

Design of a stated ranking experiment to study interactive freight behaviour: an application to Rome's LTZ

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S18 – Stated preferences e analisi delle scelte: teoria, applicazioni e sviluppi

ABSTRACT: Effective applications of city logistics measures require an understanding of several issues seldom accounted for in current academic research. Knowledge of freight distribution context, regulatory background, available policy instruments, preferences and relationship among agents in the freight distribution chain is a necessary pre-condition for optimal policy design. Stated preference techniques have emerged as a promising tool to incorporate these considerations in the study of urban freight distribution. In fact, policy interventions implemented in this sector often yield unsatisfactory results because insufficient attention is paid to behavioural and contextual aspects and, in particular, to the reactions that policies cause among agents. Therefore the empirical study of relations and interactions between agents within the supply chain represents a key area of study for improving policy performance. Earlier studies have mostly explored freight behaviour in connection to distribution service features, largely ignoring the view of wider policy variables influencing the freight distribution context. Despite recent methodological advances to model interactive behaviour, there is a large gap in the literature concerning the practical development of surveys that can be applied to specific contexts and agent-types. This paper aims to provide guidance for practitioners and academics alike, in carrying out the various complex stages required to study freight agent behaviour. To this end the development of a ranking experiment aimed at assessing agent-specific preferences for freight policy instruments is overviewed. The process of attribute selection and definition incorporating knowledge of the actual study context is outlined. In particular, we illustrate how the experimental design is refined in several stages by incorporating agent-specific priors. The results obtained are not only reliable but also relevant from a policy implementation and evaluation perspective. In particular

Keywords: urban freight distribution, group decision making, agent-specific interaction, stated preference, stated ranking experiments.

1 Introduction

Cities have historically and functionally been characterized by relevant economies of density and proximity. Cities produce ideas, innovations and generate economic growth that irradiates to other areas; at the same time they consume more goods than they produce and consequently need to be supplied from outside. Cities are characterised by both research and service production as well as various negative externalities among which the most prominent are: congestion, environmental and acoustic pollution. These are linked to the high concentration of both people and economic activities that generate a consistent, strong and, usually, rigid demand for

public and freight transportation. In order to decouple economic growth from transport demand, decision makers have adopted policies to optimise the movement of both passengers and freight so to guarantee a sustainable development. The most frequently used urban freight policies need to be analysed considering a host of factors. These include: policy characteristics, linkages with the problems they should solve, external effects, distribution of impacts among the different stakeholders, the correct level of analysis of the phenomenon, the data needed to evaluate policy results, the most likely reactions deriving from the policies implemented and, last but not least, policy-makers need to define the modelling methods adopted to forecast policy impacts.

The objective of this paper is to illustrate the potential of using a Stated Ranking Experiment (SRE) to eliciting the relevant data for estimating and quantifying the preferences of relevant stakeholders within an Urban Freight Transport (UFT) context. We investigate both retailer's and carrier's sensitivity to potential changes in policy packages that are simultaneously considered possible by the Local Authorities (transport regulators) and acceptable by the main stakeholders (retailers, own-account and carriers).

An essential aim of the project is linking the results from the experiment to real-life definition of efficient and effective policy interventions (e.g. access charging, urban distribution centres (UDC), time windows, loading/unloading bays, etc.). Ideally the experiment will allow the researcher to identify acceptability of policies, both generally and by the various stakeholders influenced by the policies. Given that urban freight distribution is a phenomenon so much intertwined and influenced by interaction effects among the actors involved, the methodology used and the approach adopted are very important in identifying not only effective and efficient measures but also, among these, a subset of policies that are also considered acceptable, if not by all, by the greatest amount of actors possible.

The innovative aspect characterizing the proposed approach relates to the contemporaneous consideration of both demand and supply operators instead of, as is usually done, studying the two aspects as separate phenomena. Under this respect it proves a complementary approach to the widely used Freight Quality Partnership (FQP) approach that adopts a more descriptive and qualitative approach.

The paper is structured as follows. Section 2 provides a literature review of both agent interaction analysis in the freight sector as well as an overview of stated preference experimental design. The description of the study context is reported in section 3 while section 4 describes the development of the survey instrument. Section 5 illustrates the deployment of the survey and section 6 concludes.

2 Literature review

2.1 Freight and agent interaction: an overview

Freight modelling is to date, typically performed by means of aggregate models that provide no satisfactory account of the critical role individual actors play in the decision making process. This represents a substantial limitation especially for policy interventions aimed at changing the reference scenario and altering the relative convenience of past actions and choices made by policy makers. This paragraph illustrates some recent achievements based on a behavioural approach to freight modelling in general and to UFT in particular. This innovative approach accounts for

the most relevant complexities deriving from modern logistic supply chain activities. More realistic estimates are derived by explicitly considering shipping behaviour, supply chain specifications, shipment characteristics, transport network conditions and other aspects previously ignored. Some authors have contended that supply chain, logistic and swift technological transformations have rendered aggregate modelling approaches obsolete. Hensher and Figliozzi (2007), argue that such approaches are not capable of fully accounting for the complexity of freight movements at different geographical scales. What is more, new delivery methods (e.g. JIT) and customer driven freight services have made UFT more complex thus paving the way to third-party logistic providers. Within the group of disaggregate models (e.g. inventory models and logistic optimisation) behavioural models explicitly consider stakeholders' utility maximization efforts. When dealing with behavioural models one has to clearly identify the key decision makers to develop a modelling framework following an actor-based micro-simulation approach (Liedtke and Schepperle, 2004). Many authors consider UFT a privileged field of application for developing appropriate actor-based micro models; these include Gray (1982), Southworth (2003), Wisetjindawat et al. (2005), de Jong and Ben-Akiva (2007), Hensher and Figliozzi (2007), Samimi et al. (2009), Yang et al (2009) and Roorda (2010). Recent developments in freight modelling mainly revolve around the analysis of decision makers' choice procedures. Freight movements are relevant but also the underlying motivations and relative convenience of each stakeholder participating in the freight movement process play a relevant role. Structural behavioural improvements with respect to standard modelling techniques have come from network and micro-simulation modelling, land use/transport network with feedback effects with specific and explicit acknowledgment of the relevance of physical characteristics of logistics networks. Previous modelling approaches have simply abstracted from these aspects. This innovations have introduced greater realism in the treatment of the behavioural aspects influencing and motivating freight stakeholders when: 1) choosing among different strategies, 2) dealing with specific constraints, 3) accounting for incentives, 4) interacting with others. These aspects are important when dealing with UFT policy analysis. In fact, interactions between existing and prospective constraints posed by new policies, motivations to choose a particular strategy or a set of constraints may change when new policies determine new states of the world. For example, policy changes related to the price of fuel, land use patterns and pricing strategies imply a shift in the constraints and alter the relative convenience of alternatives. Puckett and Greaves (2009) argue that it is important to jointly consider both the instruments available to policy makers and the set of drivers influencing freight travel behaviour to gain a better understanding of the potential impacts the implemented policies might have on market outcomes. This is exactly what policy makers would like to know *ex-ante* before actually implementing a given policy. It is not only important to identify a type of incentive/disincentive with a relevant impact but also be able to understand and quantify its impact given the reference context. To do so one has to understand which type of decision makers are involved, how they interact, under which constraints they operate, on which specific freight service attribute they negotiate and what sort of interaction is actually going on among them.

