The value of time and forecasting of flows in freight transportation.[*]

By

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Abstract

This paper concern cost benefit analysis for road infrastructure investments. It will present our findings in this area as well as it will present the current state of research. It investigates the impact of VOT for road freight when the origins of transports are taken into account and for owned and hired transports. Also distance is considered. VOT is found to be dependent on combinations of region, transported distance, ownership conditions and industry branch. However, available data does not allow for significant values in each category. Altogether the study indicates a VOT spanning from 0 to 732 SEK, which should be compared with the average value of 80 SEK used today. We further investigate the performance of estimation methods. The traditional logit model is compared with the semi-parametric weighted average density (WAD) estimator. It is found that the performance for the WAD estimator in terms of bias and mean square error is similar to the logit ML estimator for spherical errors in a latent variable specification. Dedicated methods for prediction of road freight flows as well as a integrated VOT/flow models are investigated. Three traditional gravity model specifications (OLS, NLS, and Poisson regression) are compared with a neural network specification. It is found that the Poisson model performs best in terms of root mean square error (RMSE) but also that the size of predicted flows is dependent on the method chosen to evaluate available estimation methods. The integrated models are logit models and neural networks with linear and non-linear profit functions are compared. The study indicates that the average VOT may decrease when prediction improves as models are given more non-linear specifications.

Keywords: Freight transportation, Value of time, Regional valuation, Logit model, Weighted average density estimator, Gravity model, Neural network, Cost-benefit analysis.

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1. Introduction

The paper presented here concerns the valuation of quality aspects for freight transports such as, e.g., faster and more reliable transports as well as the forecast of road freight flows. It will present our findings in this area as well as it will present an overview of the current state of research. A first conclusion is that quite little has been done in this field compared to the same issues in passenger transportation where the number of scientific papers and overviews are substantially larger. A finding especially surprising since these values are of great importance in cost benefit analysis (CBA) made for infrastructure appraisal. In order to restore a more balanced state of the art, this paper deals with the following three topics in the CBA of infrastructure investments for freight transportation:

- The estimation of values, such as the value of time and the value of delays, that shipping companies connect with attributes of road freight transportation

- The forecast of aggregated road freight flows between origin and destination nodes in a transport network

- The modelling of transport choices within a transport network

The aim is to bring together these three topics and to make some further comments on CBA and freight modelling. The structure is as follows. Section two presents a general discussion on the use of CBA for infrastructure appraisal, setting this work into a wider framework. The current state of research together with our findings for each of the above topics will then be presented together with a discussion of how this fit into the CBA tradition.

2. CBA in infrastructure appraisal

The topic in this section is to give an overview on how investments in new infrastructure, and reinvestments in old infrastructure, may be analysed within a CBA context. It especially focuses on how freight transportation attributes may be valued and how flows can be predicted, two issues of great importance in infrastructure CBA. Much political debate concerns infrastructure investments, declared by their promoters as essential for sustaining existing enterprises or for attracting people and businesses to particular regions. However, such spatial growth impacts are currently difficult to identify unambiguously, and they are even more difficult to measure. This is so partly because the impacts of infrastructure are by nature long-term or medium-term events, and uncertainty tends to increase with the time

perspective. But another important reason is the lack of reliable theoretical and applied models of the location of firms and factors of production in a dynamic spatial economy. The development within "the new economic geography" clearly points in the right direction, although substantial work remains to be done.

Such modelling difficulties arise in part because new and faster means of transportation bring not only distant markets closer, but also competitors. This two-way impact drastically reduces possibilities for making theoretical statements and forces the analysis into the study of special cases.

In applied CBA the problem may become even more challenging. Data are seldom or never of the quality we would like them to be. Applied CBA is most often limited to static analysis, in which the future indicator variables are, in most cases, forecasts of the specific country's GDP. From this, flows on links are approximated and sometimes regional adjustments are made; but if a regionally distributed growth is expected to result from an investment, this is never fed back into the model. Thus a key argument that is sometimes presented for an investment is never even handled in the formal calculus.

The position taken is thus one with only rudimentary dynamics, where firm location and regional growth patterns are taken as given as in the flow model by Tavasszy (1996). But even with this simplification, there are still several options for calculating possible impacts. If, for example, a road is straightened, there are several ways to measure the benefits from the improvement. One way is to measure product prices of goods shipped on the link. As transportation becomes cheaper, there is a gradual decrease in price and increase in demand. Another way is to explore land prices; if transport time decreases, availability of new land may increase, and demand for this land would rise relative to land currently in use. The third approach, which is most often taken, is to measure the impact only on the improved link, calculating a monetary measure of how the utility of the users of the road will change when the road is improved. In a first best economy, this last approach may be shown to capture all effects of an infrastructure investment (Mohring 1993). But in a second best economy when, for example, economies of scale exist, it has been shown by Just et al (1982) in a general theoretical setting, and by Hussain (1996) with simulations by a spatial computable general equilibrium model, that there will be impacts other than those on the improved link.

The transport link demand function approach is the most common approach in practical CBA. It is the approach used in the Swedish national planning process, which is the institutional framework within which this study has been fulfilled.

In the freight transport demand function, freight demand expressed in, e.g. transported tons or number of vehicles is given as a function of the generalised cost of transportation on a link. In Figure 1, the inverse form of this function is illustrated. The figure may be used to illustrate the difference between the partial equilibrium demand and the general equilibrium (GE) .
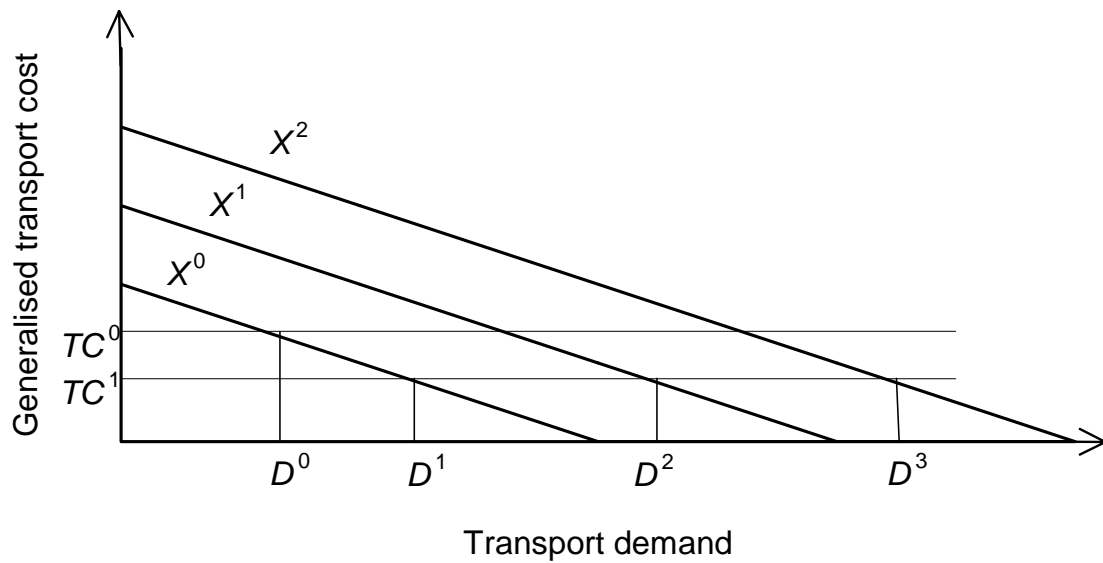

Figure 1. Partial and general equilibrium freight transport demand.

