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Stated preference experiments in Switzerland.

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Abstract

Globalization and European integration increase the claim for better quality in freight transport and logistics services. The paper focuses on the evaluation of different quality attributes of transport services in a specific logistics context for a significant segment in the Swiss freight market. The paper is based on conjoint analysis, generated by discrete binary choices between alternatives of hypothetical transport services, described by a combination of four attributes articulated on different levels. The estimated results confirm the high importance of punctuality and avoidance of damages. It could also show the statistically significantly declining value of time with increasing distance.

Keywords

Freight transport, stated preference, discrete choice model, value of time, Switzerland

1. Introduction[1]

In the last twenty years, globalization and European integration have led to a substantial increase of freight transport that was further fuelled by cheaper communication and decreasing transport costs. This process is accompanied by a structural change towards lighter and more voluminous freight goods, generally shipped at higher frequency. New production concepts and spatial distribution processes have enhanced the significance of logistics and generated demand for high quality transport and logistics services. In this dynamic process transport networks become more and more congested, leading to time delays, unreliable delivery and damages. This creates a positive feedback on the demand for high quality services. The ambition of this paper therefore is to derive empirical estimates of the valuation of relevant service characteristics in freight transport based on a model of shippers' behaviour.

The behaviour of firms with respect to demand for transport and logistics services is poorly understood, however. While the literature on individual travel behaviour abounds (for a recent overview see e.g. Hensher 2001), and economic valuations of transport qualities other than time in passenger transport are increasingly offered (e.g. König et al. 2004), equivalent research on freight transport service demand is scarce.

Focussing on disaggregate models (for a broader overview see Regan and Garrido 2001) the literature distinguishes inventory based and behavioural model of a shipper's transport decision (Winston 1983, Regan and Garrido 2001). This is misleading in so far as both types of models try to model shipper's behaviour, though from a different perspective. Inventory based models consider the decision of the inventory manager and thus link the transport (and logistics) decision to the quantity choice of the firm. Under profit maximisation the firm chooses not only a transport mode but decides simultaneously on inventories, and produced (and shipped) shipped quantities (e.g. Baumol and Vinod 1970). Behavioural models concentrate mainly on the mode choice of the shippers. While they may integrate shipment size (e.g. Abdelwahab and Sargious 1992, Abdelwahab 1998), the interest is in modelling the behaviour of a logistics manager whose objective is to choose the utility maximizing transport mode.

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This paper proposes to model this latter decision, i.e. concentrate on the mode choice but takes as a rationale cost minimization rather than utility maximization, the latter not being satisfactory as a background for management decisions (if not for the purpose of modelling principal agent problems). Basing mode choice on cost minimization permits to bridge the gap to the inventory based models and derive the specification of the empirical variables from an inventory based cost function.

The empirical data for the present study has been produced by stated preference experiments with logistics managers. Compared to passenger transport stated preference analysis in the freight market is still in its infancy as underlined recently by Regan and Garrido (2001). This can be explained to a certain extent by the difficulties to create a significant sample and to deal with the extreme complexity. An interesting overview with national case studies can be found in Danielis (2002). In Switzerland, no representative national analysis on the value of time in freight transport is available, with the exception of one first attempt regarding the transalpine freight market (Maggi, Bolis, 1999). This study includes, besides time, quality attributes, such as punctuality and avoidance of damages, which become more and more important in the context of present logistics services.

In order to monetize the significance of quality attributes in the freight transport market the stated preference surveys were to a specific freight market segment and therefore its results are not representative for the entire Swiss freight market. While this permits to have stable a relatively homogeneous dataset and stable coefficients it limits the use of the derived monetary values for cost-benefit analysis of new infrastructure investments or other investments to improve the traffic conditions on Swiss roads. A critical analysis of the role and significance of the value of travel time savings in cost-benefit analysis and of the tendency to overestimate the value of time is given by Bergkvist (2001).

In Section 2 we present some theoretical considerations on shippers behaviour and derive an empirical model. Section 3 introduces the method of conjoint analysis or stated preference (commonly used as a synonym) and the sampling approach, focussed on a significant market segment, followed by a description of the companies and the typical transport relations, which constitute the reference of the experiments in Section 4. In Section 5 we present the results of the statistical analysis of the empirical data. In the final Section 6 we draw some conclusions.

