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Freight Distribution in Urban Areas: The role of supply chain alliances in addressing the challenge of traffic congestion for city logistics

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ABSTRACT: The distribution of freight is a major contributor to the levels of traffic congestion in cities, yet it is much neglected in the research and planning activities of government, where the focus is disproportionately on passenger vehicle movements. Despite the recent recognition of the contribution of freight transportation to the performance of urban areas under the rubric of *city logistics*, we see a void in the study of how the stakeholders in the supply chain associated with the distribution of goods (whose destination is an urban location) might cooperate through participation in distribution networks, to reduce the costs associated with traffic congestion. Given that transport costs are typically over 45% of all distribution costs, with congestion contributing a substantial amount of cost in the urban setting, the importance of establishing ways in which supply chain partnerships might aid in reducing the levels of freight vehicle movements in urban areas has much merit. This paper sets out a framework to investigate how agents in the supply chain might interact more effectively to reduce their costs of urban freight distribution. We propose an interactive agency choice method as a way of formalising a framework for studying the preferences of participants in the supply chain to support specific policy initiatives. Such a framework is a powerful way of investigating the behavioural response of each agent to many policies including congestion pricing as a way of improving the efficient flow of traffic in cities.

KEY WORDS: ***Supply Chain, Interactive Agency Choice, Distribution Networks & Urban Freight.***

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1. Introduction

Cities almost by design are complex entities offering a dynamic and vibrancy that accommodates many of the desires of its resident and visiting populations. One of the common consequences of the way that cities have evolved, especially those which were substantially laid out before the advent of the automobile and the truck, is traffic congestion. Congestion is simply the result of the interaction between the amount of infrastructure capacity provided (e.g., lane kilometres) and the amount of vehicle activity (e.g., vehicles per km per hour). Although (economic) theory is clear on how pricing and investment instruments can be introduced to secure efficient utilisation of the transport network, institutional and (asymmetric) information constraints have limited the ability to deliver efficient outcomes.

A noticeable deficiency of mainstream economic theory is the implicit assumption that there are no transaction costs involved in the way that individuals make decisions, something that is clearly not true when decisions of the nature we are interested in involve multiple agents with a range of vested interests and potentially conflicting objectives embedded within a broad spectrum of degrees of trust. The delivery of freight in urban areas involves a complex array of interactions between agents in the supply chain, some of which are focussed solely on profitability while others have responsibilities for the performance of the urban fabric (such as the transport infrastructure). Despite these differences, there is one theme which is common to the interest of all parties, namely the avoidance of the (direct and indirect) costs associated with traffic congestion. It is pivotal to the challenges of city logistics[1], given its aim to '…facilitate movement of freight while managing truck volumes, particularly during peak periods of demand' (DOTR 2002).

As the major environmental externality (intra-sectoral)[2] associated with transportation systems, urban congestion in Australian cities has been estimated to cost $12.8 billion in 1995, rising under a status quo scenario to $29.7 billion by 2015 (BTE 2000). Studies

[1] City logistics is the latest terminology used to recognise the need for an integrated planning approach for tackling *freight distribution* problems. It is defined as a comprehensive framework for planning and developing freight distribution systems in urban areas that involves a broad spectrum of stakeholders such as shippers, freight forwarders, transport operators, government policy makers, logistics specialists, residents and town planners (DOTR, page 66).

[2] The claim that urban congestion is the major externality cost must be qualified by the difficulty in quantifying and valuing the full range of externalities. Congestion is relatively easier to value given its links to travel time and the extensive research on valuing travel time savings compared to valuing other externalities such as air quality, noise and accidents. The estimates by the Bureau of Transport Economics (BTE) have to be clarified. They represent '…the value of excess travel time and other resource costs incurred by the current traffic over those that would have been incurred if the current traffic volumes had been able to operate with unit costs characteristic of uncongested free flow conditions' (BTCE 1996, page 26). Thus they are an over-estimate of the cost associated with levels of congestion under non-optimal pricing given a downward sloping demand curve, described by the BTCE (1996) as "…a measure of the scale of the problem, useful in motivating the community and governments to address the issues, but not to measure the savings to be made" (page 26). This is an over-estimate due the non-optimality of a zero congestion level. The true congestion cost would be measured in reference to the unit costs associated with optimal (non-zero) levels of congestion.