A forecast of transport demand based on a general equilibrium function is of course preferable before various partial equilibrium forecasts. Generally this sort of forecasts has not been used in applied work. Instead demand has traditionally been obtained from the four-step model in which Origin-Destination (OD), mode, route, and link choices are handled more or less separately rather than simultaneously. The equilibrium demand (the transported quantity) for transports on link l by mode m may in a non-GE case be written as,

$$D_{1m} = X_{1m}[TC_{1m}(\mathbf{p}_z), C, \mathbf{p}, \mathbf{P}, \mathbf{Y}, T, S] \tag{1}$$

Equilibrium transport quantity D_{1m} for mode m on link 1 is a function X_{1m} of the generalised transportation cost TC_{1m} and other variables. TC_{1m} is a function of the prices ($\mathbf{p}_z$) of attributes

Z (such as shorter transport time) on the link for mode *m*, and changes in these would appear as shifts in the cost curve *TC* given in Figure 1. This choice of mode and link are made given the transport cost on all other links and modes in *C*. Demand is moreover dependent on the other variables in X_{1m}. Here **P** is population, **Y** is aggregated income, *T* is technology conditions such as chosen production functions and locations of firms, *S* is company characteristics, and **p** prices on other goods.

The two main aspects of this approach will be more thoroughly described below. They are the valuation of quality-related and other attributes *Z* for a given infrastructure, and the forecast of demand for freight on the link. In traditional CBA, quality aspects and flows are usually estimated separately and thus do not influence each other.

Assume that the transport time is shortened. This reduces $TC_{1m}(p_z)$ in Figure 1 from TC^0 to TC^1 and increases the transport demand from D^0 to D^1. We may then do a freight demand forecast based on a change in general economic growth (**Y**) and thus observe a shift of the demand function $X_{1m}(.)$ from X^0 to X^1 that would give this analysis a total demand of size D^2. What is then often not taken into account is that, for example, a lower transportation cost may affect population size (**P**), incomes (**Y**) and so forth, which may shift *X* to X^2 and yield a general equilibrium final demand of size D^3, which of course due to increased competition from other modes and links also may be to the left of D^2. Our point is that a modelling approach ending in D^2 is hence only partial. In a general equilibrium framework and in the case of an investment with more substantial impacts on the transport time, the separation made in (1) is by no way obvious and the following formulation would be more appropriate.

$$D_{1m}= X_{1m}(TC_{1m}(\mathbf{p}_z),\ C(\mathbf{p}_z),\ \mathbf{p}(\mathbf{p}_z),\ \mathbf{P}[C(\mathbf{p}_z)],\mathbf{Y}[C(\mathbf{p}_z)],\ T,\ S) \qquad (2)$$

In equation (2) a change in a price on a link may also have an impact on the GE demand for transportation on the link. This is because the effects of $\mathbf{p}_z$ in (2) are not limited to influence only $TC_{1m}(\mathbf{p}_z)$, but to influence the whole economy, resulting in the inclusion of the GE-effect of the investment in the CBA, yielding, e.g., the D^3 solution in Figure 1. Here we have given a medium term general equilibrium, in a long term equilibrium also *T* and *S* may be influenced by changes in prices of attributes.

In current practice the aforementioned "four step" approach is followed to a partial equilibrium. OD flows are estimated separately and the cost dependent part of the link-mode-related demand function is used as the link level in the CBA object analysis. In more

advanced simulations, those costs are aggregated up to a OD cost matrix, which may influence the level and direction of aggregated flows. Only in the MEPLAN (see ME&P (Marcial Echenique & Partners Ltd.) (1989)) structure and in models such as Friesz, Westin, and Sou (1998) is the link and OD problem solved, respectively, recursively and simultaneously.

In the following we will consider two aspects of the CBA process: the valuation of attributes for transportation modes at the company level and the forecast of OD flows at the link level, which is often made with scarce data sets.

The valuation of transport mode attributes at company level

In order to identify the demand function for a specific mode and link, the user's valuation of the transport solution has to be measured. In the CBA, the benefits or the value a transport-demanding firm attaches to a change are of interest. When the value attached to changes in transport attributes such as transport time, delays, damage, departure frequencies, accidents, and distance to the mode are in the focus instead of the mode as such, the analysis becomes attribute-oriented instead of mode-oriented (Winston 1979). The attribute-oriented approach has the advantage of each transport service being seen as a bundle of attributes. The company makes a choice between bundles of attributes, which indirectly presents a choice between modes. Beside those transport-related factors, emissions and other external environmental impacts are increasingly recognised at the company level.

The most important and obvious information on link and mode choice is the *revealed preference* (*RP*) information reflecting the actual choices made on the market. A problem with this information is that, first of all, it is generally not possible to identify the precise alternatives that were available to a company when the choice was made. Secondly, information about the demand curve outside the current set of available attributes may be difficult to identify.

An alternative would be to analyse *freight contracts* and combine those with information on utilised vehicles. Delays, damage, and transport time would be reflected as freight rates and insurance costs in the contracts. However, complete tariffs and sets of contracts are generally not available due to company secrecy. Companies are unwilling to reveal information that may be used by their competitors.

What often remains is the experimental (hypothetical) data obtained through interviews by *stated preference* (*SP*) studies. Ideally, information from each of these three sources, *RP, SP,* and actual *freight contracts* should be brought together in a single database, but generally only one of the sources is used.

SP studies are most often carried out as choice games, wherein the informant is asked to choose between two transport alternatives with different attributes. In this way, the company's and/or the informant's own preferences are stated. This may be accomplished for two transport alternatives with a single mode as well as with different modes as explicit alternatives. In the latter case, mode-related substitution elasticities may be estimated and it will be possible, for example, to model the impact an improved railroad link will have on a nearby road. As discussed above, the attribute-oriented approach may be developed even without explicitly mentioning the mode, since the attributes as such are in focus. However, in practice it has hitherto been difficult to force the analysis so far in terms of descriptions of the attributes. The evident disadvantage is that companies, when considering alternatives, in their answers may associate too much of current service and technology with a specific mode.

Although SP-studies render observations and figures relatively easily, they also have shortcomings. The number of attributes has to be limited to some extent. Too many alternatives may create time consuming interviews in which the answers are of limited quality or may result in impossible or unrealistic decision situations.