Some new approaches have been recently developed to tackle the issues raised in this section. The most prominent promoters of interactive choice experiments (IACE) for analysing urban freight transport are Brewer and Hensher (2000), Puckett and Hensher (2006; in press). Usually both financial and sample size issues render this approach difficult to implement when real-life applications are undertaken. Only a

limited number of buyers of road freight transport services or transport providers are willing to participate in a study and hence guaranteeing a sufficient participation is usually a key, and difficult to solve, issue. Hensher and Puckett have provided a solution to this issue by developing minimum information group inference (MIGI) a less data demanding methodology even if equally capable of producing relevant results. Their illustration indicates the critical areas where specific efforts are needed to gain a better understanding of UFT related decision making.

2.2 Experimental design: an overview

Stated choice (SC) experiments now have a long-standing tradition dating back to the early eighties. In fact, we can trace the first contributions in this field back to the works of Louviere and Woodworth (1983) and Louviere and Hensher (1983). Choice experiments have progressively been employed in a wider variety of research fields among which the most prominent applications have been in transportation, marketing, environmental evaluation and economics. While transportation has witnessed the most path-breaking contributions in discrete choice modelling, historically, the most relevant advances in choice experiment design have emerged in marketing and economics. It is interesting to note that there are qualified and up-to-date systematizations of both advanced and introductory scientific knowledge for discrete choice modelling (Ben-Akiva, Lerman, 1985; Hensher et al., 2005; Louviere et al., 2000; Train, 2003; Marcucci, 2005).

The administration of a choice experiment aims at acquiring high quality data to enable estimation of reliable and useful results. Depending on the research question considered, one may adopt a range of different response formats among which one recalls: choice, ranking or rating. The response format adopted plays a relevant role since it is linked to the way data are analyzed once acquired (Johnson and Desvousges, 1997; Ortúzar, Garrido, 1994; Crask, Fox, 1987; Louviere, 1992, 1988; Aaker, Day, 1990) as well as the reliability of the responses obtained.

The idea at the base of experimental design theory is to study the relative influence of independent variables (attributes) on a given observed phenomenon (outcome). The analyst tries, by means of choice experiments, to determine the influence of the various attributes employed in the design, on the choices that the sampled agents are observed to make when participating in the experiment. The ability to uncover statistically significant parameter estimates, especially when small samples are used (as is usually the case in empirical research), may be strengthened (weakened) by a good (poor) experimental design. In general, there is a trade-off between the ability a design has to identify the role of each attribute's influence on the choice outcome and its aptitude to generate statistically significant results. Thus, the choice of a specific experimental design is not irrelevant with respect to the research conclusions reached. In fact, an experimental design is, *de facto*, a matrix of values containing the levels of the attributes that will constitute the SC survey. The analyst has to optimize the allocation of the attribute levels to the design matrix given his research goals. Historically, the most common strategy adopted has been to ensure attribute levels that are uncorrelated or orthogonal (Louviere et al., 2000). However, in more recent years, numerous researchers have developed an alternative and innovative approach: efficient design (e.g., Huber, Zwerina, 1996; Kanninen, 2002; Kessels et al., 2006; Sándor, Wedel, 2001-2002-2005). The logic underlying the efficient design approach hinges upon the consideration that orthogonality is not related to relevant and

desirable properties of the econometric discrete choice models employed to analyze SC data. Logit and probit models, commonly used to estimate choice models on the basis of SC data, are not linear and do not require zero correlation between the attributes of the design (this would be important to detect independent effects when employing linear models). Almost twenty years ago Hensher and Barnard (1990) developed a distinction between design orthogonality and estimation-data orthogonality to clarify that this property is not always preserved in model estimation. To preserve this property one should require the differences in attribute levels to be orthogonal rather than the levels themselves. In other words, the attribute correlation structure should not be utilized as the sole or main design criteria. Indeed, a more important feature is the correlation of the differences in the attributes.

The first attempt to link the statistical SC properties to the econometric models used to treat such data was made in 1996 by Huber and Zwerina. These authors showed that by relaxing the orthogonality conditions of the experimental design one can reduce the asymptotic standard errors of the parameter estimates, that is, the square roots of the diagonal elements of the asymptotic variance-covariance matrix (AVC). In order to determine the AVC, in many cases, researchers have relied upon *Monte Carlo* simulations even if it can be determined analytically by taking the second derivatives of the log-likelihood function (Rose and Bliemer, 2005). When constructing an efficient design it is easier to define a single value instead of assessing the whole AVC. Various analysts have proposed different efficiency measures (e.g. d-efficiency, a-efficiency) aiming at the minimization of the specific efficiency measure identified.

