ROMA TRE
UNIVERSITÀ DEGLI STUDI

CREI Working Paper no. 4/2011

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

by

Marcucci E., DIPES, University of Roma Tre, Italy

Stathopoulos A., DISES University of Trieste, Italy

Gatta V., "Sapienza", University of Rome, Italy

Valeri E., DISES, University of Trieste, Italy

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

Marcucci E., DIPES, University of Roma Tre, Italy

Stathopoulos A., DISES University of Trieste, Italy

Gatta V., "Sapienza", University of Rome, Italy

Valeri E., DISES, University of Trieste, Italy

ABSTRACT: City logistics policies require an understanding of several issues (e.g. freight distribution context, preferences and relationship among agents) seldom accounted for in current research. Policies run the risk of producing unsatisfactory results because behavioural and contextual aspects are not considered. The acquisition of relevant data is crucial to test hypothesis and forecast agents' reactions to policy changes. Despite recent methodological advances in modelling interactive behaviour the development of apt survey instruments is still lacking to test innovative policies acceptability. This paper expands and innovate the methodological literature by describing a stated ranking experiment to study freight agent interactive behaviour and discusses the experimental design implemented to incorporate agent-specific priors when efficient design techniques are employed.

1 Introduction

Cities are characterised by relevant economies of density and proximity, produce ideas, innovations and generate economic growth that irradiates to other areas. At the same time, however, they consume more goods than they produce and, consequently, need to be supplied from outside. They are characterised both by concentrated research and service production as well as various negative externalities among which the most prominent are: congestion, visual intrusion, environmental and acoustic pollution. Their impact is particularly high in densely populated areas where economic activities are concentrated and generate a consistent, strong and, usually, rigid demand for public and freight transportation. Decision makers have adopted policies with the intent of optimising the movement of both passenger and freight so to foster a sustainable development via the decoupling of economic growth from transport demand. The most frequently implemented urban freight policies need to be analysed and evaluated considering a host of these 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, the models adopted to forecast policy impacts used to provide policy-makers with the relevant information needed for taking relevant decisions.

3

This paper illustrates the potential of using a stated ranking experiment (SRE) to elicit the relevant data for successfully estimating and quantifying the preferences of stakeholders within an urban freight transport (UFT) context. We propose an innovative methodology to investigate both retailer's and carrier's sensitivity to changes in policy packages that are simultaneously considered possible by the local authorities (transport regulators) and acceptable by the main stakeholders (retailers, own-account[1] and carriers).

The paper describes the definition, development and administration of a SRE in a real-life context where effective policy interventions (e.g. access charging, time windows, loading/unloading bays (l/u)) are envisaged and evaluated for implementation. Ideally, the experiment proposed will enable the researcher to identify both overall ex-ante policy acceptability as well as policy acceptability by single stakeholder influenced by the policy mix implemented. Urban freight distribution is a phenomenon deeply intertwined and influenced by interaction effects among the actors involved; the approach described in this paper identifies not only effective and efficient measures but also, among these, the subset that can be considered acceptable, if not by all, by the greatest number of actors possible.

The innovative features of the methodology proposed relate to the contemporaneous consideration of both demand and supply operators instead of, as is usually done, just studying the two facets as separate phenomena. Under this respect our approach proves complementary to the widely used Freight Quality Partnership (FQP) that, however, adopts a more descriptive and qualitative stance.

The paper is structured as follows. Section 2 reviews the literature on both agent interaction analysis in the freight sector as well as that of stated preference and

---

[1] By own-account we intend a specific group of retailers that, predominantly, auto-produce their own freight transportation services.

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 agents' relative convenience of past actions. This paragraph illustrates some recent findings of a behavioural approach to freight modelling, in general and to UFT in particular. This innovative method accounts for the most relevant complexities deriving from modern logistic supply chain activities. Hensher and Figliozzi (2007), argue that standard approaches do not fully account for the complexity of freight movements at different geographical scales. What is more, new delivery methods (e.g. JIT) and customer driven freight services (e.g. electronic commerce) have made UFT more complex thus paving the way to highly specialised 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 and unequivocally identify the key decision makers to develop a modelling framework adopting an actor-based micro-simulation approach capable of describing and forecasting the behaviour of the

