

Models of Organisational and Agency Choices for Passenger and Freight-Related Travel Choices: Notions of Inter-Activity and Influence

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Abstract

The study of traveller behaviour has in the main treated each agent in a decision-network as an independent decision maker conditioned typically (and exogenously) on the socio-economic and demographic characteristics of other agents and at best on a set of exogenous variables representing the (perceived 'equilibrium') influence of other agents. In many literatures it has long been recognised that agency interaction plays a (potentially) significant role in the actions of individuals. Examples at the household, community and business level abound. McFadden (2001a,b) recently stated that a high priority research agenda for choice modellers is the recognition of the role of social and psychological interactions between decision makers in the formation of preferences. Manski (2000) came to a similar conclusion and offered a plea for better data to assist in understanding the role of interactions between social agents (promoting the role of experimental choice data).

While the interest in (endogenous) interactions between agents involved in passenger travel activity is generally neglected, the absence is particularly notable and of greater concern with the renewed interest in the study of (urban) freight travel activity where a supply chain of decision-makers have varying degrees of influence and power over the freight distribution task. This paper reviews the broad literature on interactive decision making with a specific focus on choices made by interactive agents and the role of individuals in networks. A number of modelling perspectives are presented that use well established discrete choice paradigms. We highlight the challenges in designing data collection paradigms that are comprehensive, relevant and comprehensible by participating agents and suggest an agenda for ongoing research.

1. Introduction

Organisational choice recognises the inter-activity between individuals in their roles as members of organisations such as households, businesses and community groups and networks. As such, a whole new layer of interaction and influence is introduced into travel behaviour research that compounds the complexity of problem definition, model specification, data collection and analysis.

There are many dimensions of inter-activity. These include preference interactions, constraint interactions and expectation interactions (Manski 2000) that can be passive or active (by observation or direct participatory influence). Empirically, interactivity can take many forms, synthesised into three main types: endogenous interactions (the propensity of an agent to act in some way varies with the behaviour of the group), contextual interactions in which the propensity of an agent to behave in some way varies with exogenous characteristics (including perceived influence) of the group members, and correlated effects wherein agents in the same group tend to behave similarly (to varying degrees or correlation) because they have similar individual characteristics or face similar institutional environments (Manski 2000, 127). These hint at a modelling representation.

A big challenge is the recognition of the presence of endogeneity due to *reflection*. For example, the average behaviour of the group is itself determined by the behaviour of group members. Establishing the direction(s) of influence and the role of each agent (eg leaders and/or followers) is very important in formulating the interactivity. Sequential versus simultaneous negotiation is especially relevant. The papers by Arora and Allenby (1999) and Dellaert et al (1998) that study influence provide one appealing empirical approach (see below). The social psychology literature on social grouping (eg Levine and Moreland 1998) provides broad guidelines on ways in which agents interact in small groups. Although there is a large literature focussed on game theory to study interactions between agents in a decision-chain, this literature has not offered practical ways of modelling the behavioural relationships of interest to the study of traveller behaviour (see Bernstein (1996) for an excellent overview of game theory and its relevance to decision-making). Brewer and Hensher (2000) offer one empirical approach that recognises notions of cooperation and non-cooperation, trust, feedback, expectation and timing (sequential vs simultaneous group preference and choice). The latter appears to be one of only two transport paper in which two or more agents are represented endogenously in a choice revealing process¹. Gliebe and Koppelman (2002) have recently modelled joint activity participation of adult household members through simultaneous representation of each decisions maker's decisions concerning independent activity participation, allocation of time to joint activities, and the interplay between individual and joint activities.

This paper reflects on a number of issues involved in modelling joint decisions, both within and between households and firms. Important questions include: What modelling approaches have been tried? Whom do we need to interview and how, in particular in firms? How do we find them and quantify their preferences and choices? Examples include employee-employer, household partners, and shipper-forwarder interactive agents.

¹ Colleagues in econometrics and marketing at the University of Sydney advise me that this comment applies broadly to the literature in economics and marketing. Although there is a large literature in the sociological and administrative sciences on agency networks (see Stevenson and Greenberg 2000 for one excellent example), this literature focuses on structural relationships using correlation measures of performance. The choice modelling paradigms popular in travel behaviour research are typically absent (although see Podolny 1994 for an exception, using logistics regression to study exchange partners in the investment sector).

2. The Idea of Interactive Agents – Defining Relational Structures in Networks

No household or business is an island (Håkansson and Snehota 1989, Stevenson and Greenberg 2000). The reality is that households and firms exist and develop an identity based on the relations they build with other households and firms, either directly as suppliers or customers, or indirectly as collaborators or as competitors. To treat households and firms as atomistic entities making all their decisions for themselves, as is so often the approach in mainstream economic analysis (with the exception of the industrial organization literature using game theory) and in much management and transport analysis, is a serious violation of reality. Thus a central motivation herein is to explore ways in which we can treat households and firms as interconnected in large or small, tight or diffuse networks – as is the reality for most households and firms in actual economies. The dynamics of household and firms' relations – the creation of linkages, their modification or rupture, and the patterns formed – become a central focus of interest in the network view.² The management of relations also becomes a factor in households and firms' success of equal significance with the management of internal operations.³ Relations, like resources and routines, can only be changed slowly. Thus households and firms can be caught in networks that represent a threat to survival if the network as a whole is losing competitiveness. The reality of inter- and intra-firm and inter- and intra-household relations must be brought into focus, without making the mistake of claiming that network structures are always advantageous.

2.1. Identifying Interactivity Alternatives

Although we might focus a lot on how loose or tight networks or groups actually make choices and the influence on each member, an important pre-issue is establishing how groups are actually constructed in the first place. That is, what type of inter-activity is preferred by an individual that results in the establishment of a group and a structure of individuals influence? This seems like a very good starting position and indeed is one that especially needs addressing in the context of freight travel choices. In this specific context, the formation of alliances in a supply chain seems important in establishing preferred inter-activity. We detail this later in Section 7. We propose (at least) eight alternative group or network strategies⁴ that can be modelled to establish criteria for membership. These are set out below.

Autocratic or directive style (ADS): A lead agent defines and diagnoses the task, generates, evaluates and chooses among alternative solutions.

Autocratic with group information input (AGI): A lead agent defines the task. Although the leader diagnoses the cause of the problem, they may use the network as an information source in obtaining data to determine cause. Using a list of potential solutions, the lead agent may once again obtain data from the group in evaluation of these alternatives and make a choice among them.

Autocratic with group's review and feedback (AGRF): A lead agent defines the task, diagnoses its causes, and selects a solution. They then present a plan to the group for understanding, review, and feedback.

