WORKING PAPER
ITS-WP-98-4

Interacting Agents and Discrete Choices in Logistics Outsourcing: A Conceptual Framework

by

David A. Hensher
Garland Chow

February, 1998

ISSN 1440-3501

Established and supported under the Australian Research Council's Key Centre Program.

INSTITUTE OF TRANSPORT STUDIES
The Australian Key Centre in Transport Management

The University of Sydney and Monash University

NUMBER: Working Paper ITS-WP-98-4

TITLE: Interacting Agents and Discrete Choices in Logistics Outsourcing: A Conceptual Framework

ABSTRACT: This paper develops a framework within which multiple agents make discrete choices in respect of a common objective - namely the delivery of a consignment from its origin to its final destination. Ideas from game theory and discrete choice are combined to define a set of choice experiments in which agents (e.g. shippers and freight forwarders) interact in arriving at a choice outcome. Forward and backward linking stated choice experiments provide a capability to evaluate sequential-move and 'one-shot' simultaneous move negotiation regimes. We propose an empirical framework in which a controlled experiment is implemented on a sample of freight forwarders and shippers moving specific consignments to an international or domestic destination. We concentrate on the contract environment where negotiation, deals, repeat business are the trend in agent choices in logistic chains, in contrast to open-market competitive decision making.

AUTHORS: David Hensher*
Garland Chow**

CONTACT: Institute of Transport Studies (Sydney & Monash)
The Australian Key Centre in Transport Management
C37, The University of Sydney NSW 2006
Australia

Telephone:	+61 2 9351 0071
Facsimile:	+61 2 9351 0088
E-mail:	itsinfo@its.usyd.edu.au
Internet:	http://www.its.usyd.edu.au

DATE: February, 1998

**Institute of Transport Studies, The University of Sydney*
***Faculty of Commerce, University of British Columbia*

Introduction

Agency interactions between shipper and freight forwarder, and between intermediaries and shippers, are commonplace in logistics and freight transportation. Surprisingly the efforts to model the choices of shippers in respect of mode and freight forwarder have treated each agent as a mutually exclusive decision element in the supply chain. Unlike passenger transportation where the independence of agents is more acceptable, the non-independence is much more critical in the freight transportation sector. Only where agent independence is assured in a true competitive market for goods and services can we treat each observation in the same manner that they are treated in traditional discrete choice models.

Logistics decision making under a contract regime is illustrative of agency interdependency. Examples include negotiation, bargaining and sometimes arbitration between shipper and freight forwarder, and between freight forwarder and carrier. Such interactive agency decision making leading to choices which may not necessarily be each agents preferred outcome, are well encapsulated by a non-zero sum cooperative game of the Nash bargaining equilibrium structure. Such a regime is typically non-compliant with a truly competitive market where non-interactive specifications of discrete choice models can safely be assumed for modelling the choice process of each agent in the logistics chain. That is, the situation where a shipper chooses a freight forwarder from a universal finite choice set of freight forwarders in a strictly competitive regime under random utility maximisation.

Rather, what reality typically displays is a situation where shippers, through historical search and experience, have already limited their choice set to a subset of freight forwarders (often referred to as choice through bounded rationality). The market depicts a host of different contractual deals in which agency interdependencies serve to impose a recursive structure on choices made between shippers and freight forwarders, between freight forwarders and carriers, and even between shippers and carriers (bypassing the transaction cost advantage offered by an intermediary such as a freight forwarder or other third party logistics business).

This paper concentrates on the contract environment where negotiation, deals, repeat business are the trend in agent choices in logistic chains, in contrast to open-market competitive decision making. It proposes a framework within which multiple agents make discrete choices in respect of a common objective - namely the delivery of a consignment from its origin to its final destination. The theoretical framework uses ideas from game theory, discrete choice models with relatively free covariance structures (ie across-agent correlation), and forward-backward linking stated choice experiments capable of evaluating sequential-move and 'one-shot' simultaneous move negotiation regimes. We propose an empirical template in which a controlled experiment can be implemented on a sample of freight forwarders and shippers moving specific consignments to an international or domestic destination.

