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A multi-criteria analysis of stated preferences among freight transport alternatives

Abstract: The paper presents a multi-criteria methodology for analysing stated preference data on freight transport alternatives defined in terms of transport attributes. The model used is the UTA model, which, on the basis of a preference ranking and a goal programming set-up, estimates an additive non-linear utility function made of linear segments. The method is applied to a set of individual stated preference data obtained from freight transport managers, who were interviewed about the importance they gave to six transport attributes: frequency, time, reliability, flexibility, loss, and cost.

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1. Introduction[1]

This paper presents a multi-criteria analysis of stated preference data, an approach we are experimenting with in the framework of a research trying to assess the relative importance of quality attributes in freight transportation, i.e. factors like reliability, frequency, losses, flexibility, and time. This research consists in a pilot study preparing a larger scale survey and research on the factors that determine the choice of a transport alternative and/or mode. Indeed, given the continuous growth of freight transports, the increasing congestion of roads and pollution, policy makers are attempting to promote a switch from trucking to other modes like inland waterways, short-sea shipping and rail, as well as combination of these modes and trucking. Thus, it is particularly interesting to analyse how that can be organised and promoted given the determinants of modal choice. Some useful information is available about freight transport price direct and cross elasticities, for instance in Abdelwahab (1998), NEI (1999) and Beuthe and al. (2001), but they hardly take enough into account the different qualitative dimensions of transportation. A stated preference approach certainly can provide additional useful information about the real potential of a policy of mode switching, by opening the possibility of assessing with decision makers the relative importance and value they give to quality attributes like reliability, carrier's flexibility, absence of losses, frequency and transport time.

Stated preference techniques are currently used in the field of transport economics, for analysing transport choices, particularly choices made by travellers. Much information about this field of enquiry and techniques can be found, for instance, in the recent Manual published by the U.K. Department of transport (2002). Over the last few years, a number of researches using that methodology have also been published in the field of freight transportation, and a some names certainly deserve to be mentioned here: Fowkes and Shingai, Bolis and Maggi, Fridstrom and Madslien, Maier and Bergman, all of them edited in the book by R Danielis (2002), but also Jovicic (1998), Matear and Gray (1993), NERA (1997), STRATEC (1999) and INRETS (2000), to name just a few. However, most of them limited their research to very specific transport alternatives, like the choice between trucking and rail intermodal transport along a corridor, the choice between an external carrier and own transport, or simply the value of time, etc. Moreover, samples are sometimes rather small given the number of explanatory

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variables that could play a role. Altogether, more research in this field is needed, particularly in the transport context of Belgium, and this is the reason that determined our involvement.

The techniques of interviews, which are necessary to elicit the decision makers preferences are rather well developed, as they are extensively used in many fields and particularly in marketing analyses. They still are somewhat delicate to use, because interviews must be adjusted to the problem at hand, the nature of the sample and… the available budget. The associated questionnaire, including its experimental design, also raises many problems. Finally, the modelling of the decision problem and the techniques used to analyse the data constitute another area of research and experimentation.

This paper starts by describing the questionnaire developed for this research and the experimental design that is used to elicit preferences from transport managers. Then, it presents the multi-criteria methodology of data analysis that we are experimenting with in the framework of the above research. This is the UTA multi-criteria approach of preference desaggregation of Jacquet-Lagrèze and Siskos (1978 and 1982), which relies on a goal programming model to evaluate an additive non-linear utility function from a preference ranking of alternatives. Our pilot survey is not yet entirely completed, so that we cannot venture in any serious econometric analysis of a sample, but this multi-criteria method allows to compute the attributes' weights and equivalent money values for individual decision makers. It will be seen that this method, rather unusual in the field, allows a better understanding of the interviewed individuals' preference system. At this stage of data gathering, it provides interesting insights in each decision making approach and a double check of the interviews. Another advantage of the method is that it estimates non-linear partial utility functions, whereas the most usual discrete choice models provide only a linear utility function with constant coefficients.

Thus, after this introduction, Section 2 gives the general framework of the stated preference interviews, the general questionnaire and the experimental design of the preference questions. Section 3 details the UTA model as it is applied in the paper, whereas Section 4 illustrates the methodology with some results obtained with data from a small set of interviewed firms.

A caveat before closing this introduction : the conventional terminology of utility function is used throughout the paper only for convenience. Indeed, it not obvious that a competent transport manager thinks in terms of maximizing any utility value. They probably rather try to minimize some sort of generalised cost integrating many internal and external logistic factors that are influenced by the set of transport attributes.