3 Description of the study context: the roman freight LTZ

The institution of a formal LTZ in Rome historical centre can be traced back to 1989 when a 5 km² area was restricted to non-resident vehicles. The bans on traffic apply to both passenger and freight vehicles. Access and circulation in the larger peri-central area termed “LTZ Anello Ferroviario” (Limited Traffic Zone – Railway Ring) is prohibited to pre-Euro-1 and Euro-1 light and heavy vehicles. Instead the central area that is the focus of this study has a more detailed legislation in place. It corresponds to a 4 km² area in the historical centre. The entrance is reserved for the least polluting vehicles (Euro 1 and later) with permission to access the LTZ only for residents while other agents, such as retailers and freight carriers pay. The scheme operates during daytime hours (passenger cars: 06.30–18.00 Monday to Friday and 14.00–18.00 on Saturday). The passenger LTZ largely overlaps with the freight LTZ area aimed at goods vehicles that operate between 10.00–14.00 and 16.00–20.00. The charge for the yearly permit that grants access is 565€ per single number plate. Initially, the local police enforced the scheme manually and this resulted in many vehicles entering the zone illegally. The system has subsequently been automatized based on the use of cameras and optical character recognition software. The access and parking of freight vehicles is subject to specific time windows in the freight LTZ. However, a range of freight operators are exempted from payments. A synthetic summary of the regulatory regime as defined in the latest LTZ municipal resolution (n. 44 from 2007) is shown in Table 1.

Table 1 – Table legend

General regulation	
Laden weight < 35 q	Laden weight > 35 q
Transit and parking allowed from 20.00 to 10.00 and 14.00 to 16.00 and prohibited otherwise	Transit and stopovers permitted from 20.00 to 7.00 and prohibited otherwise
Exceptions from time window (around the clock transit and parking)	
Laden weight < 35 q	Laden weight > 35 q
1. Transport of perishable foods, pharmaceuticals, newspapers and precious goods	1. Trucks with justified request detailing time, place and route (for instance house moving)
2. All courier and transport companies operating as third account (if enrolled in the “National registry of auto transporters”)	
3. Trucks involved in cleaning and maintenance services on account of the municipality or ATAC	
Fee reductions	
50% reductions offered for electric cars and 25% reduction for CH4, GPL and hybrid motor/fuel	

Indeed the regulation is essentially designed to provide incentives to third account operators while discouraging lengthy parking of own account vehicles, given the shortage of on-street space in the area. The time windows are currently not systematically enforced. Due to the many exceptions to the scheme it can hardly be characterized as a congestion reducing policy. Neither can it be classified as an environmental low emission zone (LEZ) since the vehicle emissions standards are not currently part of the scheme. However, the exclusion of Euro-1 and below and the fee reduction for alternative fuels imply that environmental objectives prevail over efficiency goals.

4 Development of the survey instrument

In this section we describe the rationale behind the use of separate designs by agent-type and we illustrate the different components of the questionnaire administered. Fundamentally, in the study of urban supply chains, we need to figure out what the main driving forces behind the behaviour of supply agents are. Beyond mapping the main problems and policy solutions surrounding urban freight distribution, the main policy concern of administrators is to understand the perspectives and roles of different stakeholders in the logistic chain. Among the actors traditionally identified as essential stakeholders for urban freight logistic systems one recalls: receivers, carriers and forwarders (Ogden, 1992). In the current SRE we concentrate on

representing three main supply chain agents, that is carriers, retailers and own-account operators. The first two, transport operators and retailers that receive the goods, are well identified in the literature. Based on the stakeholder consultation, specific studies of the roman context and an analysis of the current regulation, it appeared essential to include own-account operators as well. This separate treatment and differentiation of the design according to agent-type was an important advancement to adequately describe the heterogeneity in needs and problem definition among agents. Indeed, the insight gained from the meetings with the stakeholders, regarding important agents to represent and the issues potentially generating more tension among agents, proved an important source of guidance in this process.

The most relevant part of the questionnaire is the SRE scenarios. Firstly, the selection, definition and development of the attributes to include in the rating tasks for each agent is needed. In particular we point out how the translation from the stakeholder consultation stage to the attribute definition was carried out. In doing so we highlight which specific attributes were included in the final questionnaire design. Indeed the main criteria for attribute inclusion was the level of joint acceptance of the policy measure. Following the justification for inclusion we illustrate how each attribute was defined, including the structuring in levels and ranges. An important point to keep in mind is the progressive differentiation of the attributes modelled. These were progressively differentiated according to which agent was answering the questionnaire. This procedure was adopted to account for real-world constraints and preferences of each agent-type. To a large extent the choice of attributes was based on the results from stakeholder surveys. The following sections overview the attributes included, their characterization and the reasoning behind these choices. Furthermore we also motivate the exclusion of certain attributes.

4.1 Attributes to include in SRE

Each option in the SRE is described by a set of attributes where each one can take several levels that describe ranges of variation when the alternatives are presented to the respondents. For example, when choosing between alternative policies of city logistics, among the key attributes we usually encounter entrance fees and loading-unloading regulations. Respondents then make decisions about quality and quantity differentiated versions of the policy. The attributes can be quantitative, qualitative or binary. The results are analysed to estimate the contribution of the attributes/levels to the overall utility.

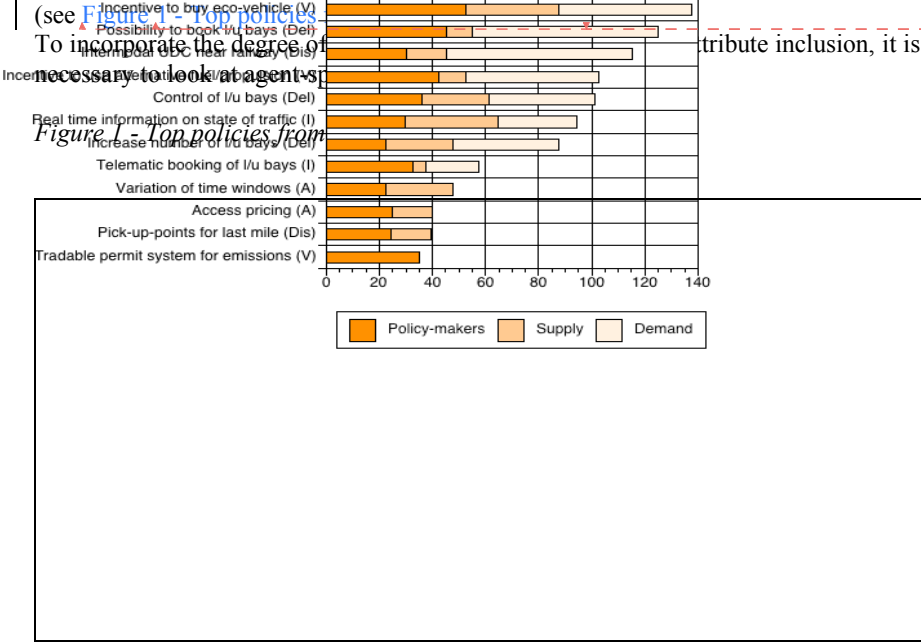
We assessed the acceptability of city logistic policies in the context of Rome's LTZ. The attributes used in the experiment were defined drawing on three main sources, namely; a) a literature survey; b) quantitative studies on city freight in Rome; c) a series of focus group meetings with relevant expert stakeholders.