Reports estimate as high as 70% for the contribution of traffic congestion to total transport externality costs. Initiatives to reduce traffic congestion will also benefit other externalities, especially greenhouse gas emissions and air quality.

A key element of the intersection between city logistics and traffic congestion is the role that agents in the supply chain can play in cooperating to change freight distribution activity. This involves a re-consideration of existing distribution networks (Chopra 2003) and ways in which we can design and activate collaborative process networks (Holmstrom *et al*. 2003). Although there is a growing and informative literature on alternative frameworks for designing freight distribution networks in a supply chain (see Panayides 2002), there appears to be a void in taking the recognised set of alternative distribution networks and formally establishing how agents in a supply chain might cooperate, and through this reveal their preferences for network strategies that can deliver reductions in traffic congestion. In the words of Golicic et al (2003, page 57) 'A large part of managing supply chains consists of managing multiple relationships among the member organisations'. The capacity for supply chain members to act strategically depends upon the type and magnitude of the relationships within the supply chain. Following the discussion in Golicic et al. (2003), the types of relationships that exist within the chain are based upon similar traits, such as activities, expectations and duration. Relationship types include arms-length relationships, alliances, partnerships and vertically-integrated firms, to give some examples. The magnitudes of relationships that exist within the chain reflect the closeness of the relationship. Relationship magnitude, which is antecedent to relationship type, can vary within any type.

The discussion above leads us to a number of very specific tasks in order to develop a behavioural model system capable of identifying initiatives that will increase the likelihood of cooperative outcomes in a supply chain designed to reduce the level of traffic congestion in cities. These tasks are:

a. Identify the *types of participants* in a supply chain and their commitment to cooperation to achieve specific outcomes. This would include self-interest outcomes of which reductions in traffic congestion would be aligned through the profitability of the business.
b. Identify *alternative distribution networks* in a supply chain and evaluate participant support for each of them.
c. Identify the factors (or *attributes*) that each party in the chain considers when deciding what participation structure to support (loose and weak partnerships, alliances, etc.)
d. Identify how these networks and influencing attributes can be combined in a choice model to evaluate strategies for freight distribution that will support reduced traffic congestion in cities. Examples might include fleet and trip consolidation to reduce the number of vehicles and kilometres required to deliver a given volume and value of freight.

These four tasks can be studied within a choice analysis framework in which we recognise the inter-relationships between agents choosing amongst a set of mutually exclusive distribution networks on the basis of a range of attributes, each of which plays a different role for each agent. Some of these attributes have a close bearing on congestion and include the loss of time in freight distribution (which translates into costs of doing business); other attributes might be new initiatives such as congestion charging designed to reduce both time losses and traffic congestion. This involves agent-specific trade-offs between attributes as well as inter-agent attribute trade-offs in the supply chain if one is to secure a cooperative outcome that delivers benefits to all agents in respect of traffic improvements.

This paper details each of the tasks, with the specific objective of developing a framework within which a modelling capability is produced, that can be empirically implemented to assess the attractiveness of specific freight distribution networks in delivering improvements to the transport system, and at the same time appeal to members of the particular supply chain. We begin by developing a conceptual framework within which each of the tasks can be studied. The frameworks are then integrated into a discrete choice modelling setting in which we specify the interdependencies between each agent in a chain. An interactive agency choice experiment will form the centrepiece of the empirical specifications in which we propose to include up to three agents per supply chain.[3] The stated choice experiments will require agents across the chain to evaluate the alternatives offered to them (as defined by a set of attributes) and to choose their most preferred. The process will accommodate cooperative and non-cooperative outcomes (using the methods developed by Hensher (2003)) and reveal how the preferences of agents in the chain take into account the level of traffic congestion and charges associated with each outcome. In this way we start to gain insights into what set of incentives will have to be provided to support a change in freight distribution in line with reducing levels of traffic congestion. Policies that do not take into account the complex interactions within the chain may yield suboptimal outcomes, based on inaccurate projections of the likely effects. The empirical study will be confined to selected freight distribution sectors, given the complexity and heterogeneity of this sector. We will be consulting with some major retail chains to establish an appropriate empirical context.

