Regional valuation of infrastructure improvements. The case of Swedish road freight.[*]

Erik Bergkvist
Department of Economics
Umeå University
S-901 87 Umeå
Sweden
E-mail: erik.bergkvist@econ.umu.se
Telefax: +46 90 77 23 02

Lars Westin
Department of Economics and CERUM
Umeå University
S-901 87 Umeå
Sweden
E-mail: lars.westin@econ.umu.se
Telefax: +46 90 77 23 02

January 1996

ABSTRACT

Is it possible to identify regional differences among shippers in their valuation of infrastructure improvements? The question is analysed within a random utility approach where parameters are estimated by a logit model. Data consists of a Swedish stated preference study from 1992. The results indicate that regional differences may exist but a considerable heterogeneity in the empirical material prohibit robust results in some cases. However, regional differences seem to exist when industrial mix, shipping distance and goods values are held constant. Independent of the limitations, the results should render implications to any infrastructure benefit analysis where parameters from spatial averages are used. The results are based on short term decisions and one should recognise that parameters may vary under mid- and long- term.

---

1. Introduction

The allocation of public investment to achieve largest utility from collective and semicollective goods is of utter importance to society. Questions on what and where to invest are in those cases explicitly addressed in cost benefit analysis (CBA). Early CBA came into use in project appraisal of infrastructure investments. Regardless of the long experience we now have from calculating benefits of infrastructure, current CBA practice is not without controversial elements.

Historically, improved transport possibilities have been strongly correlated with development and modernisation. Commonly this fact is emphasised in the political debate although it is not obvious that infrastructure investments are sufficient for development. Transportation is a mean to connect nodes, making its geographic localisation in relation to actual and potential demand important. The benefit from utilisation of a transport facility is dependent on passenger's and shipper's valuation of time as well as the number of people utilising the improved infrastructure. This also implies that infrastructure investments to a large extent are path following and located at parts of the transport network where people and activities are already agglomerated. Hence, investments have a tendency to be made where the infrastructure capital is considerable.

In the natural resource dependent Swedish economy, the magnitude of freight flows per capita are highest in the relatively sparsely populated north. Since initial estimates (Transek 1992) show that shippers have a relatively low valuation of time savings for goods transportation compared to passenger valuation of time savings, only few investments in freight infrastructure seems to be profitable while most of the infrastructure budget would be localised to the densely populated areas. Due to this, the estimates have been a source of debate regarding the correctness of today's CBA methods and especially the correctness of the parameter estimates in the models.

As a part of the debate it has been argued that the evaluation of freight transportation may differ between different parts of Sweden. One indicator of this is an earlier study of the demand

for rail transportation in Sweden, Transek/Banverket (1990), which indicated existence of regional differences in the valuation of time. Since this question was never addressed explicitly by the study, it remained unanswered. However, it indicated that the sparsely populated areas with large flows of goods in the north tended to give a higher value on time savings for freight transport compared to areas with a more dense population and relative small flows of goods. It has then been argued that if this actually is the case, today's CBA treat those regions unfair and give rise to an erroneous decision foundation.

Another source of criticism is that the long term growth effects are generally neglected in today's CBA when localisation and technology are taken as given. This is of course a problem since the interaction between infrastructure improvements and other forms of investments may change mid- and long- term conditions for growth over regions. Generally a company has to evaluate its choice of logistic system and transport solution several times. Firstly, in conjunction with its long term decisions regarding localisation and production technology, thereafter every time changes in the attributes of transport modes occur which may influence the present choice. It is also possible that changes in such attributes will induce technological shifts or changes in the market structure which makes it necessary for the company to consider a relocation or to establish new plants. Since companies differ in mobility, some has the ability to relocate rapidly and thereby adjust to changes in the accessibility while other, such as mining companies, may find those roads rough to travel. In the latter case, time values may be rigid, while for the former they may be an important part of the company strategy.

Due to data available, this study will not deal with effects beyond the short-term more thorough than what have been indicated so far, but we will recognise the existence of rigidities in relation to localisation and the restrictions they impose on the estimated parameters in the CBA. Instead our primary purpose is to identify regional differences in valuation of transportation due to factors such as preferences and localisation. The paper is organised as follows. In section two the theoretical model is presented, in section three data and their quality is discussed. In section four the empirical model will be derived from the theoretical fundaments given in section two. Our results will be presented in section five while finally the last chapter contains a discussion of our results and areas for further research.