Computerised interviews create possibilities for an improved experimental design, but a number of questions still remain regarding the design of interviews and the choice of interview respondents. From the point of view of infrastructure investments, the time perspective captured by the survey clearly should be explicit. What sort of changes are possible within the current logistic regime in a company? Are the questions directed to the right person in the company? Is it, for example, possible for a transport manager to judge how a change from one set of transport attributes to another will influence the whole product chain or even the chosen location of the workplace? Or, will the transport manager valuate only changes within the current logistic concept used by the firm? Secondly, do the receiving and the shipping firm share similar valuations of the attributes of a given shipment? If not, and if this presents a problem, how should it be addressed?

A first observation in relation to the current experiences of freight transport valuation is that, compared with passenger transportation, the research on the valuation of freight transport

attributes is still in its infancy. This is to some extent explained by the lack of link flow data at the commodity level and a seemingly larger degree of complexity in freight due to heterogeneity of flows. Passenger analysis studies the transportation of people; people are not homogeneous, but may respond to interviews regarding their destination, chosen route, valuation of attributes, etc. in a way that adds variation, but also more structure, to data. In interviewing a company about freight flow, the focus is in the current tradition placed on a "typical transport", which makes it difficult to follow the route of individual consignments. Also, in freight transportation the combination of types of goods and transport alternatives results in a larger number of choices than for passenger transportation. Demands differ not just with respect to transport time, delays, damage, etc., but also with respect to the need for a certain temperature, volume capacity, weight capacity, safety (for goods and for the surrounding environment), and other aspects related to general flexibility, information, and service.

Fridstrøm and Madslien (1995), Bergkvist and Westin (1998), Bergkvist and Johansson (1997) and Bergkvist (1998) examine these questions further to some extent. The main conclusions drawn are that the heterogeneity in the freight transport sector has been concealed by the standard econometric methods transferred from passenger studies, and that the average values reported hide a broader span of estimates reflecting the differentiated structure in the flows.

Modelling demand for transport attributes

When values of time and preferences for other quality factors in freight are estimated, it is necessary to use an economic model if meaningful economic interpretations of estimated parameters are to be produced. Surprisingly little theoretical research has been done in this area. To our knowledge, only Winston (1979) presents a theoretical model of the transporting firm. However, in previous estimations on the Swedish material, a more or less clearly adopted approach based on passenger models has been used (e.g. Transek (1992)). This is, of course, less satisfactory.

The model suggested by Winston is formulated as a utility maximising problem for a company transport planner. A profit maximising or, equivalently, a cost minimising model at the company level had been the traditional alternative. The argument given by Winston for his choice is that the company owners (i.e., its shareholders) take on all uncertainties and risks, including those associated with transportation already at the meta company level by

spreading out the risks with a diversified stock portfolio. Winston instead argues that the uncertainty concerns the transport manager in his everyday transport decisions and that an important part of the manager's personal utility maximising problem is to do a high-quality job and devise an efficient transport solution for his company. Should he fail, he may ultimately lose his position. This could also be looked upon as a principal agent problem, since we can easily imagine that the transport manager and those at the executive level of the company could have different information and goals.

From our point of view, the primary aspect of Winston's model is that he focuses on the attributes of a transport and not the transport as such, as discussed previously. Referring directly to the analyses in the seminal article by Lancaster (1971) on consumer choice, Winston argues that the transport manager does not strive to obtain transport as such, but for certain attributes (*Z*) of different transport modes, which each mode offers to a different extent. A complication compared with passenger studies is the fact that transport attributes will affect prices for production factors as well as for the produced goods, and thus also overall profits. After an adaptation of the utility maximising problem in Winston (1979) to a more traditional profit function, the profit for a *shipping firm,* conditional on attributes (*Z*), would be stated as,

$$\pi\,(p,\,w,\,Z,\,S) = \underset{l}{Max}\; pf(l,\,Z,\,S)\text{-}wl(Z,\,S)\text{-}TC(Z,\,S) \qquad (3)$$

In this profit function, *Z* is a vector of transport-related attributes and *S* the vector of observed and unobserved company characteristics. The vector *l* is production factors such as labour and capital. Total cost (*TC*) for the transport depends on the costs for transport attributes *Z* and the individual company characteristics *S*. Attributes in *Z* may be the expected number of losses, damages per shipment, the monetary freight rate per shipment, possible time delays or other relevant factors. With transport alternatives 1 and 0, and attributes z_c and z_t, the company will choose transport 1 if $\pi\,(p,\,w,\,z_c^1,\,z_t^1,\,S) > \pi\,(p,\,w,\,z_c^0,\,z_t^0,\,S)$.

In order to estimate the value of time, an assumption about the functional form of (3) has to be made. Moreover, the assumed distribution of the error term will determine what estimation model to use. If the profit function is linear and the error term is Weibull distributed, a logit model may be derived. If the error term is normal distributed, we instead obtain a probit model. These two are the most common models used, and we will return to the logit model later. Assuming that a first order Taylor-expansion of *p, w, S,* and *Z* around a

base level[1] will give an approximative profit function, the relation in (4) shows how profit depends on mode attribute changes in a linear way.

$$\tilde{\pi} = \pi(p^b, w^b, S, Z^b) + (d\pi/dp)(p - p^b) + (d\pi/dw)(w - w^b)$$
$$+ (d\pi/dS)(S - S^b) + (d\pi/dZ)(Z - Z^b) + R \tag{4}$$

In equation (4), R is the remainder of the Taylor expansion. The available data obtained from transport managers are focused on the choice with respect to Z. It is an open question to what extent the manager captures all the indirect effects on profit of infrastructure on the prices of products and inputs or even of the availability of production factors and the technology of the production function.

The difference in profit between two transport choice alternatives becomes;

$$\tilde{\pi}_1 - \tilde{\pi}_0 = (d\pi/dZ)(Z_1 - Z_0) + R_1 - R_0 \tag{5}$$

By setting up this difference, it is possible to estimate $d\pi/dZ$ and from this to calculate VOT as in (6). Here z_t is the attribute transport time and z_c is transport cost.

$$VOT = \frac{\dfrac{\partial \tilde{\pi}}{\partial z_t}}{\dfrac{\partial \tilde{\pi}}{\partial z_c}} = -\frac{\Delta z_c}{\Delta z_t} \tag{6}$$

Estimation of future flows

Along with user valuation of transport services and infrastructure, the forecast of future flows is probably the most important aspect of a CBA. Changes of flows, and changes in traffic security, are the most tangible long-run results of an improvement. Transport flows are what infrastructure is built for and if, e.g., VOT are wrong but have about the same share of gains in each project, the errors and ranking of projects will be basically the same among different investment projects, although the cost-benefit netto will be affected; however, if levels of flows are wrong, the ranking of projects is more likely to change.

Forecasts of flows are made using two different approaches. A few are network oriented, and most others are link oriented. The freight flow model STAN, used in the Swedish national

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[1] The base level is here the same as the typical transport in the survey.

freight transport planning, represents a network-oriented approach. The model finds a system optimum for flows in terms of minimum generalised transport costs. It has a multi-modal formulation; the Swedish implementation consists of road, shipping, and railroad networks. System optimum may perhaps be a correct way to model a railroad system, at least where there is a single dominating railroad company as was the case in Sweden previously. However, it may not be suitable for road freight involving many agents, and it may not be entirely suitable for rail transportation once competition is introduced. An alternative to the system optimum approach would be stochastic user equilibrium, as in the passenger transport models used in Swedish national planning. This introduces two attractive properties: dispersion of flows and decentralised decision making in the models.