2. The Choice Analytic Dimensions

The starting position in the development of a choice analytic framework is to define the choices that represent the behavioural outcomes that guide identification of what initiatives are most likely to impact in a desired way on traffic congestion.

Within a behavioural framework driven by assumptions of utility maximisation, we assume that each agent in a potential or actual supply chain, associated with a distribution activity, will participate in a specific way on the basis of having considered (i) with whom to form a supply chain, (ii) the relationship structure (type and magnitude) in the supply chain 'partnership', (iii) the way that the distribution network operates, and (iv) the attributes that

[3] This may be a subset of a much broader supply chain, in which the agents directly affected by particular policies (and directly responding to these policies) are in the model. While indirect effects may impact on the broader chain, they are not considered herein.

matter to the agent in meeting their expectations for participation in the supply chain and responding accordingly to specific policy initiatives.

The dimensions (i)-(iii) of the framework require a definition of a choice set of alternatives and associated attributes. Although these will be identified through a literature review and focus groups, we set out a likely set of contenders as a mechanism for testing the appropriateness of the approach in addressing the issues of interest. All of these dimensions (i)-(iii) may be studied as endogenous choice elements (with attributes under (iv) as exogenous influences on such choices) *or* treated as predetermined outcomes in the study of the transport distribution choice responses. The transport choice focus of our research is on the timing of the freight distribution (in respect of departure and arrival time) activity given a focus on the performance of the transport network, with a particular interest in the role of alternative congestion charging regimes on redistributing the freight movement task over the given capacity to reduce the burden on the network and improve the flow of traffic. We propose to investigate a range of congestion charging regimes such as a cordon-based charging scheme and a kilometre-based charge by time of day and location with pre-assigned contributions by each member of a supply chain (the latter being a mechanism for assessing the impact on overall behavioural response through chain sharing strategies).

2.1 Revealing the Endogenous Supply Chain Choice Sets

An appealing starting position is to identify the set of attributes that ultimately define the requirements of each agent in the supply chain. Simply put, what do they want to get out of the relationship? Once we have established these drivers, we can then look at alternative ways in which these outcomes might be delivered (essentially alternatives in the choice sets linked to (i)-(iii)).

In establishing a set of attributes that need to be assessed throughout the supply chain we need to distinguish between those attributes that are specific to freight distribution per se (what we might refer to as the *ultimate attributes* such as those involved in meeting customer needs and the cost of meeting such needs; e.g., response time, cost, reliability) and those that matter to agents in their deliberations with other agents in the supply chain (what we might refer to as *deliberation attributes* such as trust, respect, communication and power).

The full choice domain involves the choice of a distribution network and a choice of agent participation profiles. For a selected agent (e.g., the shipper), they would evaluate (a) the set of distribution networks as supply chain alternatives, as well as (b) the set of ways in which they play a role in the facilitation of the activities of the supply chain (what we call partnership options). We talk loosely about partnership options because they can range from an agent simply ‘purchasing’ services from other agents without any specific contractual arrangement, through to very strictly defined alliances which require participation only in that supply chain arrangement. We broadly describe these relationships

as choosing amongst *arms length*, *cooperative* and *integrated* relationships. There are a number of relationship styles within each of these broad classes (Golicic *et al*. 2003).
There are many potential distribution networks, although the set proposed by Chopra (2003) are a good synthesis of the main alternatives:

1. Manufacturer storage with direct shipping (also called drop shipping) (MS_DS)
2. Manufacturer storage with direct shipping and in-transit merge (MS_DS_ITM)
3. Distributor storage with package carrier delivery (DS_PCD)
4. Distributor storage with last kilometre delivery (DS_LKD)
5. manufacturer/distributor storage with customer pickup (MDS_CP)
6. Retail storage with customer pickup (RS_CP)

