln x \\
&+ \gamma_{2x} \ln p_2 D_2^{\beta_2} T_2^{\chi_2} V_2^{\delta_2} \ln x + \gamma_{3x} \ln p_3 D_3^{\beta_3} T_3^{\chi_3} V_3^{\delta_3} \ln x
\end{aligned}
$$

Regarding the use of the translog model, it needs to be clear that this model only holds when the imposed hypotheses are met (as it is the case for all types of models). The first assumption states that the companies minimise their costs. In addition, this hypothesis is connected to the possible use of Sheppard's lemma. If Sheppard's lemma does not hold, the computation of the share equations does not make any sense. Therefore, it is important to test the estimated values for the shares and the different values for the modes against real figures.

The evaluation for each model has a theoretical and practical scope. A model can theoretically be a brilliant model, but could be impossible to estimate because of a lack of data.

The linear demand models and the log-linear demand models are relatively easy to estimate in comparison with the translog demand model.

We must take into consideration that every model is a representation (simplification) of reality. In the choice of the model to be used, there will be a trade off between time and cost to develop the model.

B. Preference models or market share models

Preference models, or discrete choice models[7], such as logit and probit are probably the most widely used methodologies for mapping the mode choice process (Sayed & Razavi, 2000, p. 23; Abdelwahab & Sayed, 1998, p. 268; Nijkamp et al., 1999, p. 3; Bergkvist, 2001, p. 2).

The decision maker presumably bases his choice on the characteristics of the offered transport services, i.e. amongst others the price of the service and various Q-o-S attributes. Because an individual is not fully informed when making its decision and due to measurement errors, a random error-component is introduced into the model (Fowkes, et al., 1998, p. 717).

The random utility theory is the framework for generating discrete choice models. A certain number of decision makers n = 1,…,N needs to choose among a set of mutual exclusive alternative modes I (i = 1,…,I). The theory postulates that for decision maker n, mode i has an associated net utility u_{in}. For freight transport this level of utility can be seen as the level of profit or decrease in costs this option represents for the decision maker. However, to express the level of utility only in monetary values would not be sufficient. Q-o-S attributes such as reliability and frequency will influence the associated utility of an alternative as well.

Utility u_{in} consists of two components: v_{in} and ε_{in} so that $u_{in} = v_{in} + \varepsilon_{in}$. v_{in} is the deterministic utility of individual n choosing mode i and represented by a number of explanatory variables. The second component ε_{in} is the part that grasps the individual opinion and valuation of decision maker n for mode i. For instance, Q-o-S can be more important for one decision maker than for another. The value for this component is determined by the individual characteristics of the company and, therefore, differs for all decision makers. This part is stochastic (variations are due to coincidence) and indicated as non-observable.

[7] The discussion on the logit-model and Random Utility Theory is based on Domencich and McFadden (1975), Oum (1979), Winston (1982 and (1985), Börsch-Supan (1986), Bayliss (1988), Gujarati (1988), Judge et al. (1988), Ortúzar and Willumsen (1995), Blauwens, De Baere and Van de Voorde (1996), Meersman and Van de Voorde (1997), Abdelwahab and Sayed (1999), Sayed and Razavi (2000). In addition we refer to Maddala (1977), Ben-Akiva and Lerman (1985), Train (1986) and Witlox (1994).

The foregoing leads to the following utility function:

$u_{in} = \alpha_i + \beta x_{1in} + \delta x_{2in} + \gamma x_{3in} + \ldots + \varepsilon_{in} \quad \Rightarrow \quad u_{in} = v_{in} + \varepsilon_{in}$ (9)

The utility function needs to be transformed into a probability in order to predict the behaviour of an individual decision maker. To achieve this we assume that the stochastic components are independent and identically distributed (IID) with regard to the decision makers and thus specifying an identical distribution function $F(\varepsilon_1, \varepsilon_2, ..., \varepsilon_I)$ for all decision makers. Option i will be preferred rather than option j if

$$u_{in} > u_{jn} \qquad (10)$$

The probability that decision maker n prefers option i out of all alternative options is given by

$$\begin{aligned} &\Pr (u_{in} = \text{Max} (u_{1n}, \ldots, u_{In})) \\ &= \Pr (v_{in} + \varepsilon_{in} = \text{Max} (v_{1n} + \varepsilon_{1n}, \ldots, v_{In} + \varepsilon_{In})) \qquad (11) \\ &= \Pr (v_{in} + \varepsilon_{in} > v_{jn} + \varepsilon_{jn} ;\ \forall j \neq i) \\ &= \Pr (\varepsilon_{jn} < v_{in} - v_{jn} + \varepsilon_{in} ;\ \forall j \neq i) \\ &= \int_{\varepsilon_{in}=-\infty}^{+\infty} \int_{\varepsilon_{jn} < v_{in} - v_{jn} + \varepsilon_{in} ;\forall j \neq i} dF(\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_I) \end{aligned}$$

Expression (11) points out that the probability of choosing option i depends on the distribution function of the stochastic term.