Theoretical Framework For Choice Making In A Logistics Chain

Any situation involving interaction between two or more individuals has elements of cooperation and non-cooperation. The choice outcome matters to each of them and depends on the actions of both or all of the players. At the outset of a negotiation, each individual perceives the extent to which other participants are cooperative, defined as a commitment to choose a joint plan of action. This does not imply that either participant sacrifices their interests for the sake of the other; only that each communicates and coordinates with a view to furthering their own unchanged interests by so doing. The central position here is that the neo-classical economic view that 'private decision-making leads to everyone's good' (or agent-independent utility maximisation) depends critically on assuming a regime of perfect competition with numerous participants. In the context of shippers and freight forwarders this is an unrealistic assumption.

Game theory provides compelling support for the application of a two- (or n-tuple) person cooperative game in which the shipper and the freight forwarder can cooperate (there being nothing to prevent them from arriving at an outcome as to what each will do). Cooperation assumes compliance with two tests: (1) for *both* the freight forwarder and the shipper it cannot be bettered by some agreement, and (2) for *either* the freight forwarder or the shipper it cannot be bettered by one participant going their own way. Importantly, however, whether the freight forwarder and shipper will end up acting as a unified agent (i.e. cooperation), depends on decisions made entirely non-cooperatively by each decision unit.

There may be lots of outcomes that pass the two tests (known as von Neumann-Morgenstern solution set of the cooperative game). Fortunately Nash solved this problem of indeterminacy through bargains by recognising that the outcome of a failure to agree (all offers and counter-offers rejected) is predetermined as the status quo. The game-theoretic context is used to study the evolution through negotiation and bargaining of alternative logistics regimes offered by freight forwarders and accepted by shippers and offers an appealing framework within which to design choice experiments. The dynamics of game play is noticeably absent in the literature on stated choice experiments in general and in the revelation of the choice set and the preferred/chosen alternative logistics practices of shippers.

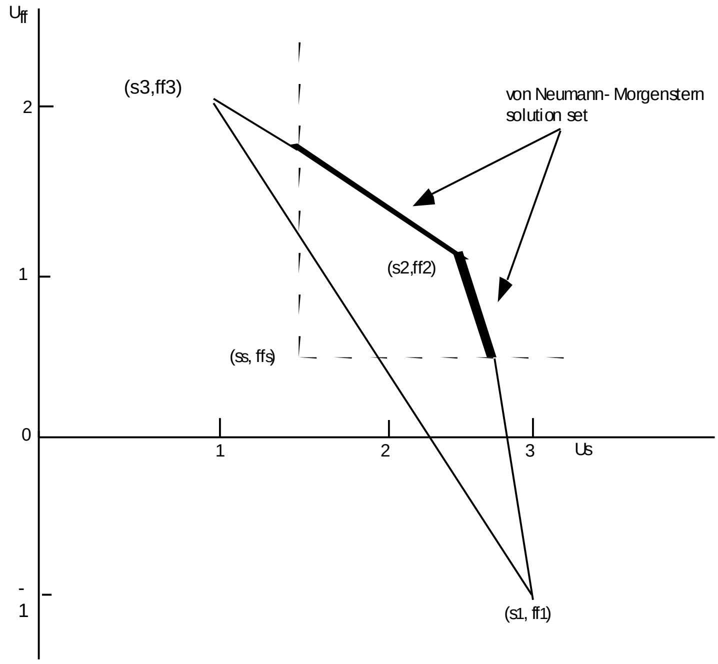
To illustrate how bargaining in a game context works, assume three alternatives in the trade, two as outsourced attribute bundles provided by a freight forwarder defined by fee per shipment, damage per shipment, on-time delivery per shipment, and transaction time per shipment; and one as internal sourcing (which for the freight forwarder is a non-accepted offer). Suppose the shippers first strategy (s_1) is to opt for outsourced bundle 2; the second strategy (s_2) is to opt for outsourced bundle 3; and the third option (s_3) is to provide the service in house. The freight forwarders strategies (ff_1, ff_2 and ff_3) consist in offering the options in the order ff_2, ff_1 and ff_3; where ff_3 is the non-offer. If they do not agree to one of these exchanges, the shipper will perform the task inhouse. The payoffs might be as given in Table 1. Each cell identifies the payoffs to each agent. For example, in (3,-1), 3 represents the payoff to the shipper and -1 is the payoff to the freight forwarder. Thus if the shipper chooses the outsourced offer bundle s_2, but the freight forwarder chooses not to accept this offer (ie to select ff_1), then the shipper receives a payoff of 1.5 and the freight forwarder a payoff of 0.5.