In describing each distribution network option, it is crucial to identify and describe each in terms of its own shared or unique attributes. For example, for the attribute 'inventory' we might have the following levels (possibly redefined in terms of level and location of storage):

1. MS_DS = all inventories stored (centralised) at manufacturer and separate deliveries to each customer
2. MS_DS_ITM = In-transit merge combines pieces of the order coming from different locations and customer gets a single delivery
3. DS_PCD = inventories held by distributors/retailers in intermediate warehouses and package carriers are used to transport products to final customer.
4. DS_LKD = higher levels of inventory (compared to all options except 6) because it has a lower level of aggregation with warehouses closer to customer and delivering direct from there.
5. MDS_CP = inventory is stored at manufacturer or distributor warehouse but customer places orders online or on phone and comes to designated collection points to collect orders.
6. RS_CP = inventory is stored locally at retail stores and purchased by customer walking into store or ordering online/by phone and collecting at the retail store.

Partnership options are also challenging constructs. The literature reveals a number of *Relationship Types* that offer appealing classifications of participating members of a supply chain in terms of their role and influence on outcomes. Hensher (2003) proposed the following cooperative/control structures:

1. *Autocratic or directive style (ADS):* A lead agent defines and diagnoses the task, generates, evaluates and chooses among alternative solutions.
2. *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.
3. *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.
4. *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 solutions. Once this information is obtained, the leader makes the choice of which alternative solution to implement.

5. *Group Consultative Style (GCS):* Same as ICS except the lead agent shares their definition of the task with the group as a whole.
6. *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.
7. *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.
8. *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.

An appealing framework in which to capture the interdependence between these supply chain dimensions is one in which we have three nested levels of choices: the choice of *distribution network* (DN) (linked to the suppliers/customer spectrum), inter-organisational *relationship type* (RT) choice (arms length (AL), cooperative (CP) and integrated (INT)), and inter-organisational *relationship magnitude* (RM) choice (degrees of closeness or strength on the relationship associated with collaboration (COLL), coordination (COOR) or cooperation (COOP)). These are summarised in Figure 1. The hierarchical relationship between DN, RT and RM choices will need to be investigated in future econometric analysis. Figure 1 assumes that the distribution network is the highest level of the decision tree (i.e., the marginal choice), making RT and RM conditional choices. The econometric method to be used is generalised nested logit (Gen_NL) where we allow one or more alternatives to appear in more than one branch across the entire nested structure. This is a generalisation of the popular nested logit model (see Wen and Koppelman (2000) for more details).