2. The questionnaire and the stated preference experiment

The stated preference data used in this paper are taken from a pilot survey of Belgian freight shippers, which is presently realised by members of a consortium of Belgian universities (Antwerp, Louvain, Ghent and Mons). The survey methodology and the questionnaire development are based on an extensive survey of the transport, marketing and statistical literature in the field. Among many other contributions, we can cite Danielis (2002), UK Department of Transport (2002), and Louvière et al. 2000). Some preliminary in-depth interviews of transport managers were also made. The questionnaire's feasibility was pre-tested and adjusted accordingly. In the end, it is a compromise between a desire to gather as much useful information as possible and the practical consideration of a survey constraints. As it was only a preparatory pilot survey, the choice of face-to-face interviews was made for the reason that it allowed the gathering of additional information in the course of the dialogue with the interviewee.

The target population of the survey is all the shippers of freight in all industries to destinations in Europe. The modes included are: rail, road, waterway, short-sea-shipping, and their inter- and multi-modal combinations. Given the small size of the country, no location of origin is excluded, even though some modes may have a reduced accessibility, like inland navigation in parts of Luxembourg province. Focusing on possible modal shifts, urban and distribution activities on short distances are excluded. There is a reduced opportunity over short distances for non-road transports, but no minimum transport distance is set for the survey, since, actually, there are cases of industrial goods transported over short distances by rail or by inland navigation.

The sample is drawn the list of all Belgian firms which have at least 20 employees. Given that this is a pilot survey, we have not chosen to proceed through random sampling, but opted for a representative quota sampling. The target normally should be that each category of commodity in the sample be in proportion to the NST-R shipment categories, that the tonnages be in proportion to the shipments by each mode, and that shipments from the different provinces be in proportion to their economic activities. However, this pilot survey of less than one hundred firms will not be able to match this target with any degree of precision.

The face-to-face interviews are based on a (paper) questionnaire made of four parts: first, general questions about the characteristics of the firm and, more specifically, the characteristics and transport organisation of the plant from which shipping flows originate (2.1); second, the description of a typical transport flow that is used as a reference transport for the stated preference experiment (2.2); third, the stated preference experiment that aims at eliciting the relative importance of the quality attributes (2.3); fourth, a set of questions about the transport manager's readiness to accept a modal switch for obtaining the alternatives preferred to the reference situation (2.4).

2.1 The characteristics of the shipping plant

- Question 1 concerns the coordinates of the plant, its economic activity code, plus the size of the firm measured by its turnover and labour force. Many of these items are filled in before the interview.
- Question 2 asks the plant's type of operation (production, wholesale merchant, logistic centre, etc.).
- Question 3 focuses on the decision making process for transport, whether the decosion is taken by the central management of the firm, the shipping plant, a forwarder, etc. This question is raised at three levels: the definition of strategic options, the decision on its characteristics, and its execution.
- Question 4 concerns the accessibility to the networks of waterways, railways, superhighways and harbours. Direct accessibility at the plant site and indirect accessibility in km are distinguished.
- Question 5 asks the level of transport budget, and its percentage of production costs as an indicator of the relative importance of the transport cost factor.
- Question 6 asks the percentage of clients located within 250 km, and their relative importance in in term of revenue.
- Question 7 asks the shipments total annual tonnage.
- Question 8 concerns the percentages of the annual tonnage shipped by the different transport modes or combination of modes.

2.2 The reference transport flow

This part of the questionnaire is focused on a typical transport flow from the plant, which will be the reference shipment for the stated preference experiment.

- Question 9 leads the interviewee to choose and describe a typical specific flow: the specific good, its origin and destination, the distance, the annual tonnage, the shipments size and frequency, the type of consignee. It also asks the value of the transported good, according to cost categories segmented with respect to value/weight ratios.
- Question 10 concerns the type of transport good category (bulk or containerised,, dangerous or not, dry or fluid, reefer or not) and the chosen mode (or combination of modes); it also asks whether there are specific circumstances about that flow that may condition its organisation (network access, loading / unloading equipment, goods fragility, etc.), how transport is managed, and under which contractual conditions.
- Question 11 asks to describe the typical flow in terms of its transport attributes: This concrete information is essential for an analytical interpretation of the preference ranking provided by the stated preference experiment. On the basis of the literature as well as some in-depth shippers' interviews, and considering an acceptable level of complexity of the interview task, six attributes are selected for defining the transport alternatives submitted to the shipper. These attributes are defined in the following way:
    - COST, i.e. out-of-pocket cost for transport, including loading and unloading;
    - TIME, i.e. door-to-door transport time, including loading and unloading;
    - LOSS as the % of commercial value lost from damages, stealing and accidents;
    - FREQUENCY of service per week proposed by the carrier or the forwarder;
    - RELIABILITY as the % of deliveries at the scheduled time;
    - FLEXIBILITY as the % of times non-programmed shipments are executed without undue delay.