Link and user oriented models of flows between two nodes may be modelled in several ways, from the macro level as well as from the micro level. From the micro level, one approach is to look at individual utility maximising problems (i.e., Small (1992) and Ben-Akiva and Lerman (1985)) in which producers choose to export their goods to regions that give them the highest expected utility (or give companies the highest profit). Variables influencing this choice would be demand over regions, costs to reach the region, and individual differences. Within this approach it has been shown that the macro-oriented gravity model (as specified below) is identical to the micro-oriented multinomial logit model when the error distributions are assumed to be the same (i.e., Anas (1983) and Mattsson (1984)). They also show that this micro approach will work with aggregated data.

In a macro-oriented approach, demand and supply are modelled on an aggregate node level. An example of this type of model is a gravity model (i.e., Sen and Smith (1995)). These models consist of attributes describing the attractiveness (size) of nodes and separation between them (distance) (i.e., Johansson and Westin (1994)), and they explain how flows from an origin node (O) to a destination node (D) depend on these attributes. We will look at these three factors and start with the impact on export flows of size in the origin node. Size is almost always related to some economic rather than geographic measure, such as node GDP or population (for an equal income distribution, a larger population implies higher aggregate income and node GDP).

In a traditional macroeconomic framework, increased population will increase the supply of the production factor labour, and real wages will be bid down. This will increase output, and GDP will rise while prices will be reduced due to lower production costs. As a consequence of this price reduction and GDP increase, internal consumption as well as exports will

increase. The effect on imports is unclear since imports tend to decrease when external goods become relatively more expensive, but they tend to increase as higher income raises consumption demand. The same process will happen in the destination node when its population increases, although in this case the incoming flows are of interest. The net effect on the node's import and balance of trade is then ambiguous and dependent on whether the export increase will be larger than the unknown net effect on imports. This ambiguity remains to be solved empirically. Other effects are also at work here, which makes it difficult to say something definite. One such effect is that a "sufficiently" large economy would not need to import goods since the internal market would be large enough to produce all demanded goods. This is also something we notice in the real world, when the proportion of trade in large economies in general is relatively smaller compared to small economies.

An increased distance between a OD pair and hence cost c will work as an added cost and increase prices in the destination node compared to the origin node. These increased prices will reduce demand and hence decrease flows. This may be formulated as;

$$X_{rs} = f(O_r, D_s, c_{rs}) \tag{7}$$

The above is the classical gravity model (Wilson (1967) and Sen and Smith (1995)). In order to estimate the model, more specific assumptions about functional form and error distributions have to be made. Flows X_{rs} from O to D are assumed to be an increasing function of the population in O and D respectively, and a decreasing function of distance c. A reasonable assumption is also that these functions are increasing/decreasing at a decreasing speed. The most common specification is the following,

$$X_{rs} = A O_r^\alpha D_s^\beta \exp(\lambda\, c_{rs}); 0 \le \alpha, \beta \le 1, \lambda \le 0 \tag{8}$$

Traditionally the model has been linearised by taking logarithms and, after that, parameters α, β, and λ can easily be estimated with OLS. However, estimation with OLS has a drawback in that it cannot handle observed zero flows between nodes. The second part of the paper deals with the question of whether alternative structures may improve the forecast of the flows. Alternative estimation methods have been suggested and are elaborated further in below.

3. The value of time in road freight transportation

This section starts with a literature overview to set the context in which VOT for road freight transportation may be examined. This is followed by a discussion concerning the special nature of VOT in this area and finally we examine how VOT can be estimated and our empirical results.

The research area in which estimation of time values for freight transportation is done is relatively new compared with time values in passenger transportation. Seminal work for the latter is, e.g., Becker (1965) and reviews may be found in Ben-Akiva and Lerman (1985) and in Small (1992), models of transport demand can, e.g., be found in Tavasszy (1996) and in the surveys by Zlatoper and Austrian (1989) and Winston (1983), whilst the only review of the value of time for freight transportation is de Jong (1996). Jong compares results (see Table 1 below) from a number of European studies but is not methodological or theoretically oriented. This is explained by the fact that most previous studies do not use freight-oriented theories. Instead, established methods from passenger studies are used. Winston (1979) is the exception. As mentioned earlier, he has developed a theoretical framework for measuring the value of quality factors among transport firms. Studies using only RP data are also scarce, but Ogwude (1993) estimates the value of transport time for Nigerian road freight transports. There are also studies containing both revealed- and stated preference data, see for example Jovicic (1998).

As seen in Table 1, large differences exist in average VOT between countries. One possible explanation is that all studies estimate VOT for a given transport, while a transport may contain one or more lorries of different size and different types of goods. The average transport in Sweden is probably made over longer distances than transports in the Netherlands. Another explanation is simply that a different methodology is used, which may give rise to differences in the estimates of VOT. Since there have been only a few studies made in Europe, the methodology has not yet reached a common state of the art. The positive side of this is that no tangible or intangible (such as prestige and path dependence) restrictions on the development of methods thereby exist. The negative side is that comparisons are problematic. But as may be seen, there may be signs of some kind of "merging". The single Swedish VOT in Table 1 from 1992, which is quite low in a European context, has, in our 1998 study presented in this paper, become an interval that encloses most other studies.

A VOT in freight transportation does not necessarily capture similar values as a VOT estimated for passenger transportation. In passenger studies it has traditionally been assumed to be the disutility of waiting to reach a destination, enduring long transport time, etc., with the main assumption being that positive utilities reside in the destination, while the trip as such only gives disutilities. Of course, this has been criticised since some people actually place a value on the trip itself as utility creating. For business travel this is probably not the case, except when work may be done on the trip. Instead, a company component is added to catch the company's value of moving their personnel to and from places more quickly. Commodities (perhaps with the exception of, e.g., vegetables) don't bother about the transport time, thus all valuation of time is connected with the companies involved in the transportation. The value they attach to transport time is also derived from several sources. One obvious source is the interest cost of capital. Faster delivery time may render faster payments and increased profits. One would also expect VOT to vary over different goods. Fresh salmon may, for example, give rise to a higher VOT than frozen salmon, although both would be regarded as fish. Hence, heterogeneity occurs not only between different types of goods, but also within a specific branch. Another source of value attached to transport time derives from the fact that improved transportation may create possibilities for reaching new markets or making efficiency gains in other parts of the production chain. Improvements may also provide a slack that create possibilities to cut delays. This fact is also a potential problem in VOT studies, since the value of decreased delays and decreased transport time may be confused in an interview situation. The solution is to give clear definitions and alternatives when the study is designed. Studies that have been done do corroborate that there are more components to the VOT than the interest cost of capital; some studies also fail in their attempts to find a correlation between VOT and the value of goods transported (i.e., Bergkvist and Westin (1996) and Fridstrøm and Madslien (1995)).

Table 1. Average VOT estimates for road freight in some European countries. Values per transport in SEK, 1996.