If one starts out from a multivariate standard normal distribution, the outcome is a multinomial probit model (MNP). The result of expression (11) is a multinomial logit model (MNL) when the stochastic term follows a Weibull distribution. This distribution is widely used in reliability and life data analysis due to its versatility. Depending on the values of the parameters, the Weibull distribution can be used to model a variety of life behaviours. If only two options are available, the probability of choosing alternative one (Pr_1) in the multinomial logit model is given by:

$$\Pr_1 = \frac{1}{1 + e^{(v_2 - v_1)}}$$

$$\Rightarrow \frac{\Pr_1}{\Pr_2} = \frac{\Pr_1}{1-\Pr_1} = \frac{1}{e^{(v_2-v_1)}}$$

$$\Leftrightarrow \ln(\frac{\Pr_1}{\Pr_2}) = \ln 1 - \ln\left[e^{(v_2-v_1)}\right]$$

$$= v_1 - v_2 \tag{12}$$

If more than two options are available, the probability of choosing alternative i is the following:

$$\Pr_i = \frac{e^{(v_i)}}{\sum_{j=1}^{I} e^{v_j}}$$

$$\Rightarrow \frac{\Pr_i}{\Pr_k} = \frac{e^{v_i}}{e^{v_k}}$$

$$\Rightarrow \ln(\frac{\Pr_i}{\Pr_k}) = v_i - v_k$$

$$\Rightarrow e^{v_i - v_k} = \frac{\Pr_i}{\Pr_k}$$

$$\Rightarrow \Pr_i = e^{v_i - v_k}.\Pr_k \tag{13}$$

This expression is independent of a third alternative. This property is known as the ‘independent of irrelevant alternatives’ (IIA) axiom. It shows once again the connection between the probability for choosing an option and its associated utility.

When the utility associated to alternative i is larger than the one associated to alternative k ($v_i - v_k > 0$) option i will be preferred over option k ($\Pr_i > \Pr_k$).
On a disaggregate level, the decision maker has a discrete choice to opt or not to opt for a transport mode. As a consequence, the logit model would lead to expressions such as $\Pr_i$ / $\Pr_k$ (= 1/0 or 0/1) and it is not possible to calculate the logarithm for these

values. Therefore, the estimation of this model is not possible for a disaggregate analysis (Gujarati, 1988). This issue could be resolved by working with values very close to 1 or 0 (e.g. 0.00000000001 or 0.99999999999).

For choice models based on aggregate data, the probabilities often are estimated by market shares for each of the modes. In general, for all i ≠ k and k being the base mode:

$$\ln \frac{S_i}{S_k} = a_{i0} + a_{i1} x_{i1} + \sum_{j=2}^{K} a_{ij} x_{ij} \qquad (14)$$

and **S_i, S_k** = market shares for respectively mode i and mode k

x_{i1} = price for mode i relative to the price for mode k

x_{ij} = other exogenous attributes which can be of an influence when choosing a particular mode (j=1, 2,…, K).

a_{i0}, a_{i1},…, a_{iK} = coefficients for the logit equation

The price variable can be represented in different ways (Oum, 1979). Each of these representations results in a different type of logit model. A first possibility is to express the relative price as a ratio, so that $x_{i1} = P_i / P_k$ (P_i and P_k are the price levels for mode i and k respectively). This leads to the *price ratio model*. An alternative is to use differences. Here the admission of $x_{i1} = P_i - P_k$ will result in the *price difference model*. Meersman and Van de Voorde (1997) added a third form by representing the relative price variable as $x_{i1} = \ln P_i - \ln P_k$.

The use of logit models to predict the evolution of market shares for the different transport modes seems to be very attractive. However, when using this model one encounters some major drawbacks concerning elasticities (cross- and substitution elasticities). Oum (1979) showed that for both the price ratio model and the difference model there exists two different measures for the substitution-elasticity between not-base modes (*≠k*). This is also the case for the third form using the logs of the price-levels. In addition, for the price ratio model the substitution- and price-elasticities are dependent on the choice of the base mode *k*. In spite of these drawbacks concerning elasticities, the logit models do allow to measure the sensitivity with regard to the relative position of two transport modes for changes in one of the explanatory variables.

The nested-logit model

Due to the limitations associated with the multinomial logit model (axiom of IIA, very strict assumptions on the distribution of the stochastic term - IID) researchers have been looking for extensions to the MNL model. The nested-logit[8] model is the most popular variant and shows how to handle the violation of the IIA property. This can be reached through relaxing the IID assumption for subsets of alternatives (Louvière J. J., D.A. Hensher & J.D. Swait, 2000, p. 65). By developing new models such as the nested logit model, practitioners try to make their instruments lean more towards human decision behaviour. However, these elaborations are being made at the expense of additional computational complexity.

