EJTIR

Issue 16(1), 2016
pp. 23-37
ISSN: 1567-7141
tlo.tbm.tudelft.nl/ejtir

Use of discrete choice to obtain urban freight evaluation data

Jesús Muñuzuri[1]
School of Engineering, University of Seville, Spain.

José Guadix[2]
School of Engineering, University of Seville, Spain.

Pablo Cortés[3]
School of Engineering, University of Seville, Spain.

Luis Onieva[4]
School of Engineering, University of Seville, Spain.

The ex-ante evaluation of urban freight solutions is a complex task, due to the interference of different stakeholder groups with different views and objectives. The multi-actor multi-criteria methods have developed as a response to this scenario, but the determination of the weights required by them remains an unclear and controversial task. We propose the use of discrete choice methods as a powerful tool to confront these multi-faced evaluation problems, since the resulting surveys are flexible and easy to respond, and do not give away the final quantitative results. We have applied this methodology to the selection of urban freight solutions in the city of Seville, in Spain, followed by the determination of the relative weights associated to different objectives, both analyses carried out from the side of the carriers stakeholder group.

Keywords: *city logistics, evaluation, MAMCA, discrete choice.*

1. Introduction: evaluation techniques for city logistics projects

The evaluation of transport-related projects has been for a long time a source of debate, and often controversy, in many European countries. Even though there is unanimous agreement on the need to obtain some kind of quantification of the expected results of transport infrastructure investments (Geurs and van Wee, 2004), the appropriate procedures and methodologies to obtain them are far from being agreed upon (Bristow and Nellthorp, 2000). Practically each European country has a different approach towards this evaluation process, taking into account different impacts and calculating different indicators, but the analytical methodologies basically fall into three main categories: cost-benefit analysis, cost-effectiveness analysis and multi-criteria decision analysis (Browne and Ryan, 2011).

When it comes to urban freight transport, the variety of actors involved (Lindholm and Browne, 2013; Macharis et al, 2015) and the need to include at the same time economic, social and environmental impacts (Behrends et al, 2008) has led the way towards a generalization of the multi-criteria approach (Keeney and Raiffa, 1976), despite some examples of the applicability of the cost-benefit analysis when economic feasibility is the key factor in the decision-making

[1] A: CM Descubrimientos, s/n, 41092 Seville, Spain T: +34 954487205 F: +34 954487248 E: munuzuri@us.es
[2] A: CM Descubrimientos, s/n, 41092 Seville, Spain T: +34 954487389 F: +34 954487248 E: guadix@us.es
[3] A: CM Descubrimientos, s/n, 41092 Seville, Spain T: +34 954486153 F: +34 954487248 E: pca@us.es
[4] A: CM Descubrimientos, s/n, 41092 Seville, Spain T: +34 954486042 F: +34 954487248 E: onieva@us.es

process (Van Duin et al, 2008). These examples are nevertheless clearly outnumbered by the applications of multi-criteria analysis for evaluating city logistics projects and policies, since the early years of the 21st century. Those early works set the basis of the methodology, comprising the identification of goals and objectives, the determination of criteria and the construction of evaluation matrices (Thompson and Hassall, 2005). Also, the need to include different stakeholder groups, like carriers, shippers, residents or administrators, each with different views and objectives, was also made clear (Taniguchi and Tamagawa, 2005).

These approaches were further developed with the formulation of the multi-actor multi-criteria analysis (MAMCA) methodology (Macharis, 2009; Macharis et al, 2014). This procedure is based on an evaluation matrix where a multi-criteria analysis is formulated independently for each stakeholder group, thus accounting for the fact that different groups will usually have a different view on the evaluated initiatives. The evaluation objectives, and also the weight for the different objectives and evaluation criteria, are therefore different for each stakeholder group.

It is precisely the influence of the set of quantitative parameters on the outcome of the analysis what has earned multi-criteria analysis its main criticisms. There is no generally accepted set of objectives for each stakeholder group (Tamagawa et al, 2010; Macharis et al, 2010), and furthermore there is no standard procedure to determine the weights for the different evaluation criteria (Sayers et al, 2003). The determination of those weights is often left to the opinion of the analysts, and the complexity and multi-dimensionality of the evaluation data will tend to obscure whether or not the decisions taken in the same domain are mutually consistent.

The most usual technique employed to help the analyst determine the set of evaluation weights is AHP (Saaty, 1980), but also other multi-criteria approaches have sought to overcome this difficulty. For example, the ELECTRE methodology (Leyva-López and Fernández-González, 2003) establishes a preference matrix for ranking actions asking the decision makers to assign weights of relative importance to each criterion and then determining threshold reference levels using the top and bottom 15%, also accounting for the fact that the best choice is not the same for each decision maker. The TOPSIS method (Hwang and Yoon, 1981; Awashti and Chauhan, 2012) is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. The PROMETHEE system (Brans and Marechal, 2005) gives the analyst total freedom to determine the weights, considering the deviation between the evaluations of two alternatives on each particular criterion. Other analysts have turned to fuzzy approaches (Khalili-Damghani and Sadi-Nezhad, 2013), using linguistic terms like “equally important” or “partially more important” to rank criteria, and finally others have skipped the weight determination step, assigning importance ratios from 0 to 3 to the different evaluation variables (Patier and Browne, 2010).