Individual Consultative Style (ICS): A lead agent defines the task and shares this definition with individual members of a participating network. The leader solicits ideas regarding problem causes and potential solutions. The lead agent may also use the expertise of particular individuals in evaluation of alternative

² See, for example, the major works of the Scandinavian “markets-as-networks” school, to be discussed below.

³ In like manner, Kale, Singh and Perlmutter (2000) refer to “relational capital” as being enhanced through firms enacting relations with each other in networks, while Dunning (2000) refers to firms' “relational assets” to make a similar point. These assets can only be productively employed by one firm interacting with another firm.

⁴ The terms or phrases, ‘network’, ‘group’, ‘decision-network’, ‘decision-chain’ and ‘supply-chain’ are essentially substitutable definers of agency interactivity.

solutions. Once this information is obtained, the leader makes the choice of which alternative solution to implement.

Group Consultative Style (GCS): Same as ICS except the lead agent shares their definition of the task with the group as a whole.

Group Decision Style (GDS): A lead agent shares their definition of the task with the participating group. The network then proceeds to diagnose the causes. Following diagnosis, the group generates, evaluates, and chooses among solutions.

Participative Style (PS): The group as a whole proceeds through the entire decision making process. The group defines the task and performs all other functions as a group. The role of the lead agent is that of process facilitator.

Leaderless Team (LT): The group has no formal leader, but rather is assembled as a leaderless team. If no substitute for task leadership, or process leadership is present, a process leader often emerges. This person may change from task to task. The group generates its own task definition, performs its own diagnosis, generates alternatives, and chooses among alternatives.

Identification of the role and influence of each agent in an organisation's choice making seems a logical first stage in the definition of the empirical setting within which to study and model such choices. What we have is a segmentation based on participatory influence on an organisation's choice outcomes; however this segmentation is crucial in determining what role each member plays in decision making so that their input (ie influence, power, preferences) can appropriately be represented. A nested logit model is one appealing model setting to reveal the probability of participation style of a group. From this framework we can establish the participants in further data collection in which the study of choice amongst alternative outcomes is the focus. As detailed in a later section, such a framework is essential in freight studies where the participants in the supply chain are quite extensive although many may have little influence on the choice outcome(s). However to a priori exclude specific participants without a formal inclusion/exclusion process is not desirable. All members of the decision-chain are assumed to bring to the choice process an implicit probability of participation which is a reflection of an agent's influence, power and preferences. The analyst's task is to reveal this probability empirically.

3. The Concept of Influence of Group Members at the Attribute and Overall Evaluation Level

Arora and Allenby (1999) and Dellaert et al (1998) are recent examples of research efforts to incorporate the individual's preferences and influence in group decisions. Key to their approach is the idea of influence patterns at the attribute level that condition the marginal utility of each attribute associated with each individual. This is designed to account for the intensity of influence of each participating individual on the contribution of each attribute in the group choice. The notion of attribute-specific influence of each individual recognises that each individual exerts differential influence on each attribute and not just on the overall preference intensity. Measuring this influence usually involves a stated influence or an outcome-based measure, the latter involving an allocation exercise. For example, Arora and Allenby asked each individual to allocate 100 points between themselves and other participating individuals with regard to the influence each would have in a decision to purchase an electric oven/range. Dellaert et al use a different empirical strategy in which each individual not only reports their own preferences; they also project the preference of other members of the group making a decision. This information is used in a second round where the same experiment is repeated but an additional piece of information is now shown to each individual, namely the predicted preference scores of the other individual(s) of that individual's preferences as they perceive them. The latter is the empirical data for establishing the influence parameters.

These studies treat each other individual as an exogenous input whereas a more interactive approach such as in Brewer and Hensher (2000) allows for feedback, revision and final decision. As Dellaert et al (2000, 144) state: ‘Future extensions could study the roles of individual family members in the family interaction (eg negotiating, bargaining, power differences) and the degree of influence individuals have in different stages of the family preference formation process’. The idea of relational trading seems central to the process.

The influencing models can be estimated through the use of a number of discrete choice models including multivariate probit, nested covariate heterogeneity logit, mixed logit, and latent class segmentation in which the full hierarchical Bayesian specification can be modelled to identify the relative influence of each attribute for each individual in the group outcome. We discuss these specifications in the next section.

4. Integrating Interactive Agency Choices and Preferences

Consider a situation in which we have two agents who interact to some extent in the determination of a choice outcome either of a cooperative or non-cooperative form. A cooperative outcome is one in which both agents agree (ie choose the same alternative). In earlier research Hensher introduced the notion of interactive agency choice experiments (IACE) (Brewer and Hensher 2000, Hensher and Chow 1999). An IACE involves two or more agents in sequential or simultaneous assessment of a common set of alternatives (the interactive choice set) with a series of rounds of assessment in which each party reviews the alternatives and makes a choice. Agreement can occur immediately, after a few rounds or not at all over the permissible number of rounds before the IACE concludes. The empirical process is discussed in some detail below. In this section we suggest how various discrete choice model frameworks can be used to capture the influence of interactivity between agents in the choice process (including the formation of preferences) that produce what we call the ‘equilibrium’ choice outcome (be it cooperative or non-cooperative). The ability to see how individual agents might modify their preferences as a result of the preferences of other agents is an important feature of the approach since it is a reflection of what actually happens in reality.

To formalise a model system to capture the interactivity, a number of possibilities exist. Four in particular are worthy of assessment – multivariate probit, mixed logit (or multinomial probit), and covariance heterogeneity (nested) logit. In presenting these specifications, we assume that the relationships between agents are contemporaneous (in contrast to lagged). All three model specifications allow for some degree of contemporaneous correlation depending on how the alternatives associated with each agent are represented in the equation system. These models can be implemented either separately for each of the eight interactive profiles in section 2.1 or by conditioning them on the membership of the eight strategy groups. In the latter case we would need to establish a conditional probability of group membership as well as a choice probability for a specific choice outcome for each agent.

Multivariate probit is a system of binary choice equations where each equation can be assigned to an alternative and an agent. Each equation is of the form $y_{im}^* = \beta_m' x_{im} + \varepsilon_{im}$; $m=1, \dots, M$; $y_{im} = 1$ if $y_{im}^* > 0$, and 0 otherwise; ε_{im} , $m=1, \dots, M$, are distributed as multivariate normal with mean vector 0 and covariance matrix R with diagonal elements equal to 1.0. Correlation between the agents and alternatives is captured through the covariance matrix. Data measuring the influence of one agent on another agent (as is Dellaert et al 1998) is introduced as one or more exogenous variables. Thus if we have three agents each involved in the evaluation of the same three alternatives, we would have nine equations. We might anticipate greater correlation across the equations defined on the same alternative.