Table 1. A bi-matrix of payoffs in an interactive logistics preference game

		freight forwarder	freight forwarder	freight forwarder
		ff_1	ff_2	ff_3 (non-offer)
shipper (outsource)	s_1	(3,-1)	(1.5, 0.5)	(1.5, 0.5)
shipper (outsource)	s_2	(1.5, 0.5)	(2.5, 1)	(1.5, 0.5)
shipper (in-house)	s_3	(1.5, 0.5)	(1.5, 0.5)	(1,2)

The off-diagonal payoffs show the expected utilities if their demands are not acceded to. It makes no difference which demand is refused. If they fail to agree the outcome is always the same - no outsourcing. The attainable region R in payoff space and the status quo point (s_3, ff_3) are shown in Figure 1. The negotiations between the shipper and the freight forwarder are assumed to be quite frank - all cards on the table. The theory of bargaining games does not say what we might hear if we witnessed the negotiations - arguments based on inter-temporal comparisons of utility, or on principles of fairness, appeals to tradition etc. but it is clear that we would not observe the dissembling maneuvres typical of real bargaining in which the shipper and freight forwarder might begin by exaggerating their true minimum terms, compromising only if necessary.

Figure 1. Outsourcing and In House Preferences



The arbitration associated with the bargaining game is defined by Nash as follows: For any point (Ua, Ub) in R, consider the quantity (Ua-Sa)(Ub-ffb), the product of the shipper and the freight forwarders utility increment from the status quo. Now find (Ua, Ub) in R that maximises this product subject to the constraints that Ua ³ Sa, Ub ³ ffb. This bargaining solution is in outcome space representing the basket of attributes which are sources of expected utility. The outcome of cooperative games, the pairs of baskets or attribute mixes, define the feasible set of distributions in outcome space. The search for the feasible sets can be implemented through choice experiments. The choice probabilities from the choice experiment provide the information to construct the expected utility matrix, an input into interactive agency utility maximisation.

The Nash solution for Table 2 (Figure 2) is (s_2, ff_2) with a probability of 0.9167 (outsource offer 2) and (s_1, ff_1) with a probability of 0.0863 (outsource offer 1). The payoffs are (2.375, 0,083). This is the best we can do - *cooperation is achieved up to a probability of 0. 9167.* This solution satisfies Pareto-optimality in that a distribution should not be chosen if there is another distribution which is feasible and which one player prefers and the other does not prefer. If there was an outcome with expected utilties Ua, Ub, one bigger and one as great as the payoffs of the Nash solution, then the latter would not maximise the product of utility gains, contrary to their definition (Gibbons 1992). It also meets the shipper’s and freight forwarder’s security levels and hence is what von Neumann and Morgenstern (1944) called the negotiation (or solution) set.

The mapping between payoff and expected utility is not exact. The off-diagonal expected utilities are likely to be different in each cell and thus the validity of the Nash solution of equal payoff does not translate into identical expected utilities in the off-diagonal cells.

Indeed, the theory sets out to describe not behaviour but non-cooperative modes of choice. This is why the off-diagonals can be equivalent. In the study of behavioural responses in preference space, this need not be so. Another way of saying this is that although the outcome of non-agreement will always be the same across all non-agreement pairs, the utility that an agent would have derived from securing a specific outcome if agreement had been reached is unlikely to be the same. Our interest is in revealing the expected utility of agency outcomes and in translating this into a set of cooperative and non-cooperative probabilities of paired outcomes. The sum of the joint probabilities in the three diagonal cells define the cooperative probability set. The choice probabilities from a discrete choice model might be as given in Table 2. These are illustrative and bear no relationship to Table 1. Cooperation is achieved up to a probability of 0.402, comprising the outsourced offer 1 (0.0667), outsourced offer 2 (0.2324) and in-house support (0.1027). These cooperative probabilities can be identified at each stage (or pass between the two agents) in the sequential-move interactive agency experiment.