Nevertheless, we believe that, despite its technical drawbacks, the multi-criteria approach still remains the best possible option for the evaluation of city logistics innovations. It is true that the outcome of the analysis is very much biased by the often subjective determination of the weights set, but still this approach confronts the analyst with his/her own decisions, and makes those decisions completely transparent. If the weights state that a given criterion is twice as important as another one, the analyst should be able to explain why this is so. This is why, in an effort to provide the multi-criteria evaluator with additional weaponry, we present here the application of discrete choice techniques to the problem of determining the evaluation weights.

The following section describes briefly the discrete choice theory and its applications to city logistics, and the remainder of the paper contains a detailed description of the type of analysis we propose and its application to the city of Seville, in Spain. This application is somewhat limited by the fact that discrete choice models are designed for application to massive survey results, where a large number of respondents provide data for the fitting of the model. In our case, the discrete choice surveys were applied to a small number of respondents, but our perception is that the methodological soundness of the technique holds, and the results obtained are at least comparable to those provided by other small-panel techniques like AHP.

2. Discrete choice in city logistics

Discrete choice models (McFadden, 1986) represent a powerful operative tool to capture the choice process followed by individuals. In general, the basic postulate establishes that each individual (or group of individuals) perform a utility analysis when asked to choose an alternative from a set of different and mutually exclusive possibilities, called the choice set. To do it, the respondent assesses the attributes characterizing each one of the choice alternatives, indirectly associating a utility level to each one of them. The alternative obtaining a higher utility level will then have a higher probability of being selected. This probability of choosing an alternative within the choice set can be represented with a logit expression, as follows:

$$P_k \equiv P_r \ [\ Alternative\ k\ ] = \frac{e^{\mu V_k}}{\sum_j e^{\mu V_j}}$$

Where j corresponds to the different alternatives in the choice set and k to the alternative in question; μ determines the scale level for the utilities, and is usually set to 1, and V_j is the deterministic component of the utility function U_j for alternative j in the choice set, as follows:

$$U_j = V_j + \xi_j = \sum_i \beta_i x_{ji} + \xi_j$$

The utility function is assumed to be linear, with x_{ji} representing the value of attribute i for alternative j, and β_i the weight of attribute i in the overall utility function (which is precisely what the analysis seeks to determine). Finally, ζ_j is the stochastic error of the utility function, representing that the alternative with highest utility will have the highest probability of being selected, but will not necessarily be the chosen one. These error components are assumed to have a Gumbel (0,θ) distribution.

Several applications have employed discrete choice models to gain insight on perceptions and preferences expressed by urban freight stakeholders. For instance, Hensher and Puckett (2005) used them to evaluate supply chain behavior as a response to congestion charging. Holguín-Veras et al (2007, 2008) provide a description based on game theory of different policy scenarios affecting both receivers and carriers, and base their analysis on preference data obtained with discrete choice models. In Stathopoulos et al (2012), 195 carriers are examined with a discrete choice approach to estimate their delivery behavioral patterns.

Our proposal also seeks to examine the possibilities offered by nested logit models (Ben-Akiva and Lerman, 1985) when applied to discrete choice experiments. These models postulate that individuals do not necessarily choose directly between all the available alternatives, but rather group them in independent categories, sub-categories, etc. The choice process is then carried out by choosing the preferred category, then the preferred sub-category, and so on.

The advantage of these models lies in the fact that, whereas in regular logit models there is only one stochastic term to explain the decisions that do not correspond directly to the result of utility evaluation, nested models have one stochastic term per level in the hierarchical structure, thus resulting in a better fitting of the model. They are therefore recommended as long as the available alternatives can be set up in a hierarchical fashion.

Assuming a two-level hierarchical model, with levels r (categories) and s (sub-categories), the expression of the utility function is then given by:

$$U_{r-s} = V_{r-s} + \zeta_{r-s}$$

$$U_{r-s} = V_r + V_s + V_{rs} + \zeta_r + \zeta_{rs}$$

And the new probability of choosing a given alternative can be expressed as follows:

$$P(r,s) = \frac{e^{\mu (V_s + V_{rs})}}{\sum_{p \in S_{rt}} e^{\mu (V_p + V_{rp})}} \cdot \frac{e^{\theta (V_r + V'_r)}}{\sum_{q \in R} e^{\theta (V_q + V'_q)}}$$

However, the characteristics of nested models require larger data sets for the correct estimation of parameters, and here the analyst is constrained by the number of available completed surveys. This is why we chose a multinomial logit model for the first step of our analysis, where we tested the perception of several city logistics policies, and a nested logit model for the second step, in order to quantify the perceived weight of a reduced number of attributes involved in those policies. The following sections describe these two steps, which result in an estimation of the relative weights of the different objectives sought by carriers in city logistics policies.

3. First step: use of discrete choice for alternative pre-selection

Our first application of discrete choice analysis corresponds to the selection of alternatives to address city logistics problems in a given urban environment. In this case, the environment corresponds to the Seville city center, which presents the typical delivery difficulties encountered in most medium-size European cities (Muñuzuri et al, 2012a). We presented a panel of 10 local carriers a series of urban freight solutions, taken from Muñuzuri et al (2005), for them to select what in their opinion were the most appropriate ones:

- Joint deliveries: force carriers to cooperate in order to be granted access to the city center.
- Night deliveries: allow carriers to deliver at night as long as residents are not disturbed.
- On-line load zone reservation: establish the possibility to reserve load zone spaces in advance.
- Road pricing: charge carriers for entering the city center.
- Information systems: develop real-time systems to inform carriers of congestion, availability of load zones, etc.
- Access time windows: establish fixed schedules for entering the city center.
- Urban distribution centers: areas where the goods are transferred for their final delivery by electric vehicles.
- Freight mini-hubs: areas where freight vehicles are allowed to park and the final delivery is completed on foot.
- Enhanced police control: guarantee that regulations are followed by carriers.