Covariance heterogeneity is a modification of a nested logit model in which the inclusive value (IV) parameters are functions of exogenous variables. We treat the nested structure along similar lines to the combining of two data sources (eg RP-SP) from the single agent to reveal scale differences between data sources. However the contrast is between data sources associated with the same choice set but two (or more) agents involved in the same choice setting. The scale (or inverse standard deviation) parameter provides a measure of the influence of unobserved effects parameterised by contextual variables including data measuring the influence of one agent on another agent's choice.

The mixed logit model (see Hensher and Greene 2001, Train 2002) allows us to represent agents (ie observations) that interact to be correlated through the specification of choice sets and alternatives in choice sets. Agency interaction is analogous to multiple choice sets for stated choice modelling associated with each individual, and since such observations are (potentially) correlated, we can think of the interactive agent problem as nothing more than potentially correlated observations. Each identical alternative across agents can have identical (ie generic) parameters or unique (ie alternative-specific) parameters. Each observation is defined by a set of alternatives in a choice set, a choice outcome and a set of alternative, agent and context-specific attributes. Some of these context-specific attributes can be related to the preference function of the other interactive agent (s). We now detail how interactivity might formally be revealed.

In proposing a mixed logit framework for capturing the interactivity between agents we need to clarify the options available for specifying the relationships between the choices of each agent. There are essentially five alternative behavioural specifications (Table 1) of which specification C is particularly attractive. We view each agent in a choice outcome as participating in a contemporaneous way. Each agent brings to the choice table a set of clearly defined influences as measured by attributes of alternatives, but in addition they also carry unmeasured factors that are sources of unobserved variability (often described as unobserved heterogeneity and accommodated by random effects). Such variability plays a very large role in the interactive process leading to choice outcomes that are both cooperative and non-cooperative. It is also assumed that an agent's preferences can influence the choices made by other agents and indirectly leads to review and revision (or maintenance) of preferences for specific alternatives.

Table 1 Alternative ways of Representing Interactivity between Agents

Specification	Contemporaneous Correlation	Random Effects	ARI Process	q=1,...Q agents; i=1,...j,...I alternatives
A	x	x	x	e_{iq} iid
B	✓	x	x	e_{iq} independent across agents, generalised deviation from IIA
C	✓	✓	x	$e_{iq} = \eta_{iq} + \varepsilon_{iq}$ with cov (η_{iq}, η_{jq}), ε_{iq} is IIA
D	✓	x	✓	$e_{iq} = \rho_i e_{iq-1} + \eta_{iq}$ η_{iq} is IIA
E	✓	✓	✓	C plus D

Formally the interactive agency choice problem associated with specification C in Table 1 is given in equation (1).

$$U_{iq} = f(U_{q^i}, U_{q^{j^i}}) = V_{q^i} + e_{q^i} = V_{q^i} + (\eta_{iq^i} + \varepsilon_{iq^i}); \eta_{iq^i} = \alpha X_{q^i} + \phi V_{q^i} \quad (1)$$

Where

- U_{q^i} = utility function associated with agent q^i for alternative i
- $U_{q^{j^i}}$ = utility function associated with agent q^j for alternative i
- V_{q^i} = observed components of the utility function associated with agent q^i for alternative i
- e_{q^i} = unobserved components of the utility function associated with agent q^i for alternative i
- ε_{iq^i} = IID component on the unobserved effects which is IID over the alternatives and does not depend on

underlying parameters or data.

η_{iq} = the random term with mean zero whose distribution over agents and alternative depends on underlying parameters and observed data relating to alternative I and individual q'.

αX_q = the parameterised exogenous attributes related to agent q'

ϕV_q = the parameterised preference function for agent q' that represents the contemporaneous interactivity between agents.

The unobserved effects can be correlated amongst alternatives in a given choice set. One way to recognise this is to permit correlation of attributes that are common across alternatives. This engenders a covariance matrix with off-diagonal estimates identifying the dependency of one attribute on another within and between alternatives (depending on whether the attribute parameters are generic or alternative-specific). It also has interesting ramifications for correlated choice sets.

Let us define the utility expression for each alternative as $U_{qit} = \beta_q X_{qit} + \epsilon_{qit}$. Since β_q is random, it can be rewritten as $\beta_q = \beta + u_q$ where β is fixed (ie the mean) and u_q is the deviation from the mean. Then $U_{qit} = \beta_q X_{qit} + (\epsilon_{qit})$. There is correlation over alternatives because U_q is the same for all alternatives. That is, each agent's preferences are used in the evaluation of the alternatives. This indicates that $Cov[(u_q X_{qit} + \epsilon_{qit}), (u_q X_{qis} + \epsilon_{qis})]$ equals⁵ $\sigma(u_q) * X_{qit} * X_{qis}$ where $\sigma(u_q)$ is the variance of u_q . In addition, however, there is also correlation over choice sets (or agents) for each alternative because u_q is the same in each choice set (or agent's choice set). Again another way of stating this is that each agent uses the same preferences to evaluate (relative) utilities in each choice set (or agent's choice set). Thus $Cov[(u_q X_{qit} + \epsilon_{qit}), (u_q X_{qis} + \epsilon_{qis})]$ equals $\sigma(u_q) * X_{qit} * X_{qis}$. The behavioural implication is that random preferences induce correlation over alternatives *and* choice sets within and between agents.

Thus both correlated alternatives and interactive agent's choice sets usually go hand in hand (assuming that one identifies the set of choice sets associated with each agent)⁶. Correlation over alternatives and not over interactive agent choice sets could however be established by specifying utility as $U_{qit} = \beta_{qt} X_{qit} + \epsilon_{qit}$ where β_{qt} represents preferences instead of β_q . Thus preferences vary over agents *and* over choice sets with β_{qt} independent over choice sets for each agent. This is likely to be an unreasonable assumption for most situations. In particular, preferences might vary over choice sets for each individual, but it is doubtful that they are independent over choice sets for each sampled individual. If there is some correlation in preferences over choice sets for each individual, then random parameters implies correlation over choice sets and over alternatives. In general, the mixed logit model can accommodate (i) correlation over alternatives and not over choice sets by assuming β_{qt} is IID over choice sets, or (ii) correlation across choice sets but not over alternatives by fixing all of the parameters except those representing the alternative-specific constants (ASC's) and assuming that ASC parameters are IID over alternatives but the same for each individual across the choice sets.