Table 2. A Bi-Matrix of Choice Outcomes in an Interactive Logistics Outsourcing Preference Game

		freight forwarder	freight forwarder	freight forwarder
		ff_1	ff_2	ff_3
shipper	s_1	*(.208,.250)*	(.208,.583)	(.208,.168)
shipper	s_2	(.375,.250)	*(.375,.583)*	(.375,.168)
shipper	s_3	(.417,.250)	(.417,.583	*(.417,.168)*

An Empirical Paradigm - Interactive Stated Choice Experiments

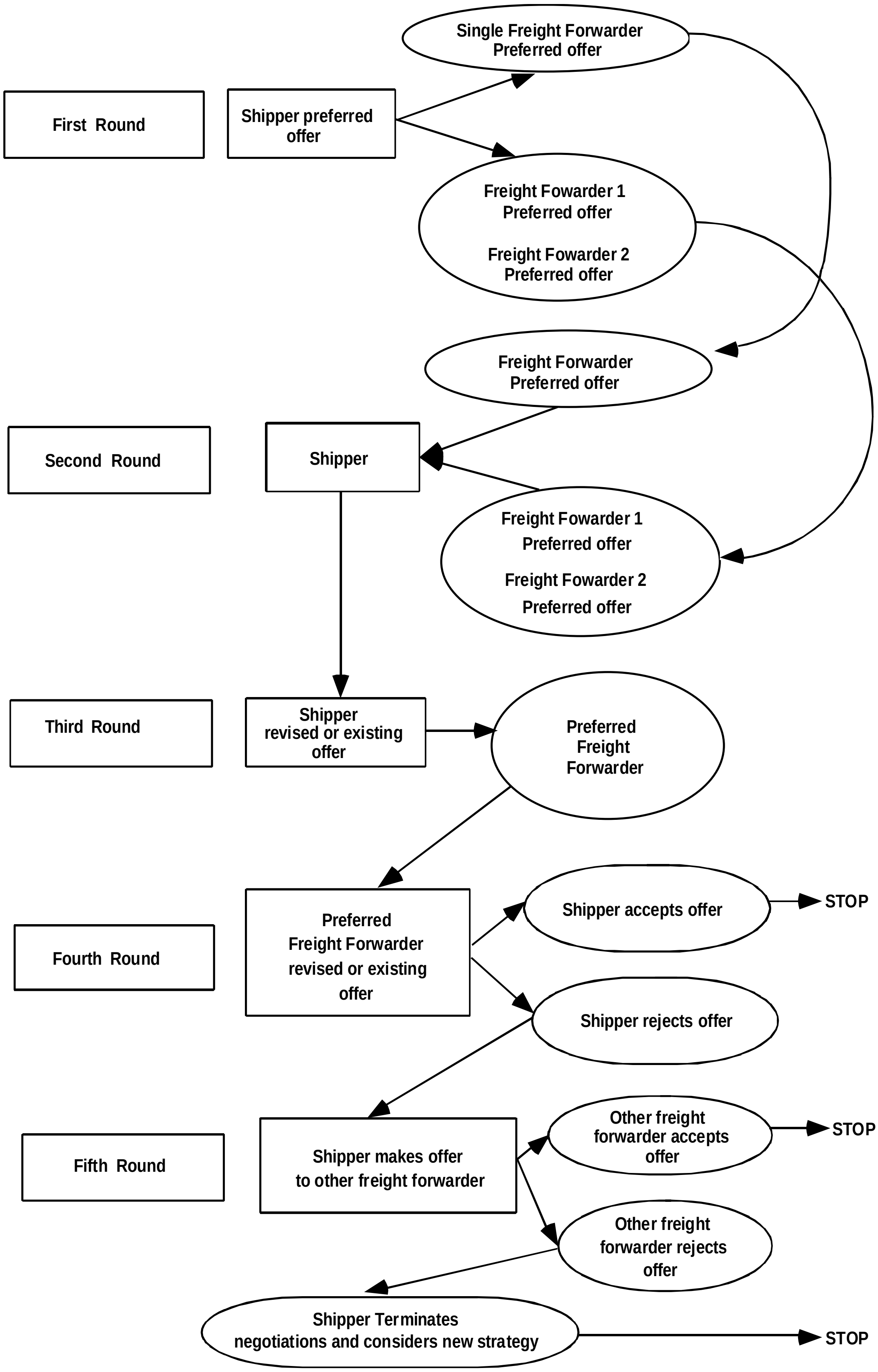
The theoretical ideas developed above can be translated into a stated choice experiment in which each agent makes a choice in the light of the attribute levels associated with each alternative. These choices may be in the context of knowledge of the other agent's preferred offer or without such knowledge. Through a simultaneous or sequential move strategy, the stated choice experiment is offered to both parties who might agree in one pass or who require a series of passes before a final 'equilibrium' outcome is arrived at. The possibility of non-agreement is also very real. We refer to such an experiment as an Interactive Agency Choice experiment (ICE). An ICE experiment can involve multiple agencies such as a shipper and competing freight forwarders. We develop the approach in the context of one shipper and two freight forwarders, recognising that the method can be generalised to any pair or n-tuple of agents.