2. Modelling shipper's transport mode choice

We model the choice of the logistics manager of a firm who minimizes cost of transport for a given shipment either on the distribution or on the receiving side by choosing an abstract mode of transport.[2] We will be using the term shipper independently from whether a mode choice is being made on the receiving or distribution side. This implies that we assume a logistics manager considering CIF pricing on the distribution side and FOB pricing on the receiver side (Winston 1981). The logistics manager is constrained in this decision by upper level choice of profit maximizing quantity and intermediate level decisions on warehousing, frequency and shipment size. As a consequence, it is sufficient to consider the short run decision of the choice of a transport mode. While this is usual in literature, reference is normally made to a utility function (objective function) of the decision maker motivated in general terms by cost or profit considerations (e.g. Bergqvist 2001).

The cost of transporting a given shipment over a certain distance (**d**) depends on the freight rate (**r**) which is in most countries and for any carrier a function in **d** (for a given weight and value). Three elements have to be added to the direct monetary cost of a shipment. A first one is the inventory cost (interest rate, depreciation etc.) for the time the goods are under way. Definig inventory cost per time unit (**t**) as (**u**) and assuming constant speed the cost of the mobile inventory is simply **ut**. A further cost factor is represented by the unreliability of the transport system, e.g. due to congested roads or lack of punctuality of trains. This requires the shipper to foresee either a buffer stock at destination - creating an additional inventory cost – or to negotiate a contract with the receiver containing a fine for late delivery. The second option is chosen here for illustrating cost minimization by the shipper.[3] Assuming an unknown constant fine (**L**) for late delivery[4] and writing ($\mathbf{P_L}$) for the probability of arriving late, the cost of late delivery will equal simply the expected value of the fine $\mathbf{P_L * L}$. Finally, we have a similar cost element caused by damage and pilferage during transport. Assuming again that the contract between shipper and receiver foresees a fine to be paid by the shipper

[2] The notion of an "abstract mode" has been introduced by Quandt and Baumol 1966. It seems appropriate in our context, given that earlier analysis in a similar context (Bolis and Maggi 2003) confirmed the absence of mode specific preferences from the shipper's part.

[3] Baumol and Vinod 1970 model the inventory cost as a function of transport time as a fraction of a year (t), frequency of shipment as the intervale between shipments as a fraction of a year (s), shipment size (T) and the probability of delivered quantity falling short of demanded quantity. Assuming a Poisson distribution of the demanded quantity, and setting k as the the value of the distribution table for a desired level of probability, the necessary safety stock becomes $k((s+t)T)^{1/2}$. (Baumol and Vinod 1970, 418-419)

[4] The extent of the delay is assumed to be irrelevant for the amount of the fine – "late is late".

in case of damage, the cost will be $\mathbf{P_D}$*$\mathbf{D}$ where ($\mathbf{P_D}$) stands for the probability of damage or pilferage and (**D**) stands for the value of the unknown damage which can be assumed without loss of generality to equal the value of the shipment. This gives the following cost function to be considered by the logistics manager for a given shipment:

$$\mathbf{C = r(d) + u*t + P_L*L + P_D*D} \qquad \mathbf{(1)}$$

Introducing this cost function in a binary choice made by the shipper among alternative abstract modes **i** and **j**, and making the usual assumption for a logit model about the distribution of unobserved errors, the probability of a specific shipper being observed in our experiment to choose mode **i** rather than **j** as a function of freight rate, distance, transport time and the probabilities of paying given fines for delay and damage, is:

$$\mathbf{P_i = 1 / \{1+ exp[r(d_i) - r(d_j) + u*(t_i - t_j) + L_i (P_{Li} - P_{Lj}) + D_i (P_{Di} - P_{Dj})]\}} \qquad \mathbf{(2)}$$

The parametrization of this function for the estimation of the discrete choice model is straightforward except for the freight rate. The freight rate for a given weight and value is normally composed of a fixed base rate and a decreasingly increasing charge as function of distance. Neglecting for simplicity the fixed part, and following König (2004) we write **r(d)** as $\mathbf{rd^{\varepsilon}}$. with $\mathbf{0 < \varepsilon < 1}$. We thus can write our model to be estimated as:

$$\mathbf{P_i = 1 / \{1+ exp[\alpha r(d_i^{\varepsilon} - d_j^{\varepsilon}) + \beta(t_i - t_j) + \gamma(P_{Li} - P_{Lj}) + \delta(P_{Di} - P_{Dj})]\}} \qquad \mathbf{(3)}$$