  Some of the criteria are defined in % of occurrences in order to encompass the idea of probability or risk affecting these criteria. In the same question, it is also asked to indicate whether some other relevant factors are taken into account.

- Question 12 asks to give a weight of relative importance to all those factors as far as this specific flow is concerned.

2.3 The stated preference experiment

This experiment is based on an orthogonal design of 25 transport alternatives defined by various levels of the six main attributes (Addelman, 1962). Thus, it will focus on the main effects of attributes, and set aside their interactions. Given available statistical evidence and the main forecasting purpose of our research, this restriction seems appropriate. The attributes are defined as above, but their levels are given in percentages of variations with respect to the status quo transport solution (alternative 1), which is included among the 25 alternatives. This specification allows the use of the same set of alternatives in all interviews[2]. Moreover, it clearly defines the appropriate reference situation from which a potential modal switch should be envisaged (Department for Transport, 2002, Ch.12). Each alternative is presented on a separate card with its full profile of factors. Part of the set of alternatives is presented in Table 1. A full profile presentation is particularly recommended when the purpose is to identify the relative importance of qualitative attributes for hypothetical new transport solutions.

The respondent is then asked to rank them by considering each alternative's full profile. To do so, it is suggested to proceed in two steps: first, to make up three stacks divided on the basis of a rough degree of preference; second, to rank the alternatives inside each class (with always the possibility of rearranging the stacks).

Given that the interviews are face-to-face with the possibility of helping the decision maker and listening to his/her oral comments, some additional information is gathered. Likewise, the interviewer observation of preference ranking provides a better understanding of its process, as well as insights into whether the decision maker ranks according to a lexicographic order or uses threshold values in assessing alternatives. These observations are useful for interpreting the individual decision maker's preferences and checking the results of the multi-criteria analysis.

[2] In some cases, the status quo may very well have an attribute with value close or equal to 100% (or 0%). This would constraint a positive % variation (or negative one). Such a possible situation is pointed out to the decision maker who should take it into account in his / her preference ranking.

Table 1 : Some examples of full profile alternatives

	Frequency	Time	Reliability	Flexibility	Loss	Cost
1	0%	0%	0%	0%	0%	0%
2	0%	10%	10%	20%	-10%	-20%
3	0%	20%	20%	-20%	10%	-10%
4	0%	-10%	-10%	10%	-20%	20%
5	0%	-20%	-20%	-10%	20%	10%
6	10%	0%	10%	10%	10%	10%
-	-	-	-	-	-	-
15	20%	-20%	10%	0%	-20%	-10%
16	-10%	0%	-10%	-10%	-10%	-10%
17	-10%	10%	-20%	0%	10%	20%
-	-	-	-	-	-	-
23	-20%	20%	10%	-10%	0%	20%
24	-20%	-10%	20%	0%	-10%	10%
25	-20%	-20%	-10%	20%	10%	0%

2.4 Modal switch behaviour

It must be underlined that none of the alternatives, except the status quo, is characterised by a specific mode use, though they do not necessarily refer to the same mode as the status quo, since they are hypothetical alternatives. Hence, the stated preference experiment does not explicitly introduce any mode choice; it just provides an order of preference among alternatives without any reference to a mode. As it is likely that some alternatives will be preferred to the status quo solution, we can presume that, normally, such preferred solutions would be chosen if they were available without any modal switch, but we cannot infer from the preference order that a modal shift, if needed, would be accepted. In order to find out whether some alternatives preferred to the status quo would be chosen even if they required a modal shift, some additional questions are raised in the fourth part of the survey.

- Question 13 asks whether the decision maker has in the past considered the possibility of switching mode, and, in that case, which mode was considered.
- Question 14 asks whether the decision mode would accept to switch mode if one of his preferred alternatives was made available, and, in that case, which mode would he/she choose.

- Question 15 asks whether there would be switching difficulties specific to the various modes that could be envisaged.
- For the most likely alternative mode, Question 16 asks whether these difficulties would be minor, important and costly, or insuperable.
- In case of willingness to switch mode, Question 17 asks whether it would involve an investment in equipment or infrastructure.
- In case of unwillingness, Question 18 asks to indicate the variations of the attributes levels that would be required in order to bring about a modal shift.

This last part of the survey is not analysed in the present paper[3]. Only some of the individual preference ranking data will be used to illustrate the multi-criteria methodology.

3. The UTA model

The problem is to compare, rank and value a set of actions, or choice alternatives, with respect to *N* different criteria which measure the utility of these alternatives. The measurements of these alternatives are given by the vector $g(a) = (g_1(a), g_2(a), \ldots, g_N(a))$ for any project **a** belonging to A. As an example, for a highway project, the $g_i(a)$'s could be the cost-benefit ratio, its favourable impact on safety, on environment, etc. In our case, the criteria will be the characteristics of the transport solutions under consideration: their Cost, Reliability, Frequency, Flexibility, Time, and Safety. These characteristics were discussed and defined in Section 2.