An extensive review of the current city logistics literature with an agent-based perspective was performed suggesting a set of potential conflicting policy components when evaluated by different agents in the chain. For instance night-time deliveries were potentially efficiency enhancing for carriers but seen as a contributor towards operational cost by retailers. However, before pondering a differentiated agent-specific design it was necessary to select which attributes to include in the SRE. The main contribution to the definition of attributes included came from reviewing the quantitative studies on city logistics carried out in Rome, and the series of

stakeholder surveys organized. An important phase of the expert surveys was the questionnaire given to each respondent to indicate the most appropriate policies to relieve the identified problems of city logistics in the LTZ. However it was necessary to carry out a series of evaluations before translating the policies identified by the stakeholders into attributes to use in the SRE. The main criteria applied in the selection of appropriate attributes were the following:

- attributes are salient to the majority of respondents;
- support for a policy attribute is shared among respondents;
- attributes are plausible/believable in the eye of respondents;
- attributes reflect plausible changes to the current policy scenario.

The policies selected by the stakeholders in the consultation stage could not simply be used in the SRE but needed to be revised according to the above criteria. In **Error! Reference source not found.**, an overview of the link between the stakeholder survey results and the SRE is reported. Among the policies that gathered the most support in the stakeholders' survey each of the five policy macro categories are represented (Vehicle, Information, Loading/unloading, Distribution and Access policies). Not surprisingly, among the top rated policies we encounter those inducing least costs to users such as incentives and an information provision service, in line with the well-known equity-efficiency trade-off. Surprisingly policies that generally are seen as highly unacceptable, such as pricing, did make it into the list of the top 12 policies



As can be observed in **Figure 1**, concerning the delicate question of time windows, agents were, on the whole, reluctant to propose it. Indeed, city access time and

delivery time restrictions appear to be a core issue behind disagreement among different agent-types.

Table 2 - Top stakeholder policies and translation into SRE attributes

List	Macro categories	Policy measure	In SRE
1	Vehicle	Incentive to buy vehicle with higher environmental standard	Pilot**
2	Information	Real time information on reservation of l/u bays	No
3	Vehicle	Incentive to use alternative propulsion systems	No
4	Loading/unloading	Policies of control of (illegal) use of l/u bays	Redefined
5	Distribution	Promotion of intermodal UDC such as the <i>Scalo san Lorenzo</i> , for specific types of goods	Pilot**, No*
6	Information	Realization of a free information service via SMS/Internet reporting on state of traffic	No
7	Loading/unloading	Increase the number of l/u bays	Yes
8	Loading/unloading	Implement a computerized booking/payment service for loading-unloading bays	No
9	Accessibility	Variation of time windows and exemptions granted	Yes
10	Accessibility	Introduce system of tradable permits related to environmental standard (standard Euro-1-2-3-4)	No
11	Accessibility	Pricing, including fee differentiation, time articulation, exemptions	Yes
12	Distribution	Realization of pick up points for the final delivery	No*

NOTES: * Attributes not included in SRE but covered in section on behavioural reactions, ** Tested in the pilot survey

The main rationale for the current attribute-selection criteria is that the level of shared support for a policy would facilitate the introduction and continuation of a policy. Notably there is a strong, and mutual, support for the eco-vehicle incentive, information provision and number of loading and unloading bays (l/u). On the other hand, there are a few policies that receive unbalanced support like the bookable l/u bays, while others, such as tradable permits, gain only a unilateral support. Indeed, policies supported by a single agent only, or, as for time windows, by policy makers

and freight operators alone, run the risk of not gaining the necessary support to be successfully implemented. In particular, policies requiring a joint effort among operators such as time windows and pick-up-points fare badly in our survey. During the in-depth interviews it was revealed how retailer representatives were, overall, positive towards innovative freight policies as long as retailers themselves sustained none of the costs of keeping them alive. On the other hand, freight carriers are interested in typical transport oriented problems like vehicle standards, l/u bays and time windows. This implies a more realistic stance on behalf of freight suppliers towards policies impacting on their daily operations. These operators have a negative view of both UDC and pick-up-points: policies that introduce a rupture in the chain of distribution. Reasons for this reluctance revealed in the discussions are a fear of losing control and legal responsibility of the goods transported especially for express couriers that have a highly specialized and efficient distribution chain.

Based on these two lines of reasoning – relevance and acceptance – six attributes were finally selected to undergo pilot testing with real operators, namely:

1. number of l/u bays;
2. probability to find l/u bays;
3. time windows;
4. exemption from time windows;
5. entrance fees;
6. exemptions from entrance fees.

The degree of realism and plausibility in terms of introduction were the most relevant criteria in the attribute definition stage. In fact each of these six attributes have been on the political agenda for a while and all were perceived as realistic measures to be included in policy mixes.

Subsequently we discuss the inclusion/exclusion rationale and the subsequent definition and refinement of each attribute.

Loading/unloading bays

L/u bays availability and management was one of the most discussed issues in the focus groups. The inclusion of this attribute was thus self-evident. Rather the challenge lied in appropriately defining the attribute in question. The main issue was that several important dimensions of the attribute emerged as significant for the interviewees in the stakeholders' meetings. For instance, both the number of bays, as well as the possibility to find them free when needed, were seen as important features. Based also on earlier studies in Rome (STA, 1999), showing that both these features were indeed important for operators, it was decided to represent both the characteristics pertaining to the l/u bays in the SRE. Regarding the number of bays, this was revealed to be a classical problem of the LTZ area in the stakeholder meetings. Although the construction of additional l/u bays has been on the political agenda for a long time, the proposals have not made their way towards realization. This means that the number of l/u bays in the LTZ are fixed at the restrictive number of 400. It was decided that the current level would be used in the SRE in view of the unfeasibility of any imminent change in their number.