The distance dependent values of time, reliability and safety will be calculated in the usual way as:

$$\beta / \alpha \mathbf{d^{\varepsilon}} \quad \mathbf{= dC/dt / dC/dr} \quad \text{value of time} \qquad \mathbf{(4)}$$

$$\gamma / \alpha \mathbf{d^{\varepsilon}} \quad \mathbf{= dC/dP_L / dC/dr} \quad \text{value of reliability} \qquad \mathbf{(5)}$$

$$\delta / \alpha \mathbf{d^{\varepsilon}} \quad \mathbf{= dC/dP_D / dC/dr} \quad \text{value of safety} \qquad \mathbf{(6)}$$

Several comments have to be made. Having chosen as a rationale for the objective function the cost as perceived by the logistics manager, α has either to be restricted to equal 1, or the "valuation" of the freight rate by the decision maker has to be motivated. Under the first hypothesis, the value of time equals simply the (distance dependent) inventory cost,[5] and the

[5] When shipments are made at regular intervals, transport time does not affect the receipt of goods as long as punctuality is constant. Or as Baumol and Vinod (1970, p.415)) put it: "If a batch is shipped out weekly, a batch will also normally arrive at the terminus weekly, no matter whether the transit time is two weeks or three months."

values of reliability and safety equal the unknown fines. The second hypothesis, that we will follow here, implies that the logistics manager will evaluate proposed changes in transport cost with respect to its impacts on necessary and costly changes in inventories, frequencies and shipment size. As a consequence, time savings and increases in reliability and safety will be evaluated at the "net impact on cost" provoked by a change in the transport cost.

A second comment regards the derivative of cost with respect to transport time. Differences in transport time can be due either by to a difference in speed for a given distance, a different distance with common speed or differences in both speed and distance. Taking the partial derivative with respect to time as in (5) implies constant distance and hence increasing speed. The estimated value of time will thus be relevant for using in CBA regarding projects that increase speed on given links. For projects that imply a shorter distance, the derivative with respect to time would be:

$$\mathbf{r^*v^*\varepsilon/d} + \beta / \alpha\mathbf{d}^{\varepsilon} \qquad \mathbf{(7)}$$

where (**v**) stand for distance. The first term corresponds to the distance dependent tariff savings. We will report only the value of time in (5) in this study.

The specification chosen for estimating the binary choice model using LIMDEP software wa the following:

$$C = \beta_{p*}\left(\frac{Transportdistance}{Mean - transportdistance}\right)^{\varepsilon_{Dist}} * Price + \beta_z Time + \beta_s Damage + \beta_{Pu} Punctuality + \varepsilon \; .$$

3. The experiment

The research project is based on a standardised interview and a conjoint – or stated preference analysis for hypothetical transport services based on a computer experiment. The experiment consistently refers to a typical transport-relation chosen by the logistics managers. The logistics context of the transport relation was described by four variables, whereas the hypothetical transport services were characterized by four attributes (price, time, punctuality and avoidance of damage) according to the literature. Hence, the experiment was based on the following attributes and attribute levels.

Table 1 Quality attributes and their levels

Transport service				**Logistics context**		
Price	Avoidance of damage	Time	Punct-uality	Notice time	Mode	Frequency
-20.0%	98%	-20.0%	98%	Immediately	Truck	Daily
-10.0%	96%	-10.0%	95%	Same day	Rail	Every 2 days
0.0%	94%	0.0%	90%	Next day	combined	Every 4 days
+ 10.0%		+ 10.0%				weekly
+ 20.0%		+ 20.0%				

The four variables at the right hand side of the table, where used during the interview, introducing the experiment, in order to characterize the logistics context of the chosen typical transport relation. Originally, the logistics context was described by four different variables. The fourth variable referred to the possibility to trace and track the shipments. After all experiments it had to be recognised that this variable didn’t discriminate the different shippers and therefore could not help to improve the model. Meanwhile, the variables to describe the transport service were fully integrated in the experiment. The variance among different levels for price and time is large compared to real offers. The logistics managers after some explanations accepted the hypothetical character of these values. However, during the preparation of the experiment they stressed, that a similar scale was not acceptable for the other two variables. In fact, several of the interviewed logistics managers during the pre-test insisted to consider an even smaller scale, since the values refer to the percentage transport volume of the typical transports relation consigned with these characteristics (i.e. reliability and safety).