A number of experiments can be administered to a sample of shippers and their associated freight forwarders for a specific consignment. The shipper is first selected and interviewed in respect of a particular consignment being shipped between a given origin and a given destination. It is assumed that a freight forwarder will be contracted to undertake the transhipment unless there is no agreement, in which case the shipper undertakes the logistics task in-house. After the shipper has completed the first round of the choice experiment involving the evaluation of say three alternatives defined in terms of transaction time, total cost and service reliability scenarios, which is repeated a total of 3 times, each freight forwarder is asked to make an offer in the context of the same choice experiment but under two information scenarios - with and without knowledge of the shippers preferred choice on each of three replications. In an n-tuple experiment with two freight forwarders, each freight forwarder evaluates the situation under two 'competitive' contexts - the presence and absence of a 'competitor'.

A set of first round responses are then fed back to the shipper who assesses the 'preferred offers' of each freight forwarder and then repeats in a second round the same experiments, revising or staying with their preferred first round offer. The outcome is then fed back to each freight forwarder who then re-evaluates their position in the face of the shipper's second-round response (this time there is no scenario of ignorance of the shipper's preferred response). The freight forwarder is now however supplied with the shipper's first *and* second round 'preferred' offers. Each freight forwarder is also supplied with the first round offer of the other freight forwarder (assumed to be known via the shipper - although we could consider later information feedback via the shipper which is partial in that it might only be an indication that the other freight forwarder is currently preferred). Each freight forwarder then makes a further offer which may maintain their first round offer in the presence and in the absence of a competitor. The outcome is then fed back to the shipper who in a third and final round evaluates the offers and selects a freight forwarder or decides to undertake the logistic task in-house. This eliminates the competing freight forwarder or both freight forwarders.

The selected freight forwarder is then given one final opportunity to accept or reject the offer from the shipper. If the offer is accepted, that is the end of the process; if he rejects the offer the shipper gives the other freight forwarder the opportunity to accept the offer. If the other freight forwarder accepts the offer that is the end of the negotiation process; if he rejects the offer the shipper is assumed to terminate the negotiations and consider other options. The experiment does not extend into the negotiation space of the new option set. Figure 2 summarises a possible interactive agency path.