The participating carriers were briefed on the details of each solution before asking them to fill in the discrete choice survey. The objective here was not to obtain an analytical result based on quantitative parameters, but rather to gain some insight with respect to the relevance of each solution in the eyes of carriers. This allowed us to make a pre-selection of the solutions with a higher expected impact (either positive or negative), and use them for the quantification of weights for the carriers' objectives in the second step of our analysis.

Thus, most of these solutions were considered here only with two levels (i.e. with or without the corresponding solution), although we considered several exceptions. In the case of UDCs, their implementation may follow a voluntary or a compulsory scheme depending on whether carriers are forced to use the UDC or not. On the other hand, freight mini-hubs can also be voluntary or compulsory, their use can be subject to a fee or not, and vehicles using those mini-hubs may be allowed to move during banned access hours or not. The result is the set of possibilities displayed in Table 1.

Table 1. Solutions proposed and different levels of each one

Solutions:	Level 1	Level 2	Level 3	Level 4
Joint deliveries	Without joint deliveries	With joint deliveries	-	-
Night deliveries	Without night deliveries	With night deliveries	-	-
On-line load zone reservation	Without reservations	With reservations	-	-
Road pricing	Without road pricing	With road pricing	-	-
Information systems	Without information systems	With information systems	-	-
Access time windows	Without access time windows	With access time windows	-	-
Urban distribution centres	Without UDCs	With UDCs, voluntary use	With UDCs, compulsory use	-
Freight mini-hubs	Without mini-hubs	Voluntary, with cost, movement allowed	Voluntary, with low cost, movement not allowed	Compulsory, without cost, movement not allowed
Enhanced police control	Without increased control	With increased control	-	-

The objective of this first experiment, as was explained to the participating carriers, was then to estimate weights associated to each logistic solution, in order to rank them with respect to their expected capacity to alleviate freight delivery problems in Seville. To do so, we provided each panel member with a survey containing pairs of hypothetical alternative scenarios (choice sets), each one of them formed by a combination of urban freight solutions. The urban freight solutions corresponded then to the attributes of the alternatives in the choice set, and each possible scenario would be given by a combination of levels of the different attributes.

- To form these alternatives, we used effects coding (Bech and Gyrd-Hansen, 2005) to code the different possibilities for each solution. Table 2 shows this type of coding for attributes with two, three and four levels, and Table 3 shows the coded levels for each attribute in our analysis. This coding of the alternatives is required in the first place to process and interpret the results, and also to build the survey using a D-efficient approach (Kuhfeld et al, 1994). We carried out the latest task using the analytic procedure described in Muñuzuri et al (2012b), while taking into account the following issues:
- The choice sets contained only two alternatives each. This makes the process easier for the respondent, avoiding situations like A seems better than B and B seems better than C, but C seems better than A.
- We built 100 choice sets, but each survey contained only 10 choice sets, to avoid the effects of tiredness in the responses. This means that all the individual surveys contained different choice sets. This procedure is typically used in many stated preference works (Bunch et al, 1993; Burton et al, 2001; Ryan and Gerard, 2003).
- The alternatives presented to the respondents are merely hypothetical, as corresponds to a stated preference survey.

- The panel members were assumed to have a sufficiently homogeneous opinion, so that no segmentation of the panel was deemed necessary, and we assumed that the assumption of identically distributed and independent error terms could be relaxed (Timmermans, 2004).

Table 2. Effects coding for attributes with two, three and four levels (each attribute requires a number of auxiliary variables equal to the number of levels minus one)

Attribute	Variable
X	x_1
Level 1	-1
Level 2	1

Attribute	Variables	
X	x_1	x_2
Level 1	-1	-1
Level 2	1	0
Level 3	0	1

Attribute	Variables		
X	x_1	x_2	x_3
Level 1	-1	-1	-1
Level 2	1	0	0
Level 3	0	1	0
Level 4	0	0	1

Table 3. Effects coding of the attributes in our analysis using 12 variables

Urban freight solution	Nº of levels	Auxiliary variables	Level 1 coding	Level 2 coding	Level 3 coding	Level 4 coding
Joint deliveries	2	RCONJ	RCONJ=-1	RCONJ=1	-	-
Night deliveries	2	RNOCT	RNOCT=-1	RNOCT=1	-	-
On-line load zone reservation	2	GDIN	GDIN=-1	GDIN=1	-	-
Road pricing	2	RPRIC	RPRIC=-1	RPRIC=1	-	-
Information systems	2	SINFO	SINFO=-1	SINFO=1	-	-
Access time windows	2	VENT	VENT=-1	VENT=1	-	-
Urban distribution centres	3	TERM1, TERM2	TERM1=-1, TERM2=-1	TERM1=1, TERM2=0	TERM1=0, TERM2=1	-
Freight mini-hubs	4	LANZ1, LANZ2, LANZ3	LANZ1=-1, LANZ2=-1, LANZ3=-1	LANZ1=1, LANZ2=0, LANZ3=0	LANZ1=0, LANZ2=1, LANZ3=0	LANZ1=0, LANZ2=0, LANZ3=1
Enhanced police control	2	VIGIL	VIGIL=-1	VIGIL=1	-	-

Table 4 shows one of the choice sets in the survey, coded with the corresponding values of the auxiliary variables, and Table 5 shows the same choice set, decoded as it was presented to the respondents. In this case, as an example, both tables show the case of the respondent choosing the first alternative in the choice set. The results of the full survey were fed into the econometric software Limdep®, and the multinomial logit model for a linear utility function produced the results shown in Table 6. Figure 1 contains the actual output report provided by the Limdep® package.