It is not difficult to comprehend that the axiom of IIA is likely to be violated in the mode choice decision process. Some alternatives will share common unobserved components among one another opposed to alternatives of a different type. That is why the structure of the nested logit model is characterised by grouping subsets of alternatives into nests or hierarchies (Louvière J. J., D.A. Hensher & J.D. Swait, 2000, p. 138; Ortúzar & Willumsen, 1995, p. 218). For instance, in freight transport, a decision maker needs to choose among four alternatives road, rail, inland navigation and short sea shipping.

In this case one can assume that the two latter options are correlated opposed to road and rail when deciding over mode choice. Inland navigation and short sea shipping will be put into one nest. The utility levels associated to these two modes will inevitably be characterised more or less by an additional and specific set of variables other than the general attributes such as cost.
These specific variables are not important when determining the utility associated with road or rail performances. As a consequence, the residuals for the utility levels associated with short sea shipping and inland navigation will not always be independent.

[8] Also known as the Hierarchical- or Tree-logit model

The foregoing indicates that the nested logit model will try to partially overcome the assumption of independent random residuals associated with the MNL model. In the MNL model it was stated that for decision maker n the utility associated to mode i was given by:

$$u_{in} = v_{in} + \varepsilon_{in}$$

η_{water}

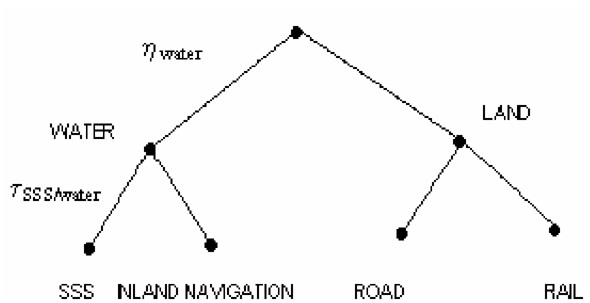
To illustrate[9] the nested logit model we defined that the choice set I is divided into exclusive groups I_1, I_2,…, I_k,… where mode i belongs to group I_k and therefore its associated utility is expressed as follows:

$$u_{in} = v_{in} + \varepsilon_{in} = v_{in} + \eta_k + \tau_{in/k} \forall in \in I_k \forall k$$
$$with$$
$$E[\varepsilon_{in}] = E[\eta_k] = E[\tau_{in/k}] = 0$$
$$\text{cov}[\eta_k, \eta_h] = \text{cov}[\eta_k, \tau_{in/k}] = \text{cov}\left[\tau_{in/k}, \tau_{jn/k}\right] = 0$$

(15)

We see that the residual or stochastic term ε_{in} can be divided into the sum of two random variables. η_k is the term that belongs to the group of alternatives k. It is the same for all its elements and represents the variables that influence choice specific to alternatives belonging to group k. $\tau_{in/k}$ is specific to this alternative i for decision maker n. All terms are independent and have an expected value equal to zero.

The decision process in freight transport can be illustrated by using the following tree:



[9] The illustration of the nested logit model is based on Cascetta (2001) and Ortúzar & Willumsen (1995)

Here decision maker n first chooses the nest that groups transport over waterways and then opts to send its goods by short sea shipping. The probability that decision maker n adopts the short sea shipping alternative is given by the following expression (where $Pr_{SSS/water}$ is the probability of choosing short sea shipping out of the group of transport over waterways):

$$\Pr_{SSS} = \Pr_{SSS/water} . \Pr_{water} \tag{16}$$

After a brief introduction to the nested logit model (NL) it seems that this model offers a solution for the violation of the IIA property. The NL model does so because it takes into account that the choice for some alternatives can be correlated amongst each other. The model divides the set of alternatives so these can share common unobserved components among one another compared with alternatives belonging to other nests. Like a tree and its branches, where the leaves represent the alternatives.

The MNL model does not take these components into account so it is subject to potential violations of the IDD assumption associated with the random components of the different alternatives. As a result, the MNL model could lead to the wrong conclusions (Louvière J. J., D.A. Hensher & J.D. Swait, 2000, p. 138 & 144).