specific actors involved (Liedtke and Schepperle, 2004). Various authors (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; Roorda, 2010) consider UFT the most appropriate field of application for developing actor-based micro models. Freight movements are as relevant as the underlying motivations determining the relative convenience of each stakeholder in taking a specific action or making a given choice. Structural behavioural analysis represents a substantial improvement with respect to standard modelling techniques. The specific advantages of explicitly allowing for behavioural considerations when modelling freight movements become evident when considering network and micro-simulation modelling, land use/transport network with feedback effects, the relevance of physical characteristics of logistics networks. Previous modelling approaches mostly abstracted from these aspects. These innovations have introduced greater realism in the analysis by explicitly accounting for 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 facets are for UFT policy analysis, acceptability and impact assessment. 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 the state of the world is altered. For example, policy changes influencing fuel prices, land use patterns and pricing strategies modify the constraints and alter the relative convenience of each option. 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 policies implemented 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; 2008). Usually both financial and sample size issues render this approach difficult to implement for real-life applications. Only a limited number of buyers of road freight transport services or transport providers are willing to participate in a study and hence it is difficult to guarantee a sufficient participation. Hensher and Puckett (2008) 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 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 variety of research fields among which the most prominent applications have been in transportation, marketing,

environmental evaluation and economics. While transportation has witnessed path-breaking contributions in discrete choice modelling, historically, the most relevant advances in choice experiment design have emerged in marketing and economics[2].

A choice experiment aims at acquiring high quality data to generate reliable and useful estimates of the parameters of interest. Depending on the research question considered, one may adopt a different response format among: choice, ranking or rating which plays a relevant role since it is linked to the way data can be analyzed once acquired (Johnson and Desvousges, 1997; Ortúzar, Garrido, 1994; Crask, Fox, 1987; Louviere, 1992, 1988; Aaker, Day, 1990) and to the reliability of the responses obtained.

Estimation of statistically significant parameters, especially when small samples are used (as is usually the case in empirical research), may be aided (impaired) by a good (poor) experimental design. Thus, the choice of a specific experimental design is not irrelevant with respect to the research conclusions reached.

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, more recently, efficient design, an alternative and innovative approach, has been developed numerous researchers (Huber, Zwerina, 1996; Kanninen, 2002; Kessels et al., 2006; Sándor, Wedel, 2001; 2002; 2005). The logic underlying efficient design hinges upon the consideration that orthogonality is not related to relevant and desirable properties of the discrete choice models employed to analyze SC data. Logit and probit models,

---

[2] Qualified systematizations of both advanced and introductory scientific knowledge for discrete choice modelling include, among others, the following: Ben-Akiva, and Lerman (1985), Hensher et al. (2005), Louviere et al. (2000), Train (2003), Marcucci (2005).

commonly used for estimation, using SC data, are not linear and do not require zero correlation between the attributes of the design[3]. Almost twenty years ago Hensher and Barnard (1990) clarified the distinction between *design* orthogonality and *estimation-data* orthogonality evidencing that this property is not always preserved in model estimation. This last characteristic would only be guaranteed if the differences in attribute levels were orthogonal rather than the levels themselves. In other words, the attribute correlation structure should not be utilized as the sole or main design criteria and, indeed, a more important element is the correlation of the differences in the attributes.

Huber and Zwerina (1996) made the first attempt to link the statistical SC properties to the econometric models used to treat such data. The authors showed that by relaxing orthogonality conditions the asymptotic standard errors of the parameter estimates (e.g the square roots of the diagonal elements of the asymptotic variance-covariance matrix –AVC–) can be reduced. Researchers have, in many cases, used *Monte Carlo* simulations to calculate the AVC 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, evaluate and consider a single value instead of assessing the whole AVC. Various analysts have proposed different efficiency measures (e.g. d-efficiency, a-efficiency) to measure the desirability of the design obtained.

---

[3] This would be important to detect independent effects when employing linear models.

Table 1 – General regulation of the LTZ in Rome

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	

3 The study context: the roman freight limited traffic zone

The institution of a formal limited traffic zone (LTZ) in Rome's historical centre can be traced back to the late eighties when a 5 km^2 area was restricted to non-resident vehicles. The bans on traffic apply to passenger and freight vehicles alike. Access and circulation in the larger peri-central area termed "LTZ Anello Ferroviario" (LTZ–Railway Ring) is prohibited to pre-Euro-1 and Euro-1 light and heavy vehicles. The

central area, focus of this study, has a more detailed legislation in place. It corresponds to a 4 km^2 area in the historical centre. Least polluting vehicles (Euro 1 and later) alone are allowed to enter the LTZ with access permission awarded for free only to residents while other agents (e.g. retailers and freight carriers) must pay an access fee. The scheme operates during daytime hours (passenger cars: 06.30–18.00 Monday to Friday and 14.00–18.00 on Saturday). The passenger and freight LTZ largely overlaps where the latter is aimed at goods vehicles and operates between 10.00–14.00 and 16.00–20.00. The yearly permit costs 565€ per 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 using cameras and optical character recognition software. Specific time windows apply for access and parking of freight vehicles. Nonetheless, a wide range of freight operators is exempted from payments. A synthetic summary of the regulatory regime presently in place, as defined in the latest LTZ municipal resolution (n. 44 from 2007), is shown in Table 1.