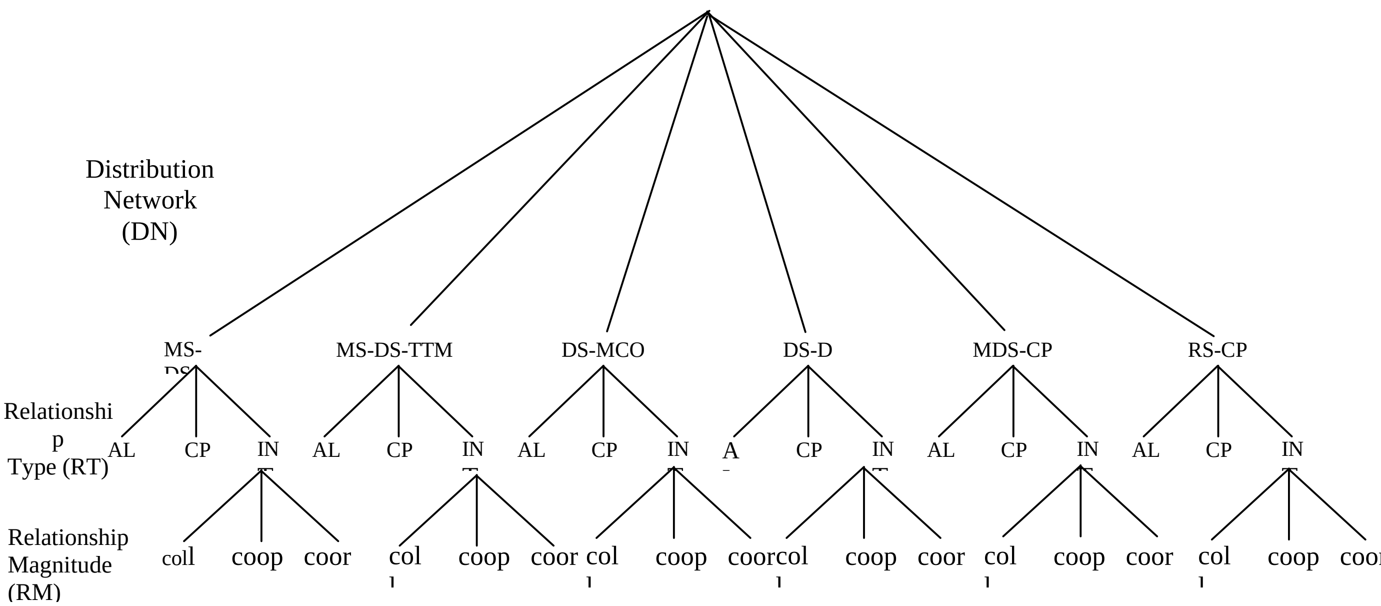

Figure 1 The supply chain choice environment

The three choices in Figure 1 represent what we refer to as *the prior condition of transport distribution activity*, and play a significant role in determining the profile of urban freight distribution traffic on the road network by time of day and location. Without a recognition of these prior conditions in the formal modelling of distribution choice behaviour (either exogenously or endogenously), there is high risk of biased inference of the influence of specific transport policies (e.g., congestion charging) on behavioural response. Furthermore, the inclusion of such prior conditions raises major concerns about the majority of urban freight distribution modelling which believes in mirroring the frameworks used in urban passenger travel demand (as promoted in the 2003 Austroads workshop on urban freight movement modelling).

Given our focus on freight distribution and implications of inter-organisational relationships for traffic congestion reduction in cities, we want to identify which elements of relationship type and magnitude influence the ability to progress on this policy issue. *To reveal the set of necessary and sufficient conditions to secure inter-organisational related gains in combating the growth of traffic congestion will be major progress in promoting incentives to remove a persistent barrier*.

Given the choices associated with the prior conditions, what types of influences on each of the three choices are promoted in the literature? Table 1 synthesises the major 'attributes' that appear to influence the choice of distribution network, relationship type and magnitude. The *choice amongst distribution network* alternatives is assumed to be strongly influenced by a set of attributes that define customer needs (essentially agents downstream in a directional supply chain) and attributes that define the 'cost' of meeting customer needs together with RT and RM. The *choice amongst relationship types* (or governance alternatives) is a function of a number of generic influences including management style within the supply chain (e.g. autocratic or directional, consultative, and leaderless team), and the specific role of each agent as indicated by each agent, together with the relationship magnitude. The *choice amongst relationship magnitudes* (also known as relational intensity) is driven by degrees of trust, commitment, mutual dependence, organisational compatibility, vision, leadership, support from top management etc. The higher the levels on these essentially qualitative indicators, the 'closer' an organisation is likely to be to an integrated relationship in the RT choice set.

These attributes can form the basis of the specification of a set of indirect utility expressions for alternatives listed in Figure 1 in a nested discrete choice modelling framework for the three choices or as exogenous contextual covariates in the indirect utility expressions associated with the choice amongst transport distribution activity alternatives (in particular departure and arrival times by time of day).