We now have a number of alternative econometric frameworks within which to represent the choice process of agents who are influenced by the choices and preferences of other agents in a contemporaneous way. Hensher and Rose (in progress) are revisiting an enhanced data set from the telecommuting study reported in Brewer and Hensher (2000) to investigate the strengths and weaknesses of each of the methods

⁵ Sigma is the standard deviation for the normal and lognormal and the spread for the uniform and triangular distributions.

⁶ The only circumstance in which you can distinguish correlated choice sets from correlated alternatives is by ignoring the dependency between choice sets or assume that it does not exist.

outlined above⁷. The next task is to take a closer look at the empirical framework within which we can quantify the formation of an equilibrium set of preferences and choices.

5. Interactive Agency Choice: A Conceptual and Empirical Process

Agents interact at various stages in the decision making process ((Podolny 1994). Agents bring different perspectives and influence (as suggested in a previous section) to the formation of preferences and in the final (or ‘equilibrium’) choice outcome. The *equilibrium* choice outcome can be one of cooperation or non-cooperation, with the latter outcome helping to reveal the set of constraints that deny cooperation.

To illustrate how agents interact in the decision-making process, we propose a very general framework in which both sequential and simultaneous preference formation and choice outcomes are established. The empirical process is very similar for sequential and simultaneous assessment, although the sequential process presents an opportunity to add richness in the details that are revealed by each agent in the interactive choice process. It also adds a great deal of complexity as the number of agents increases since the order sequences increase exponentially. To simplify the sequential process to a manageable dimension, some rules may have to be introduced. One potentially useful rule is to structure the sequence according to the influence of each agent. This is a topic for future research.

We will assume that a previous stage in the decision making process has identified the relevant set of decision makers, their relative influence and the probability of a specific interactivity-alternative profile existing in the sampled population. The latter is crucial for predictions. The focus in this section is on the mechanism for structuring the interactive empirical process leading to choice outcomes, based on an interactivity-alternative profile of two agents (interacting as *autocratic with group's review and feedback – ie AGRF*). With two agents there may be no natural ordering and thus two sequences may be appropriate. Furthermore, each agent in the preference formation process may initially have no knowledge of the other agent’s preferences. This will be revealed through the consultation process via feedback of choice responses and/or explicit statements on the role of specific attributes.

To give some structure to the empirical process we will assume that a stated choice experiment pivoted around existing experience is an appropriate setting for revealing preferences and choices. Given two agents, we assume that the starting order of the interactive agency choice experiment (IACE) has been randomised (but that order sequence can and should be tested in model estimation). In Brewer and Hensher (2000) we assumed a priori that the employee is ordered in the sequence before the employer in the assessment of distributed work alternatives. At the commencement of an IACE, it is reasonable to assume that each agent has a varying amount of knowledge of the other agent(s) preferences and a view on the influence of each agent. Indeed there is a continuum of knowledge and influence that is postulated to impact on the formation of preferences and the resulting choices made by each agent. At one extreme, we might posit no knowledge and no idea of relative influence; at the other extreme we might have full (perceived) knowledge and a precise view on agent influence.

The priors we suggest setting at the commencement of the IACE are (i) group strategy membership (ii) level of knowledge of other agent(s) position on specific attributes and outcomes, and (iii) perception of relative degree of influence of each agent in the decision-making process. This last element is linked to (i) in that membership of a group strategy suggests part of the profile of the influence structure; however in (i)

⁷ We have collected additional data and re-analysed the interactive agency choice of distributed work practices for a sample of 60 pairs of employees and employers, using the more advanced statistical methods in the text. The earlier work by Brewer and Hensher (2000) used sequenced multinomial logit models..

example involving a shipper and one or more freight forwarders (ie logistics providers), and assume three attributes (door to door travel *time*, consignment *cost* and *reliability*) each at three levels. The IACE might involve three choice designs (SCI, SCII, SCIII)

Table 3. Design Strategies for IACE's

a. SCI: Shipper and single freight forwarder choice set fully interactive and evaluated simultaneously

Alt 1			Alt2			Alt3		
time	cost	reliability	time	cost	reliability	time	cost	reliability

b. SCII: This is the same as for SCI but treated sequentially with shipper choosing and then freight forwarder given knowledge of the shipper's first round preferred offer

c. SCIII: Interactive Logistics service providers choice sets

Mixing the three logistics service provider attribute offers in a subset of alternatives. Shipper evaluates offers from three freight forwarders and then each freight forwarder reviews shippers preferred offer and provides feedback until a cooperative or non-cooperative outcome.

Alt 1 (L11 L21)			Alt2 (L11 L22)			Alt3 (L11 L23)		
time	cost	reliability	time	cost	reliability	time	cost	reliability
Alt 1 (L12 L21)			Alt2 (L12 L22)			Alt3 (L12 L23)		
time	cost	reliability	Time	cost	reliability	time	cost	reliability
Alt 1 (L13 L21)			Alt2 (L13 L22)			Alt3 (L13 L23)		
time	cost	reliability	time	cost	reliability	time	cost	reliability

Note: $L_{ij|kl}$ = i th (or k th) logistics service provider and j th (or l th) alternative

These choice experiments will produce a set of expected utilities leading to the determination of (non-) cooperative choice probabilities associated with each mixture of outcomes evaluated by a logistics service provider and a shipper. The analysis of each pass in the interactive choice experiment can be represented as a recursive discrete choice paradigm in which the prior agent's choice conditions the subsequent agent's choice. The recursive structure embodies the shipper and the logistics service provider 'flip-flopping' as the prior and subsequent agent in each round of the IACE. Sequential estimation of each agent's choice process at each pass in the sequential negotiation process will enable the analyst to track the choices made and their revisions up to the point of cooperation or experiment termination if there is no agreement after a predetermined number of rounds.

5.1 A Sequential Recursive Model Estimation Strategy

Using the logistics service provider setting again, a series of discrete choice models can be estimated to evaluate potential influences on the shipper's and the logistics service provider's preference for the each of three offers. In addition to the design attributes, the role of contextual variables describing the shipper and the logistics service provider(s), as well as structural influences on the execution of the interactive agency choice experiment (IAACE) can be included. The following steps highlight a possible sequential recursive estimation procedure for an experiment (with three replications), involving a shipper and one logistics service provider:

- *Step 1:* First sequential move offer of shipper - three choice sets per shipper. As the first experiment there is no involvement of the logistics service provider. Information is included on the perceived influence of the other agent(s).
- *Step 2:* First sequential move offer of logistics service provider - the same three choice sets as per the shipper. The knowledge of the shipper's offer is revealed to half of the logistics service providers only. We might include a variable representing the actual offer from the shipper for the subset who are informed of the shipper's choice. If the shipper and logistics service provider agree on the offer in pass 1 for a specific replication, then that concludes the IACE for the agency pair. This state of negotiation is identified by a 'pass agreement' dummy variable (=1 if agree and 0 otherwise). At each step we seek information of the role played by each agent in influencing the outcome.
- *Step 3:* Evaluate the influences on the pass agreement (1,0) outcome for the first sequential move offers. These influences include design attributes, individual characteristics and each agent's perception of the opportunities and constraints associated with alternative offers.
- *Step 4:* Calculate the expected utility matrix for the shipper and the logistics service provider and identify the cooperation probability for each alternative. The non-cooperation probabilities for each off-diagonal pair of alternatives are also identified.
- *Step 5:* Second sequential move of the shipper given the logistics service provider's offer in pass 1, for situations of non-agreement in round 1. For Step 5 and beyond, all logistics service providers have knowledge of the shipper's preferred offer. We evaluate the shipper's offer that may or may not be revised from pass 1, in the light of knowledge of the logistics service provider's preferred offer (which is different to that of the shipper in pass 1). We might include a variable representing the actual offer from the logistics service provider in the previous round.
- *Step 6:* Evaluate the influences on the pass agreement (1,0) outcome for the second sequential move offers, following the approach in Step 3.
- *Step 7:* Calculate the expected utility matrix for the shipper and the logistics service provider and identify the cooperation probability for each alternative in pass 2.
- *Step 8:* Second sequential move of the logistics service provider given the shipper's revised or maintained offer in pass 2, for situations of non-agreement in round 2. We evaluate the logistics service provider's offer that may or may not be revised from pass 2, in the light of knowledge of the shipper's preferred offer (which is different to that of the logistics service provider in pass 2). We include a variable representing the actual offer from the logistics service provider in the previous round.
- *Step 9:* Evaluate the influences on the pass agreement (1,0) outcome for the third sequential move offers, following the approach in Step 3.
- *Step 10:* Calculate the expected utility matrix for the shipper and the logistics service provider and identify the cooperation probability for each alternative in pass 3.

The process continues subject to the number of steps required to achieve a cooperative outcome and the limits on sample size for model estimation.

6. Data needs

The data requirements for revealing empirically the formation of preferences which guide the decision-making process leading to choice outcomes in the presence of interactive agents are an order of magnitude more demanding than what we require for independent agents. The complexity is as much due to the myriad of possible ways in which agents interact with feedback and negotiation leading to an 'equilibrium' set of preferences as it is due to the logistics of collecting data in which interaction and feedback between agents is required. Whether in time we can skip to the equilibrium setting⁸ and avoid the preference

⁸ This point was discussed extensively by the author and Axel Boersch-Supan in 1998 when developing a contemporaneous model form for interactive agency (unpublished). We suggested that for most applications that the final choice outcome is all

formation stage remains to be seen. Until we know what decision-chain's of agents occur in the context of making a single (cooperative) choice as well as the membership of consideration and choice sets, and the probability of membership of each alternative decision-chain, sampling of appropriate persons to interview is not possible⁹.

Whom do we need to interview and how in households and firms? When sampling combinations of respondents, the proper unit of analysis for the study of interactions is the decision-chain or group and not the individuals that comprise the group. Hence the sampling unit is interactive agents. Identifying who should be included in the agency set really depends on who participates in the process leading to a choice outcome. This involvement can be passive or active. In a household setting, given the object of choice (eg vehicle type and number, residential location, distributed work practices) one might relatively easily start with a series of questions designed to reveal who makes a contribution to the choice outcome in an endogenous sense of interactivity. We would exclude individuals who are exogenous constraints (eg children) unless they actually influence the choice outcome endogenously through bringing to the table their own preferences, influence and power. Sometimes this influence can be active; other times it might be passive. In the context of a business, the appropriate participant(s) becomes more complex, possibly involving more than one person in one or more organizations.

Establishing participation eligibility is a major task and one in which extensive discussion within an organisation is required. In the telecommuting study (Brewer and Hensher 2001), we allocated considerable resources to discussions within an organization to identify eligible agents (subsequently paired to represent employee and immediate supervisor), using subjective priors on the location of influence and power (resting in the immediate supervisor). However we subsequently noted that even the immediate supervisor is constrained to varying degrees by their supervisor and hence their preferences as revealed in the IACE were in part constrained by their expectations of support from their immediate supervisor. How far one goes to capture these additional effects should be guided primarily about their impact of the formation of preferences and the equilibrium choice outcome. There are no simple rules here, only guiding principles. The extent of the decision chain is likely to vary by the choice under examination. The opportunities for research endeavour on this theme alone are substantial.

It is currently an open question as to whether data collection can be undertaken using methods other than face-to-face. While an internet-based strategy has enormous appeal, given the steep learning curve at this juncture, we promote a face-to-face strategy. The subtleties of interaction may well be missed via other data collection media. We are currently trialling email on a logistics project involving paired participants in two countries involved in the transport and display of rare artworks. Although this will establish if email is viable, it does not guarantee the full evaluation of suitable information for modelling choice outcomes. Only the in-depth face-to-face strategy is likely to establish suitable benchmarks for determining information compromises through less direct data collection paradigms.

Having determined which agents will participate in the data collection process, one needs to decide whether each agent is interviewed sequentially with/without feedback or simultaneously. If sequential, the order of agency exposure and feedback may be crucial. This may be reasonably clear in some settings (such as the telecommuting study of Brewer and Hensher (2000) where the employee might reasonably be the first agent in the sequence); however in general the sequence is by no means obvious. Does it really matter if feedback is included? Possibly to a lesser extent than if no feedback, but this is worthy of

that is of interest. The downside of this however is that we might fail to reveal the barriers that may create non-cooperative outcomes or even cooperative outcomes that are not necessarily the preferred outcome for one or more agents but is arrived at as a consequence of beliefs about the influence and power of other agents in the group. Hence the equilibrium choice outcome is in a sense a non-optimal one for specific subsets of agents.

⁹ Anything is in one sense possible but not recommended. One could screen to establish who to interview or even interview 'everyone' and try and establish influence and power at a later stage.

empirical investigation. Does first-exposure of preferences condition subsequent preferences of each agent or not? The simultaneous paradigm avoids this issue (to some extent) but has its downside where agents tend not to discuss as a group but prefer to put their position (ie choice preference) to other agents for consideration (avoiding direct negotiation)¹⁰. Even in a simultaneous setting, specific agents can force their views early as a reflection of influence and power. To measure such influence during data acquisition is essential. The big question is – how best to capture such influence and power? What measurement scale is appropriate? The Dellaert et al (1998) paper offers one appealing metric to project the preferences of other individuals in a family as a basis of each agent’s perceptions of the preferences of the other agents:

"Firstly, please evaluate each [travel] package by rating it on a scale from 0 to 10 (0 = very unattractive to 10 =very attractive) based on your own individual preference for the choice situations. Secondly, also rate each package as you think your wife and child [/ your husband and child/ your father and mother] would rate the package, by giving two more ratings that you think best represent their individual preferences."