Table 1 – Main regulatory characteristics of Rome freight LTZ

Indeed, the regulation is essentially designed to incentivate the use of third account operators while discouraging lengthy parking of own account vehicles, given the shortage of on-street parking in the area. Time windows are currently not systematically enforced. The scheme, due to the many exceptions, can hardly be considered as a congestion reducing policy nor can it be classified as a pure environmental low emission zone (LEZ) since 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 suggest that environmental objectives prevail over efficiency goals.

4 Development of the survey instrument

This section describes the rationale behind the use of separate designs by agent-type and illustrates the different components of the questionnaire administered. Fundamentally, when studying urban supply chains one has to figure out what are the main driving forces at the base of supply agents behaviour. Beyond mapping the main problems and policy solutions surrounding urban freight distribution, policy administrators need to understand the perspectives and roles of different stakeholders in the logistic chain. Receivers, carriers and forwarders are, traditionally, considered as essential stakeholders in urban freight logistic system analysis (Ogden, 1992). The current SRE concentrates on representing three main supply chain agents: carriers, retailers and own-account operators. The first two, transport operators and retailers that receive the goods, are well identified in the literature. Stakeholder consultations, specific studies of the roman context and an analysis of the current regulation, all suggest it is essential to include own-account operators as well. This separate treatment and differentiation of the design according to agent-type represents an important advancement to adequately describe the heterogeneity in needs and problem perception among agents. Indeed, the insight gained from the meetings with the stakeholders regarding which agents to represent and the issues potentially generating more tension among them, proved an important source of guidance in this process.

The first issue to be dealt with is the definition, selection, and development of the attributes to include in the SRE for each agent. In particular, we illustrate in detail

how we moved from the stakeholder consultation stage to the attribute definition. In doing so we highlight and motivate which specific attributes were included in the final questionnaire design. Indeed, the level of joint policy acceptance was the main criteria for attribute inclusion. Following the justification for inclusion we report how each attribute was defined and structured in levels and ranges. An important point to keep in mind is the progressive differentiation of the attributes modelled that were progressively differentiated by agent-type. This procedure was adopted to account for real-world agent-type constraints and preferences. The choice of attributes was, to a large extent, based on the results from the stakeholder surveys. The following sections overview the attributes included, describe their characterization and illustrate the reasoning behind the choices made. Furthermore, we also motivate the exclusion of certain attributes.

4.1 Attributes to include in SRE

Each alternative in the SRE is described by a set of attributes that can take several levels to describe ranges of variation when the alternatives are presented to the respondents. For example, when choosing between alternative city logistics policies one usually, among key attributes, encounters entrance fees and loading-unloading regulations. Respondents are asked to rank alternative versions of the policy differing in attribute quality and quantity.

In order to acquire the necessary data to assess the *ex-ante* acceptability of city logistic policies in Rome's LTZ we defined the attributes used in the experiment by drawing on three main sources, namely; a) literature survey; b) previous quantitative studies on city freight distribution in Rome; c) series of focus group meetings with relevant expert stakeholders.

We performed an extensive review of the current city logistics literature with an agent-based perspective that indicated a set of potentially conflicting policy components when regarded and evaluated from each different agent-type perspective in the chain. For instance night-time deliveries were considered efficiency enhancing by carriers but considered only to contribute towards operational cost increases by retailers. However, before pondering any differentiated agent-specific design it was necessary to select the attributes to include in the SRE.

Reviewing the quantitative studies on city logistics previously carried out in Rome (Filippi and Campagna, 2008; STA, 1999) and considering the series of stakeholder surveys organized provided the greatest contribution to the definition of the attributes to be included in the SRE. An important phase of the expert surveys[4] was the questionnaire asking the respondents to indicate the policies reputed most appropriate to mitigate the identified city logistics problems (Stathopoulos et al. 2010).