It is worth noting that almost all the weights for the different solutions came out negative, which shows the opposition of carriers in Seville to the actions that represent additional regulations or restrictions, or additional complexity. However, the objective of multi-actor, multi-criteria analyses is not to benefit or harm any particular stakeholder group, but rather to find a solution that results as balanced as possible for all of them. As a matter of fact, the perception of many solutions with an almost zero weight could end up being a very positive factor, in case these same solutions were viewed by other stakeholders as positive.

Table 4. Example of coded choice set

RCONJ	RNOCT	GDIN	RPRIC	SINFO	VENT	TERM1	TERM2	LANZ1	LANZ2	LANZ3	VIGIL	CHOICE
-1	-1	1	1	-1	1	0	1	1	0	0	-1	1
1	1	-1	-1	1	-1	1	0	0	1	0	1	0

Table 5. Example of decoded choice set, as shown to the respondents

Joint deliveries	Night deliveries	On-line load zone reservations	Road pricing	Information systems	Access time windows	Urban distribution centres	Mini-hubs	Enhanced police control	CHOICE
NO	NO	YES	YES	NO	YES	Compulsory	NO	YES	X
YES	YES	NO	NO	YES	NO	Voluntary	Movement allowed, with cost, voluntary	NO	

Table 6. Weights estimated by the discrete choice analysis for the different urban logistics solutions in Seville

Urban freight solution	Weight
Joint deliveries	-3.61
Night deliveries	-0.18
On-line load zone reservation	-0.52
Road pricing	-2.58
Information systems	-0.18
Access time windows	-0.74
Voluntary UDCs	-0.05
Compulsory UDCs	-1.50
Voluntary mini-hubs with cost and movement allowed	1.77
Voluntary mini-hubs with low cost and movement not allowed	-0.85
Compulsory mini-hubs without cost and movement not allowed	-3.83
Enhanced police control	-0.18

4. Second step: use of discrete choice for the estimation of weights for stakeholder objectives

The second step of our discrete choice analysis was related to the determination of weights for the different objectives associated to a group of stakeholders in urban freight transport. Again, we focused on the carriers group, and based our analysis on the two logistics solutions that were identified as most relevant in the discrete choice experiment of the previous section, Joint Deliveries and Road Pricing. The fact that the coefficients of the utility function linked to these two policies were both negative is irrelevant here, since the objective was not to assess their implementation, but to use these policies to quantify the relative importance of the different carriers' objectives that configure them as attributes. We chose the two most relevant policies in the hope that carriers would have a more clear opinion on the impact of their attributes, and would thus be able to fill in the surveys more easily.

```
                  +---------------------------------------------+
                  | Discrete choice (multinomial logit) model   |
                  | Maximum Likelihood Estimates                |
                  | Dependent variable               Choice     |
                  | Weighting variable                  ONE     |
                  | Number of observations              100     |
                  | Iterations completed                  9     |
                  | Log likelihood function       -20.13500     |
                  | Log-L for Choice   model =     -20.1350     |
                  | R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
                  | No coefficients    -69.3147  .70951  .66990 |
                  | Constants only.  Must be computed directly. |
                  |                  Use NLOGIT ;...; RHS=ONE $ |
                  | Response data are given as ind. choice.     |
                  | Number of obs.=   100, skipped   0 bad obs. |
                  +---------------------------------------------+
    +---------+--------------+----------------+--------+---------+----------+
    |Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
    +---------+--------------+----------------+--------+---------+----------+
     JOINTD    -3.607078141      1.2581036       -2.867   .0041
     NIGHTD    -.1787846016      .75046844        -.238   .8117
     ONLINE    -.5188077547      .72274145        -.718   .4729
     ROADPR    -2.582974669      1.0766256       -2.399   .0164
     INFOSY    -.1839115688      .79600891        -.231   .8173
     ACCSTW     -.7446397276      .89738737        -.830   .4067
     VOLUDC    -.5468028988E-01  .46688625        -.117   .9068
     COMUDC    -1.496185663      .81241840       -1.842   .0655
     VOLMH1     1.769275838      1.0633280        1.664   .0961
     VOLMH2    -.8488481060      1.0356895        -.820   .4124
     COMMHU    -3.827600909      1.9410649       -1.972   .0486
     POLICE    -.1838809761      .69530722        -.264   .7914
```

Figure 1. Output report provided by Limdep® for the multinomial logit analysis

In our case, the alternatives resulting from the combination of these two solutions were the following four:

1. With Joint Deliveries and Road Pricing
2. With Joint Deliveries and without Road Pricing
3. Without Joint Deliveries and with Road Pricing
4. Without Joint Deliveries and without Road Pricing (current scenario)

The aim of the analysis was to determine the relative weights of the objectives assigned to carriers, which can also be viewed as the attributes shaping the different policy alternatives. We considered the four following objectives as the most relevant ones for carriers:

- Variation of delivery time (measured in minutes per delivery)
- Variation of operational cost (measured in euros per delivery)
- Variation of management time (measured in minutes per delivery)
- Variation of service level (measured in a Likert scale between -4 and +4)

At this point, and given also the negative evaluation provided by the carriers participating in the first step of the analysis, we expected negative weights for the first three objectives (the higher the delivery time, the cost or the management time, the lower the utility), and only a positive weight for the last one.

Again, the analysis was carried out using a stated preference approach, passing surveys to carriers containing several two-option choice sets where they had to indicate their preferred one.