Country	Year	Method	Value of time
Sweden	1992	Logit	52
The Netherlands 1	1986	Factor cost	182
The Netherlands 2	1991	Factor cost	195

The Netherlands 3	1992	Logit	325
The Netherlands 4	1995	Logit	299-325
Great Britain	1995	Logit	273-351
Norway	1994	Box-Cox Logit	0-520
Norway	1995	Box-Cox Logit	0-340
Denmark	1996	Logit	234-533
Sweden	1998	Logit	0-732
Denmark	1998	Logit	17-55

Sources: de Jong (1996) except for the last three rows from Bergkvist (1998)

A further question is to decide who should represent the company. In most studies the transport manager has been chosen. Fridstrøm and Madslien also interview higher company officials, but they do not use this information in their estimations. Is the manager always the right person? Winston discusses this and finds that he (or she) probably is, but that this choice also limits the model to everyday decisions and that long-term impacts on VOT are thereby difficult to approximate. It is also a reasonable choice if the transport manager has all relevant information on everyday transports, but it may also be the case that levels below the manager have the right to make their own decisions. This may be the case when a problem occurs and decisions about shipping or receiving must be made on short notice. If these problems and decisions are of great enough significance or frequency, there is a risk that today's VOT studies miss these urgent *transports with a possibly high VOT*.

Other complications might include such things as whether the company own their transport capital (internal) or hire the service (external). Especially in a Stated Preference choice game, one may expect that internal transports may result in high VOT since the managers are more likely to include costs such as driver salaries, although this should be separated from a pure VOT.

The length of the transport may also affect VOT in several ways. One is that companies with a need for fast transports may have located themselves close to the main market or main resource; this may show up as a higher VOT for short transports compared with longer ones. Another reason may be a more relativistic view, which could be that companies do not care

so much about the savings in minutes or hours as they do about how much the percentual saving could be. For a long transport time, such as several days, a one-hour decrease in transport time may be of little importance, while this one hour may be very important if the transport time is only two hours long. A ten percent cut in transport time is then more likely to be valued similarly for short and long transports than a one-hour cut in transport time. This is also the finding in Bergkvist (1998).

A shortcoming in some studies is that time is varied in one direction only. The survey starts by defining a typical transport, then the respondent chooses between this and a transport with a longer time and, e.g., decreased damage. The alternative chosen is then either advanced to the next game, where it is compared with a new alternative with an even longer transport time or with the typical transport. However, dependent on whether time is always increased or always decreased, we will arrive at two different VOT situations: the willingness to pay for an improvement or the willingness to pay to avoid an impairment. Fridstrøm and Madslien (1995) show that there are in fact different VOT, and that the VOT to avoid impairments is higher than the VOT for gaining improvements. Put another way, the compensating variation (CV) seems to be higher than the equivalent variation (EV). Companies respond in a conservative way.

In transportation economics, estimation of VOT is usually made with a discrete choice regression model. The problem is often stated as a choice of a transport alternative that gives the largest utility or highest profit. As utility and the relevant profit is usually not easily observed, we may at most hope to observe how changes in utility or profits are valued. Discrete choice models provide a way to evaluate choices made and to estimate parameters which, given the assumptions made, may be interpreted as VOT, value of damage, and so forth.

The use of discrete choice models is not limited to this area, however. Other examples may be found in research regarding labour force participation (Amemiya, 1981; Newey et al., 1990), absenteeism (Barmby et al., 1995), discrete contingent valuation (Hanemann, 1984, 1989; Li, 1996), bioassay problems (Berkson, 1944), choice behaviour (McFadden, 1974) and choice of transportation modes (Horowitz, 1993a; Ben-Akiva and Lerman, 1985).

The estimated parameters from a discrete choice model are, however, only identifiable up to scale. Ratios of parameters may nevertheless provide correct and relevant economic information. The VOT as defined in (6) is such a ratio.

If we follow McFadden's (1981) random utility (here profit) model and recognise that profit (π) as defined in (3) is not observable but may be divided into one deterministic part (v) and one stochastic (ε) we get; $\pi_{in} = v_{in} + \varepsilon_{in}$. Then a latent variable approach is taken which concerns only choices between alternatives. With two transport alternatives, the choice indicator variable Y_{in} takes on the values 1 and 0 only. The n_{th} company will choose mode Y_{1n} instead of Y_{0n} when $\pi_{1n} > \pi_{0n}$ and correspondingly also $v_{1n} - v_{0n} > \varepsilon_{0n} - \varepsilon_{1n}$. Then $P(Y=1)=P(\pi_{1n} > \pi_{0n})$, and assuming a type I extreme value distributed error term yields the logit model. For the logit model, the well-known independence of irrelevant alternatives (IIA) (see Greene (1993)) assumption must also hold.

If those assumptions are wrong, the estimated parameters may be biased, c.f. Ruud (1983). Conditions under which this is not the case are further proved and explored in Horowitz (1993b), Yatchew and Griliches (1985), and Lee (1982). The main conclusion is that when samples are large and distributions are unimodal, ratios of parameters may be estimated quite confidently. If sample sizes are small and heteroskedasticity and bimodality are present, this is not generally the case. This presents a motive to try less restrictive estimators. Among these, the semiparametric estimators have a strong attraction and some work has accordingly also been done in this area. The reviews by Härdle and Manski (1993), Horowitz (1993b), and Powell (1994) give some examples. Small sample performance of different semiparametric estimators are also studied by, e.g., Powell et al. (1989), Horowitz (1993a, 1993b), and Ichimura (1993).

A general result from this research is that, with spherical error distributions, severe losses in terms of bias and mean square error (MSE) incurs using semiparametric estimators compared with using such standard parametric models as, e.g., logit estimation. Unfortunately, semiparametric estimators are generally difficult to compute since their objective functions are not necessarily unimodal. An alternative is the weighted average density derivative (WAD) estimator. This estimator is not in need of an optimisation procedure when unknown parameters are estimated. It is hence non-iterative and reasonably fast. We have for this reason used it. Nevertheless the WAD estimator also has drawbacks. The bandwidth is a free parameter, and no analytical results exist to guide the econometrician with respect to how it is to be set.

We will investigate the stability and possible existence of different VOT for road freight transports. This is done with respect to transport distance, location of the shipping firm,

industry branch, goods value, and ownership conditions. The data is from a Stated Preference study carried out in Sweden in 1992 (Transek (1992)). It contains 277 interviewed companies and more than 7 000 observations, of which 5065 were usable once apparently unrealistic and erroneous answers were removed. The hypothesis to be tested is whether different VOT exist even when differences with respect to region, transported distance, and industry branch have been taken into account. To analyse this question we utilise a logit model.

Sweden is divided into two regions (North and South), and transport time is used to measure transport distance. Transports shorter than three hours are considered to be "short distance" while the remaining are considered to be "long distance". The results from a base estimation and an estimation where region and distance are controlled for are found in Table 2. The results indicate that there may be some regional differences when distance is taken into account. However, the impact of regional location is small compared with the impact transportation distance seems to have.