In a following stage the results were evaluated according to several criteria to ensure an appropriate attribute selection for the SRE. The criteria applied were the following: saliency, shared support and plausibility with respect to changes of the current scenario. The attributes selected by the stakeholders in the consultation stage could not automatically be used in the SRE but were revised according to the criteria above.

Volvo REPORT (2010) provides a detailed overview of the link between the stakeholder survey results and the attributes used in the SRE. Among the policies that gathered the largest support in the stakeholder survey five macro-policy categories are represented: vehicle, information, loading/unloading, distribution and access policies.

---

[4] The results presented here are part of a greater study (Volvo Research and Educational Foundation, project SP-2007-50 - Innovative solutions to freight distribution in the complex large urban area of Rome) where a great deal of attention was paid to the attribute definition phase. A group of experts was interviewed and long-lasting discussions ascertained which where the most relevant and informative attributes to include in the study so to correctly characterize the policy intervention measures to be tested.

Not surprisingly, among the top rated policies we encounter those inducing least costs to users (e.g. incentives and an information provision services) in line with the well-known equity-efficiency trade-off. To incorporate the degree of shared support, as a pre-condition for attribute inclusion, it is necessary to look at agent-specific support for policies.

Agents were, on the whole, reluctant to propose the use of time windows probably considered a delicate instrument. 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 Scalo San Lorenzo, 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 l/u 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* |

An important rationale for the current attribute-selection criteria is that a high level of shared support would facilitate the introduction and continuation of a policy using such an attribute. Notably there is a strong, and mutual, support for the eco-vehicle incentive, information provision and number of l/u bays. On the other hand, policies sustained by a single agent only, such as tradable permits or, as for time windows, by policy makers and freight operators alone, run the risk of not gaining the necessary support for a successful implementation. In particular, policies requiring a joint effort among operators such as time windows and pick-up-points fare badly in our survey.

Out of the twelve policies, based on the criteria of relevance and acceptability, six attributes were selected to undergo pilot testing with real operators, namely:

1. number of l/u bays;

2. probability to find l/u bays free;

3. time windows;

4. exemption from time windows;

5. entrance fees;

6. exemptions from entrance fees.

Each of these six attributes have been on the political agenda for a long period and all were perceived as realistic measures to be included in future policy mixes.

Subsequently, we discuss in detail the inclusion/exclusion rationale and the 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 main challenge surrounded the attribute definition. Some critical aspects concerned some attribute dimensions that interviewees considered relevant during the stakeholders' meetings. For instance both the number of bays and the possibility to find them free when needed were considered important. Earlier studies in Rome (STA, 1999), testify that both these features are indeed important for operators and, therefore, it was decided to represent both these characteristics of the l/u bays in the SRE. Although the construction of additional l/u bays has been on the political agenda for decades, the proposals have never made it to the implementation phase. This means that the number of l/u bays in the LTZ is fixed at the restrictive number of 400.

Probability to find l/u bays available

Related to the number of l/u bays it is necessary to consider the probability of finding them available. Evidence from the stakeholder discussions and the pilot study both indicated that some agents were not so much interested in the number of bays but rather in the probability of finding them available for l/u operations. Various policies proposed for implementation foresee the increase of controls in order to guarantee a correct occupation especially since a large portion of occupations of the l/u bays in Rome's LTZ is currently illegal. The focus on the probability imples the focus is on the policy outcomes rather than the policy itself since there are several possible methods or policies that could feasibly eliminate illegal or inappropriate use. Given that the outcome was to increase the probability of finding the bays free this also

emerged as the most appropriate attribute definition. Lack of appropriate mapping of the current probability of finding the bays available led us to examine the issue empirically by controlling a sample of bays and registering the number of occupied and available l/u bays during week-day rush-hour. The findings indicated that the current probability corresponds to a 13% chance of finding a bay available, on average. It was not always possible to assess whether the spaces were unavailable 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 different areas potentially generating a large amount of disparity among agent's perceptions. Defining an attribute in probabilistic terms may provoke an excessive cognitive burden for respondents, but was a necessary condition to ensure a general interpretation of the perceptions of this complex issue.

Separating the number of bays from the probability measure allows several possible modelling options for the perception of 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 corresponds to the prevalent way respondents consider and evaluate 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 pertain both to the definition and the representation of the attribute. In particular, there are several ways to approach the definition; Should the attribute be described in terms of number of hours of closure? Should the exact hours of the day when the area is closed for deliveries be specified? Should we enumerate how many

"windows" to utilize in the characterization? When describing the attribute to the respondent one has to clearly define 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, described in the following:

- o identify the most desired hours for freight delivery;

- o put together time window scenarios that represented variations on the *status quo* and which could easily be interpreted by the researcher (e.g. number of hours and their distribution over the day);

- o represent these scenarios to respondents;

- o test the comprehension of the scenarios and their desirability in a pilot study;

- o re-define the time window attribute in view of pilot study results.