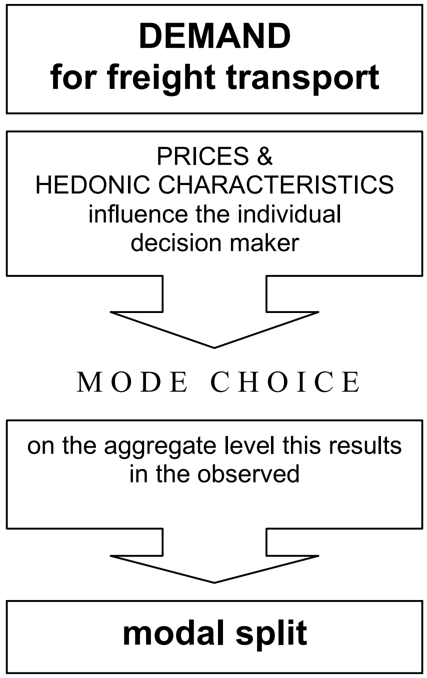
Therefore, Louvière et al. (2000) state that researchers will continue to estimate and implement models based on the MNL paradigm but expect that an increasing number of modelling developers will progress to the use of NL models, moreover because of an emergence of software that is readily available and able to deal with this data-processing technique (Louvière J. J., D.A. Hensher & J.D. Swait, 2000, p. 182).

3. Importance of Quality of Service attributes in demand modelling

When modelling the mode choice in freight transport it is important to identify all the influential determinants that can play a role in the decision process. Mostly due to the difficulty of obtaining relevant data, some of the earlier demand models concentrate - only - on cost elements, transport time and product characteristics. Some authors try to distillate the mode choice out of a limited number of cost variables - see Jeffs (1985), Friedlaender & Spady (1980) and Oum (1979). However, along the line of the evolving transport system other parameters can play a significant role in the decision process as well. For a certain number of goods the freight transportation system is increasingly characterised by smaller and more frequent shipments with an outspoken preference for flexibility, reliability and availability. Therefore the limited number of variables such as lot size, transport costs and delivery times are no longer sufficient to determine the modal split (Pauwels, 1998b, p. 27). Moreover Jeffs and Hills state that maybe cost is not a very important determinant of mode choice after all (Jeffs and Hills, 1990, p. 32).

This is why some of the articles on the subject of mode choice focus on the identification of other determining factors - see Cullinane & Toy (2000), Matear & Gray (1993), Jeffs & Hills (1992) and McGinnis (1989). The majority of these articles is based upon surveys performed with decision makers to uncover which and how different attributes of the modes affect the mode choice. The result of these surveys is a ranking of all-possible determinants according to their importance in and influence on the decision process. These *alternative* characteristics of transport services are of a qualitative - behavioural nature and categorised under the common name *hedonic characteristics*.

Figure 4: Concept



The concept is explained in Figure 4. The demand for freight transport leads to a mode choice problem for the individual decision makers. The prices and hedonic characteristics of the different modes such as reliability, frequency of service, availability and flexibility influence the way demand is assigned to the modes. On the aggregate level this behaviour results in the observed modal split.

Surveys where respondents need to rate or rank characteristics is the most obvious and elementary manner to identify influential attributes. These give rise to an overall list of rankings. A more powerful tool is to compute estimates for monetary **valuations** and elasticities concerning these hedonic attributes. This permits a more substantiated comparison. In addition, attention is paid to the qualitative differences between modes and how these differences play a role in the decision process – see Maggi & Bolis (1999), Jovicic (1997 & 1998) and Abdelwahab (1998).

Through identifying the variables that affect the mode choice, it may be possible to instigate a modal shift towards modes with an inferior generalised cost and integrate these modes in the European Transport Networks. After all, when transport companies are informed of the factors important in the choice of service, one can offer what decision makers want and in this way attract more freight (Matear and Gray, 1993, p. 25).

Moreover, Inrets (2000) indicates that quality is a very important factor of competition in freight transport and 'non-quality' can be perceived as a type of cost. Next to the price, the quality attributes offer an additional possibility to make a mode more attractive. If we can match the attributes of intermodal transport to the expectations of decision makers concerning Q-o-S it may be possible to achieve the necessary shift towards a more responsible situation.

Price- and transit time elasticities (Abdelwahab, 1998, p. 261) and other elasticities concerning Q-o-S (Maggi & Bolis, 2001, p. 12) were found to be higher for rail than for truck – see Table 1. This means that the relative market share for rail transport is more sensitive to changes in modal attributes than the one for trucking. This might be due to the fact that road transport is perceived to be qualitatively superior to rail and combined transport. Because users of trucking services are satisfied on the level of Q-o-S, qualitative improvements can have a weaker impact on the road market share than similar improvements on rail or combined transport services (Maggi, R. and S. Bolis, 2001, p. 12).

These findings indicate that elasticities are not constant but dependent on the market shares achieved by each mode.