Probability to find l/u bays available

An issue related to that of the number of l/u bays is that of the possibility to find them available. The stakeholders' discussions and the pilot study indicated that some agents were not so much interested in the number of bays in absolute terms, but rather in the probability of finding them available for l/u operations. Since a large portion of occupations of the bays in Rome's LTZ is illegal, many of the policy proposals revolve around ways to increase controls over their proper occupation. Since there are several possible methods or policies that could feasibly eliminate illegal or inappropriate use we concentrate on policy outcomes rather than policy means. Given that the outcome was to increase the probability of finding the bays free, this was found to be the most appropriate attribute definition. The lack of appropriate mapping of the current probability of finding the bays available led a member of the research team to examine the issue empirically by controlling a sample of bays and registering the number of busy and available spaces during week-day rush-hour. The findings indicated that the current probability corresponds to a 13% chance to find a bay available, on average. It was not always possible to assess whether the unavailable spaces were so due to illegal or legal parking. The attribute was formulated as a probability percentage to avoid the issue of an unequal distribution of bays and freight activity among areas generating a large amount of disparity among agent's perceptions. Defining an attribute in probabilistic terms may be difficult to evaluate for respondents, but was a necessary condition to ensure a general interpretation of the perceptions of this complex issue.

An important point to make for the case of separating the number of bays from the probability measure is that it allows for the modelling of several possible ways to perceive the attribute in the estimation phase. Indeed, it is possible to test the fit of models with the two attributes kept separate or interacted, if that is the prevalent way respondents deal with the attributes.

Time windows

The importance of time window regulations is well established in the literature. However this policy purports a series of important difficulties in its characterization. The difficulties are present both in defining and representing the attribute. In the problem the definition phase the relevance of how to conceive the attribute rises. Should the attribute be described in terms of number of hours of closure, using the specific hours of the day when the area is closed for deliveries and defining how many "windows" to utilize in the characterization? In the phase of representing the attribute, or communicating it to the respondent, one has to clearly represent different time window configurations and allow the respondent to compare options without too much effort.

The design of the time window attribute was carried out in several stages, these were to:

- identify the most desired hours for freight delivery;
- put together time window scenarios that represented variations on the *status quo* and which were also possible to interpret for the researcher(e.g. represent: a) the number of hours, b) the distribution over the day of the hours with the corresponding value);

- represent these scenarios to respondents,
- test the comprehension of the scenarios and their desirability in a pilot study;
- re-define the time window attribute in view of the pilot study results.

To identify the most sought after delivery hours a study by STA (1999) was used. Based on this study a total of 100 points was distributed among the 24 hours of the day to represent the degree of desirableness of each hour by retailers. The initial plan was to study both the importance of *a)* the number of hours of access to the LTZ and *b)* their specific distribution over the 24 hour working day.

The first set of attributes that came out from this exercise consisted of five different scenarios, varying both the number of hours and their distribution according to desirability. These are illustrated in [Table 3](#).

Several sets of questionnaire designs were tested; among these the time window attribute was the most critical. Since there were no previous studies using a SRE to study time windows, several designs were tried. Among these a circular clock-inspired representation, a drawing with bars representing the time and several word descriptions were tested.

Drawing on piloting with students and personnel of Rome Tre University, the horizontal bars representing the time windows was regarded as most comprehensible. However due to coding needs from the design software adopted (Ngene, 1.0) a description in words was chosen. The last issue concerned framing the attribute, whether in positive (hours open) or in negative (hours closed) terms. Based on the pilot with the operators it was decided that most of them reasoned in terms of number of hours of access, rather than hours of closure, thus the attribute was rephrased in terms of hours of access.

Table 3 - Time window original scenarios

Scenario	Number of hours of closure	Desirability of hours
<i>Status quo</i>	8	sq
Sq-plus	8	Higher than sq
Sq-minus	8	Lower than sq
Plus[□] - Minus[▪]	10	Lower than sq
Minus[□] - Plus[▪]	6	Higher than sq

NOTES: [□] referred to the number of hours of closure with respect to status quo (plus and minus); [▪] referred to the desirability of the hours with respect to the status quo (plus and minus).

Fees

A price attribute is usually included when creating a choice or ranking experiment. This allows the researchers to calculate implicit prices of other attributes using marginal rates of substitution (MRS). The importance of the entrance fees was established during the discussions with stakeholders with particular attention to carriers. Due to the large increases in recent years, from a 35€ euro annual fee to 565€

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euro for each number plate, this attribute proved quite a sensitive issue. It was decided to represent the attribute as the *status quo* level, including both upward and downward variations.

4.2 Excluded attributes

Some of the policies that emerged as interesting or important from the relevant literature or stakeholder meetings were not used in the choice experiment. The reason for the exclusion is connected with failing one of the criteria used in selecting the attributes. Moreover, there were further issues arising during estimation. These were the occurrence of an unanticipated or irrational sign of certain coefficients leading to the attribute needing to be reformulated or excluded on account of not being well comprehended by respondents in the pilot study. What is more, some attributes were shifted to a different section of the questionnaire due to their inherent complexity that forbade their inclusion in the multi-attribute SRE. These attributes, such as the UDC were studied in the context of the scenarios and behavioural reactions.

Exemptions from time windows and fees

As mentioned earlier, the current exemptions and other types of user differentiation were regarded as important issues for the overall acceptance of LTZ regulations. For this reason, the exemptions, in the form of a binary presence/absence attribute, were initially included in the SRE for both fees and time windows. The intent was to assess whether the presence of exemptions would lead to a positive effect on the utility of the respondent. The pilot, however, provided mixed indications on this point. The preliminary findings from the estimation on the pilot sample indicated a negative or non-significant coefficient for the exemption-attribute. Odd as this appeared at first, it was clearly dependent on the current real-life exemptions that many agents already possessed. Indeed it was found that the presence of an exemption already achieved would not generate utility for the agent. On the other hand the loss of the exemptions currently held would generate strong reactions, such as choosing the *status quo* option as a protest, thus yielding uninformative utility estimates. This combination of real-world exemptions with the attribute set-up offered in the SRE lead to the exclusion of the two exemptions following the results of the pilot with operators.