A principle assumption of the research project regards the relation between the transport service and the logistics context. The underlying hypothesis was that logistics managers evaluate the transport services in the context of the logistics context of a specific transport which may vary within the same company. Hence the evaluation of the transport service quality is not necessarily depending on the attributes of the company but on contracts between shipper and receiver regarding specific transports. For a tentatively more sophisticated treatment of interaction see Hensher (2003).

After having described the typical transport relation and its logistics context, the logistics managers were faced with the (binary) choice between two alternative and hypothetical transport services, each being defined by a combination of quality attributes at different levels. By the choice they made the logistics managers expressed their preference for one of the two combinations. The experiments were carried out with the commercial software CBC (Choice-Based Conjoint) by Sawthooth, 2003.

Figure 1 Example of a binary choice situation

Which of the following alternatives would you choose for the typical transport relation?

Transport price	**Price plus 10%**	**Present price**
Damage	**98% undamaged**	**94% undamaged**
Time	**10% longer**	**Present time**
Punctuality	**present**	**95%**

The basic assumption of the experiment is that the choice of a transport service alternative is based on the linear addition of preferences for single items (partial preferences). During the experiments these choices were repeated twenty times, as a rule for two typical transport relations. The collected data base is constituted by 66 valid experiments and 1320 binary choices, available for the statistical analysis.

In the light of the high cost of the field research in form of a stated-preference analysis and computer-based experiment in the transport market, the project had to be restricted to a relevant market segment. Thus, 35 logistics managers of medium and large companies of the food and wholesale sector finally agreed to join our sample. However, the logistics operators were asked to choose transport services on the supply - and distribution side using different transport modes for the experiment. Neither forwarders nor transport operators were included in the sample, since the evaluation of the quality aspects is meant to reflect the perspective of the “consumer” of transport services.

4. Descriptive results

The focus of the project was the market segment of wholesale and food. The sample is constituted mainly by medium and large companies. More than fifty percent of the investigated companies had more than 250 employees, exceeding by far the medium size of the Swiss firms. Therefore the sample is not representative for the chosen market segment as far as the company size is concerned. The main concern was to include companies with a wide range of transport requirements and a specialized logistics department with high experience (more than 500 shipments per week), a large number of different articles and a high number of suppliers as well as clients. These companies, however, outsource to a considerable degree logistics services. The tendency to outsource logistics services clearly increases with the declining strategic importance of these services as shown in the following table.

Table 2 Outsourced logistics services

Logistics services	**Number of companies in the sample**
Electronic data elaboration	3
Inventory control	5
Storage	10
Quality control	3
Packaging	7
Labelling	6
Transport	33

As a consequence of the high degree of outsourcing of the transport services the analysed companies dispose of relatively few own transport means. The following table indicates the type of transport means and the number of companies in the corresponding categories. The first cell, e.g., indicates that 19 companies do not own one single truck and only 3 companies have more than 50 trucks in their company fleet.

Table 3 Number of own account transport means

	0	<9	10-49	>50	Total
Trucks	19	5	7	3	34
Semi-trailer	27	6	0	2	35
Small truck < 3.5 tons	25	8	2	1	36
Swap bodies	25	0	0	0	25
Containers	34	1	0	0	35
Railwaggon	34	0	0	0	34

An essential feature of the whole experiment with the logistics managers regards the typical transport relation. In spite of our relatively homogenous sample, compared to other comparable studies, the variance in the typical transport relations is quite impressive. The following table summarises the most important characteristics of these transport relations.

Table 4 Characteristics of the typical transport relations

	Minimal value	Mean value	Median value	Maximum value
Weight of transport goods in kg	4	9’100	7’250	26’000
Value of transport good pro kg	0.02	24.6	4	300
Transport costs	8.6	869	580	5’500
Transport time	0.5	48	6	672
Value of shipment in CHF	60	106’500	20’000	2’220’400
Distance in km	18	695	189	8’000

This heterogenity in the chosen transport relations constitutes a major difficulty in the interpretation of the results and makes it particularly difficult to draw general conclusions on the basis of the investigated sample. A problem that can hardly be avoided in the analysis of disaggregated demand behaviour in the freight market.