To identify the most sought after delivery hours a study by STA (1999) was used. The initial plan was to study both the importance of the number of hours of access to the LTZ and their specific distribution over the 24 hour working day.

Five different scenarios, varying both the number of hours and their distribution according to desirability, were the first set of representation devised.

Fees

A price attribute is usually included when creating a choice or ranking experiment 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 since this agent-type is the most likely to be directly influenced by this attribute. Due to the large increases in recent years, from a 35€ euro to a 565€ euro annual fee fo each number plate, this attribute

proved quite a sensitive issue. It was decided to represent the attribute as the *status quo* level with both upward and downward variations.

4.2   Excluded attributes

Some of the attributes that emerged as interesting or important from the relevant literature or stakeholder meetings were not used in the SRE. The reason for the exclusion is connected with failing to meet one the criteria used for the attribute selection process previously described. Unanticipated or irrational sign of certain coefficient became manifested themselves during the pilot estimation. Therefore a reformulation or attribute exclusion, on account of not being well comprehended by respondents in the pilot study, was deemed necessary. 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. Some of these attributes, such as the UDC, reserved lanes, etc. were studied in the context of the scenarios and behavioural reactions, others, such as entrance fee exemption and time windows exemption, are excluded altogether.

Exemptions from time windows and fees

As mentioned earlier, the current exemptions and other types of user differentiation were regarded as important 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 with the intent 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. 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 became clear that his was due to the exemptions currently in place that many agents already possessed. 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 cost increases 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. It was decided that the UDC be inserted in a specific section of the questionnaire but not included in the ranking experiment due to the interest for this attribute combined with the difficulties described above.

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 (WE could explain in more detail what exactly happened in each wave). In Table 3 an overview of the content of the SRE for each agent-type is reported.

The presence of the time window attribute only for own-account operators represents the main difference among agent-types. This is due to an anchoring affect around the *status quo* condition. Indeed, only own-account operators are currently *de facto* facing time window restrictions, whereas carriers operating as third account can access the LTZ at all times, along with a series of other exemptions awarded according to specific goods categories. As described for the exemptions, thus, the introduction of restrictions 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 3 - 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	• number of l/u bays • prob. l/u bays available • time window • LTZ access fee	• number of l/u bays • prob. l/u bays available • carrier LTZ access fee	• number of l/u bays • prob. l/u bays available • 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

policy bundles according to their preferences. They were also solicited to indicate whether a policy was considered unacceptable and thus not part of their policy-ordering. For each choice task the respondent is also asked to perform the same ranking procedure for their *typical* commercial partner. This means requiring respondents to state, to the best of their knowledge, the ranking their freight partners would provide among the available options and whether any of the alternatives would be considered unacceptable by their partners. In Figure 1 an example of a SRE task is reported.

Figure 1 - Example of a ranking task

	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?			

After selecting the attributes to include in the SRE, the next important step 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 4.

Table 4 - 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€

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 and for this reason it is often more informative to include more than two levels to describe an attribute, when appropriate, and to allow for the estimation of non-linearities in the utility deriving from different levels.

A second issue is how to distribute the levels. The literature recommends that levels be evenly spaced to aid interpretation of the coefficients. What is more, if levels are also symmetrical with respect to the *status quo*, this allows for the control of asymmetrical effects related to 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 variations. The level range is particularly important for the price attribute which is 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 Table 5 all attributes are characterized by 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.

Joint stakeholder meetings were an important source of information concerning the attribute distribution and range. 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?"* 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 representing a minimum increase desirable for operators of freight distribution and the second defining 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 meetings both the feasibility of fee increases and the likely 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. Great effort was dedicated to define one improved and one deteriorated level for the time window attribute. 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 with respect to the *status quo* level of approximately 600€. Since past policy changes have been quite abrupt, the attribute proposed for the SRE had a wide range of variation going from 200€ to 1000€. The quantitative nature made it a simple task to ensure that the levels were both symmetrical and evenly spaced over the 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 face-to-face interviews. In fact, various contact methods were considered in the first instance and one evaluated in practice. Contacting potential interviewees by phone was tested but, after a pilot attempt (30 phone calls were made) with a low 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[5].