Table 1 Candidate Attributes for each Prior Conditions Choice Set

Distribution Network			**Relationship Type**	**Relationship Magnitude**
Cost of meeting customer needs		**Customer needs (i.e. retail outlet)**	**Alternatives: Arms Length, Cooperative, Integrated**	**Degrees of relational intensity**
Supplier(s) of goods	***Distributor of goods***			
Inventories	Order processing	Response time (from order to delivered)	Management style	Degrees of trust
Transportation: (travel time, costs, service (damage), congestion charges……)	Transportation : travel time, costs, service (damage), congestion charges……)	Product variety (# of products desired from distribution network)	Specific role of each agent	Commitment level
Facilities and handling	Fleet characteristics	Product availability (probability of being in stock when ordered)	Relative influence of each agent	Mutual dependence
Information	Delivery restrictions	Customer experience (ease of ordering)	Expected duration of the relationship	Organisational compatibility
	Reverse logistics capability	Order visibility (ability to track from placement to delivery)	Expected net benefits of the relationship	Support from top management
		Returnability (ease of returning unsatisfactory merchandise)		Degree of vision
		Transportation service (damage level etc)		Relative influence of each agent

The attributes that are directly related to traffic levels and congestion reside within the utility expressions of each of the distribution network alternatives. We need to think carefully about how one can specify the potential gains in overall level of traffic congestion in moving from one DN to another. The key to this will be the amount of reduction in travel time, linked in part to vehicle kilometres but also to the spatial context of a movement associated with a particular DN alternative. For example, DN's that involve a high amount of movement outside of the peak periods, leaving short trips in the peaks, will be relatively more attractive than those that require more freight vehicle movement in the peaks in spatial contexts where congestion is at its worst. The location of manufacture and storage will have an impact on the ability of a specific DN to be able to assist the congestion reduction task. *However we can assess the behavioural response to a range of congestion charges across all DN's and associated RT's and RM's to establish whether the sharing of the burden in the supply chain is more achievable under certain supply chain configurations*, leading to either a greater or lesser sensitivity to the charges. The opportunity to distribute the financial burden of a congestion charge across a supply chain (especially if it is vertically integrated and collaborative) has important implications on the sensitivity to such a charge and the extent to which it is passed on to the final customer or absorbed to varying degrees by the agents in the supply chain. There may indeed be a new competitive advantage revealed in specific supply chains to gain the benefits of a congestion charging regime (in terms of improved travel times) whilst spreading the amount of the charge across agents in an efficient manner with regard to each agent's price sensitivities. That is, rather than having a single agent in a chain pay the entire congestion charge, optimising over the charge across agents with respect to each agent's willingness to pay for savings in distribution costs could lead to economic efficiency gains for all members of the supply chain.

2.2 Exogenising the Prior Conditions in Urban Freight Distribution Choice

Golicic et al. (2003) suggest that supply chains tend to stay intact once formed. Thus the distribution level of service and cost can also be specified in the urban freight distribution choice per se, defined *conditional on* the prior conditions, with the distribution network type interacted with trip attributes. Hence an appealing stage one investigation will treat the prevailing membership of a supply chain as exogenous, focusing on group decision making under alternative congestion pricing regimes. The process that leads to the formation of a supply chain can be investigated in future research once we have gained useful research experience within the less demanding task.

2.3 Defining the Transportation Choice Context for Empirical Inquiry

The specific transportation choice within which to evaluate congestion charging will be important. We have chosen the choice of time of day to distribute goods and services. This decision is not only influenced by the attributes of distribution (e.g., travel time, time variability, freight rates, congestion scheme and charges) but also by other input costs associated with production and attraction distribution points (e.g., input cost differentials if delivering late in evening compared with during day for receiver of goods) and also the extent to which partners in the chain cooperate. The latter is defined by the relationship structure and magnitude, as well as by the type of distribution network associated with a given sampled supply chain.