Table 2. Swedish VOT estimates for road freight for 1992 measured in 1996 SEK[2]. Values are given for regions and different transported distances. Lower and upper bounds are given within a 5 percent significance level*. Values per transport in 1996 SEK.

	Mean value	Variance	Lower bound	Upper bound
Base model	**37**	23	27	47
Region-distance model:				
Short distance: North region	185	1 745	0	269
South region	**732**	8 259	550	914
Long distance: North region	32	55	0	47
South region	**40**	51	26	54

Source: Bergkvist and Westin (1998). *Asymptotic confidence intervals. Boldface figures are significant at a 5 percent level.

A t-test shows that the only VOT significantly different from any other VOT in Table 2 is the VOT in the south of Sweden for short distance transports. Thus, the main conclusion is that

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[2] Values originally estimated in 1992 SEK, conversion to 1996 SEK done with constant 2,65.

companies located in the North seem to have a zero or a very low VOT, and that short distance transports have a substantially higher VOT than both long and base model transports.

When the material is divided further to take account of the fact that different industry branches may have different VOT, we obtain the results shown in Table 3. From the table we can see that regional differences exist only for the food and tobacco sectors, and that no sector has significant differences in VOT due to distance. It can also be seen that only three sectors have a significant VOT. The main reason why the model did not converge for some sectors is the lack of variation in the data material. This would have been less likely with a larger survey. For now, we may only conclude that the current material does not allow for a more thorough examination. In a separate estimation we also tested the popular hypothesis that the value of transported goods should influence the VOT. However, neither a division into high and low total value nor value per kg indicated that VOT is related to the value of goods in this material.

Table 3. Value of time for branches of the Swedish manufacturing industry. SEK per hour valued at prices of 1996.

	Base model	North region	South region	Short distance	Long distance	North short	North long	South short.	South long
Food, tobacco	**69**	**56**	**77**	329	80	334	8	363	119
Engineering	**58**	1839	**40**	1868	**64**	-14840	1458	1844	27
Pulp, paper	29	**27**	37	(-)	(-)	(-)	(-)	(-)	(-)
Wood man.	72	11	106	(-)	(-)	(-)	(-)	(-)	(-)
Chemicals	29	-32	215	(-)	(-)	(-)	(-)	(-)	(-)
Metal	5	11	19	(-)	(-)	(-)	(-)	(-)	(-)
Mineral	119	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Other man.	1	5	8	(-)	(-)	(-)	(-)	(-)	(-)

Boldface figures are significant at a 10 percent level. A (-) means that this model did
not converge.

We also ask if VOT is dependent on whether the company owns its lorries (internal) or hires (external) lorries. It is also here tested whether such previously indicated differences instead depend on transport distance.

So far we have discussed absolute changes in transport time. The tendency so far is that short transports seem to have a higher VOT compared with longer transports. One hypothesis is, then, that there may be a more or less constant relative VOT with respect to total transport time. In order to test for this, relative time values are presented below in Table 4. Relative VOT gives the value of a one percent change in transport time. This calculation show how the span between the different standard VOT decreases when they are calculated in relative terms. For the standard VOT, the difference is up to 17 times between highest and lowest, while it is about 2 times for the significant relative VOT. Not only the scale is changed but also the ranking. Long transports are valued higher when measured relatively, and then, of course, they contain a larger absolute time saving.

For the standard VOT Table 4 illustrates that the first clear indication of higher VOT for internal and short transports disappears if further divisions are made. When the material is divided to take account of both distance and ownership conditions, the results become less clear. Internal transports no longer inhibit a significant VOT. A look at the number of observations, though, reveals that internal transports account for only about ten percent of the total sample; it again seems as if the number of observations is too small to manage even relatively modest attempts to divide the material. A likelihood ratio test nevertheless shows that the model with a division into both long-short and internal-external is significantly better than the others.

Table 4. Swedish VOT for different types of road freight with regard to distances and ownership conditions. Values are expressed in 1996 SEK.

	VOT	Relative VOT*	Log likelihood
Base model	**37**	9	-3236
Internal	**241**	11	
External**	**34**	9	-3228
Short	**509**	7	
Long	**37**	10	-3204
Internal: Short	1516	20	
Long	130	9	
External: Short**	**379**	5	
Long**	**40**	12	-3172

Figures in boldface are significant at a 5% risk level.
* The value of a one percent change in transport time. Calculated as (VOT times the average transport time for that category)/100.
** Since the logit model is non-linear, the VOT for a complete data set may be lower than for each subset.

Heterogeneity can with this type of models, unlike OLS, create biased estimates. We needed to explore this further and to see if there were other estimation methods that were better suited for these kinds of problems. We estimated ratios of parameters in discrete choice single-index models using the weighted average density derivative (WAD) estimator. A plug-in estimator of the optimal bandwidth for the WAD estimator derived by Powell and Stoker (1996) is used to come around the problem of a completely free parameter. The performance in small samples is also explored. Finally we use parts of the stated preference data in the VOT estimations from the food/tobacco sectors and from engineering as an application of the estimator.

It was found that the WAD estimator improved the performance in the engineering sector compared with traditional parametric models. A bootstrap technique was used to create confidence intervals that could be compared with standard asymptotic confidence intervals. Monte Carlo simulations were also used to see how the methods perform under different disturbances. The WAD estimator was found to estimate regression parameters up to scale. Also the performance of the WAD estimator in terms of bias and mean square error are similar to a logit estimator for spherical errors in a latent variable specification. With heteroskedastic errors, the WAD estimator is, however, found to perform better.

4. Modelling road freight flows and transport choice

In infrastructure appraisal, the forecast of flows is critical since changes in costs and benefits are dependent on the volume of traffic. At the link level, forecasts are often made with a gravity model. Such a model may be theoretically motivated or chosen in a more ad hoc manner in relation to a data set. (Compare the discussions in Sen and Smith (1995), Fotheringham and Haynes (1984), Fotheringham and O'Kelly (1989), and Erlander and Stewart (1990)). In gravity models, the attractivity of and friction between nodes are used to forecast flows. Attractivity is generally approximated by the size of a node, such as population or GDP. Nodes may be cities, functional urban areas, counties, countries, etc. Distance between nodes is often modelled as a metric distance or transport time, but also qualitative measures such as road width or a general quality index may be introduced.

Finally a measure of flows has to be introduced: What should be used: weight, volume, or value? Often the available data restricts the choice. But given that we have relevant variables

and a theoretically motivated model, the model still remains to be operationalised and estimated.

After linearising the gravity model described in equation (8) above, it may be estimated with OLS. However, OLS does not allow for zero flows between nodes. Since many transport networks are characterised by zero flows between some nodes, this information must be used and not discarded or distorted. Hence, alternative methods such as non-linear least squares (NLS) or Poisson regression have been suggested and used with some success (Sen and Smith (1995)).

Flows are not necessarily linear or quasi-linear in node size or distance, nor do they always possess a symmetric cumulative distribution function. They may be highly non-linear, which is likely if, for example, agglomeration effects, harbours, airports, etc. are recognised. This may be dealt with by modelling with, e.g., dummies if the information allows this. But the choice of an estimator that is more capable of handling non-linearities may also improve the outcome.