---

[5] The letters were progressively sent out according to interviewing needs. In fact, the letters were in general mailed 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 mailing was also performed according to geographical and density of contact criteria.

Once the letters were sent and the control letter received[6] 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 were directly contacted by the interviewers who directly walked into the shops mentioning the contact letter received. The carriers, on the other hand, 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

Efficient design is especially desirable in a context characterised by: 1) established difficulty to contact freight operators and to gain the necessary information due to privacy issues, 2) lack of interest among agents, 3) lack of appropriate prior information needed to map specific logistic chains and, 4) the generally high costs of face-to-face interviews. Indeed, a more efficient design not only improves data quality but also leads to cost savings. For instance statistically efficient designs may require smaller numbers of respondents while allowing researchers to extract richer preference and choice information. Researchers should always try to use the most efficient designs available but this is much more so in our specific research context for the motivations reported above.

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

---

[6] Within all mailing waves we included a letter addressed to ourselves to ensure that once we received it the other addressees would, most likely, have also received it.

achieving a predefined research-objective in a cost-efficient manner. In traditional applications the attributes and levels of a design are defined in advance on the base of personal judgement and prior findings, and choice sets generated by a randomized procedure (Louviere, 1988). The current work instead is based on efficient experimental design theory. This means there may be an evolution of the design that 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. Ideally the sample should be distributed in such 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 so to provide confirmative results.

5.2.1 First wave

The novelty of the attributes and the lack of any prior studies to rely on in the definition of the sign and dimension of the coefficients lead the team to test different approaches. 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 of working with a design in blocks, where a segment of the design is given to each respondent, given 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 appears in the design. Given that six attributes were present in the initial design, the number of combinations of the design would be equal to $2^5 \times 2^3 \times 2^2 = 1,024$. 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 agent-types interviewed – own-account retailers, third account retailers and carriers – was deemed premature due to the lack of prior information regarding taste heterogeneity among them.

5.2.2   Second wave

For the second wave of the design some important novelties were incorporated. Based on the estimates from the first wave it was possible to obtain indications of the magnitude and sign of each coefficient. Based on these results differentiation in the SRE design properties is introduced. A first aspect 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 attributes selected, some agent-specific considerations were made. The main difficulty concerned the time window where econometric estimates were not plausible. Since attribute improvements proved irrelevant for carriers and retailers, given that neither operator currently abide by time window restrictions, it was decided that the time windows be used solely for own-account operators. Moreover, a differentiation in the design priors was introduced. Given that estimates of attribute coefficients were available for each agent-type they were incorporated marking the refinement process needed to implement an efficient design where efficiency refers to the precision with which coefficients are estimated. Efficient designs produce reliable parameter estimates for a given sample size or, alternatively, can produce attribute estimates of a

pre-determined level of reliability at a lower cost. In our case, we applied the widely used d-efficiency criterion along with other criteria used in finalizing the design:

- o *level balance*: each attribute appears equally often and;
- o *utility balance*: options in each choice set have similar probabilities of being chosen.

Since nine choice sets were created for each SRE, level balance could only be ensured for the three-level attributes. Finally, an important rationality test was included to check for respondent consistency in ranking performed by duplicating one of the ranking exercises.

5.2.3 Third wave

The third wave should ideally confirm and solidify the coefficient estimates derived from prior waves in view of the final and most comprehensive one. The main novelty of this wave was the inclusion of non-linearities in attribute level effects. By estimating effects coding on all attributes, it was possible to control for non-linear effects[7]. Substantial level-specific effects were found for the fee attribute, and in several cases for remaining attributes. This lead to the specification of a non-linear design. At this stage all attributes were defined as agent-specific. It should be mentioned that when defining the priors for the coefficients, not only a mean prior but also a prior distribution was proposed. Different distributions can be used and, in our case, depending on the attribute modelled, normal or uniform forms only were used.

---

[7] An advantage of effects coding over dummy coding is that it avoids correlation with the baseline estimate.

5.2.4 Fourth wave

The design of the fourth wave chiefly confirmed the approach previously used. In conclusion, the criteria used to model the design in the previous waves was characterised by the following elements:

- o agent specific models;

- o priors based on estimates of ranking data in previous waves;

- o effects coded priors where appropriate;

- o unitary or normal distribution of priors according to *a priori* beliefs;

- o use of d-efficiency criterion to select design;

- o use of further design criteria such as level balance and utility balance;

- o inclusion of a control for ranking consistency.