Table 1: Transport Mode Elasticities

	Road	**Rail**	**Combined**
Cost	-0.48	-0.68	-0.59
Time	-0.19	-0.27	-0.24
Reliability (% of transport services in a year arriving on time)	0.52	0.75	0.65
Flexibility (notice time for transport order in hours)	0.02	0.03	0.02
Frequency (number of guaranteed shipments per month)	0.05	0.07	0.06

Source: Maggi, R. and S. Bolis, 2001, p. 12

However, the market share for road transport is quite robust because of a history of problems concerning Q-o-S for rail freight. Even if combined transport was able to compete with road in terms of Q-o-S attributes such as delivery times, reliability and flexibility, it would be necessary to offer an additional discount over the price as incentive to make use of rail transport (National Economic Research Agency (*n/e/r/a*), 1997, p. 18). This allows concluding that another possible explanation could be the (wrong) perception of the quality offered by rail and inland navigation.

On the one hand, the targeted modal shift seems to be difficult to attain because of the established market share for road transport. However, due to the many possible improvements that can still be made concerning Q-o-S to the rail and combined transport networks, a certain transfer must be feasible.

3.1 Identification of the relevant Q-o-S variables

Q-o-S is not a single variable, but rather a set of elements (Jeffs & Hills, 1989, p. 45). It is a set of elements that next to price or cost, influences the mode choice of individual decision makers. The identification of this category of variables could be done by a number of surveys which reveal the criteria in the optimisation process of the decision makers. For the purpose of illustration some of the surveys are discussed below[10].

Because in previously published articles the models rely too heavily on the economic cost factor, the survey by Jeffs and Hills (1990) attempts to clarify the actual parameters which should be included in modal split models. To gather the data set, about a hundred transport decision-makers were interviewed (interviews were undertaken between October 1982 and August 1983). They all belonged to firms categorised under one industrial domain; the paper, printing and publishing sector. The object of the interviews was to assess the respondent's perceptions on the importance of certain attributes.

The survey by Matear and Gray (1993) was conducted to determine the factors that have an impact on the choice of decision makers for freight services between Great Britain and Ireland. The modes considered are short-sea, air and sea transport. Out of 500 surveys sent, a total of 132 useful replies were received from the sample (survey conducted in the period April – May 1990). Respondents were asked to rate a list of service attributes on a one to five scale according to the importance the service attributes played in their choice of service. In addition to this ranking based upon the mean scores a Principal Components Analysis was used to group service attributes.

The report *Potential for rail freight* by n/e/r/a (1997) examines the potential for rail freight in Great Britain. It tries to pinpoint the determinants of rail freight demand so the Rail Regulator (commissioner of the report) can promote the future development

[10] Quality requirements are not the same for shippers as for transportation companies. That is why in some of the surveys a distinction is made between these two segments – see Matear & Gray (1993) and Jovicic (1997). We preferred to concentrate on the point of view of shippers – i.e. production- and trading companies.

of rail freight. A brief literature review in the appendix of the document refers to a couple of studies on mode choice behaviour.

Based on Revealed Preference data gathered for Danish international long-distance goods transport, Jovicic (1998) computed a ranking of eight pre-chosen quality parameters. The main goal was to observe how important the chosen parameters are for transport buyers (producers of goods and trading companies).

The research work done by INRETS (2000) was funded by the European Commission and the aim of the project was to assess and improve the quality of current intermodal transport for the final user – shippers, consignees and intermediaries (Inrets, 2000, p. 13). To attain this goal nearly 200 interviews were carried out with customers or potential customers of intermodal transport in the European Union and Switzerland. One of the results presented in the paper were the decisive factors in the mode choice between intermodal and road transport (based upon the number of respondents).

A content analysis provides a useful preparation for a future Stated Preference experiment as it identifies and justifies the attributes to be used (Cullinane and Toy, 2000, p. 41). A first analysis was done by McGinnis (1989) and reviewed the period from the seventies to the eighties.
The object of the study was to investigate the *relative importance of cost and service in freight transportation choice*. Cullinane & Toy (2000) published the second one. In combination a total of over 80 route/mode choice related articles were analysed. A total of 18 Q-o-S attribute categories could be identified as being used in the mode choice process.

In Table 2 we mention the most influential attributes in mode choice behaviour per article based on the specific research question that was put forward. Where possible we used the terminology of the content analysis by Cullinane ant Toy (2000).

Table 2: Most influential attributes

Authors	Type of respondents	Research question	Ranking of attributes
McGinnis (1989)	All kinds (U.S.)	Variables that were found to affect freight transportation choice	Cost/Price/Rate Transit time reliability Speed Loss/Damage Shipper market considerations
Jeffs and Hills (1990)	Transport decision-makers within the paper, printing and publishing sector (U.K.)	To assess the respondent's perceptions on the importance of certain attributes	Customer service level Transit time reliability Flexibility Loss/Damage Speed
Matear and Gray (1993)	Irish companies which send and/or receive goods to or from Great Britain and the other way round (U.K. & Ireland)	To determine the Q-o-S attributes important in the choice of freight transport service	Flexibility Loss/Damage Transit time reliability Cost/Price/Rate Good relationship with carrier
Jovicic (1996)	Transport buyers for all types of commodities (Denmark)	To rank the eight quality parameters in order of importance based on the respondent's perception	Transit time reliability Speed Cost/Price/Rate Customer service level Flexibility
n/e/r/a (1997)	Shippers concentrating on unitised freight collected through more than 1000 telephone surveys (Europe)	Ranking of factors (excluding cost) affecting unitised freight mode choice	Reliability Speed Flexibility Controllability/Traceability Environment
Inrets (2000)	Customers or potential customers of intermodal transport in the EU and Switzerland	Decisive factors in the mode choice between road and intermodal transport	Cost/Price/Rate Flexibility Best matching logistic structure Speed Transit time reliability