5. Results

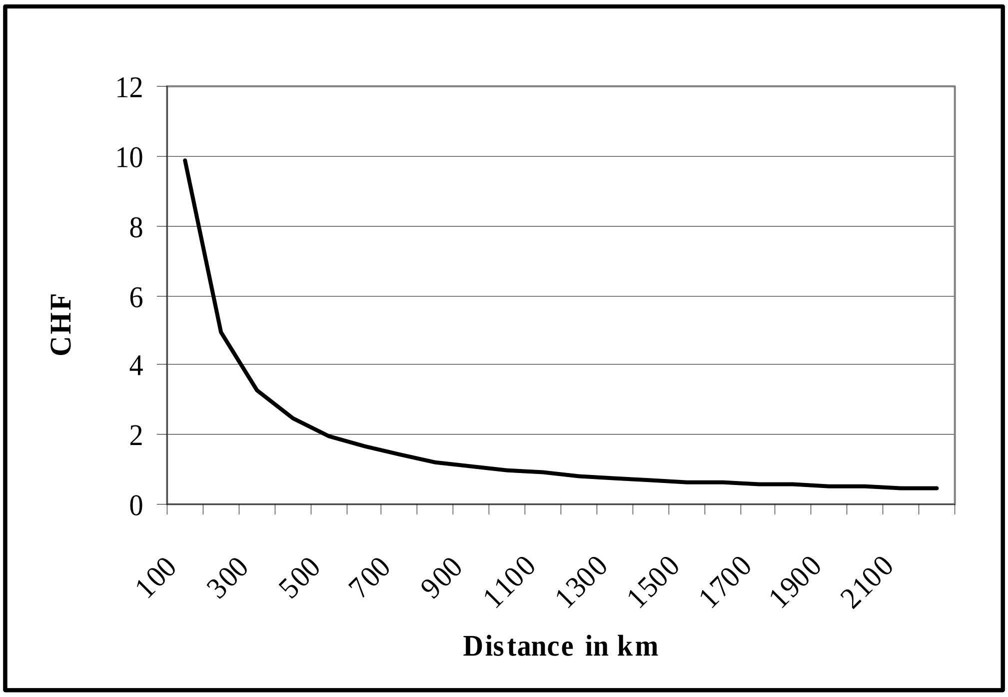
Table 5 Model estimations with and without elasticity parameter

Variables	Unit	Entire Sample: Binomial-Logit	Entire Sample: Elasticity-parameter
Price (t-ratio)	%	-3.173 (15.503)	-4.106 (-20.6713)
Time	%	-.4894 (-3.620)	-0.517 (-3.79733)
Avoidance of damage	%	41.402 (13.974)	42.523 (14.2033)
Punctuality	%	28.580 (9.994)	29.375 (-10.141)
Elasticity parameter			-0.846 (-4.504)
N		1320	1320
Log L		-573.763	-560.030
Log L (0)		-914.081	-914.954
Rho-square		0.369	0.388

All parameter values are statistically significant and present the correct sign. The introduction of an additional model specification with the elasticity parameter could improve the values the single parameters as well as the overall model fit, expressed by the higher value of the Rho-square and log likelihood. Within the results of single models the parameter values can not be compared directly, because they refer to different scales (Urban, 1993).