Urban Distribution Centre

The introduction of an UDC is another issue on the political agenda to optimize freight movement in the roman LTZ. In the stakeholder survey the discussions tended to describe the probability of success as very low due to the absence of operator support and financial constraints. A different line of reasoning lied behind the exclusion of this attribute. Indeed the main reason was the lack of shared support from the agents in the stakeholder survey. The lowest support came from the carriers who regarded the participation in a UDC scheme as merely contributing to the costs with no clear benefits yielded. Lastly, when defining the UDC attribute in a practical sense, several difficulties were encountered. These were due to the need to define the

characteristics of the UDC beyond its mere presence/absence. This meant clarifying the fee levels, opening hours and other features, with the associated risk of mis-specifying the attribute or only seizing the acceptance for the specific UDC defined and nothing else beyond that. Due to the interest for this attribute combined with the difficulties described above, it was decided that the UDC be inserted in a specific section of the questionnaire but not included in the ranking experiment.

4.3 Agent specific SRE

Following the pilot of the SRE with operators, and in line with the differentiation required by the efficient design, some respondent-type differentiation of the choice tasks was necessary. In [Table 4](#), an overview of the content of the SRE for each agent-type is given.

As can be noted, the main difference among agent-types is the presence of the time window attribute only for own-account operators. This fact is due to an anchoring affect around the *status quo* condition. Indeed, only the own-account operators are currently *de facto* facing time window restrictions, whereas the carriers operating as third account can access at all times, along with a series of other exemptions based on goods category. As described for the exemptions, thus, the introduction of restriction for operators that have none in real life is very penalizing. In line with these observations and the results from the pilot study, the attribute was included only for own-account agents.

Table 4 - Content of SRE per agent-type

	Own-account	Retailer	Carrier
N. of exercises	10 ranking exercises	10 ranking exercises	10 ranking exercises
Attribute considered in SRE	<ul style="list-style-type: none"> • number of l/u bays, • probability to find l/u bays free, • time window, • LTZ access fee. 	<ul style="list-style-type: none"> • number of l/u bays, • probability to find l/u bays free, • carrier LTZ access fee. 	<ul style="list-style-type: none"> • number of l/u bays, • probability to find l/u bays free, • LTZ access fee.
Response format	ranking: own-account and potential partner	ranking: retailer and partner	ranking: carrier and partner

Regarding the response format, the SRE took shape as a ranking among three policy options, where one was the *status quo* LTZ regulation. The agents were asked to rank the policy bundles according to their preferences. They were also allowed to indicate whether a policy was unacceptable and thus not part of their policy-ordering by indicating a “no” for one policy. For each choice task the respondent is asked to perform the same ranking procedure for their commercial partner. This means requiring respondents to state, to the best of their knowledge, what their freight partners would choose among the options and whether any of the alternatives could be considered unacceptable by partners. In Figure 2 an example of a choice task is given.

Figure 2 - Example of a ranking task

Attributo	Policy 1	Policy 2	Status quo
Loading/Unloading bays	400	800	400
Probability to find L/U bays free	20%	10%	10%
Entrance fee	1000 €	200 €	600 €
Policy ranking:			
Which ranking of the policies, IN YOUR VIEW, would your partner provide?			

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After selecting the attributes to include in the SRE, the next important issue is to determine the appropriate levels and ranges for each attribute.

The levels that characterize the attributes should ideally be both plausible and policy relevant, although a choice experiment may also test currently unavailable but possible alternatives (e.g. a new mobility control policy). In defining the levels it is important to consider the number of levels, how they are spaced among them and what range they vary over. The attributes, levels, distribution and range are illustrated in Table 5.

Table 5 - Attribute levels and ranges used in the SRE

Attribute	Number of levels	Level and range of attribute (sq underscored)
Loading/unloading bays:	3	<u>400</u> , 800, 1200
Probability to find l/u bays:	3	<u>10%</u> , 20%, 30%
Time windows:	3	OPEN from 18:00 to 08:00 e from 14:00 to 16:00; <u>OPEN from 20:00 to 10:00 e from 14:00 to 16:00</u> ; OPEN from 04:00 to 20:00
Fees:	5	200€, 400€, <u>600€</u> , 800€, 1000€

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The first issue is to determine the number of levels to include. For instance a two-level attribute only allows for the estimation of linear effects. Yet, the indirect utility function of an attribute may exhibit non-linear effects. For this reason it is often more informative to include more than two levels to describe an attribute, when

appropriate, to allow for the estimation of non-linearities in the utility drawn from different levels.

A second issue is how to distribute the levels. The literature recommends that levels be evenly spaced which aids in the interpretation of the level coefficients. What is more, if levels are also symmetrical with respect to the *status quo*, this allows for the control of asymmetrical effects concerning gains and losses.

The ranges of the levels are of particular importance. Indeed, a sufficiently wide range of levels should be used to avoid respondents ignoring the attribute due to a lack of difference in levels. The level range is particularly important for the price attribute if it is to be used to calculate implicit prices of other attributes using willingness to pay (WTP) estimates. Moreover the payment vehicle should be chosen to match the setting.

As may be observed in the above table all attributes are given at least three levels. This allows for controls for non-linear effects in the attribute levels during estimation. Such effects are of great importance when considering reactions to policies since there might be large effects on well-being derived from specific levels, and indifference, or a linear utility relation, between some other levels of an attribute.

Regarding the attribute distribution and range, the joint stakeholder meetings were an important source of information. On this occasion the six selected attributes were presented and agents asked to provide indications of ranges. Typical questions posed were: “*What is the minimum increase in the number of l/u bays you would consider necessary?*”, etc, for each attribute. Based on the ranges provided by the stakeholders a maximum increase for each attribute was defined for the two l/u bays and the fees. For the time windows, instead, the stakeholders were asked to suggest two alternative scenarios to the current one. The first, a minimum increase desirable for operators of freight distribution, the second, a maximum sustainable reduction concerning the number of hours. Moreover, a meeting with local policy-makers, responsible for promoting and planning changes to the LTZ regulations was organized.