Source: Inrets, 2000, p. 25; n/e/r/a, 1997, p. 90, Jovicic, 1996, p. 4; McGinnis, 1989, p. 40-42; Matear & Gray, 1992, p. 28; VEV, 1999, p. 32; Cullinane and Toy, 2000, p. 46-51 and Jeffs & Hills, 1990, p. 39

The attributes 'Transit time reliability', 'Speed' (or transit time), 'Flexibility' and 'Loss/Damage' are found to be most influential next to the Cost, Price or Rate for the considered transport service. The attribute Cost/Price/Rate occurs in four out of five rankings where cost was not excluded.

In Table 2 we see which attributes were indicated as influential in the choice process for different types of decision makers. The attributes that appear in the rankings are more or less the same for all surveys, although their places in those rankings are somewhat different. This means that different types of decision makers choose modes based on the same quality criteria, but that the order in which these criteria are applied is different for other types of decision makers. Product characteristics and location can explain this distinction.

We can conclude that next to an economic cost factor, other variables are important when modelling the mode choice process. Especially elements such as 'Transit time reliability', 'Speed' (or transit time), 'Flexibility' and 'Loss/Damage' seem important. These additional variables can exert a great influence on a decision maker’s choice process.

3.2 Models and Monetary Valuation

The role of Q-o-S attributes in mode choice modelling is like that of any other variable in a quantitative analysis: independent variables are admitted in the specification to determine the value of an unknown element; in this case Q-o-S variables are admitted to define the probability of choosing a certain transportmode.

A next step is to attach to these variables a monetary valuation so one can understand their relative importance when decision makers make certain choices over modes.

A. Modelling

The methodology commonly employed in this field of study is to invite respondents to play a Stated Preference game using a software package[11]. - see Maggi & Bolis (1999), Jovicic (1997 & 1998), Bergkvist (2001) and Fridstrom and Madslien (1994). During this game, respondents are asked to rate a number of hypothetical transport performances. These ratings represent a certain level of utility[12] and are transformed into probabilities. A logistic regression relating the computed probabilities to the attribute values[13] admitted in the transport performances, results in estimates for the coefficients. Once these estimates are calculated the monetary values for the Q-o-S attributes can be computed.

B. Valuation of Quality of Service

Typically the monetary valuation of the Q-o-S attributes is calculated by dividing their estimated coefficients by the estimated coefficient of the cost variable using the outcome of the model (Fowkes & Shinghal, 2001, p. 6; n/e/r/a, 1997, p. 92-93; Jovicic, 1998, p. 6; Jovicic, 1997, p. 6; Maggi & Bolis, 1999, p. 29).

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[11] E.g. LASP (Fowkes & Tweddle, 1988), MINT and TRIO (e.g. Fridstrom & Madslien, 1994, 1995). Research by Danielis and Rotaris (1999) points out that LASP is mostly used when gathering SP data for transportation research (Danielis & Rotaris, 1999, p. 5).

[12] See Random Utility Theory in part 2.B

[13] In some form, e.g. in Maggi & Bolis (1999) the differences in attribute values are related to the probabilities

1. *A separate valuation for each attribute*

An interpretation for the coefficients that were estimated based on the SP experiments can be given using the log odds ratio $Log\frac{P_B}{P_A}$. In this context, the ratio represents the logarithm of the probability of choosing alternative B over the probability of choosing alternative A. It is determined by the values for all variables characterising both alternatives A and B.

$$Log\frac{P_B}{P_A} = \alpha + \beta_1\left(Cost_B - Cost_A\right) + \beta_2(Time_B - Time_A) + \ldots^{14} \qquad \text{(a)}$$

In expression (a) coefficient β_1 for instance represents the magnitude with which the log odds ratio will change when the difference in cost between alternative A and B equals EUR -1 (or any other currency that is used).

The methodology is illustrated by using the data of Jovicic (1997), listed in Table 3. It is important to remark that only in-mode alternatives were used. For instance, alternatives A and B displayed in expression (a) are both performed by the same mode, e.g. road. In that way, one computes coefficients and valuations for each mode separately. First some variables used by Jovicic (1997) are explained below.