Since the last wave of interviews involved, by far, the greatest number of interviewees an additional feature was introduced to ensure the quality of the data gathered. In previous waves one set of ten identically ordered ranking tasks was administered to all respondents in a given agent-specific group. However, for the fourth wave, to avoid acquiring low data quality due to problems deriving from specific task positioning (e.g incomplete comprehension of early task or fatigue in the later) we developed an algorithm for shuffling the tasks so to ensure each task appeared in different positions within the SRE in the three different versions of the choice task created for each agent-type.

6 Summary, conclusions and future research

The paper 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. This motivates and justifies our approach aimed at modelling

preferences of three different agent-types and their likely interactions with their "typical" business partners. The section overviewing the development of the survey instrument includes a description of the essential activity of organizing focus group meetings. The stakeholder meetings proved fundamental for identifying the main freight distribution problems in Rome's LTZ. This phase produced a clear view of the perceptions of the main problems 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 from this consultation phase was the identification of the attributes considered most critical for inclusion in potential policy-mixes to be implemented. 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 the development and refinement 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. The present study has acquired the necessary data to formulate analytically sound and empirically verifiable proposals incorporating knowledge of agent-specific behaviour. The main problems and potentially feasible solutions identified in stakeholder surveys were extremely useful in the progressive specification of the various attributes purposely

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[8].

The data acquired will 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. enumeration of potentially feasible and relevant policies based on stakeholders' opinions and preferences;

3. the design of a SRE differentiated using agent-specific attributes and specification.

The data acquired open 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", namely retailers and freight carriers. Moreover, 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

---

[8] The questionnaire was implemented thanks to the newly released Ngene 1.0 software by Choicemetrics.

experimentally in past research. A further point that would be relevant to investigate relates to 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.

Finally, we would like to stress the great benefits provided by the methodology proposed in terms of greater accuracy of the estimates obtainable given a specific budget for interview administration or, alternatively, the reduction of the budget needed to reach a predetermined level of accuracy . This last aspect may be crucial in different empirical research situations.

7   Bibliographical references

Aaker, D., Day, G., (1990), Marketing Research, Wiley and Sons.

Ben-Akiva, M. and S.R. Lerman (1985) Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, USA.

Brewer, A. and Hensher, D.A. (2000). "Distributed work and travel behaviour: The dynamics of interactive agency choices between employers and employees", *Transportation*, Vol. 27, pp. 117-148.

Crask, M., Fox, R., (1987), "An exploration of the interval properties of the three commonly used marketing research scales: a magnitude estimation approach", *Journal of the Market Research Society*, 29 (3), pp. 317-39.

de Jong, G., and M. Ben-Akiva (2007) A micro-simulation model of shipment size and transport chain choice. Transportation Research Part B 41: 950–965.

Gray, R. (1982) Behavioural Approaches to Freight Transport Modal Choice. Transport Reviews, 2(2), pp. 161-184.

Hensher, D. A. and Puckett, S. M. (2008) "Power, concession and agreement in freight distribution chains: subject to distance-based user charges", International Journal of Logistics Research and Applications, 11: 2, 81-100

Hensher, D., and Figliozzi, M. A. (2007). "Behavioural insights into the modelling of freight transportation and distribution systems." *Transportation Research Part B: Methodological*, 41(9), 921-923.

Hensher, D.A., Rose, J.M. and Greene, W.H. (2005) *Applied Choice Analysis: A Primer*, Cambridge University Press, UK.

Hensher, D.A. and Barnard, P.O. (1990) The Orthogonality Issue in Stated Choice Designs, in Fischer, M., Nijkamp, P. and Papageorgiou, Y. (Eds.), Spatial Choices and Processes, North-Holland, Amsterdam; 265-278.

Huber, J. and K. Zwerina (1996) The Importance of Utility Balance in Efficient Choice Designs. *Journal of Marketing Research* 33, 307-317.

Johnson, L., Desvouges, W., (1997), Estimating Stated Preferences with Rated-Pair data: Environmental, Health, and Employment Effects of Energy Programs, *Journal of Environmental Economics and Management*, 34, 79-99.

Kanninen, B.J. (2002) Optimal Design for Multinomial Choice Experiments. *Journal of Marketing Research* 39, 214-217.

Kessels, R., Goos, P. and Vandebroek, M. (2006) A comparison of criteria to design efficient choice experiments, *Journal of Marketing Research*, 43(3), 409-419.