The model assumes the existence of a utility function:

$$U(g(a))=U(g_1(a),g_2(a),\ldots,g_N(a)), \tag{1}$$

which satisfies the classic axioms of decision theory, namely the axioms of comparability, reflexivity, transitivity of choices, continuity and strict dominance.

The utility function is additive,

$$U(g(a)) = \sum_{i=1}^{N} u_i(g_i(a)) \tag{2}$$

[3] This part of the survey (involving a modal shift) could very well provide different estimates values, since there is some statistical evidence that estimates derived from a modal split analysis may differ from those derived from a single mode analysis.

with $u_i(g_i) \geq 0$ et $\frac{du_i}{dg_i} > 0$.

The additive function implies in particular that the partial utility of a criterion $u_i(g_i(a))$ depends only on the level of that particular criterion[4]. This function provides an aggregation of the criteria in a common index to compare and value the alternatives under consideration. It ranks the project in a complete weak order *R*: if *P* indicates a strict preference and *I* the indifference between two projects a and b, then

$$U[\mathbf{g}(a)] > U[\mathbf{g}(b)] \Leftrightarrow a\,P\,b \qquad (3)$$

$$U[\mathbf{g}(a)] = U[\mathbf{g}(b)] \Leftrightarrow a\,I\,b \qquad (4)$$

The UTA method, proposed initially by JACQUET-LAGREZE and SISKOS (1978 and 1982), estimates the function U on a set of reference alternatives projects A, by the method of linear goal programming proposed by CHARNES and COOPER (1961 and 1977), which provides an approximation by linear intervals of a non-linear function.

In order to apply that method, the field of variation of each criterion $\left[g_{i^*}, g_i^*\right]$, defined by its least favourable value of that criterion $\left(g_{i^*}\right)$ and its best value $\left(g_i^*\right)$, is divided in α_i equal intervals $\left[g_i^j, g_i^{j+1}\right]$. The variables to be estimated by the program are the partial utilities at these bounds, say $u_i(g_i^j)$. The utility at intermediate values of the criteria are given by linear interpolation. Thus, for $g_i(a) \in \left[g_i^j, g_i^{j+1}\right]$,

$$u_i\left[g_i(a)\right] = u_i(g_i^j) + \frac{g_i(a) - g_i^j}{g_i^{j+1} - g_i^j}\left[u_i(g_i^{j+1}) - u_i(g_i^j)\right]. \qquad (5)$$

For each pair of projects (a, b) belonging to A', the decision-maker must express his/her preferences or indifferences. Under the version proposed by Despotis et al (1990), so-called UTASTAR version, the results of these comparisons are introduced as constraints consistent with conditions (3) and (4), i.e.

$$\sum_{i=1}^{N}\left\{u_i(g_i(a)) - u_i(g_i(b))\right\} + \sigma^+(a) - \sigma^-(a) - \sigma^+(b) + \sigma^-(b) \geq \delta \quad \Leftrightarrow a\,P\,b \qquad (6)$$

$$\sum_{i=1}^{N}\left\{u_i(g_i(a)) - u_i(g_i(b))\right\} + \sigma^+(a) - \sigma^-(a) - \sigma^+(b) + \sigma^-(b) = 0 \quad \Leftrightarrow a\,I\,b \qquad (7)$$

[4] For a discussion about the additive utility functions see Keeney and Raiffa (1976) and Fishburn (1967)).

with all σ^+ and $\sigma^- \geq 0$.

σ^+ corresponds to a positive error with respect to the difference between utility levels, whereas σ^- indicates a negative error. These errors are all non-negative, they represent the possible errors of an action's utility estimation. The objective function F to be minimised is the sum of these errors:

$$F = \sum_{a \in A'} \left[\sigma^+(a) + \sigma^-(a) \right]$$

The parameter δ on the right side of the inequality (6) must be strictly positive. Its value can very well influence the solution of the program. Hence, in the course of estimation, it must not initially be given a high value (Beuthe and Scannella, 1996 and 2001). The hypothesis that the partial utilities increase with the value of the criteria imposes a series of additional constraints:

$$u_i(g_i^{j+1}) - u_i(g_i^j) \geq s_i \qquad j=1,2,...,\alpha_i\ ,\ i=1,2,...,N \tag{8}$$

where s_i must be (strictly) positive. Like for δ, it is better to give it initially a small value. Finally the partial utilities are normalised by the conditions

$$\sum_{i=1}^{N} u_i(g_i^*) = 1\ , \tag{9}$$

$$\text{and} \quad u_i(g_{i^*}) = 0 \quad \forall\ i \tag{10}$$

Equation (9) indicates that the values of $u_i(g_i^*)$'s, the criteria's utilities at their highest levels, correspond to the criteria's relative weights in the utility function.