Table 7 contains the possible attribute values that were used to build the surveys. In the case of Joint Deliveries, we considered that the variation in cost could be either positive, if carriers had to pay for the service, or negative, if this initiative resulted in a reduction in the size of the fleet. With respect to delivery times, they may be reduced, but also increase, if the transshipment procedures are not ideally organized. Management requirements may also increase, due to the company's having to adapt its practices to the joint delivery operations, but may also decrease, given that the final delivery in the city center would not have to be managed by the company itself any more. Finally, the level of service was expected to decrease, due to the reduction in reliability and flexibility and the loss of direct contact with the customers.

On the other hand, in the case of Road Pricing, cost variations will always be positive whereas delivery times are likely to decrease, and the management associated to route planning, payments, etc. is likely to increase. Finally, the influence on service levels is likely to be small, either positive due to the additional reliability enabled by reduced congestion levels, or negative if the pricing fees lead to a reduction in the fleet and thus a reduction in delivery service levels and flexibility.

Table 7. Attribute levels for each alternative in the survey

Alternative1: with Joint Deliveries and Road Pricing

Cost variation	Time variation	Management variation	Service variation
0.5	2.5	-0.5	-4
3.5	0.5	0.5	-3
6.5	-1.5	1.5	-3
2.5	-2	2.5	-2
5.5	-4	3.5	-2
8.5	-6	4.5	-2
4.5	-6.5	5.5	-1
7.5	-8.5	6.5	-1
10.5	-10.5	7.5	0

Alternative 2: Joint Deliveries only

Cost variation	Time variation	Management variation	Service variation
-1.5	2.0	-1.0	-1
0.5	-2.5	2.0	-2
2.5	-7.0	5.0	-3

Alternative 3: Road Pricing only

Cost variation	Time variation	Management variation	Service variation
2.0	0.5	0.5	+1
5.0	-1.5	1.5	0
8.0	-3.5	2.5	-1

Alternative 4: Current Scenario

Cost variation	Time variation	Management variation	Service variation
0.0	0.0	0.0	0

In this case, it was not possible to use the survey building procedure described in Muñuzuri et al (2012), since the two possibilities in each choice set had to correspond to different alternatives, and the algorithmic procedure does not guarantee a balanced presence of the four alternatives: since Alternative 4 has only one possible combination of the attributes, it would appear only once in the survey, whereas Alternative 1, with 9 possible combinations, would appear 9 times more. Therefore, we imposed that each possible choice set (combinations of the four alternatives taken two at a time) had to appear the same number of times. Then, the actual values of the attributes were chosen randomly from the available possibilities shown in Table 7. This resulted in an initial design with 108 choice sets, which we then doubled so that 12 respondents were asked their opinion on 18 choice sets each. Table 8 shows an example of one of these choice sets.

Table 8. Example of choice set to determine the weights of objectives for the carriers group

Choice set	Alternatives	Variation of operational cost	Variation of delivery time	Variation of management time	Variation of service level	Choice
1	With joint deliveries and road pricing	2,5	-10,5	7,5	-3	1
	Only with joint deliveries	2,5	2	2	-2	0

The question was then how to distribute these alternatives in two levels, where the respondent would have to choose about joint deliveries in the upper level and about road pricing in the lower one, or vice versa.

When applying the hierarchical approach to a discrete choice preference analysis, there are multiple possible structures for the decision tree, resulting in different expressions for the utility functions. We tested all of them, and the best structure (R^2=0.860) is represented in Figure 2. The same analysis performed in a non-hierarchical manner resulted in R^2=0.849, thus confirming the expectations about the better performance of hierarchical models.

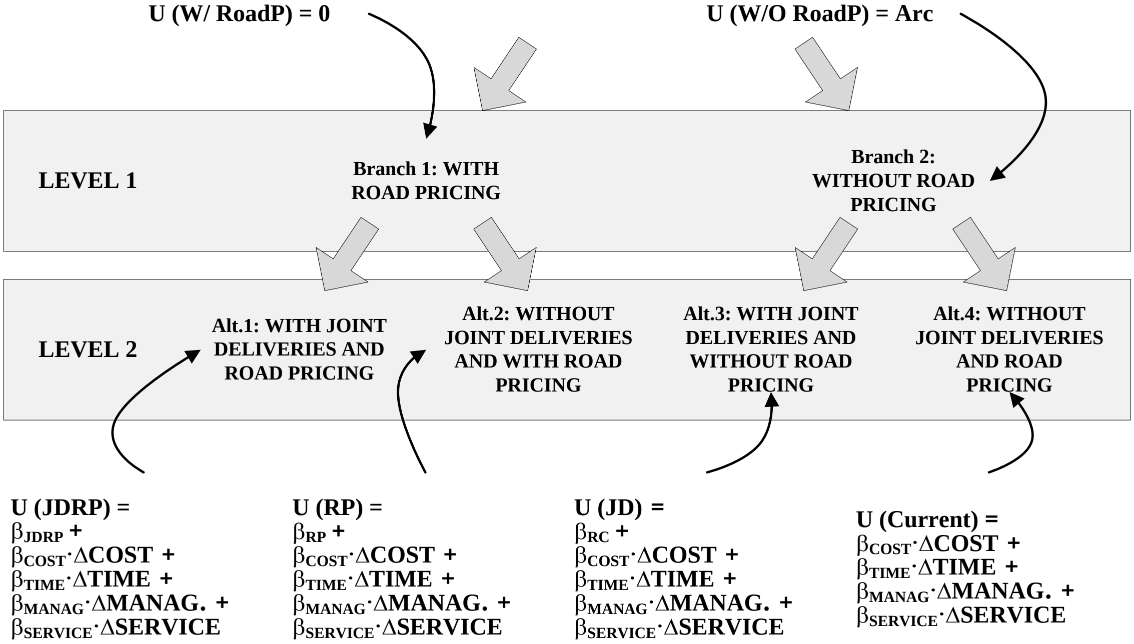

Figure 2. Structure of the hierarchical tree and of the resulting utility functions