NLS and Poisson regression have the same functional form as OLS and may thus handle non-linearities in the same way. However, the assumptions about the error for NLS and Poisson may be more correct, and their ability to handle zero flows is also an advantage compared to OLS. A class of non- and semi-parametric estimators known as neural networks (NN) has recently emerged in this area. Neural networks emanate from physics, medicine and computer science but have also been applied in economic studies. NN has also gained popularity in regional- and transportation science (Dougherty (1995)). In regional science, the number of applications is less than in transportation economics, and studies here are more oriented toward gravity model estimation (i.e. Fischer and Sucharita (1994), for a review see Nijkamp et al (1996)).

Fischer and Sucharita (1994) estimate telecommunication flows between regions in Austria with a traditional OLS estimated Gravity model. The result is compared with a feed-forward neural network and concludes that the NN gives somewhat better forecasts. The evaluation of non-linear estimators and the forecast they give is though still under discussion since no unambiguous measure exists and the measure to be used depends on the situation (i.e., Cameron and Windmeijer (1996)).

Although we may expect the number of studies on the analytical properties of neural networks to increase in the future, there are currently few such studies. White and Kuan

(1994), and Rumelhart and McClelland (1986) and others have nevertheless presented a substantial work, but a common result is that restrictions have to be put on the neural networks if more definite conclusions are to be obtained. This in turn reduces their usability since flexibility and versatility are decreased. For example, normal interference is seldom possible. If data allows, evaluation is usually made by a division of the data into two or three sets, a train (estimation) set, a test set, and (but not always) a verification set. With those sets it is possible both to train and to make "out of sample" evaluations of a model.

We further explore ways to estimate and forecast freight flows with gravity models. The data set (TØI (1988)) is from Norway and consists of inter- and intra-regional road flows of general cargo between Norway's nineteen counties, although the intra-regional flows are here excluded. As indicated above, OLS, NLS, and Poisson estimations are compared with a feed-forward back-propagation neural network. A comparison between models is made with the root mean square error (RMSE) defined in (9) and by residual plots.

$$RMSE = [\frac{1}{N} \sum_{i=i}^{N} (X_i - \hat{X}_i)^2]^{\frac{1}{2}} \quad (9)$$

In (9) X is actual transport flow and $\hat{X}$ the flow forecast. Estimation with OLS and Poisson is straightforward, and global results are easily found; for NLS global results are not analytically guaranteed but are fairly easy to find. For the neural network, the situation is different since it is not possible to know when a global optimum is achieved. A neural network is able to adapt to any non-linear structure (White et al (1989)). This strong result is, however, useless for forecasting purposes unless performance is validated and overfitting avoided with an out of sample test set. The reason is that the structure of a NN is not given a priori, and several free parameters have to be set in the estimation. A trial and error process must take place in order to find the best NN, an effort that should be taken into account if estimation with NN is chosen.

Results with both intra- and interregional flows are presented in Table 5.

Table 5. Root Mean Square Error (RMSE) for estimators of a gravity model with intra-regional flows.

Data set	Estimator			
	OLS	NLS	Poisson	NN
Training set	838	**168**	408	574

Test set		520	177 194	443	**341**

The result in Table 5 is that the NN performs best. Though NLS is very good at forecasting the estimation sample, it completely fails on the test set. Poisson, whilst not best on any set, shows a more even behaviour. Finally, OLS seems to be on the average a little worse.

Below, a different subset of the Norwegian data is used. In this case intra-regional flows are excluded. Intra-regional flows were assumed in the original data set to have a distance of 30 km; this was done by the data suppliers (TØI, 1988) and was not possible for us to undo. This introduced a censoring of the data and made data less well-behaved. Theoretically, this is something that can be handled with a Tobit model; however, the results we got with this model were not encouraging and so we abandoned it (Bergkvist and Westin (1997)). By excluding intra-regional flows we instead get a model truncated at 30 km, although not purely so since some intra-regional flows may actually have had a longer distance than 30 km. This thus give an indication of how the models react on the different problems with the data set.

Different numerical measures-of-fit are also compared and a sensitivity analysis of the estimators performed. The original data set is randomly divided into test and estimation sets five times. Parameters are estimated on each train set and a forecast made for each of the estimations. Averages and standard deviations are then calculated and inferences made. Obviously a larger number of such sets would be interesting, but current software limitations make the production of each set time consuming. This limited approach did, however, provide useful insights. Moreover, numerical elasticities were calculated in order to analyse the behaviour of the neural networks further. Table 6 contains the RMSE values for the material where intra-regional flows are excluded.

Table 6. Root Mean Square Error (RMSE) for the methods when inter-regional flows only are considered.

	Estimator			
Data set	OLS	NLS	Poisson	NN
Train set	54	34	34	**29**
Test set	92	53	57	**47**

The best results are in boldface.

Also in this case the NN is the best forecasting method in terms of RMSE, OLS is the least useful, while NLS and Poisson regression are very close in performance and are not far from the NN. Since measures-of-fit for non-linear estimators may not be interpreted as easily and intuitively as the standard R^2 for OLS, several measures are compared. Many of those are nevertheless scalings of RMSE, so the ranking of the estimators is not changed. Other measures may have other advantages, however. The R^2_{Corr} measure suggested by Cameron and Windmeijer (1996), defined in equation 10, for example, is bounded between zero and unity. Here x is the actual flow, $\hat{x}$ the flow forecast, $\bar{x}$ the average flow and $\bar{\hat{x}}$ the average of the forecast.

$$R^2_{Corr} = \left[\sum_{i=1}^{N}(x_i - \bar{x})(\hat{x}_i - \bar{\hat{x}}) \right]^2 / \sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(\hat{x}_i - \bar{\hat{x}})^2 \tag{10}$$

The results from this test are found in Table 7.

Table 7. R^2_{Corr} on the out-of-sample set for the different methods. Inter-regional flows only.

| | Estimator | | | |
	OLS	NLS	Poisson	NN
Test set	0,56	0,76	0,74	**0,81**

The best result is in boldface.

The neural network still performs best, and no other change in ranking has occurred. Another measure of fit that may be used focuses on the share of the predictions that fall outside a specified range. Here we calculate the share of observations for which, $(x_i - \hat{x})/x_i > 0.20$ is true. In Table 8 the results for the share relative error measure is reported.

Table 8. Share of predicted inter-regional flows with a relative error larger than 20 percent, on the out-of-sample set.

| | Estimator | | | |
	OLS	NLS	Poisson	NN
Test set	86,1	80,9	**79,1**	87

The best result is in boldface.

In Table 8, we have a change in the ranking since the Poisson regression now yields the best result while the NN now performs worst and close to OLS. NLS and Poisson are also close in performance in this case, a matter we will investigate further when the five different randomly divided data sets are analysed.