Figure 2. An Illustrative Interactive Agency Process



A number of deign strategies can be considered to take into account the nature of the set of agents. For illustration, if we assume three attributes (door to door travel *time*, consignment *cost* and *reliab*ility) each at three levels, the stated choice experiments involve three designs (SCI, SCII, SCIII):

SCI: Shipper choice set of 3 alternatives each with 3 attributes at 3 levels:

Alt 1	Alt1	Alt1	Alt2	Alt2	Alt2	Alt3	Alt3	Alt3
time	cost	reliab	time	cost	reliab	time	cost	reliab

SCII: Independent Freight forwarder choice set same as for shipper plus the shipper first round preferred offer

SCIII: Interactive Freight Forwarder choice set of 9 alternatives each with 3 attributes at 3 levels but mixing the two freight fowarder attribute offers in a subset of alternatives:

Alt 1 (F11|F21)	Alt1 (F11|F21)	Alt1 (F11|F21)	Alt2 (F11|F22)	Alt2 (F11|F22)	Alt2 (F11|F22)	Alt3 (F11|F23)	Alt3 (F11|F23)	Alt3 (F11|F23)
time	cost	reliab	time	cost	reliab	time	cost	reliab
Alt 1 (F12|F21)	Alt1 (F12|F21)	Alt1 (F12|F21)	Alt2 (F12|F22)	Alt2 (F12|F22)	Alt2 (F12|F22)	Alt3 (F12|F23)	Alt3 (F12|F23)	Alt3 (F12|F23)
time	cost	reliab	time	cost	reliab	time	cost	reliab
Alt 1 (F13|F21)	Alt1 (F13|F21)	Alt1 (F13|F21)	Alt2 (F13|F22)	Alt2 (F13|F22)	Alt2 (F13 |F22)	Alt3 (F13|F23)	Alt3 (F13|F23)	Alt3 (F13|F23)
time	cost	reliab	time	cost	reliab	time	cost	reliab

Note: Fij|kl = ith (or kth) freight forwarder and jth (or lth) alternative

In experiment SCIII there are 9 alternatives being evaluated for each freight forwarder which indicate what the 'offer' is from the competing freight forwarder.

These choice experiments will produce a set of expected utilities leading to the determination of cooperative choice probabilities associated with each mixture of outcomes evaluated by a freight forwarder and a shipper. The analysis of each pass in the interactive choice experiment is best 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 freight forwarder 'flip-flopping' as the prior and subsequent agent in each round of the ICE. Sequential estimation of each agent's choice process at each pass in the sequential negotiation process will enable us 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.

A series of choice models can be estimated to evaluate potential influences on the shipper's and the freight forwarder's preference for the each of three offers. In addition to the design attributes, the role of contextual variables describing the shipper and the freight forwarder, as well as structural influences on the execution of the interactive choice experiment (ICE) can be included. The estimation procedure is recursive multinomial logit, although nested logit, heteroskedastic extreme value and multinomial probit models could also be estimated (Hensher et al (Forthcoming)). The following steps highlight the sequential recursive estimation procedure for an experiment involving only a shipper and 1 freight forwarder:

- *Step 1*: First sequential move offer of shipper - 3 replications per shipper. As the first experiment there is no involvement of the freight forwarder.
- *Step 2:* First sequential move offer of freight forwarder - the same 3 replications as per the shipper. The knowledge of the shipper's offer is revealed to half of the freight forwarders 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 freight forwarder agree on the offer in pass 1 for a specific replication, then that concludes the ICE for the agency pair. This state of negotiation is identified by a 'pass agreement' dummy variable (=1 if agree and 0 otherwise).
- *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 freight forwarder 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 freight forwarder's offer in pass 1, for situations of non-agreement in round 1. For Step 5 and beyond, all shippers have knowledge of the freight forwarder's preferred offer. We evaluate the shipper's offer which may or may not be revised from pass 1, in the light of knowledge of the freight forwarder'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 freight forwarder 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 freight forwarder and identify the cooperation probability for each alternative in pass 2.
- *Step 8*: Second sequential move of the freight forwarder given the shipper's revised or maintained offer in pass 2, for situations of non-agreement in round 2. We evaluate the freight forwarder's offer which 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 freight forwarder in pass 2). We include a variable representing the actual offer from the freight forwarder in te 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.
- *Step10*: Calculate the expected utility matrix for the shipper and the freight forwarder 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.