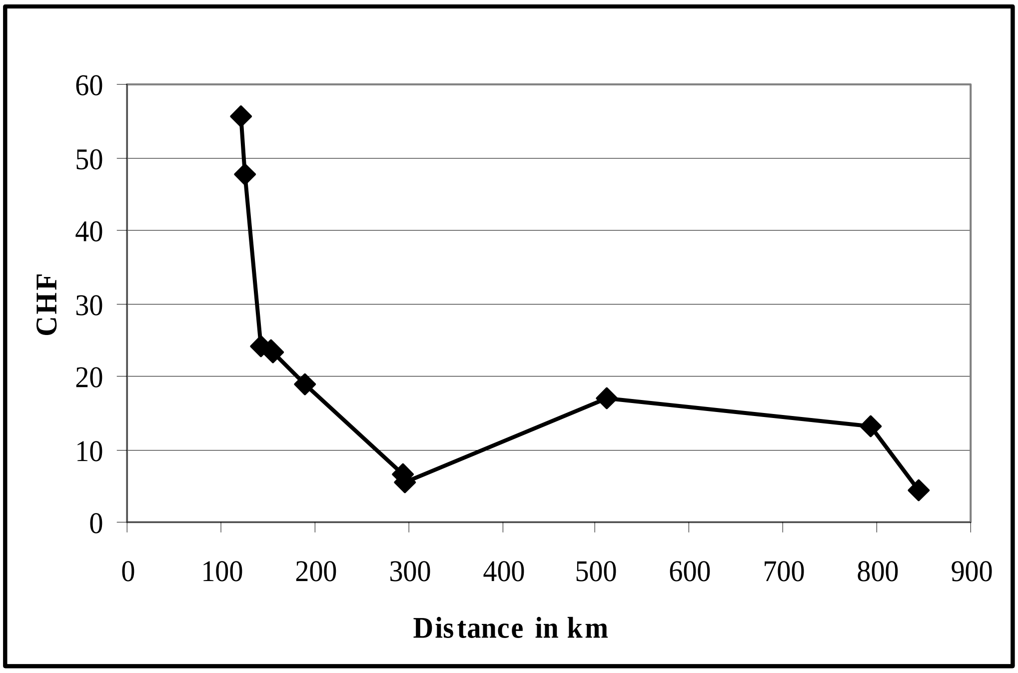
In the figure below, the elasticity parameter of the price variable contributes to showing up the relation between the value of time and the distance.

Figure 2 Relation between the distance and the value of time



A similar figure emerges for various segments introduced in our sample. It clearly underlines that the value of time sharply decreases with the distance. The segments are based on different criteria such as logistics context, transport mode, transport in the internal, the import and export market, each segment represented by a different mean distance.

Figure 3 Value of time for different market segments



A similar relationship could be identified neither for other quality attributes nor for the value of the freight goods. The monetary values of the three different quality attributes, as used in the SP-experiments, correspond to the declared willingness to pay for an improved quality of transport services for a shipment of 7.25 tons over a distance of 189 km:

Table 6 Monetary value the different service quality aspects

	Reduction of transport time	**Increase of punctuality**	**Avoidance of damages**
Willingness to pay	/ 1 hour	/ 1%	/ 1%
CHF	**16.19**	**48.23**	**78.01**
CHF/Tonne	**2.23**	**6.65**	**10.76**

The estimated value of time must not to be mixed up with the transport operator's costs. The saving of one hour of transport operational costs is worth considerably more than the estimated value of time, which reflects the shipper's perspective and is comparable with the values in international studies. These results cannot be applied to the whole freight transport market for several reasons: in particular, the lack of statistical data, which would bring about a classification of the typical transport relations and help determine to what degree they represent the transport market.

However, the results seem to be in line with the results of similar studies, cited by DeJong (2000), with the exception of Small et al. 1999, a study carried out in the United States. It was not possible to consult the original study and we ignore the precise reference of the study. In any case the indicated values seem to represent an outlier.

Table 7 Selected international studies with value of time estimations

Authors (Studie)	Year	VOT (in CHF)
Bergkvist/Westin (S)	1998	1.9 - 43.3
Small et al. (USA)	1999	261-400
Bergkvist/Westin (S)	2000	1.5
De Jong et. al. (F)	2001	7.5 – 16.5
DeJong/Rand (NL)	2004	25.3
Mean value in Europe		29.5

Source: DeJong, 2000.

6. Conclusions

The empirical study on the individual demand behaviour of logistics managers and the subsequent model estimation yield interesting results that are new for Switzerland. The study has clearly shown that shippers and their logistics managers evaluate quality attributes such as punctuality and avoidance of damages at least as highly as travel time savings.

An important result refers to the monetary values of the different quality attributes of transport services, which are much higher in the internal market than in the import and export segment, with its clearly longer average distances. The relation between the value of time and distance was confirmed when an elasticity parameter was introduced into the model. This result will have to be taken into account when defining a framework for the cost-benefit analysis of infrastructure investments or other measures for the improvement of road traffic conditions.

The study revealed no statistically significant relations between essential characteristics of the companies and their evaluation of quality attributes. This seems important in so far as the sample refers to a market segment, which is quite homogenous as compared to similar studies. This implies that the differences in the evaluations cannot be traced back to the characteristics of the company but rather stem from differing claims on transport service quality. However, in the scope of this study it is not possible to compare the evaluation of quality attributes among different productive sectors and the study fails to make statements on representative monetary values for the various quality attributes.

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