2. A model of the shipping firm

As indicated above, the shipping firm makes decisions about its shipping policy on different time scales. In the short run, the combination of modes and routes which best fits its needs given its logistic system is chosen. In the medium- and long- term, the decision also involves the logistic system and the location of the complete firm or parts of it, in relation to markets and suppliers. On the other hand, given a chosen localisation, the actual handicraft of managing daily transport decisions is often, especially in larger companies, elevated from the executive level to some department of transportation with a transport manager in charge. This person is therefore the one who makes day to day decisions about transportation and mode choices. Since the manager is a human it is impossible to exclude such things as incomplete information, opportunistic and non-costminimising behaviour. Moreover, he has to take into consideration the demand from the receivers. Nevertheless, since he may lose his job if making wrong judgements he will probably try to make firm compliant decisions.

Having observed this, we consider it less desirable to use a pure cost minimising approach while modelling the shipping firm and more fruitful to use a random utility approach. In the following we develop a model which utilises results by Winston (1979) and Johansson and Mortazawi (1995) which are heavily dependent on the seminal work by McFadden (1973). We assume that the shipping firm may be described by the following utility function for the daily decisions by the transport manager:

$$U(h(Z,T), S, W) \qquad\qquad (1)$$

The utility function is assumed to be weakly separable in $h(Z,T)$. The subutility function $h(.)$ is increasing in Z, where Z is a vector of modal attribute values. The parameter T is a mid- or long- term technology parameter. It is exogenous to the transport manager and will change only when company management change production technology, logistic concept or localisation. S is a vector of unobservable individual preferences about different modes and W is utility from goods. Hence, following Lancaster (1971) and Winston (1979) we assume the

manager to be more interested in the attributes of modes than the modes as such. The subutility function $h(.)$ is maximised subject to the following constraints:

$$Z - Bx \text{ £ } 0 \tag{2}$$

$$tx \text{ £ } Q \tag{3}$$

$$x \text{ ‡ } 0 \tag{4}$$

The first constraint is a mode related technology constraint relating attributes to modes by the parameters in matrix B. The attributes in Z may for example be the reciprocal values of the expected number of losses or damages per shipment or the rate per shipment or possible time delays. The vector x gives the number of shipments per mode. The second constraint (3) is a constraint on the daily amount shipped, where Q is the average daily amount shipped and t is a vector of coefficients indicating the capacity of each shipment over modes. The last constraint is an ordinary nonnegative restriction. The assumption that we only study average daily shipments may be criticised but it's a useful simplification and moreover consistent with the question in the survey. Maximisation of (1) subject to (2)-(4) render the following Lagrangian when the constraints are binding,

$$L = h(Z,T) + \text{l } (Bx\text{-}Z) + \text{m}(Q - tx) \tag{5}$$

All Lagrange multipliers are in this case positive. First order conditions with respect to modal attributes become,

$$\frac{\P L}{\P Z} = \frac{\P h}{\P Z} - \text{l } = 0$$

or

$$\frac{\P h}{\P Z} = \text{l} \tag{6}$$

The multiplier λ may thus be interpreted as a vector of marginal changes in utility from a small change in a modal attribute belonging to Z. Suppose that Z_t is the modal attribute transport time and Z_c the attribute transport cost then,

$$\frac{\frac{\partial h}{\partial Z_t}}{\frac{\partial h}{\partial Z_c}} = \frac{\lambda_t}{\lambda_c} \tag{7}$$

which is the value of change in time. The indirect utility function at the given daily amount shipped is,

$$V = max \ U(h(Z,T),S, \ W) = V(Q). \tag{8}$$

A first order Taylor-expansion of this utility function and insertion of first order conditions gives the expression,

$$V = U(h(\ 0,T),S, \ W) + \frac{dU}{dh}\lambda \ Z + R \tag{9}$$

The term R is the remainder of the higher order polynomials of the Taylor-expansion. The expression in (9) will be very useful when we derive the econometric form of the model in the sequel.

3. The Swedish truck data

The data we use in this study is the result of a Stated Preference study conducted in Sweden 1992. The goal of the study was to construct a model which could forecast companies' choices between lorries and other modes from their attributes. Time values for different kinds of lorry transports was a necessary part of this work. Interviews were computerised and 277

companies participated. Companies with less than 10 employees were excluded from the study, which was made as a stratified probability sample, where the stratification variables were,

- Company type
- Company size
- Municipal localisation.