Estimation is potentially quite complex. The need to preserve the sequential structure as well as recognise the possibility of non-independence between alternatives across the agents suggest that a multinomial multi-period probit (MMP) specification is desirable. Although more complex than the family of logit models where at best the variances are free (but all covariances are set to zero - see Hensher et al forthcoming), recent developments is estimation using simulated moments developed by McFadden (1989) and others can be implemented to obtain estimates of the choice probabilities.

In the example of one pair of shipper and freight forwarder, the model system involves interdependence between a shipper and a freight forwarder, in which there are 6 alternatives in the choice set (3 for the shipper and 3 for the freight forwarder): Us_i and Uff_i, I=1,2,3. Multinomial probit can be used to obtain parameter estimates and to identify the nature of interaction as revealed through the covariance of the random component of each utility expression. Table 4 illustrates a possible covariance matrix for the random components of the utility functions associated with each alternative, for one pass. The non-zero off-diagonal variances identify the non-independence of the alternatives across agents. Lagged effects can also be introduced to accommodate the recursive nature of negotiations across passes.

Table 3. Structure of the error covariance matrix for interactive agency choice modelling

	Us1	Us2	Us3	Uf1	Uf2	Uf3
Us1	S_{s1}^{2}					
Us2	0	S_{s2}^{2}				
Us3	0	0	S_{s3}^{2}			
Uf1	S_{s1f1}	S_{s2f1}	S_{s3f1}	S_{f1}^{2}		
Uf2	S_{s1f2}	S_{s2f2}	S_{s3f2}	0	S_{f2}^{2}	
Uf3	S_{s1f3}	S_{s2f3}	S_{s3f3}	0	0	S_{f3}^{2}

Conclusions

This paper has introduced the idea of interactive agency choice into logistics channelling where the linkages between actors or agents in the supply chain (ie carrier, freight forwarder, shipper) are best represented as interdependencies or less-than-fully competitive actions, which through negotiation and bargaining within sub choice sets produce outcomes which may or may not be the utility maximisation solution under independent choosing; yet which are a more realistic reflection of what we 'observe' actually occurring in practice.

The idea of interactive agency choice has wider application in many areas of transportation decision making than has been assumed in the literature of traveller behaviour. Indeed the interdependencies between individuals in a household and even between individuals in a particular peer structure are examples of the potential failure of the independency imposed on nearly all discrete choice models in transportation (there may be exceptions but we are not aware of them, although DePalma and Lefevre (1983) recognised the issue many years ago). Brewer and Hensher (1997) have recently implemented the approach developed herein in the context of negotiations between employers and employees to identify the constraints on telecommuting and incentives required to support telecommuting.

References

Brewer, A. and Hensher, D.A. (1997) Distributed work and travel behaviour: the dynamics of interactive agency choices between employers and employees, paper presented at the **8th International Conference on Travel Behaviour Research**, Austin, Texas, 21-25 September.

De Palma, A. & Lefevre, C. (1983) Individual decision-making in dynamic collective systems, **Journal of Mathematical Sociology, Vol. 9:** 103-124.

Gibbons, R. (1992) **A Primer in Game Theory**, Harvester Wheatshaef, New York.

Hensher, D.A., Louviere, J. and Swait, J. (forthcoming) Combining Sources of Preference Data, **Journal of Econometrics**.

McAfee, R.P. and McMillan, J. (1996) Competition and game theory, **Journal of Marketing Research, XXXIII**, 263-267.

McFadden, D. L. (1989) A method of simulated moments for estimation of the multinomial probit without numerical integration, **Econometrica**, 57, 995-1-26.

Porter, M.E. (1990) **The Competitive Advantage of Nations,** New York: The Free Press.

Reiss, P. C. and Spiller, P.T. (1989) Competition and entry in small airline markets, **Journal of Law and Economics, 32 (2),** S179-S202.

Reiss, P.C. (1996) Empirical models of discrete strategic choices, **American Economic Association Papers and Proceedings**, May, 421-426.

Von Neumann, J. and Morgenstern, O. (1944) **Theory of Games and Economic Behaviour**, Princeton, N.J.: Princeton University Press.

ITS

INSTITUTE OF TRANSPORT STUDIES

The Australian Key Centre in Transport Management

The University of Sydney and Monash University