The timing of urban freight distribution appears to be one of the most important issues for transportation planning since it offers the greatest opportunity to make an impact on the performance of existing infrastructure capacity, taking advantage of the underutilised capacity of roadways at certain times of day. Given that it is relatively more attractive to relocate the time at which goods are delivered to their point of use (either in final consumption or as an input in a further production stage), compared to influencing passenger activity temporally, taking pressure off the road network at particular times of the day (at particular locations) is a worthy task. There is much merit in seeking out ways of achieving this provided that it can be shown to be supported by the ultimate decision makers in the supply chain. The failure to have much impact in the past may be a consequence of an overemphasis on the decision making dominance of the freight distributor rather than all relevant influencing players. It may also be due to an inadequacy in the whole approach adopted to study the issue of urban goods distribution, especially a strong focus on mode and route choice. Not only is mode choice moot for urban goods movement, route alternatives are often limited as well. The absence of adequate revealed preference data on the timing of freight distribution as well as information on the role of congestion charging schemes promotes the case for a stated choice approach (Louviere et al 2000, Hensher et al 2004), to which we now focus.

3. The Role of a Stated Choice Experiment Paradigm in Revealing Supply Chain Preferences

The plan is to use a stated choice (SC) experiment with multiple choice sets and have each agent in a three-agent supply chain evaluate a number of time of departure and/or arrival alternatives or scenarios defined in terms of distribution attributes and other attributes as appropriate (e.g., impact on input costs and extent to which congestion charge will be passed onto non-chain members) and to choose the most preferred scenario. This will be repeated a number of times with different levels of the attribute set, seeking out the preferred scenario. Each participant in the three-agent chain will assess the exact same scenarios and make a choice. The feedback between agents leading to final agreement (i.e., cooperation) on the consensus scenario or to non-agreement (i.e., non-cooperation) defines the interactive agency choice experiment (IACE), originally developed in a passenger context by Hensher (2003). The key distribution attributes are travel time, travel time variability, and a congestion charge (specified by its type, size and allocation amongst agents in the chain)[4].

[4] Key papers that have reviewed the evidence on what attributes are likely to influence freight distribution decisions from the perspective of the agents in the supply chain are Chopra (2003), Danielis and Rotaris (2000), Cullinane and Toy (2000) and Golicic *et al*. (2003). These attributes may have different degrees of relevance for each of the main agents in a chain: *Commodity shipper* (e.g., manufacturer/owner); *broker/freight forwarder* (who collects and distributes to destination); and *customer at destination* (e.g., a major retail outlet). The often cited *Distribution Attributes* are: Cost, price, rates; Speed (overall delivery and

Structuring the congestion charge to evaluate how it is shared is a challenge. One possibility is to specify the split of the congestion charge as follows: rather than listing the charge as, say, $10, listing it as "the shipper pays $4, the freight forwarder pays $5 and the retailer pays $1". On can also explain precisely how the charge is paid (perhaps specifying the way that costs change for each firm as a result of the charge). This specification will allow us to assess what leads agents in the supply chain to agree to, or not to agree to, share the congestion charge. The possibility of passing the entire charge onto the end consumer is also worthy of consideration.

In selecting the final set of SC design attributes we may need to take into account (from prior evidence) the possibility that some attributes only have relevance to a subset of agents in the supply chain. With overlapping attributes we have the equivalent of pooling data across agents (equivalent to pooling data from more than one data source). If we think of this in a nested logit framework, then what we have is three data sets each with their own scale parameters to represent the differences in variance in the unobserved effects (see Hensher *et al*. in press). Generalising the nested logit framework to include cross-correlated nested logit (see Bhat 2003), we can establish the influence of interdependency in choice making across the agents.

The exact mechanism for executing the choice experiment is considered in another paper (Puckett and Hensher in progress), where we also consider a range of ways of having multiple agents participate in the choice experiment, given the need to both capture information on the preferred action of other agents in the chain, and to use this information in any revision and negotiation between agents in arriving at a cooperative or non-cooperative outcome. The IACE perspective reveals important barriers to inter-agent preference revelation and hence choices due to a concern about the reaction of one agent. This *second-best guessing strategy* often reveals a sub-optimal preference that is negotiable once both parties gain a greater awareness of each others preferences. This information-trading perspective offered by the IACE framework is a powerful framework, in which to identify perceived barriers to effective decision making and to provide a ‘trading’ environment in which agents may move toward an outcome which is the closest to the joint utility maximisation outcome.