Data was divided into subsets according to distance and geographical location of the firm. Due to the stratification a weight vector was used. Interviews took place at the companies, with the transport manager as the respondent in most of the cases. The respondent was requested to specify a recently carried out transport and its attributes. This transport was assigned as starting point in a game of selection, where pairwise alternatives where presented and the manager was asked to choose the best. The alternatives were systematically varied by the computer. This was carried out during approximately one and two hours and the result became something between ten and thirty observations per company. Together this makes the dataset to consist of about 7000 observations. Attributes being varied were,

- Time
- Transportation cost
- Percent deviation from arrival time (on the same day)
- Percent deviation from arrival time (on wrong day)
- Per mill damage

Short distance transport is defined as a transport taking less than three hours of time, which is approximately no more than 200 kilometres. When the data is divided into subsets dummy variables are used in order to preserve degrees of freedom. Regional differences are estimated for municipals divided by their municipal code into two regions, a north and a south region. The division into North and South is shown in figure 1. The south border of the north region consists of the counties Jämtland and Gävleborg.

Figure 1.   Regional division of Sweden into the regions North and South.
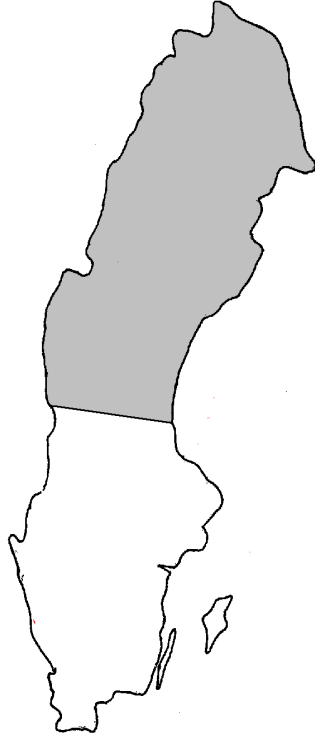
4. The econometric model and estimation of parameters

The model approach taken here is random utility. Hence the utility of the firm's decision maker is at stake and not only the cost of the firm. The appropriate specification of a calculable indirect utility function then becomes.

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

This is the random utility model as specified by McFadden 1981. Here u_{in} is the deterministic part and e_{in} the stochastic part for mode i and transport manager n. The stochastic part is derived from several facts such as:

- Unobserved attributes

- Preference differences

- Measurement errors

- Instrumental variables

Hence utility is not an observable quantity, while the choice which render the greatest utility is. Since this model only concerns the choice between two modes the choice indicator variable Y_{in} can only take values 1 and 0. Manager n will choose mode Y_{1n} instead of Y_{0n} if $V_{1n} > V_{0n}$ and hence $u_{1n} - u_{0n} > e_{0n} - e_{1n}$. This implies that $P(Y=1)=P(V_{1n}>V_{0n})$, and the distribution of the error term will determine which probability distribution function to use. Assume that the error terms are type I extreme value (Weibull) distributed, then the difference between them will follow a logistic distribution, and the probability of choosing mode 1 becomes,

$$P(Y_{1n} = 1) = \frac{1}{1 + e^{-q(V_{1n} - V_{0n})}}$$

Above is q a scale parameter not possible to distinguish from the $V:s$ with the implication that the estimated parameters are not directly interpretable alone. Since each transport manager n will meet a separate attribute value vector Z for each of the two modes, we define for notational convenience Z_{in} as the attribute value vector of mode i facing the nth transport manager. The difference of the utility function for manager n in the choice between mode 1 and 0 will be;

$$V_{1n}\text{-}V_{0n.} = a_1 - a_0 + \frac{dU}{dh}|\ (Z_{1n} - Z_{0n}) + e_{1n} - e_{0n}$$

The equation for the model with dummy variables depicted in table 1 is then, if we for notational convenience define the vector $b = \frac{dU}{dh}|$.

$$V_{1n}\text{-}V_{0n.} = a_1 - a_0 + b(Z_{1n} - Z_{0n}) + D_1(a_1 - a_0 + b(Z_{1n} - Z_{0n})) +$$
$$D_2(a_1 - a_0 + b(Z_{1n} - Z_{0n})) + D_3(a_1 - a_0 + b(Z_{1n} - Z_{0n})) + e_{1n} - e_{0n}$$

Where:

D1 = Dummy variable short distance

D2= Dummy variable South region

D3 = Dummy variable South region, long distance.

The parameter vector $\frac{dU}{dh}|$ is estimated with weighted exogenous sample maximum likelihood (WESML).

5. Results

Parameter estimates are presented in table 1 below, but as indicated earlier they are not directly interpretable. However, in this case, where we utilise a logit model quotients between parameters may be taken in order to obtain estimates of the desired time value, as in equation (7). We define a "Base model" which only consists of the five attributes described in chapter three and a "Region model" which also contains a division into the previous described two regions and a further division into long- and short- distance transports from these regions. A short transport is considered to take less than three hours. Not all parameters are significant on the 90%-level why any conclusions based upon these parameters has to be made with care.