Whether this is adequate to reveal power and influence is an interesting research question, but it does at least reveal useful information that may condition each agent’s own preferences and choice outcomes, cooperative or non-cooperative. As an example of a stated choice survey instrument, we reproduce in Table 4 a showcard used in the telecommuting study of Brewer and Hensher (2001). The design of an SC experiment is no more complex than single agent instruments, even though the collection strategy is different. The showcard and choice response moves between the agents until there is agreement (or the experiment concludes). The wording on an attribute will differ for employee and employer. For example, in Table 4, for an employer on the productivity attribute we would say “If an employee telecommutes their productivity will be....”.

Table 4 Example Show card for a Stated Choice Experiment (employee wording for each attribute)

	TELECOMMUTING ONE DAY A WEEK	TELECOMMUTING TWO DAYS A WEEK
If I telecommute, the level of contact necessary with other people for my work would be	Lower	Lower
If I telecommute, the amount of control I have over my work would be	Lower	Lower
If I telecommute, my personal productivity will be	Lower	Lower
If I telecommute access to information necessary for my job would be	Location-dependent	Location-dependent
If I telecommute, my career prospects will be	Lower	Lower

- Contact 0=Lower, 1=Unchanged, 2=Higher
- Control 0=Lower, 1=Unchanged, 2=Higher
- Productivity 0=Lower, 1=Unchanged, 2=Higher
- Information 0=Location- dependent, 1=Limited away from the work place, 2=Location independent
- Career 0=Lower, 1=Unchanged, 2=Higher

¹⁰ It is interesting to note how email correspondence is often much different to face to face verbal dialogue. Anecdotally, we see agents saying things by email that they dare not say face to face. They may regret what they say in time, but they feel more secure at a distance in saying it.

7. The Urban Freight Distribution Task: Towards the Development of the Interactive Organisational Choice Process in a Supply Chain

Despite the significance of freight to our daily lives, few of us understand its importance (or we take it for granted) and fewer still understand the complexity involved throughout the decision chain in sourcing, purchasing, packing, moving, storing, and delivering freight. There are a number of challenges that must be met head on. These include:

- The need to establish a united view on freight logistics issues of mutual interest. The traditional modal interests must be developed into a multi-modal view and combined with the interests of non-transport operators to address freight logistics issues at a higher level than is currently the case. A united industry approach requires leadership and a fundamental shift in industry culture to address the new drivers of economic success – knowledge and *relationships*. Multi-modalism behaviourally translates into an interactive agency problem and decision chains.
- Inadequate freight logistics infrastructure in key parts of the transport network, resulting in increased transport costs and the inability of some businesses to access the full range of freight logistics services available to their competitors.

Research into the *movement* of urban freight is best focused within a supply chain setting, adding a new perspective on what choices have to be studied, formalised and modelled. A supply chain (decision chain or decision network) is formally a set of linkages that involve participation by agents, elements, relations and mechanisms. Within the freight transport context, an agent is a shipper or a transport provider, an element is a commodity or a vehicle, a relation is one between a commodity and the vehicle technology used to deliver it, and a mechanism is a choice such as routing or timing of delivery. The interactions between these four dimensions of a supply chain define the urban freight distribution task (Boerkamps et al 2000, Russo and Comi 2001).

This task involves more than traditional transport decisions such as trip timing, routing, choice of vehicle type, etc.; it also requires an understanding of how each agent in the supply chain chooses to interact with other agents (or go it alone) and which subset of decisions and attributes matter to them in the 'chain alliance'. This suggests a focus on a hierarchical structure that starts with understanding the way in which each agent chooses membership of a supply chain. There are many supply chain structures, including a single-agent chain where the shipper, forwarder, and distributor are one and the same; a two-link chain comprising a shipper and a forwarder and so on. Knowing the structure (and modelling membership) of the supply chain is critical in tracking the agents who make the various decisions that define the freight distribution task. Very little data have been collected on this issue, apart from some narrowly-defined case studies. Data pertaining to a comprehensive overview of all supply chains appear not to exist. Identification of the relevant decision variables is of great importance, particularly because some may be outside the distribution system, such as marketing requirements.

The choice of a supply chain structure will be influenced by the attributes that are important to each agent and how each potential member of a supply chain can deliver these attribute levels to the satisfaction of other agents seeking out a preferred supply chain structure. *Here the notion of influence is important.* A good descriptive model of supply chain structures should include two sets of channels: marketing and physical distribution. A marketing channel is a string of actors that, as a group, perform all actions to interconnect producers and consumers aimed at fulfilling the marketing task. Actors can be producers, trade intermediaries or retailers. Within each marketing channel, several physical distribution channels can be used to deliver the goods. The structure of freight flows is dependent on two successive choices: that of marketing channel(s) followed by selection of a physical distribution channel. Once the behavioural choice of a supply chain is known and formalised we then have a framework within which to start detailing the

formation of choice sets and the matrix of choice components and associated attributes. This is where we start thinking about the transport choices such as selection of vehicle type, routing, and timing and the role of specific attributes such as cost, damage minimisation, reliability, and other transactions costs. The role of each choice and attribute for each agent will vary depending on the supply chain structure. For example, if an intermediary is involved then maybe the shipper does not care about specific attributes such as travel time and routing as long as goods arrive at an agreed time. Thus although the shipper initiated the freight activity another agent in the supply chain decides on routing and timing. An interactive agency perspective is appropriate in revealing the role of agents in the transport distribution task and hence who needs to provide preference data.

The most important behavioural aspects that shape freight transportation are contained in the markets for infrastructure, commodities, transport services and traffic services¹¹. The infrastructure market decides on infrastructure supply given traffic demand; the commodity market determines goods flows, connecting goods demand and supply via supply chains; the transport services market results in commodity movements between places by transport modes by connecting commodity flows with their logistics demands to the available transport modes (including truck types) and services; and the traffic services market deals with vehicle movements on the infrastructure, resulting in network loads. All four markets are important. Understanding the commodity and transport services markets better will enable us to 'feed' the infrastructure and traffic services markets with the real behavioural basis for commodity and vehicle movements.