Putting together all these elements, the following linear program is obtained:

$$\text{MIN} \quad F = \sum_{a \in A'} \left[\sigma^+(a) + \sigma^-(a) \right]$$

subject to:

$$\sum_{i=1}^{N} \{ u_i(g_i(a)) - u_i(g_i(b)) \} + \sigma^+(a) - \sigma^-(a) - \sigma^+(b) + \sigma^-(b) \geq \delta \quad \Leftrightarrow \text{a } P \text{ b} \tag{6}$$

$$\sum_{i=1}^{N}\{u_i(g_i(a))-u_i(g_i(b))\}+\sigma^+(a)-\sigma^-(a)-\sigma^+(b)+\sigma^-(b)=0 \quad \Leftrightarrow \text{a } I \text{ b} \tag{7}$$

$$u_i(g_i^{j+1})-u_i(g_i^j)\geq s_i \qquad \forall \text{ i}, \ \forall \text{ j} \tag{8}$$

$$\sum_{i=1}^{N}u_i(g_i^*)=1 \tag{9}$$

$$u_i(g_{i^*})=0 \qquad \forall \text{ i} \tag{10}$$

$$\sigma^+(a)\geq 0, \sigma^-(a)\geq 0 \quad \geq 0 \qquad \forall \text{ a} \in \text{A'} \tag{11}$$

$$u_i(g_i^j)\geq 0 \qquad \forall \text{ i}, \ \forall \text{ j}, \tag{12}$$

where the relation (5) is used to calculate the utilities of the $g_i(a)$ between two consecutive bounds. This is the basic UTA-UTASTAR model that we shall use. The interested reader may find a few other specifications as well as a set of comparative simulations in Beuthe and Scannella (1996 and 2001). Some of these specifications include additional constraints for handling further information that may be given by the decision maker.

The program above may have two types of solution: either all errors have zero values and F = 0, or some errors are positive and F > 0. In this second case, there does not exist a non-linear additive utility function that perfectly represents the preferences expressed by the decision maker. If we exclude the case of a decision maker who would be unable to reasonably compare the projects or who would be irrational in the sense of exhibiting intransitive preferences, the presence of errors may indicate that the decision maker preferences are characterised by partial utilities which are not independent of each other or which are not monotonically increasing. But, it may also be the case, more simply, that the intervals chosen should have been more numerous or defined in a different way.

The specification of an additive function and its derivation from separate assessments of partial function supposes an assumption of preferential independence. Its means that, if two projects are characterised by the same values for some criteria, the preferences between them depend only on the values taken by the other criteria. How much this hypothesis is acceptable in practical applications may vary from case to case. von Winterfeldt and Edwards (1973) are of the opinion that an additive function could be used as a good approximation. Indeed an additive function of non-linear partial utility functions is quite a flexible specification, and it can provide an estimation that implicitly takes into account a certain degree of interdependence among criteria. Stewart (1995) empirically demonstrated that it was indeed a robust specification. Furthermore, through a set of simulations, Beuthe and Scannella (2001) showed that the UTA model is quite able to obtain useful results with F equal or close to 0, even in case of interdependence between criteria.

Whether F equals zero or not, the program's solution may not be unique, as it is often the case in linear programming. This problem must then be solved by a post-optimality analysis of results. Jacquet-Lagrèze and Siskos (1978) have simply proposed to use a function which is the average of the extreme optimal functions obtained from a sensitivity analysis applied on the last bounds of each criterion. This sensitivity analysis is made with an additional constraint

$$\sum_{a \in A'} \sigma(a) \leq F^* + \theta \ , \qquad (13)$$

where θ is a small positive number. This procedure was shown to provide a practical and efficient method of estimation.

To conclude, this is a multi-criteria model specifically designed to derive utility functions of the basis of ranking data. It is, thus, particularly appropriate for our purpose.

4. Intermediary results of the multi-criteria analysis

Even though the size of this exploratory survey will not go beyond 100 interviews, it will permit the use of some of the classical econometric tools for analysing discrete choices among transport alternatives: different types of probit and logit models, and hedonic analysis of transport cost over qualitative attributes and other explanatory variables. The number of interviews at this time is not sufficient to seriously attempt such analyses. However, we can already apply the UTA multi-criteria analysis to individual preference observations. This task was performed with the MUSTARD software (Scannella, 2001, Scannella and Beuthe, 2001 and 2002).