This hierarchical structure, together with the survey data, resulted in the estimation of the β parameters of the utility functions, which correspond to the weights of the four objectives assigned to the carriers stakeholder group. The resulting parameter values are shown in Table 9, taking into account that the sign of the parameters is modified so that they all appear positive. Thus, instead of e.g. "Variation of delivery times", with a negative weight of -0.23, the new objective is formulated as "Reduction of delivery times", with a positive weight of 0.23. The output report provided by Limdep® is shown in Figure 3, whereas the non-hierarchical results (slightly worse than the nested case) are shown in Figure 4.

Table 9. Weights obtained for the carriers' objectives in the hierarchical discrete choice analysis

Carriers' objective	Weight	Normalized Weight
Reduction of delivery time	0.23	0.07
Reduction of operational cost	0.73	0.23
Reduction of management time	0.02	0.01
Increase of service level	2.20	0.69

```
              +----------------------------------------------+
              | FIML: Nested Multinomial Logit Model         |
              | Maximum Likelihood Estimates                 |
              | Dependent variable             DECISION      |
              | Weighting variable                  ONE      |
              | Number of observations              432      |
              | Iterations completed                 18      |
              | Log likelihood function       -41.91128      |
              | Restricted log likelihood     -299.4396      |
              | Chi-squared                    515.0566      |
              | Degrees of freedom                   10      |
              | Significance level             .0000000      |
              | R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj  |
              | No coefficients   -299.4396  .86003  .85324  |
              | Constants only.  Must be computed directly.  |
              |                  Use NLOGIT ;...; RHS=ONE $  |
              | At start values    -45.0029  .06870  .02349  |
              | Response data are given as ind. choice.      |
              | The model has 2 levels.                      |
              | Coefs. for branch level begin with ARC       |
              | Number of obs.=   216, skipped   0 bad obs.  |
              +----------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
         Attributes in the Utility Functions
 BJDRP     .5145064146      .97585948         .527   .5980
 BCOST    -.7324173149      .25511444       -2.871   .0041
 BTIME    -.2341593015      .10251155       -2.284   .0224
 BMANAG    .2579134910E-01  .96511601E-01     .267   .7893
 BSERV     2.205716634      .70702635        3.120   .0018
 BRP       .8005335062      .72641983        1.102   .2705
 BJD      -1.912131290      .86565253       -2.209   .0272
         Attributes of Branch Choice Equations
 ARC       .7223135785      1.5181448         .476   .6342
         Inclusive Value Parameters
 WROADP    1.209832700      .48239789        2.508   .0121
 WOROADP   .8938046977      .40486382        2.208   .0273
```

Figure 3. Output report provided by Limdep® for the nested logit analysis

The results of the nested model thus provide the basis for assessing quantitatively the perception of carriers of the implementation of urban freight policies, whether they are one of the two pre-selected ones in the first step of the analysis or not. The actual implementation of any one of the solutions listed in section 3 can be reduced to a set of values for the four objectives, which together with the weights of those objectives as shown in Table 9 would result in the quantitative estimation of the carriers' perception towards that solution.

The results in Table 9 show clearly the preponderance of the service level objective, which speaks against the introduction of policies that may affect this aspect, like joint deliveries or accessibility restrictions. A possible explanation for this perception is the fear of losing market share in case of reducing service levels in such a competitive environment. The importance of direct costs is also evident from the results, with a weight that is three times bigger than the one estimated for the reduction of delivery times. Finally, the complexity in the management of the system has a comparatively negligible weight, which means that this objective can be viewed as irrelevant, or that very large variations in the management effort would be required for carriers to take into consideration the corresponding logistic solution. This in turn opens the door to urban freight initiatives that increase the need for management dedication, like the on-line reservation of load zones or the introduction of information systems.

```
+---------------------------------------------+
| Discrete choice (multinomial logit) model   |
| Maximum Likelihood Estimates                |
| Dependent variable               Choice     |
| Weighting variable                  ONE     |
| Number of observations              216     |
| Iterations completed                  9     |
| Log likelihood function       -45.00414     |
| Log-L for Choice   model =     -45.0041     |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| No coefficients   -299.4396  .84971  .84467 |
| Constants only.  Must be computed directly. |
|                  Use NLOGIT ;...; RHS=ONE $ |
| Chi-squared[ 4]         =    451.15490      |
| Significance for chi-squared =  1.00000     |
| Response data are given as ind. choice.     |
| Number of obs.=   216, skipped   0 bad obs. |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 BJDRP    -.7379812599      .83165472        -.887   .3749
 BCOST    -.7332520798      .16911410       -4.336   .0000
 BTIME    -.2825502603      .77035236E-01   -3.668   .0002
 BMANAG    .1173476539E-01  .10435201         .112   .9105
 BSERV     2.152166621      .39117688        5.502   .0000
 BRP      -.1735297427      .66294039        -.262   .7935
 BJD      -1.312424247      .65633239       -2.000   .0455
```

Figure 4. Output report provided by Limdep® for the non-hierarchical logit analysis

5. Conclusions

Urban freight solutions, like many other administration-promoted initiatives, require detailed evaluation processes to help decide on their implementation. However, the interaction of multiple stakeholders with different views and objectives often complicates the urban freight environment in the search for a quantitative evaluation of prospective projects. This is why multi-actor multi-criteria methodologies have proved useful in the evaluation of urban freight solutions in many pilot and implementation scenarios. Nevertheless, the main drawback of these methods lies in the determination of the weights for the different objectives associated to the different stakeholders, forcing the analysts to use procedures based on the AHP technique.