Liedtke, G., and H. Schepperle (2004) Segmentation of the Transportation Market with Regard to Activity–based Freight Transport Modelling, International Journal of Logistics: Research and Applications, Vol. 7, No. 3, pp. 199-218.

Louviere, J., (1988), Analyzing Decision Making Metric Conjoint Analysis, *Quantitative Applications in the Social Sciences* (67), Sage University Paper, SAGE Publication Inc.

Louviere, J., (1992), Experimental Choice Analysis: Introduction and Overview, *Journal of Business Research*, 24, pp. 89-95.

Louviere, J.J. and D.A. Hensher (1983) Using Discrete Choice Models with Experimental Design Data to Forecast Consumer Demand for a Unique Cultural Event. *Journal of Consumer Research* 10, 348-361.

Louviere, J.J., and G. Woodworth (1983) Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregated data. *Journal of Marketing Research* 20, 350-367.

Louviere, J.J., D.A. Hensher, and J.D. Swait (2000) *Stated Choice Methods—Analysis and Application*. Cambridge University Press, UK.

Marcucci E., (Ed), (2005) Introduzione ai modelli a scelta discreta per lo studio dei trasporti, (An introduction to discrete choice models to study transportation) Carocci Editore, Roma.

Ngene 1.0, Choicemetrics Pty Ltd, http://www.choice-metrics.com.

Ogden, K. W. (1992). *Urban goods movement: a guide to policy and planning*, Ashgate, Aldershot, UK.

Ortuzar, J., Garrido, R. (1994) "A practical assessment of stated preferences methods", *Transportation*, 21, pp. 289-305.

Puckett, S. M., and Greaves, S. (2009). "Estimating Policy-Induced Changes in Freight Vehicle Emissions in Sydney." Institute of Transport and Logistics Studies Working Paper, The University of Sydney.

Puckett, S.M., Hensher, D.A. (2006) Modelling interdependent behaviour utilising a sequentially-administered stated choice experiment: analysis of urban road freight stakeholders, Paper presented at the 2006 Conference of the International Association of Travel Behaviour Research, Kyoto, Japan.

Puckett, S.M., Hensher, D.A. (2008) The role of attribute processing strategies in estimating the preferences of road freight stakeholders under variable road user charges. Transport. Res. E., 44,379-395.

Roorda, M. J., R. Cavalcante, S. McCabe, and H. Kwan (2010) A conceptual framework for agent-based modelling of logistics services. Transportation Research Part E: Logistics and Transportation Review, Vol. 46(1), pp. 18-31.

Rose, J.M., and M.C.J. Bliemer (2005) Constructing efficient choice experiments. Report ITLS-WP-05-07, Institute of Transport and Logistics Studies, University of Sydney.

Samimi, A., A. Mohammadian, and K. Kawamura (2009) Integrating supply chain management concept in a goods movement microsimulation. IEEE International Conference on Service Operations, Logistics and Informatics, July 22 - 24, 2009, Chicago, IL, USA.

Sándor, Z., and M. Wedel (2001) Designing Conjoint Choice Experiments Using Managers' Prior Beliefs. *Journal of Marketing Research* 38, 430-444.

Sándor, Z., and M. Wedel (2002) Profile Construction in Experimental Choice Designs for Mixed Logit Models, *Marketing Science* 21(4), 455-475.

Sándor, Z., and M. Wedel (2005) Heterogeneous conjoint choice designs. *Journal of Marketing Research* 42, 210-218.

Southworth, F. (2003) Freight Transportation Planning: Models and Methods. Transportation systems planning: methods and applications, by K. G. Goulias.

STA. (2001). "Quadro conoscitivo del problema della distribuzione delle merci nel Centro Storico di Roma." Rome.

Train, K. (2003) *Discrete Choice Methods with Simulation*. Cambridge University Press, UK.

Volvo Research and Educational Foundation (2010), *Innovative solutions to freight distribution in the complex large urban area of Rome*, Final report, project SP-2007-50.

Wisetjindawat, W., S. Matsumoto, and K. Sano (2005) Supply Chain Simulation for Modeling the Interactions in Freight Movement. Journal of the Eastern Asia Society for Transportation Studies, 6: 2991 – 3004.

Yang, C. H., J. Y. J. Chow, and A. C. Regan (2009) State-of-the Art of Freight Forecasting Modeling: Lessons Learned and the Road Ahead. Proceedings, 88th Annual Meeting of the Transportation Research Board, Washington DC, 11–15 January 2009.