Flexibility : Dummy variable
0 = one can not change previously agreed transport
1 = shipments weight and delivery time can always change

Damage : *per thousand* units of the shipment that goes to waste due to/during transport activities

Delay : *per centage* of transport performances that arrive later than the agreed point of time

Info. System : Dummy variable
0 = only information about the shipment at the destination
1 = information about the shipment at all times

[14] Based on Bolis, S. & R. Maggi, 1999, p. 23

Table 3: Valuation of Q-o-S attributes

Q-o-S Variable	**Flexibility**	**Time** (hours)	**Cost** (Dkr)	**Damage**	**Delay**[15]	**Info. System**	**Frequency** # dep. per week
Coefficients							
Road	0.4497	-0.06489	-0.00063	-0.061	-0.3280	0.5645	n.a.
Rail	1.274	-0.0444	-0.1796e-2	-1.080	-0.1199	2.240	0.6411
Sea	0.2018	-0.802e-2	-0.533e-3	-0.911	-0.222	0.7184	0.2469
Valuations							
Road	712.23	103	1	96.825	519.48	894.04	n.a.
Rail	709.35	24.70	1	601.34	66.76	1247.22	356.96
(in Dkr) *Sea*	n.s.	15.04	1	1708.7	416.76	1346.83	462.88

Source: Jovicic, 1996, p. 5-7

Here the log odds ratio will decrease by 0.00063 if the cost of the transport performance by road increases by DKR 1. The ratio will decrease by 0.06489 if the time for this transport increases by one hour.

Dividing the coefficients for the other variables by the coefficient for the cost variable results in the values listed in Table 3 under ‘Valuations’. These numbers need to be understood in the way that to a change in the log odds ratio of 0.00063, one can link the monetary value of DKR 1. This relationship can be used to know the valuations for the remaining attributes by dividing their coefficients by the coefficient of cost. The correct interpretation for e.g. the value of 66,76 in Table 3 is that on average shippers are willing to pay 66.76 Dkr to reduce the number of delays by 1%.

[15] Proxi variabele voor Q-o-S variabele ‘Reliability’

2. *A uniform valuation*

Although the valuation method expounded above expresses all attributes in monetary terms, it uses a different unit for each of them ('Time' is in DKR *per hour*, 'Reliability is in DKR *per % of delay* etc.). Therefore it is not easy to rank the variables. A uniform valuation does allow such a general ranking.

In order to do this, Jovicic (1996) proposes to combine the SP data with RP figures concerning transport performances. By making use of the average values for selected variables and collecting data on the number of annual shipments it is possible to express the value of the attributes in a sole monetary unit. By means of example, the following calculation combines the data out of Table 3 with RP data on the annual number of shipments and averages for the modal attributes for a certain railway company listed in Table 4.

Table 4: Averages for the modal attributes and the weekly number of shipments

Mode attributes	Averages	Weekly number of shipments
Transport Time	61.73 hours	100
Transport Cost	9129.11 Dkr	
Risk of Damage	9.31 ‰	
Risk of Delay	4.27 %	

Source: Jovicic, 1996, p. 7

The annual value of transport time (AVTT), the annual value of reliability (AVR) and the annual value of damage claims (AVD) are calculated as follows:

AVTT = 24.70 Dkr/hour/sh. x 61.73h x 100 sh./week x 52 weeks
= 7.928.601 Dkr
AVR = 66.76 Dkr/%late x 4.27 %late x 100sh./week x 52 weeks
= 1.482.339 Dkr
AVD = 601.34 Dkr/‰ dam. x 9.31 ‰ dam. x 100sh./week x 52 weeks
= 29.112.072 Dkr

After calculating and adding up all annual values, the figures can be expressed in a percentage valuation. For the company concerned, this gives an idea how the Q-o-S attributes can be valued. In this study transport costs were most important in the total sum of values representing 46.83 %. Risk of damage was second with 28.72 % and transport time third, its value representing 7.82 % of the total value.

3. *Attribute values as a percentage discount of the freight rate*

Another useful tool to compare the values attached to different attributes is to express these values in terms of a percentage discount of the freight rate. As it was the case for the first methodology applied by Jovicic, this tool does not provide for a uniform valuation but a separate one for each attribute (because it still uses separate units per attribute). However, this methodology enables us to express the valuation for the attributes relative to a common footing i.e. the freight rate.

This approach was first introduced by Fowkes & Tweddle (1988) and more recently used in a literature review issued by the National Economic Research Associates (1997). These studies focus on rail transport and investigate a possible modal shift form road to rail. SP data was collected for different market segments (bulk freight - unitised - RoRo) and afterwards used as input for a model. As a result they obtained estimates for the coefficients for cost and other attributes.

As in Jovicic (1996) the next step was to divide these coefficients by the coefficient for cost, but in this set of studies, the obtained valuations for each attribute were then expressed as a percentage of the freight rate. For numerical evidence see the values listed in Table 5.