Table 1. Estimates of parameters for regional differences with regard to shipping distance in Swedish truck transportation, 1992.

Parameter	Base model Estimate	Std. Err.	t-value	Region model Estimate	Std. Err.	t-value
1. Constant	-0.023	0.031	-0.73	0.044	0.058	0.75
Cost	0.001	0.000	17.15	0.001	0.000	10.96
Time	0.013	0.004	2.87	0.013	0.008	1.62
Deviation on day	0.165	0.037	4.42	0.084	0.061	1.37
Deviation wrong day	0.084	0.019	4.34	0.146	0.047	3.10
Damage per mill	0.019	0.004	4.77	0.042	0.011	3.96
2. Intercept dummy, short distance				-0.275	0.168	-1.64
Cost dummy, short distance				0.007	0.001	5.48
Time dummy, short distance				0.554	0.327	1.69
Dev. on day, dummy, short distan				0.735	0.289	2.55
Dev. Wrong day, dummy, short				0.555	0.293	1.89
Damage per mill, dummy, short				0.239	0.084	2.86
3. Intercept dummy, South				0.098	0.179	0.55
Cost dummy, South				-0.006	0.001	-4.03
Time dummy, South				0.137	0.385	0.35
Dev. on day, dummy South				-0.672	0.288	-2.33
Dev. Wrong day, dummy South.				-0.581	0.303	-1.92
Damage per mill, dum. South.				-0.250	0.087	-2.87
4. Intercept dummy, South, long dis.				-0.131	0.193	-0.68
Cost dummy, South, long distance				0.005	0.001	3.78
Time dummy, South, long distance				-0.138	0.385	-0.36
Dev. on day, dummy, South, long				1.002	0.310	3.23
Dev. Wrong day, South, dum, long				0.502	0.307	1.64
Damage per mill, dummy, long				0.222	0.088	2.53
-2 Log Likelihood	6489			6373		

After performing a likelihood ratio test it is evident that the model with divisions into regions and long- and short- distance, gives significantly better representation of the data material than a undivided model would present. One explanation to the differences between our study and the study by Transek (1992) is a difference in the treatment of companies with "wrong" time values. In Transek (1992) a transformation is used and separate time values are estimated for these companies. This imposes additional interpretational problems why we decided to do without this transformation. We have tried other models as well and one surprising fact we found was that the companies were quite indifferent when they were divided into groups with regard to the total value of the goods being transported a finding also supported in Fridstrøm and Madslien (1995). This in contrast to capital cost theory. We also excluded all non-manufacturing industries but this model produced the same time values as in table 2. It seems

as if they are using the same pricing policy as the freight sellers who mainly consider the length of the transport in their general tariff. Many of these companies are however such big transport buyers that they have separately negotiated contracts with their providers. Table 2 shows the estimated time values with confidence intervals. The mean value for all transports was found to be 14 SEK per hour and transport. An earlier study by Transek (1992) suggested the mean time value to 30 SEK per hour and transport.

Table 2.   Value of time with confidence intervals for Value of Time at the 95% level

	Mean value	Variance	Lower bound	Upper bound
Base model	14	22,7	4	23
North region short distance	70	1745	0	154
South region short distance	277	8259	95	459
North region long distance	12	55	0	27
South region long distance	15	51	1	29

Here we can distinguish that it is only the short transports in the southern region that are separated from the values of the base model. The difference here is however of a great magnitude. As mentioned earlier there is great heterogeneity in the material and therefore we divide the material into their respective industry to see if the results from the aggregate model holds for all categories. Time values are presented in table 3. As is evident from this table, only two industries show significant values which is to be taken as another proof of the material's great heterogeneity. One branch also exhibits the existence of regional differences. When aggregating manufacturing into two groups[1], only the high processing group displayed a significant value of time which was 16 SEK per hour. The confidence interval ranged from 3 to 29 SEK per hour.

---

[1] Group one with a higher degree of processing consisted of subgroups 2, 4, 6, 7 and 8 from table 4.

Table 3. Value of time for different branches of manufacturing industry. SEK per hour. A *
indicates that the value is significant at a 10% risk level. A (-) means that this model
did not converge.