We can classify decision makers into two broad classes: shippers (those with ownership rights on the commodities which can be the manufacturer or even an intermediary) and transport providers (those responsible for collecting, moving and delivering goods to final consumers or warehouses). The shipper and the transport provider represent the main actors involved in the production and consumption of goods, the shippers routing of freight, the determination of freight rates and the carriers routing of the freight traffic (Friesz 2000). There is gap in our understanding the key decisions made by the shipper and transport provider in moving goods between two spatial locations (an origin and a final destination). The shipper has goods that need delivery – this defines the initial origin and final destination of the goods – and also has preferences that dictate what matters to the shipper in deciding on how best to move their goods. The transport provider determines how best to move the goods between their origin and destination which may involve trip chaining between various initial, intermediate and final destinations. The set of choices/decisions to be made and associated attributes relevant to the shipper and to the transport provider are not the same set. Shippers are mostly concerned with efficient operation of marketing channels, while transport providers are mostly concerned with efficient operation of distribution channels. There must however be an overlapping set of attributes that form the basis of a contract between the two or more agents in the supply chain to secure the movement of goods. This interface is at the centre of the IACE approach.

The key relationships between agents, freight distribution channels and supply chains are summarised in Table 5. Supply Chains (SC1,...,SC4) are examples of the freight distribution channels and agents. SC4

¹¹ For all supply chain settings, urban freight distribution involves (at least) five components of freight movement and their four interacting markets. The components are: (1) the spatial organisation of activities which describes the location of facilities, where goods are produced and consumed, and where people live and work. (2) The commodity market which connects demand and supply of goods resulting in trade relations between the origins and destinations of goods. (3) Transport services that are needed to facilitate the demand for goods transport. These services include vehicles and terminal facilities together with the spatial and temporal patterns of freight flows classified by consolidation profile (containers, pallets, boxes, etc.). (4) The traffic system supplies infrastructure which is used by vehicles in delivering transport services. (5) The availability of infrastructure which is a basic condition to meet traffic demands. The capacity of links and nodes in the (road) infrastructure network and the traffic flows (passenger and freight) on the network are interdependent resulting in capacity adjustments and/or congestion feedbacks (e.g., changes in route and trip scheduling).

for example, involves a freight forwarder in all channels of freight distribution and so is the only agent to study. The decisions made by the freight forwarder would determine the profile of traffic on the network in respect of vehicle type, routing and time of day. Thus, given a specific supply chain structure, the appropriate agents responsible for freight distribution will be identified as well as their degree of influence, and then we have to establish what set of transport-related decisions they consider and what attributes influence the choice made for each transport-related decision. The transport related decisions of potential interest are summarised in Table 6. An origin can define a particular consignment or an aggregation of similar consignments from a single enterprise (e.g., a factory or warehouse) or all entities in the same geographical location (e.g., a Port). A knowledge of the movement of a specific consignment from a specific location, by a vehicle type, by time of day, by route to a specific destination in the distribution channel (i.e., $P \rightarrow DC \rightarrow W \rightarrow R \rightarrow IS/C$) and the associated decision maker in each freight distribution link (e.g., $P \rightarrow DC$, $W \rightarrow R$) provides the necessary information to model the behavioural dimensions of the urban freight distribution task.

Table 5. Alternative Supply Chain Structures with respect to Freight Distribution

Notes: Agents: Shippers {Producer (P), Distribution Centre (DC), Wholesaler (W), Retailer (R), Final Consumer (C), Internet Shopper (IS)} and Transport providers (Freight Forwarder FF). Freight Distribution (FD): FD1= $P \rightarrow W$ or $P \rightarrow DC \rightarrow W$; FD2 = $W \rightarrow R$; FD3 = $R \rightarrow IS$ or $R \rightarrow C$.

Supply Chain Profiles (__ = agent providing freight distribution)	Freight Distribution FD1	Freight Distribution FD2	Freight Distribution FD3
SC1	<u>P</u> → W	<u>W</u> → R	<u>R</u> → IS
SC2	P → <u>DC</u> → W	W → <u>R</u>	R → <u>C</u>
SC3	P → <u>W</u>	<u>FF</u>	<u>FF</u> (R → IS)
SC4	<u>FF</u>	<u>FF</u>	<u>FF</u>

Note: C is a passenger trip whereas IS is a freight trip.

Table 6. Main Behavioural Choices in the Distribution-Focussed Supply Chain

Amount of commodity by type to move (tonnes or items) from origin (production)
Shipment characteristics (size, value, fragility, special features) from origin (inventory specs)
Frequency of shipments from origin (inventory specs)
Vehicle type(s) required for shipments from origin
Departure time of trips (ie scheduling)
Vehicle trip chaining choice (simple vs complex chains) (consolidation issue for FTL and LTL)
Routing of vehicles from origin to destination
Origin-destination movement by commodity, vehicle type and departure time

Certain types of commodity movements are often combined with other shipments to produce a Less-than-Truck-Load (LTL) activity involving many destinations; for other commodities, a Full-Truck Load (FTL) is appropriate. The LTL/FTL distinction has important implications for choices made. An LTL configuration is a more complex trip chaining activity than an FTL (Hensher and Reyes 2000). For each behavioural choice made by a shipper and/or a transport provider, we need to identify the set of alternatives and the attributes that drive the selection of an alternative. Table 7 summarises attributes likely to be important in the selection of a supply chain (SC1,...,SC4) and in the choice of routing, timing, consolidation, vehicle type, etc.

Table 7. Attributes of Interest to Specific Agents in the Supply Chain

Freight Movements and Commercial Services		Possible Explanatory Variables
Shipper (What does the transport provider deliver):	Transport Provider (What does the road environment deliver):	
Reliability	Reliability	On-time requirements
Damage/risk minimisation	Damage/risk minimisation of vehicle and goods (ride quality)	Fragility and theft sensitivity of commodities
Cost /Rates	Tolls and vehicle running costs	Tariffs
Transactions time	Transactions Time	
Delivery time	Delivery Time	Lead time
	Perceived Safety	

There will exist a set of attributes that are relevant to the shipper and a set that are relevant to the transport business. The shipper may focus more on the service attributes (e.g., reliability, damage) and cost (in a generic sense), with limited interest in how the transport provider moves the goods (i.e. vehicle type, routing, scheduling), as long as the goods arrive when and in the condition agreed for the freight rate struck.