We have demonstrated here the capabilities of a different approach, based on discrete choice models, to determine weights and evaluation parameters for urban freight solutions. The main argument in favor of this approach is that it is much easier to apply from the side of the "expert" or "respondent", since it only requires him or her to state which one is better in a pair of alternative hypothetical scenarios, instead of directly assigning points or weights to the different concepts evaluated. This fact is likely to ease the burden on respondents. Besides, the quantitative objective of the analysis is much more hidden in a discrete choice survey, which also eliminates the possibility of bias caused by the respondent anticipating the outcome.

We have tested the methodology through its application to the evaluation by carriers of a series of urban freight solutions in the city of Seville. First, we used discrete choice to determine which solutions would be more relevant in the eyes of this stakeholder group, and then we applied a nested logit model to use the evaluation objectives as attributes of those relevant solutions, in order to estimate weight values for those objectives. Given the reduced number of respondents and the fact that we wanted to estimate average weights for the carriers group, we assumed that the extra time or cost imposed on carriers would be similar for all of them, whereas they may have a different perception of it depending on what it represented in terms of percent variations. This would be an interesting task to undertake in future research, with the inclusion of respondent-specific variables in the analysis, nevertheless requiring a much larger sample of participating carriers.

Despite lacking validation through comparison with other techniques, the results have revealed some interesting insights on the perception of the proposed solutions by carriers in the city, like the overwhelming comparative weight of customer service or the residual weight of management time. Apart from the quantitative estimations, these outcomes provide us with relevant information on the behaviors and motives of the surveyed stakeholder group. Also, the first step of the analysis, used to identify the solutions with the highest expected impact, also allow us to extract some conclusions, and to confirm some expectations, with respect to the acceptability of the different urban freight solutions by carriers in the city of Seville:

- Joint deliveries: the loss of direct contact with their customers gives this solution the largest negative weight in the list.
- Night deliveries and information systems: the weight obtained by both solutions is again negative, but this time very small. There is therefore a high probability of these weights really being equal to zero, which means that they are more irrelevant, that is, less taken into account than other solutions when deciding upon the whole combination.
- On-line load zone reservation: again, a technological solution with a small negative weight, showing a high probability of being equal to zero.
- Road pricing: highly negative, due to its direct cost implications and uncertain results in terms of improved mobility.
- Access time windows: despite the fact that this solution restricts the movements of carriers (Deflorio et al, 2012; Quak and de Koster, 2006), the low value of its negative weight is probably due to its being preferred over other possibilities.
- Voluntary UDCs: negligible weight, possibly because the solution is not perceived as positive, but can in any case be avoided by carriers.
- Voluntary mini-hubs with movement allowed: positive weight, since new infrastructures are offered to carriers, who can again reject their use if they do not result in any gains for them.
- Compulsory UDCs or mini-hubs: negative weights due to the movement restrictions imposed on carriers.
- Enhanced police control: also negligible weight, since this solution also incorporates the need for carriers to adjust to regulations when making deliveries.

Acknowledgements

The authors wish to acknowledge the financial support provided by the Spanish Ministry of Economy and Competitiveness through project ECOTRANSIT (Reference TEC2013-47286-C3-3-R).

References

Bech, M. and Gyrd-Hansen, D. (2005). Effects coding in discrete choice experiments. *Health Economics*, 14, 1079-1083.

Behrends, S., Lindholm, M. and Woxenius, J. (2008). The Impact of Urban Freight Transport: A Definition of Sustainability from an Actor's Perspective. *Transportation Planning and Technology*, 31(6), 693-713.

Ben-Akiva, M. and Lerman, S.R. (1985). Discrete Choice Analysis. MIT Press, Cambridge.

Brans, J.P. and Mareschal, B. (2005). Promethee Methods. In Figueira, J., Greco, S. and Ehrgott, M. (eds) *Multiple Criteria Decision Analysis: State of the Art Surveys*. International Series in Operations Research & Management Science, 78, 163-186. Springer, Boston.

Bristow, A.L. and Nellthorp, J. (2000). Transport project appraisal in the European Union. *Transport Policy*, 7, 51-60.

Browne, D. and Ryan, L. (2011). Comparative analysis of evaluation techniques for transport policies. *Environmental Impact Assessment Review*, 31, 226–233.

Bunch, D.S., Bradley, M., Golob, T.F., Kitamura, R. and Occhiuzzo, G.P. (1993). Demand for clean-fuel vehicles in California: a discrete-choice stated preference pilot project. *Transportation Research A*, 27A(3), 237-253.

Burton, M., Rigby, D., Young, T. and James, S. (2001). Consumer attitudes to genetically modified organisms in food in the UK. *European Review of Agricultural Economics*, 28(4), 479-498.

Deflorio, F. P., Gonzalez-Feliu, J., Perboli, G. and Tadei, R. (2012). The influence of time windows on the costs of urban freight distribution services in city logistics applications. *European Journal of Transport and Infrastructure Research*, 12(3), 256-274.