Table 5: Results of SP studies in the UK: The valuation of Q-o-S attributes in terms of a percentage discount of the freight rate

Attribute	MVA (1992) Petrol	Fowkes (1989) Oil Products	Fowkes (1989) Consumer durables	MVA (1991) Accompanied Ro-Ro	Tweddle (1995-1996) Lo-Lo users
Reliability (% on time deliveries)	0.7	1	3	3.6	3.3
Flexibility (number of days to give notice)	4.5				
Intermodality (switch to rail)	12	14	9	6.1	1.3
Transport Time (in 1/2 days)		10	14	11.3	2.3

Source: n/e/r/a, 1997, p. 85-100

To interpret these figures, the percentages can be read as a discount or a premium on top of the current freight rate. For the attribute reliability in the MVA (1992) Petrol study, the number of 0.7 means that on average, the firms are willing to pay 0.7% on top of the current rate for 1% more on time deliveries. We would like to remark that these numbers need to be read with care. The interpretation for *Intermodality* is different than for the other variables; for the attributes reliability, flexibility and transport time a higher number means a higher positive valuation of the variable. For intermodality the interpretation is the other way round. I.e. a high number for this variable means that decision makers demand an important reduction in transport cost to make use of an intermodal system, valuating this characteristic relatively low.

C. Remarks on the valuation methodologies

In the previous paragraph we identified the determinants of freight mode choice out of a number of surveys. Here we tried to substantiate these findings with numerical evidence out of the same and other additional studies. To achieve this goal a monetary valuation can be computed for the various Q-o-S attributes. However, it is important to remark that a valuation itself expressed in different units does not permit to compare and eventually rank the attributes in order of importance in the decision process. This is why we focused on two sets of studies – Jovicic (1996 & 1998) and a couple of UK studies (MVA 1991 & 1992; Fowkes 1989, 1991 & 1992; Tweddle, 1995 & 1996) – that elaborated some alternative methods which facilitate such a comparison. In Jovicic (1996) the methodology was to calculate annual values for all attributes and to express these numbers in a percentage of total annual cost.

The UK studies used another approach to facilitate the ranking of attributes in the decision process. After calculating the coefficient estimates and attaching a monetary valuation to the attributes, these numbers were expressed as percentages of the freight rate. This permits a comparison between Q-o-S attributes relative to a common footing; the freight rate. An important remark is that the results of the studies differ for various market segments. For example, intermodality is valued high for Lo-Lo users (they are willing to pay a premium to make use of intermodality), relatively low for Bulk transports and low for Accompanied Unitised freight (Fowkes – 1989, MVA/ITS – 1990, MVA – 1991 & 1992).

The importance of the attributes reliability, cost/price/rate, speed/time and damage/loss & safety was demonstrated in the previous paragraph. These findings can be confirmed by the monetary valuations examined in this part of the review.

4. Concluding remarks

In the first part we reviewed some of the models currently used in freight transport modelling. The models discussed were the translog-model, the multinomial logit (MNL) model and the nested logit (NL) model. The translog model departs from the cost minimizing character of firms. The different modes are seen as input whereas the output is defined by the total quantity of goods that needs to be transported. The advantage of the translog-model is the flexible functional form, to which in a simple way a number of restrictions can be added. In this way, the translog-function can be extended with hedonic characteristics.

The MNL model starts from a ‘random utility’-model, where the choice for a certain transport mode represents a certain level of utility. The axiom, ‘independent of irrelevant alternatives’ stands for both the strength as the weakness of the model. In addition, the parameters are heavily dependent on the choice of the base mode. The NL model seems to be preferable with respect to the MNL model because it takes into account the common unobserved components for the alternatives belonging to the same nest. The translog model as well as the logit models can be applied to aggregate and disaggregate data.

The second part was concerned with the identification and valuation of the most important Quality of Service attributes while assessing transport performances. Based on a couple of surveys that reviewed different market segments, the identification of influential factors while choosing a mode could be determined. Next to the cost of transport, attributes such as 'Transit time reliability', 'Speed' (or transit time), 'Flexibility' and 'Loss/Damage' are considered to be most important.

To confirm these results we reviewed a couple of methods that try to compute a monetary valuation for the different attributes. A distinction was made between methodologies that present a separate valuation for each attribute and others which present results expressed only in monetary terms. For the latter SP data need to be combined with RP data.

With regard to what we found in the second part of this research paper, we conclude that when modelling the choice of mode, it is necessary to admit some attributes representing the Quality of the Service in the demand models we discussed in part one. This effort will help to explain the choice of mode by individual decision makers, their behaviour resulting in the observed modal split. When policy makers are aware of the impact that certain measures can have on this choice behaviour, adjustments can be made towards a more promising and responsible transport environment.

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