Its use can be illustrated with several cases of firms from various industrial sectors, as exhibited in Table 2. This table shows that transport cost is the most important factor in seven cases out of eight. The other factors take some importance in one or two cases according to the particular circumstances of the transport; otherwise they receive small weights. For instance, time and reliability are important for the textile firm and the producer of electronics, which ship over rather long distances. Reliability, flexibility and absence or losses appear important for the pharmaceutical firm, which seems ready to pay for it. The absence of loss is very important for one of the steel making firm shipping by waterway. Obviously, these comments are just descriptive of a few particular situations. A serious analysis of possible explanatory factors can only be performed on a sample of meaningful size, and also with the help of appropriate econometric techniques. That will be the next task starting as soon as the survey is completed, but it is not this paper's subject .

Table 2: Relative weights of attributes

Attributes	Steel multim. 991 km 240 hours C= .038	Steel waterway 404 km 55 hours C= .017	Textile multim. 2104 km 120 hours C= .11	Electron. road 800 km 48 hours C= .12	Chemical rail 1200 km 48 hours C= .002	Cement road 123 km 3 hours C= .25	Packing road 500 km 10 hours C= .16	Pharmacy road 240 km 24 hours C= .37
Frequency	**.007**	**.003**	**.081**	**.174**	**.002**	**.001**	**.003**	**.076**
Time	**.029**	**.008**	**.267**	**.360**	**.001**	**.001**	**0**	**.045**
Reliability	**.114**	**.001**	**.145**	**.139**	**.009**	**.011**	**.066**	**.358**
Flexibility	**.042**	**.004**	**.060**	**.069**	**.002**	**.002**	**.002**	**.127**
Loss	**.090**	**.327**	**.146**	**.043**	**.001**	**0**	**.001**	**.187**
Cost	**.723**	**.658**	**.301**	**.215**	**.985**	**.985**	**.928**	**.207**
F=Σ errors	**.009**	**.345**	**.163**	**.225**	**.011**	**.021**	**.011**	**.409**
Kendall	**.972**	**.947**	**.933**	**.962**	**.889**	**.945**	**.976**	**.930**

Note: C corresponds to the cost per tonne/km.
Source: computed from data gathered by FUCAM, RUG, UA et UCL

Meantime, it is still interesting to further analyse a particular case, in order to illustrate the potential of this multi-criteria methodology for assessing the qualitative factors' equivalent money value. Let us take the case of the steel making plant using a multi-modal solution (barge, rail, truck) for transporting coils towards Italy over a distance of 991 km. As can be seen in Table 2, the estimated weights of the additive decision function were: 0.007 for Frequency, 0.029 for Time, 0.114 for Reliability, 0.043 for Flexibility, 0.084 for Loss and 0.723 for Cost. Five alternatives were deemed preferable to the status quo solution, and, in the last part of the questionnaire, the decision maker expressed the intention of switching mode if they would be made available.

As you will remember, the UTA model permits the estimation of non-linear functions made of a number of linear segments. The following Figures 1 to 5 illustrate the partial utility functions estimated by MUSTARD for the various attributes but one, i.e. frequency. In effect, this particular attribute with a negligible weight had an entirely flat partial function. Hence, only the five other functions are illustrated here. To well understand these graphs, note that:

- the abscissa scale for the attributes is centred around the status quo value of a zero percentage of variation;
- for the Time, Loss and Cost attributes, the abscissas have been defined in negative percentages of increase, in order that a higher level on the scale correspond to a more favourable level. Hence, their utilities are increasing with the attributes' values;
- the utilities are scaled with respect to a zero utility level at the status quo point where there is a 0% variation.

Figure 1: Partial utility function of Time (weight: .029)

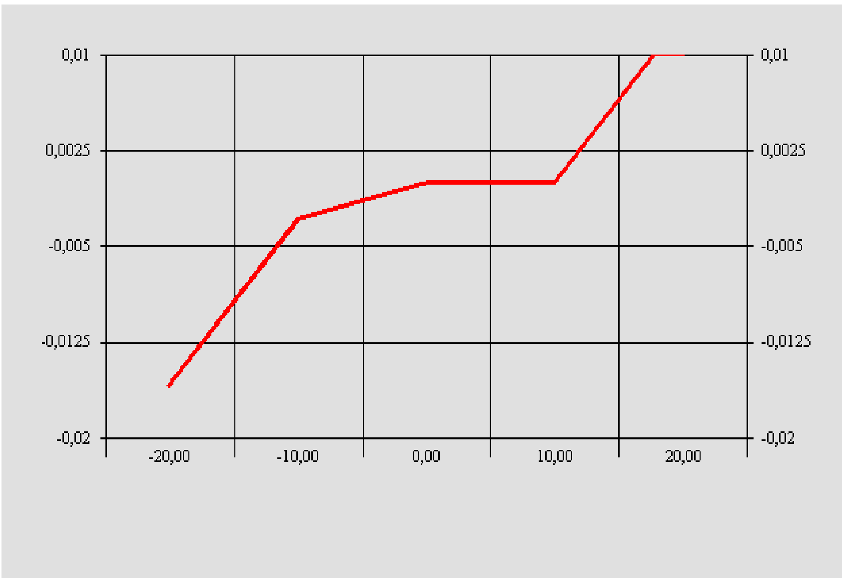


Figure 2: Partial utility function of Reliability (weight: .114)