In the relevant meeting both the feasibility of fee increases and potentialities of construction of l/u bays were discussed. Based on comments from local planning functionaries these attributes were further redefined to achieve realism and properly mirror plausible policy changes.

Drawing on these results the minimum and maximum points of the attribute ranges were defined. For the l/u bay attributes the minimum coincides with the current situation. Instead the range is extended to reflect the stakeholder opinions and the three levels are then equally distributed. This implies that the policy scenarios only proposed an increase in the levels. The time window attribute was reduced from five to three levels due to its complexity. This attribute was instead bi-directional, and great effort was dedicated to define one improved and one worsened level for the time window. Due to the qualitative nature of the attribute it was not possible to ensure that the levels were evenly spaced. Lastly, the entrance fee attribute was defined to vary in both directions compared to the *status quo* level of approximately 600€. Seeing as the past policy changes have been quite abrupt, the attribute proposed for the SRE had a wide range of variation, from 200 to 1000€. The quantitative nature made it a simple task to ensure that the levels were both symmetrical and spaced evenly, over five levels.

5 Deployment of the survey

5.1 First contact with potential interviewees

Potential interviewees were contacted by mail before approaching them in person for the face-to-face interview. In fact, various contact methods were considered in the first instance and one evaluated in practice. Contacting the potential interviewees by phone was tested but, after a pilot attempt (30 phone calls were made) with a zero success rate, we reverted to a more traditional and expensive mail contact.

A standard contact letter was prepared to explain both the motivations and scope of the research. Each letter was completed with the individual contact information and a signature of a member of the research team to provide some personalization and an institutional guarantee for the research project. The letter also provided all the standard guarantees concerning privacy issues and data treatment and dissemination. The letters were progressively sent out according to interviewing needs. In fact, the letters were in general sent out around one week ahead of the planned interviews. Particular attention was paid to both the timing and need for sufficient potential contacts to perform the forecasted interviews for each wave. The mail was also performed according to geographical and density criteria. The first letters were sent out to periphery zip areas since they were characterised by a lower density of contacts.

Once the letters were sent out and the control letter received (within all mailing waves we included a letter addressed to ourselves to ensure that once we received it the other addressees would also have received it) we transferred the information to the interviewers who could then start contacting the various interviewees.

Two different contact methods were used due to the physical dislocation of the interviewees. All retailers and own-account located within the LTZ perimeter and were directly contacted by the interviewers walking into the shops and mentioning the contact letter that was previously sent out. On the other hand, the carriers, frequently located far from the city centre and far apart, were contacted by phone and asked for an appointment for administering the questionnaire.

5.2 Overview of efficient design in four waves

In view of the known difficulty to contact freight operators and to gain the necessary information due to privacy issues, lack of interest among agents, lack of appropriate prior information needed to map specific logistic chains and the generally high costs of face-to-face interviews, efficient designs are especially desirable in this context. Indeed, a more efficient design not only improves data quality but also lead to cost savings. For instance statistically efficient designs may require smaller numbers of respondents while allowing researchers to extract richer preference and choice information. Statistically speaking, *ceteris paribus*, researchers should try to use the most efficient designs available.

In what follows, a brief overview will be given as to the design criteria used in each of the four waves of the SRE. The assignment of specific values to the attributes describing the choice sets ideally occurs in some systematic manner aimed at achieving a predefined research-objective in a cost-efficient manner. In traditional applications the attributes and levels of a design were all defined in advance based on judgement and prior findings, and choice sets were then generated by a randomized

procedure (Louviere, 1988). Instead the current work is based on the theories on efficient experimental design. This means there may be an evolution of the design which is upgraded in several, so-called waves, where each wave represents a change in the structure of the design incorporating the findings from prior interviews. Based on suggestions from John Rose, the recommended basic formula is to carry out the design in four waves. Ideally the sample should be distributed in a way to interview 10% of the sample in each of the first three waves, whereas the largest portion should be saved for the last wave, roughly representing 70% of the interviews and providing confirmative results.

At the outset of the study, due to the novelty of the attributes, there were no prior studies to rely on in the definition of the sign and dimension of the coefficients. In the course of the work three design strategies were tested. In the first instance a d-efficient design with very broad priors and the sign of the coefficient of the attribute was tried. Due to the low precision of the priors used, characterised by large standard deviation of the coefficients, it was not possible to make the design converge based on the limited sample size planned for the first wave of interviews. In the second stage an orthogonal experimental design was tested. This approach implies that each column containing attributes in the design matrix is perfectly uncorrelated with every other attribute (Louviere, Woodworth, 1983). It proved impossible to generate a design with the criteria of orthogonality given the small number of choice sets defined (9 sets). Due to the inconvenience in working with a design in blocks, where a segment of the design is given to each respondent, in the small sample-size foreseen for the first wave a third approach was devised. The third and final design tested was a fractional factorial design. This implies that only a subset of the possible level combinations appear in the design. Given that six attributes were present in the initial design, the number of combinations of the design would be equal to $2^5 \times 2^3 \times 2^2 = 1,024$ combinations. Instead, nine choice sets were created with Ngene 1.0 software, which were only a selection of the complete factorial design. Differentiating the design according to the types of agents interviewed – own-account retailers, third account retailers and carriers – was deemed premature due to the lack of prior information regarding taste heterogeneity among the operators.

For the second wave of the design some important novelties were incorporated. Based on the estimates obtained from the sample in the first wave it was possible to obtain indications of the magnitude and sign of each coefficient. Whereas, for the first wave all agents had seen the same attributes in the SRE, all with the same design properties, now some differentiation is introduced. A first factor of differentiation concerns the attributes to utilize. As described earlier, several among the attributes originally tested were eliminated following the pilot survey. However, even for the four selected attributes, some agent specific considerations were made. The problematic attribute in this sense was the time window, which did not provide a plausible econometric estimate for the agents. Since the attribute improvement would tend to be irrelevant for two agent-types, carriers and retailers, given neither currently abide by any time window restrictions, it was decided that the attribute be used solely for own-account operators. Apart from this change, another concerning the design priors need to be mentioned. Since now, attribute coefficients were available for each attribute and agent, these also could be incorporated into the design that became closer to an efficient design. Efficiency refers to the precision with which coefficients are estimated; more efficient designs give more precise parameter estimates for a given sample size. In our case, we applied the widely used efficiency criterion of d-

efficiency. Beyond this criteria, further efficiency enhancing criteria used in finalizing the design were:

- level balance: the levels of each attribute appear equally often and;
- utility balance: the options in each choice set have similar probabilities of being chosen.