Geurs, K.T. and van Wee, B. (2004). Land-use/transport Interaction Models as Tools for Sustainability Impact Assessment of Transport Investments: Review and Research Perspectives. *European Journal of Transport and Infrastructure Research*, 4(3), 333-355.

Hensher, D.A. and Puckett, S.M. (2005). Refocusing the modelling of freight distribution: Development of an economic-based framework to evaluate supply chain behavior in response to congestion charging. *Transportation*, 32, 573–602.

Holguín-Veras, J., Silas, M., Polimeni, J. and Cruz, B. (2007). An Investigation on the Effectiveness of Joint Receiver–Carrier Policies to Increase Truck Traffic in the Off-peak Hours, Part I: The Behavior of Receivers. *Networks and Spatial Economics*, 7, 277–295.

Holguín-Veras, J., Silas, M., Polimeni, J. and Cruz, B. (2008). An Investigation on the Effectiveness of Joint Receiver–Carrier Policies to Increase Truck Traffic in the Off-peak Hours, Part II: The Behavior of Carriers. *Networks and Spatial Economics*, 8, 327–354.

Keeney, R.L. and Raiffa, H. (1976). *Decisions with Multiple Objectives: Preferences and Value Trade-offs*. Wiley, New York.

Khalili-Damghani, K. and Sadi-Nezhad, S. (2013). A hybrid fuzzy multiple criteria group decision making approach for sustainable project selection. *Applied Soft Computing*, 13, 339–352.

Kuhfeld, W.F., Tobias, R.D. and Garratt, M. (1994). Efficient experimental design with marketing research applications. *Journal of Marketing Research*, 21, 545-557.

Leyva-López, J.C. and Fernández-González, E. (2003). A new method for group decision support based on ELECTRE III methodology. *European Journal of Operational Research*, 148, 14–27.

Lindholm, M. and Browne, M. (2013). Local authority cooperation with urban freight stakeholders: A comparison of partnership approaches. *European Journal of transport and infrastructure research*, 13(1), 20-38.

Macharis, C. (2009). The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: theory and practice. *Journal of Advanced Transportation*, 43(2), 183–202.

Macharis, C., DeWitte, A. and Turcksin, L. (2010). The Multi-Actor Multi-Criteria Analysis (MAMCA) application in the Flemish long-term decision making process on mobility and logistics. *Transport Policy*, 17, 303–311.

Macharis, C., Milan, L. and Verlinde, S. (2014). A stakeholder-based multicriteria evaluation framework for city distribution. *Research in Transportation Business & Management*, 11, 75-84.

Macharis, C. and Milan, L. (2015). Transition through dialogue: A stakeholder based decision process for cities: The case of city distribution. *Habitat International*, 45, 82-91.

McFadden, D. (1986). The Choice Theory Approach to Market Research. *Marketing Science*, 5(4), 275-297.

Muñuzuri, J., Cortés, P., Guadix, J. and Onieva, L. (2012a). City logistics in Spain: Why it might never work. *Cities*, 29(2), 133-141.

Muñuzuri, J., Cortés, P., Rodríguez, M. and Grosso, R. (2012b). Use of a genetic algorithm for building efficient choice designs. *International Journal of Bio-Inspired Computation*, 4(1), 27-32.

Muñuzuri, J., Larrañeta, J., Onieva, L., & Cortés, P. (2005). Solutions applicable by local administrations for urban logistics improvement. *Cities*, 22(1), 15–28.

Patier, D. and Browne, M. (2010). A methodology for the evaluation of urban logistics innovations. *Procedia Social and Behavioral Sciences*, 2, 6229–6241.

Quak, H. and de Koster, R. (2006). The impacts of time access restrictions and vehicle weight restrictions on food retailers and the environment. *European Journal of Transport and Infrastructure Research*, 6(2), 131-150.

Ryan, M. and Gerard, K. (2003). Using discrete choice experiments to value health care programmes: current practice and future research reflections. *Applied Health Economics and Health Policy*, 2(1), 55-64.

Saaty, T.L. (1980). *The Analytical Hierarchy Process*. McGraw-Hill, New York.

Sayers, T.M., Jessop, A.T. and Hills, P.J. (2003). Multi-criteria evaluation of transport options—flexible, transparent and user-friendly? *Transport Policy*, 10, 95–105.

Stathopoulos, A., Valeri, E. and Marcucci, E. (2012). Stakeholder reactions to urban freight policy innovation. *Journal of Transport Geography*, 22, 34–45.

Tamagawa, D., Taniguchi, E. and Yamada, T. (2010). Evaluating city logistics measures using a multi-agent model. *Procedia Social and Behavioral Sciences*, 2, 6002–6012.

Taniguchi, E. and Tamagawa, D. (2005). Evaluating city logistics measures considering the behavior of several stakeholders. *Journal of the Eastern Asia Society for Transportation Studies*, 6, 3062 – 3076.

Timmermans, H. (2004). Retail location and consumer spatial choice behavior. In Bailly, A. And Gibson, L.J. (eds) *Applied Geography: a World Perspective*, 133-147.

Thompson, R.G. and Hassall, K. (2005). A methodology for evaluating urban freight projects. In Taniguchi, E. and Thompson, R.G. (eds) *Recent Advances in City Logistics*.. Elsevier, Amsterdam.

van Duin, J.H.R., Quak, H.J. and Muñuzuri, J. (2008). Revival of cost-benefit analysis for evaluating the city distribution centre concept? In Taniguchi, E. and Thompson, R.G. (eds) *Innovations in City Logistics*. Nova Science Publishers, New York.