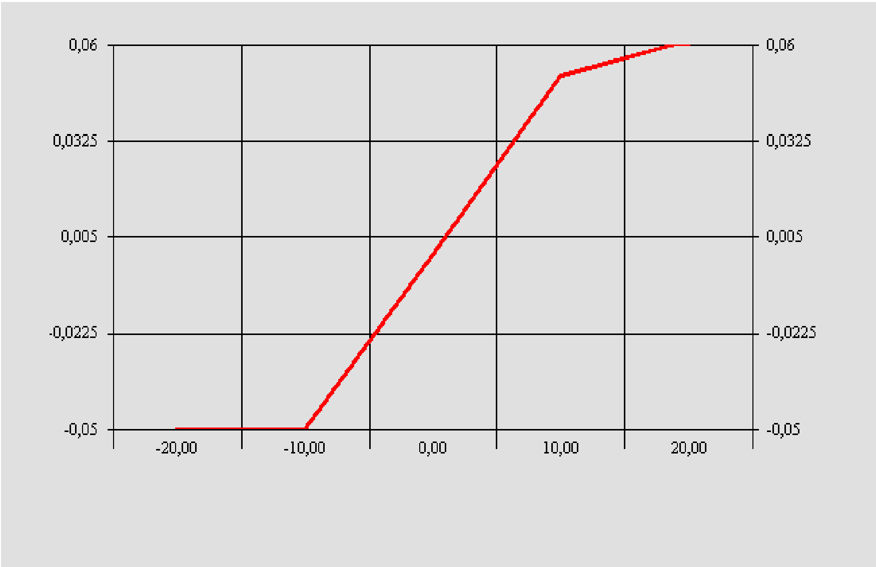


Figure 3: Partial utility function of Flexibility (weight: .043)

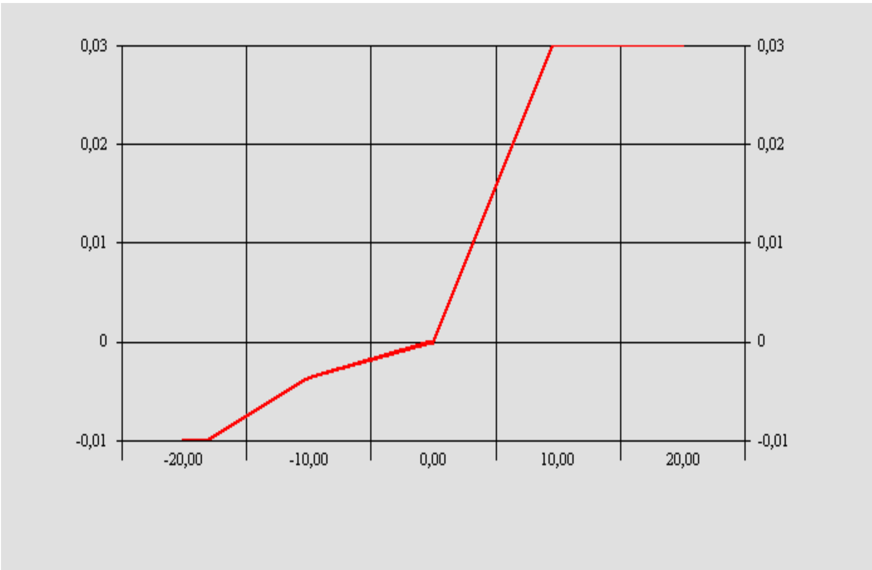


Figure 4: Partial 'utility' function of Loss (weight: .084)