Since nine choice sets were created for each SRE, the level balance could only be ensured for the three-level attributes. Finally, an important rationality test was included, to test respondent consistency in ranking. This was performed by duplicating one of the choice sets and including it twice in the ranking tasks. A failure to respond identically to both scenarios could indicate a learning effect or a lack of attention to the task.

The third wave should ideally confirm and solidify the prior coefficient estimates in view of the final, and most comprehensive wave. The main novelty in this wave was that the prior data available from the sample was large enough to carry out a control for non-linearities. By estimating effects coding on all attributes, it was possible to control for non-linear effects. An advantage of effects coding over dummy coding is that it avoids correlation with the baseline estimate. Significant level-specific effects were found for the fee attribute, and in some cases for others. This led to the inclusion of level-specific design specifications for those attributes where such effects were found. At this stage all attributes were defined specifically to be agent-specific. It should be mentioned that in the definition of the coefficients for the priors, not only a mean prior is defined but also a prior distribution which may take many forms and for this study the prior distributions chosen were normal or uniform forms in all cases, depending on the attribute modelled.

The design of the fourth wave chiefly confirmed the approach used in prior waves. To sum up, the criteria used in creating the design in the previous waves had the below mentioned characteristics:

- agent specific models;
- priors based on estimates of ranking data in previous waves;
- effects coded priors where appropriate;
- unitary or normal distribution of priors according to where appropriate;
- use of d-efficiency criteria to select design;
- use of ulterior design efficiency criteria such as level balance and utility balance;
- inclusion of a control of ranking consistency.

Seeing as the last wave of interviews would be the, by far, most numerous in terms of sample size, an additional feature was necessary to ensure the goodness of the data gathered. A feature not dealt with in earlier stages, due to the technical unfeasibility, was the order of the tasks in the SREs. In earlier waves one set of ten identically ordered choice tasks was given to all respondents in an agent-specific group. However for the numerous last sample a novelty was introduced to avoid gaining lower quality data on specific tasks such as the first (due to non comprehension) or very last (due to fatigue). Thus we developed an algorithm for shuffling the tasks, to ensure each task appeared in different positions within the SRE. Thus, for each agent-type, three different versions of the choice task were created.

6 Summary, conclusions and future research

In this last section we provide a synthetic summary of the paper, draw some conclusions and define future research endeavours.

The paper first reports a synthetic literature review of both agent interaction in freight and experimental design followed by a description of the study context and the roman freight LTZ. The section overviewing the development of the survey instrument includes a description of the essential activity of organizing focus groups meetings. The numerous stakeholder meetings proved fundamental for identifying the main freight distribution problems of the city of Rome in general and those of the LTZ in particular. This phase produced a vivid and clear picture of the perceptions and possible solutions foreseen by the three stakeholder-types involved in this phase: local policy makers, demand (retailers) and supply (transport providers). The main output of this phase of consultation was the identification of the attributes considered most critical in the definition of potential policy-mixes. It was considered fundamental to individuate the critical attributes, regarded as such by a wide range of stakeholders. Several criteria were employed in selecting the specific attributes used in the SRE. This approach assured two positive outcomes. On the one hand it provided attributes considered relevant by interested stakeholders and, on the other, it identified attributes viewed as significant and important for a balanced group of stakeholders. In fact, policy evaluations ought to address both relevant and collectively important issues/attributes aimed at providing policy-makers with indications of potentially effective and acceptable solutions. Subsequently the paper describes, in detail, the various phases of development of a SRE for three different agent-types in Rome's LTZ. In fact, a major innovation of the present research is the sub-division of the analysis to consider three different agent-types: carriers, retailers and own-account. Most of the recent literature on city logistics acknowledges, in principle, the importance of agent-specific measures. However, no study, to the best of our knowledge, has acquired the necessary data to formulate analytically sound and empirically verifiable proposals incorporating knowledge of agent-specific behaviour. This paper represents the first attempt to define and validate agent-specific freight analysis and policies. The main problems and potentially feasible solutions identified in the stakeholder surveys were extremely useful in the progressive specification of the various attributes specifically conceived to map the preferences of each agent-type. Innovative solutions were also adopted in the questionnaire design strategy pertaining to a novel use of prior information to seize the trade-offs of different agent-types. More precisely, the design strategy relied on state-of-the-art efficient design theory, implemented thanks to the newly released Ngene 1.0 software.

The data acquired allow for the estimation of agent-specific models that are useful for analyzing the most promising and potentially acceptable policy-mixes. The results obtained are not only reliable but also relevant under a policy implementation and evaluation scenario. The research produced is not only innovative under several aspects but also provides socially relevant results. In brief, the research approach described in this paper allows for the :

1. identification of the most relevant problems for the LTZ in Rome for the main significant stakeholders;
2. acquisition of stakeholder-specific judgments concerning the present regulatory framework;

3. enumeration of potentially feasible and relevant policies based on stakeholders' opinions and preferences;
4. individuation of agent-specific utility attributes;

The finding of the present paper has opened the door to several promising future research explorations. A central extension concerns the estimation of potential shared acceptability of policy interventions by “couples of agents”, that is retailers and freight carriers. In particular, it would be of interest to detect potential distribution channel effects for each category of goods. Another important extension would be to include and evaluate other potentially relevant attributes in the policy mix scenarios such as time window exemptions, entrance fee exemptions, etc. The reactions to such policies are likely to be strongly differentiated for different agents and have rarely been explored experimentally in past research. A further point that would be relevant to look at is reaction to extended “what if” scenarios. This would allow practitioners to predict the degree of acceptance and foresee behavioural adjustments as a response to wider contextual changes, such as fuel-price changes, tax restructurings or changes in related policies such as parking.

Acknowledgements

We gratefully acknowledge funds from Volvo Research and Educational Foundation, project SP-2007-50. We would also like to thank the participants in the Kuhmo Nectar Conference in Valencia 2010 along with the interviewees participating in the various stakeholder surveys.

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