	Base model	North region	South region	Short dist.	Long dist.	North short di.	North long di.	South short di.	South long di.
1. Food, tobacco	26*	21*	29*	124	30	126	3	137	45
2. Wood man.	27	4	40	(-)	(-)	(-)	(-)	(-)	(-)
3. Pulp, paper	11	10*	14	(-)	(-)	(-)	(-)	(-)	(-)
4. Chemicals	11	-12	81	(-)	(-)	(-)	(-)	(-)	(-)
5. Mineral	45	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
6. Metal	2	4	7	(-)	(-)	(-)	(-)	(-)	(-)
7. Engineering	22*	694	15*	705	24*	-5600	550	696	10
8. Other man.	0,25	2	3	(-)	(-)	(-)	(-)	(-)	(-)

6. Concluding comments

The principal result is that regional differences seem to exist when estimated in this model context. Unfortunately all companies with less than ten employees were excluded from the data collecting process, why it is impossible to have any opinion about these small and perhaps new industries' valuation of time. What is interesting is that the differences remain regardless of shipping distance which indicates that it is in fact the localisation of the firm that may induce these differences in time valuation. In contradiction to the preliminary indication, northern localised firms does not have the same high valuation of time as the southern firms but the greatest differences are related to shipping distances. The plausible policy implication is deepened on the time perspective. In order to gain largest possible social benefits if the short term prevails policymakers should improve infrastructure where companies possess the highest valuation of time. On the other hand, companies actually seem to localise according to the existing infrastructural net, and it is therefore possible to invest where today's capacity is low and await companies' relocalisation. This second approach may be chosen if it is desirable to even out regional growth. Further studies should focus on small companies which were excluded in this study and on large companies whose actions and desires may change the whole logistic system. The relation between network accessibility and company preferences should also be explored more thoroughly.

References

Ben-Akiva, M. and S.R. Lerman (1985) *Discrete Choice Analysis; Theory and Application to Travel Demand,* MIT-press

Becker, G. (1965) A Theory of the Allocation of Time, *Economic Journal* 75, 493-517

Fowkes, A.S. et. al. (1991) Investigating the Market for Inter-Modal Freight Technologies, *Transportation Research. Part A No.* 4, 1991.

Fridstrøm, L. and Madslien, A. (1995) *Engrosbedrifters valg av transportløsning,* Transportøkonomiskt Institutt, Oslo, TØI rapport 299/1995.

Hau, T. D. (1986) Distributional Cost-Benefit Analysis in Discrete Choice, *Journal of Transport Economics and Policy,* September 1986.

Jong, G. C. (1996) *Freight and coach value of time studies,* The Hague Consulting group. PTRC 1996.

Lancaster, K. (1971) *Consumer Demand,* Columbia University Press, New York & London 1971.

McFadden, D. (1981) Econometric Models of Probalistic Choice, *Structural Analysis od Discrete Data with Econometric Applications,* Manski, C.F. and McFadden, D. (Eds.) MIT Press, Cambridge, Massachuetts

Mohring, H. (1976) *Transportation Economics,* Ballinger Publishing Company, Cambridge Massachusetts, 1976.

Mortazavi, R. and Johansson, P. (1995) The Value of Travel Time: An Empirical Study Using Repeated Samples, Three Papers on the Economics of Recreation, Tourism and Property Rights, *Umeå Economic Studies* No. 396.

Ogwude, I.C. (1993) The Value of Transit Time in Industrial Freight Transportation in Nigeria, *International Journal of Transportation Economics,* October 1993

Oum, T.H. A Cross-Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada, *The Bell Journal of Economics,*

Small, K.A. and Rosen, H.S. (1981) Applied Welfare Economics with Discrete Choice Models, *Econometrica,* Vol 49, No. 1. 1981.

Small, K.A. (1992) *Urban Transportation Economics,* Harwood Academic Publishers, Switzerland.

Transek (1992) *Godskunders Transportmedelsval,* maj 1992.

Transek/Banverket (1990) *Godskunders Värderingar,* oktober 1990

Troung, T.P. and Hensher, D.A. (1985) Measurement of Travel Time Values and Opportunity Cost from a Discrete Choice Model, *The Economic Journal, June* 1985.

Troung, T.P. and Hensher, D.A. (1985) Valuation of Travel Time Savings, A Direct Experimental Approach, *Journal of Transport Economics and Policy, September* 1985

Winston, C.M. (1979) *A Dissagregated Qualitative Mode Choice Model for Intercity Freight Transportation,* Dissertation-thesis, MIT-press

Winston, C.M. (1981) A Dissagregated Model of the Demand for Intercity Freight Transportation, *Econometrica* Vol. 49, No. 1. 1981.

Winston, C.M. (1983) The Demand for Freight Transportation Models and Applications, *Transportation Research. Part A No. 6,* 1983

Zlatoper T.J. och Z. Austrian (1989) Freight transportation demand. A survey of recent econometric studies. *Transportation Research* 16, s. 27-46, 1989.