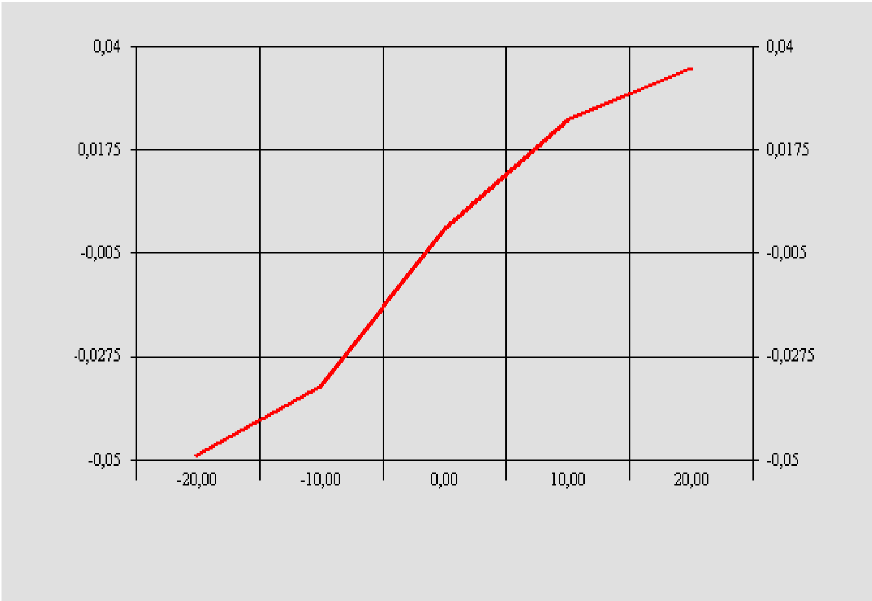
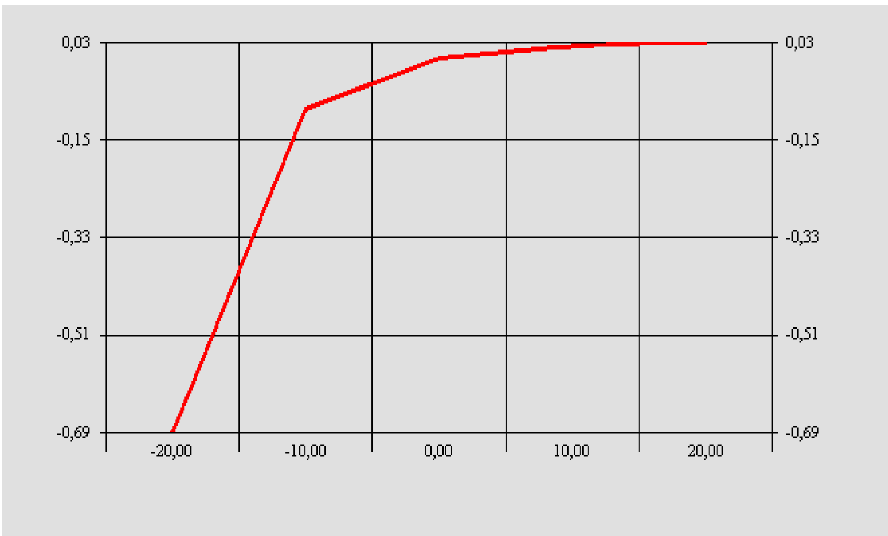


Figure 5 : Partial 'utility' function of Cost (weight: .722)



The presentation of the functions on similar size graphs should not lead us to forget the small weights affecting some of these attributes that hardly play any role in the actual decision making. Actually, a further computation of the same UTA model with a more strict specification, the so called Quasi-UTA specification (Scannella, 2001) that imposes a function that is either strictly concave or convex (or linear), leads to even smaller weights for all attributes but for Cost, which receives a weight of .951. Then, the Cost's utility function simply jumps from the –20 to the –10 level, and remains horizontally flat thereafter. Naturally, such a specification leads to a loss of accuracy, but it is not sizable in this case, since the sum of errors increases from .009 to .05, and the Kendall coefficient decreases only from .997 to .923. Hence, it is quite clear that cost is the major factor in the transport manager's decision, and that whereas he/she would be ready to accept a 10 % increase in price for an improvement of the service quality, there would be a high reluctance to go beyond that level.

An attractive feature of this non-linear methodology is that it allows the computation of different money equivalent values for an increase and a decrease of an attribute from the status quo level, i.e. different willingness to pay and willingness to accept compensation. For example, the steel making plant would appear ready to pay an additional .07 EURO per tonne for a gain of one day over the present time of ten days, but would demand a compensation, or a reduction, of 2 EURO for a one day increase in transport time. Furthermore, for a one percent improvement in reliability the firm would be ready to pay .08 EURO more per tonne, whereas, a one percent loss in reliability would justify a reduction of 1.7 EURO per tonne.

4. Conclusion

This is a research in progress, and it is too early to draw definite conclusions on the use of this methodology. Let us tentatively state that, this multicriteria tool provides some interesting insight on the preference system of each decision maker, and a double-checking of the stated preference order through the levels of the Kendall coefficient and errors. It also directly provides equivalent money values of the willingness to pay and the willingness to accept compensation. These, as well as the basic weights, can be averaged over the samples to have a more general view of the role played by the transport attributes in various industries and locations. Naturally, this method can also provide a global money equivalent value for each alternative as seen by the different transport managers. Such estimates may reveal itself a useful input in some ulterior econometric modelling.

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