To capture these behavioural relationships and formally model the interdependencies between them across the supply chain requires the following tasks:

- The conceptual and theoretical foundations of the relationships between the key agents and associated decisions that impact on the freight distribution task
- The theoretical design of stated choice (SC) experiments (together with revealed preference data on an existing decision-chain) that recognise the interactive nature of the key agents in the distribution of goods in an urban area. These designs will include the choice between supply chain structures involving various combinations of producer-wholesaler-retailer-consumer interactions and the role of each agent in the linkages between each adjacent agent, especially shipper and transport provider. The SC designs should pivot off the currently identified supply chain structure for each agent.
- The empirical design of interactive agency stated choice experiments to establish a way of identifying how shipper and transport provider process relevant information on specific choices and associated attributes and interact with the other agent(s) to arrive at a cooperative outcome (i.e., action to move urban goods by a specific supply chain).
- Having identified alternative supply chain structures and the embedded set of choices made by each agent and their associated attributes, one needs to set up a formal econometric modelling system having the capability of handling the complex error and correlation structures that will exist when integrating choice sequences made by interacting agents (along the lines set out in Section 4).
- Estimation and interpretation of alternative model paradigms based on an investigative stated choice survey for a specific commodity segment.

The key relationships are succinctly summarised in Figure 1. To estimate a set of supply chain and freight distribution models empirically requires identification of relatively homogeneous market sub-segments such as general carrier and specialist commodities. The selection might be based on the following premises:

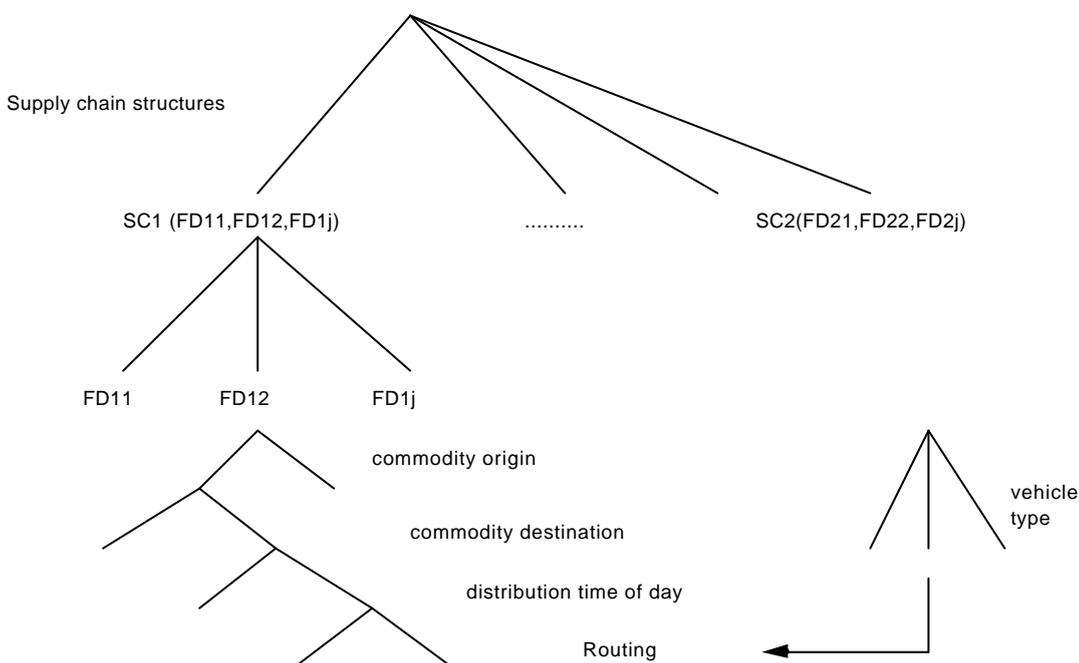
- The sectors should represent a sizeable amount of urban freight movement activity.
- The full range of vehicle types should be covered by the sectors, ranging from rigid small vans through to large double articulated trucks.
- The trip chaining routing should include simple one-stop activity for specialist commodities and multiple stops for general carriers so as to represent the diversity of spatial activity and the mix of hot and cold starts for air quality impact assessment.

- The inclusion of general carriers can represent couriers, a big component of urban freight vehicle activity, to some extent (small vans).
- That a sufficient number of popular supply chain structures can be observed enabling a rich analysis of the choice amongst such decision network structures
- The behavioural modelling should as a minimum focus on the two crucial elements of choice of vehicle technology and choice of routing (trip chain). The latter can be linked back to the spatial outcomes so crucial for identifying spatial patterns of vehicle movements and hence the key performance outputs such as greenhouse gas emissions and air pollution, congestion and transport financial costs.

Figure 1. Schematic Overview of an Integrated Freight Distribution System

Note: For each $FD_{ij}|SC$ and Vehicle Type, $Prob_{odtr} = (Prob_{r|odt} * Prob_{t|od} * Prob_{d|o} * Prob_o) * Prob_{vtype}$

Summation across all FDs, SCs and Vtypes provide an origin-destination trip table by time of day and routing.



It is essential that one samples by service class or freight commodity, simply because this influences the importance weights attached to the attributes in a significant way. For example, shippers of perishable vegetables will place a much higher relative weight on damage minimisation and on time delivery than shippers of bulk coal who might focus more on freight rates. Services such as a courier will focus on travel time and reliability and possibly perceived safety.

A mixture of revealed and stated preference data is desirable, sourced from a face to face survey (see Louviere et al 2000). The revealed preference (RP) data would represent a specific consignment recently completed in which details are sought on the vehicle technology and trip routing, delivery and commodity profile. A distinction between at least two levels of attributes is desirable— tactical and strategic. The former relate to expected loading factors and local limitations (e.g., length restrictions, prohibitions of heavy vehicles on certain roads, etc.), while the latter relate to distribution concepts, (e.g., range and number of distribution centres). The SC data should involve variations around the RP levels of key attributes that require SC enrichment to ensure sufficient variability in the attribute levels for establishment of consistent and efficient parameter estimates. This enrichment process enables the analyst to keep data

collection costs down through increasing the amount of information per sampled trip. Identifying the relevant individuals in an organisation to interview is always a challenge (as discussed in section 6), but in the urban freight context the contenders are the logistics/transport manager for a shipper organisation and the general manager/client manager for the transport provider.

8. Conclusions and Directions for Ongoing Research

There is much to do in revealing the structure and performance of interactive agency decision-making leading to specific choice outcomes. Although there is a large and diverse literature in sociology, psychology, marketing and economics (in particular) that promotes notions of interactive decision making with a strong emphasis on group formation and decisions, there is an apparent dearth of empirical frameworks that have the capability of quantifying the influences of one of more interacting agents and the specific mechanisms for revealing the role of each agent's preferences in arriving at choice outcomes. Conceptual frameworks abound but do little in translation to modelling frameworks capable of embellishing the travel behaviour model systems that currently exist. This paper has offered some directions for the continuing research program.

Establishing new modelling paradigms is one big challenge; but equally challenging is defining the data requirements including what types of data to obtain, who to source data from, how best to collect such data and what sampling strategies are appropriate. These will remain high agenda research themes for the immediate future.

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