This becomes apparent when we contrast the preferences and outcomes at the first three passes of an IACE. The traditional independent assessment approaches (without feedback and revision) are equivalent to a first-pass approach, stopping well short (potentially) of revealing the utility-maximising cooperative equilibrium. Conversely, the IACE approach enables respondents to learn about each other’s preferences as the number of interactions among agents increases (i.e., as the number of passes in the IACE increases). The gain in information regarding each other’s preferences allows the group to move toward an outcome that

travel time); Transit time reliability (and punctuality); Characteristics of the goods; Service (including damage risk, response time, flexibility, and attitude); and Transhipment (whether door-to-door or consolidated and moved between large and small vehicles – collectors and distributors).

maximises joint utility; this is a process-oriented method that reveals greater behavioural insight than a one-shot, outcome-oriented method.

3.1 Simulated Agents

One idea to minimise the difficulty of securing the support of each agent in the chain to participate in a group-centred experiment is to administer the experiment to individuals, whilst simulating the responses of other members of the supply chain. The motivation for this is that the information regarding interaction that really matters to the analyst may only be each agent's reaction to the perceived actions of other agents in the group. If this is true, and if the actions of other agents are replicated effectively, respondents could participate at a time of their own choosing, independent of the others in the group; this would simplify data collection greatly.

Conceivably, it may be immaterial for the analysis if the respondents are actually interacting, or if they simply believe that they are interacting with one another; it would even be sufficient that the respondents are aware that the actions of the others are simulated, as long as respondents acted as though the simulated agents were real. That is, the results achieved through having the agents in a group respond in a simulated setting may be similar to those achieved when the group interacts directly. If simulated properly, each of the agents in a particular choice setting could attempt to reach agreement with the simulated agents. What would be observed would be the behaviour of each agent in the choice setting, responding to the simulated preferences and actions (i.e., preference revision, concession and reciprocation of concession) of the other agents. The end result may be that, although agents from the same real-world group could reach different agreements in the same simulated choice setting, the behaviour of each agent in that choice setting would be the same as if the agents had interacted directly. Hence, the preferences and revealed measures of influence for each agent could be captured through simulation just as if the agents interacted directly. We investigate this in Puckett and Hensher (in progress).

3.2 Contextual Capture

In addition to the SC experiment, additional context capturing questions will be asked. In particular, relationship magnitude and relationship type will be identified through questions that gauge the agents' perceptions of the structure of the supply chain relationship. Agents will be asked questions regarding their motivation to form the relationship, including the key factors in the decision to form the relationship, along with questions that allow an agent to rate their perceptions of the relationship magnitude and relationship type (and their perceptions of what the other supply chain members perceive the relationship type and magnitude to be). This will yield index variables that can be interacted with the SC design attributes, and that could be used to explain some heterogeneity around the means of specific design attributes. An interesting hypothesis is that cooperative chains are likely to reach agreement in the experiment sooner than non-cooperative chains. A related hypothesis is that preferred scenario outcomes will vary systematically with relationship type and magnitude.

4. Conclusions

This paper sets out the elements of a new approach to revealing opportunities to redistribute urban freight traffic across all times of day to improve the performance of the existing road capacity. We recognise that the full participation of members of a supply chain who have an active role to play in decision making, which impacts on the distribution of urban freight, is essential to establishing real opportunities to influence the distribution activity.

While much of the literature on logistics chains emphasises decisions and relationships between agents (see Taniguchi *et al*. 2003, 499), there appears to be a void in formal methods of conceptualising, through to the specification of a behavioural model, a mechanism for investigating the behavioural support for specific policies that can contribute to the redefinition of the urban freight distribution task in a way that can improve the performance of the existing infrastructure. Issues such as reducing traffic congestion are increasingly high on government agendas, yet establishing the role of various congestion charging regimes and their effectiveness in delivering benefits to the agents in a supply chain are poorly understood. Ongoing research using the ideas set out in this paper is designed to contribute to filling this void.

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