The results are shown in Table 9, below. Now we get a more unambiguous result. The NN is best in most cases, but the bad result for set five increases the mean just above the NLS. Poisson regression is never best, but has the smallest standard deviation. The NLS has the lowest mean and a deviation very close to the Poisson model. The NN clearly is very dependent on how the data set is divided.

Table 9. Root Mean Square Error (RMSE) for the different methods and five different test sets.

Set	Estimator OLS	NLS	Poisson	NN
1	76	43	48	**42**
2	56	43	42	**38**
3	66	**25**	31	27
4	55	39	37	**35**
5	60	**49**	51	60
Mean	62,6	**39,8**	41,7	40,4
St.Dev	8,6	9,0	**8,1**	12,2

The best results are in boldface.

Finally, numerical elasticities were calculated for the NN around the mean of other variables, as the variable of interest is varied from its minimum to its maximum value in the data set. It was found, as is presented in Table 10, that the NN does not have a constant elasticity with respect to any of the variables.

Table 10. Analytical** and numerical* elasticities for parameters in the gravity model.

Variable	OLS**	NLS**	Poisson**	NN*
O_r	0.60	0.48	0.50	-0.004, 0.006
D_s	0.57	0.77	0.79	0.05, 0.35
c_{rs}	-0.002 c_{rs}	-0.0054 c_{rs}	-0.0045 c_{rs}	-1.7, 0

Moreover, the elasticity for the variable "population in the origin node" O_r shows both negative and positive values in the NN estimation. Also, here the close similarity between NLS and Poisson is indicated. All methods nevertheless give the expected signs for the variable "population in the destination node" D_s and for distance c_{rs}. Unfortunately we know nothing about the significance for the NN since no such properties are known. A future research task could be to use, e.g, jack-knifing techniques or bootstrap estimation to evaluate and investigate this.

We finally investigate the connection between and performance of a logit model and a feed-forward neural network. Both are estimated on the data used earlier. Here we not only estimate VOT with a linear profit function, we also use a non-linear profit function similar to the non-linear utility function Mortazavi and Hultkrantz (1997) used to estimate VOT, but we also predict mode choice. With such a profit function VOT will not be constant since it will depend on variations in all explanatory variables. Prediction may be used if one wants to analyse flows after, e.g., a reduction in transport time. We will get an analytical VOT for the logit model with a linear profit (LL) function, and a numerical VOT for the logit model with a non-linear (NLL) profit function and both NN.

The neural network architecture that Schintler and Oluritimi (1997) refers to as the adaptive logit model was found to give the best results. This architecture has strong similarities to the logit model. Since the NN will not yield a unique result when estimated again, even on the same data, 60 and 30 estimations were made for the NN with the linear (LNN) and non-linear (NLNN) functions respectively. Mean and variance were then calculated in order to study their ability to produce stable results. Since we have more data here than for the estimations made earlier for the gravity model, we also use a verification set. This set is used as a cross verification set to validate results from the train set and to help adjust parameters. This makes the estimation process generally more simple while keeping the test set a pure out of sample set. Results are found in Table 11.

Table 11. Estimated values of time and percent correctly predicted transport choices from logit and neural network estimations on the Swedish road freight stated preference data from 1992.

Model	Value of time SEK 1992	Percent correctly predicted			Log-likelihood
	Training set ($n=4\,000$)	Training set ($n=4\,000$)	Verification set ($n=500$)	Test set ($n=565$)	

LL	15	68.13	70.60	68.50	-2565
NLL	3[*]	70.45	72.80	71.33	-2425
LNN (average of 60 estimations)	-0.90	69.44	70.94	69.51	-2402[**]
NLNN (average of 30 estimations)	(-20, 1)[***]	67.39	67.41	66.96	-2377[**]

* Estimated for an increase from 1 to 2 hours in transport time, an average transport time of 20 hours and other variables set to zero.
** This is the log-likelihood value for the unrestricted NN.
*** VOT from the best predicting and worst predicting NLNN.

No dramatic differences in forecasting performance between the best and worst models were found. The best results were given by the NLL and some of the NLNN estimations. Since the non-linear models are extensions of the linear models, with quadratic terms and cross terms, we can perform a likelihood ratio test which shows that the non-linear models are significantly better than their linear competitors for both the logit model and the NN specification. However, we cannot conclude from this that the NN are significantly better than the logit models; we can only indicate that this seems to be plausible. There are also similarities in the estimated VOT, as the linear models yield higher VOT. A first conclusion is that the NN gives lower VOT than the corresponding logit model. A second strong conclusion is that the use of just a single NN estimation is not recommended. The negative VOT may seem disturbing, but it should first be said that they are not significant, and second, that negative VOT cannot be ruled out. A negative VOT may occur, for example, when companies decide to use the transport as a storage facility. It has been put forward by Mohring (1976) that producers of seasonal goods may be willing to do this during certain seasons.

Neural networks seem to be a flexible and versatile tool for modelling data and for tasks such as forecasting. This, due to their functional form, is decided by the structure of the data during the trial-and-error process that precedes the estimation phase. This is an advantage at the same time as it is a problem. The trial-and-error process can be quite time consuming and it gives no guarantees of finding the optimal structure, only the best from a set of trials. Moreover, it is also unstable once the best structure has been found, since global convergence cannot be guaranteed, and a random initialisation to get new start values for parameters is therefore necessary. A different result is therefore generated for each new estimation, even on the same data. Hence, multiple and time consuming estimations are a necessity. This also

seems to be a more general result that concerns not only NN, namely that the more complex and non-linear a model gets (and also, often, the more realistic), the more problems are encountered when we want to solve the model without ambiguities. The development in this paper also follows this pattern: the more we develop and complicate our models, not just NN, the more difficult they are to interpret, even though, as in the comparison between the logit model and NN, they manage to represent data in a significantly better way. As a gravity model NN are performing well, but not much better than other top performing models. A final conclusion, then, is that NN usually perform well, but it is not possible to a priori be sure that they will perform best.

5. Conclusions

Even though CBA is not a new topic in economics, the use of CBA for appraisal of freight transport infrastructure is still in many ways in a state of basic research. Although said as a statement, this fact also implies that the space for further research is rather wide. We have in the above studies identified some specific areas into which research may be directed. These areas are of theoretical as well as of applied interest.

A strong conclusion from this paper is that freight transportation is characterised by a sometimes large heterogeneity between companies and shipments, and that this has been difficult to handle properly in earlier studies. A first necessary step to try to handle this is to follow up the empirical studies that have been made, compare methodologies and to make new ones to try to straighten out raised question marks. Most of whom remaining because to few companies are taking part in made studies, making them sensitive to division into subgroups when heterogeneity problems occur. Another consequence of this is that there exist different VOT for different kind of shipments and these VOT may differ from 0 to 732 SEK. A way to handle this could be to use a relative VOT, since these differ less than the traditional absolute VOT.

Another strong conclusion is that forecasts of flows must be made within a context, it makes a difference on what method to use depending on whether flows are short or long distance. Different estimation methods perform different in these cases and may even render a different ranking to projects.

One type of transports, short transports, also seem to have a higher VOT than other transports, something that could be a sign that companies with a high VOT have located themselves close to their markets.

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