Improving Our Understanding of Freight Travel Decision Making: Motivations, Constraints, Incentives and Interactions

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Abstract

Key advances have been made in recent years relating to the modelling of decision-making process underlying the movement of freight. In the area of network modelling, micro-simulation techniques of freight travel choices, modelling of land-use/transport network feedback effects, and accounting for physical characteristics of logistics networks have added important structural behavioural elements to models from which standard models centring on techniques such as assigning commodity flows have only abstracted. Furthermore, recent empirical applications have added to our understanding of the relative merit that freight-related transport policies could have in achieving desired objectives.

Developments in both network modelling and empirical freight travel behaviour applications have extended the manner in which analysts account for multiple behavioural dimensions that shape how freight is ultimately carried. These dimensions include forces motivating freight stakeholders to enact particular strategies, constraints that restrict a subset of potential strategies from being observed, incentives to encourage desired behaviour, and the impacts of interactivity across interdependent freight travel decision makers.

This paper highlights some key developments that have been made in these areas, supplementing discussions of advances in research with empirical tools that may show promise in improving our ability to faithfully represent determinants of freight travel behaviour in network models and policy applications.

Keywords: Freight travel, group decision-making, freight modelling, micro-simulation
1 INTRODUCTION

The quality of recent research into freight travel decision-making is a welcome signal for an area that some may feel does not receive sufficient attention. There is no doubt that research into freight-related travel behaviour tends to involve considerable complexities that may not be present in passenger-centred applications. However, many important contributions have been made over the past few years that stand to lead the way to a new generation of effective modelling approaches relating to the behaviour that freight stakeholders make – and, quite importantly, will make under new constraints and opportunity sets – regarding the ways in which freight is carried and received.

Indeed, the advancements that have been made underscore the vast potential for innovation that is strongly correlated with the very complexities that may have served as barriers to freight-related research applications. As techniques are developed, tested and refined, and as our understanding of decision-making settings and processes improves, there should exist ever greater opportunities to succeed in executing research applications that yield tangible, critical insight into current and potential decision-making structures relating to the movement of freight.

Behind the freight-related decision-making structures we seek to understand are many interrelated constructs, which could likely be considered from many angles. As an at least somewhat parsimonious approach, this paper considers four constructs that may be pivotal for improving our understanding of freight travel behaviour: motivations, constraints, incentives and influence. The motivations of freight stakeholders – that is, considering both how freight stakeholders behave and why they behave the way they do – may be the most approachable of these constructs, but that makes it no less important to understand. One of the primary obstacles to obtaining useful insights into freight travel is the complex and heterogeneous nature of what actually motivates freight stakeholders to adopt particular strategies or preferences. Hence, two difficult but imperative obstacles to overcome are finding appropriate stakeholders to gain information from, and to know how to use such information representatively; without satisfying those obstacles, there is little hope of representing the preferences of freight stakeholders in any meaningful way.

The constraints that freight stakeholders face are similarly complex and heterogeneous. These constraints are of considerable importance in the analysis of freight travel decision making under the status quo; however, the scale and scope of constraints on freight-related behaviour may change drastically under evolving economic and policy landscapes. That leaves a great deal of ground for freight researchers to cover in an analysis of both current and potential future freight travel behaviour. Current travel behaviour can be shaped by constraints set both by decision makers within a given freight travel setting and by stakeholders and policy makers outside of a given freight travel interaction.

For example, Holguín-Veras (2007a,b) discusses the importance of delivery windows set by receivers of goods; regardless of a receiver’s status within a freight travel interaction (i.e., whether the receiver has direct input into how a consignment destined for its site is
carried), the constraints on delivery conditions set by the receiver with respect to delivery times have a clear impact on how the consignment is moved. In the absence of this constraint, the decision makers involved could feasibly optimise the movement of the consignment in a different way. Hence, traffic models and policy analyses that fail to account for such constraints could lead to erroneous conclusions.

The impacts of potential constraints arising in the future are likewise important to evaluate, although these constraints require a different means of evaluation. Whilst extant constraints such as delivery windows and access restrictions can be observed, potential constraints such as carbon taxes, new vehicle emissions zones and changes in fuel costs need to be considered from an experimental perspective. Indeed, it may be fruitful to examine interactions between extant and potential constraints, as the motivations to choose particular strategies and set particular constraints (or, conversely, the resistance to choosing alternative strategies and constraints) may change under new policies and states of the world. Market- and policy-driven changes in fuel, vehicle and land use are key examples of shifts in constraints that could alter the fundamentals underlying freight travel decision making.

Related to both motivations and constraints, it is a basic economic tenet that decision makers respond to incentives. If we are able to gain insight to both why freight stakeholders prefer certain strategies and what constraints govern the strategies available, it becomes feasible to evaluate the incentives (or disincentives) that could be offered to encourage desired shifts in behaviour. Hence, it is important to consider the instruments available to those who influence freight travel behaviour in tandem with the context of what drives and shapes freight travel behaviour to gain a fuller picture of the potential impacts of changes in the market on how freight is carried. This may sound tautological, but the implication is that it is not enough to understand that incentives matter, but rather we must understand the context within which a given set of incentives may operate if we hope to understand the impact these incentives may have.

An example of this relationship is the role that tax structures may have on freight-related emissions. It may be relatively clear that the incentive of tax breaks to freight transport firms for the use of low-emissions vehicles could result in some reduction in freight-related emissions. What is less clear is whether a given set of tax breaks would result in a desired level of emissions abatement. By understanding freight transport firms’ preferences with respect to vehicle choice and cost (motivations), and the relative flexibility that freight transport firms may have in choosing a particular vehicle mix (constraints), we would improve our capability to evaluate the impact that a given tax-related incentive may have on freight-related emissions. Ultimately, our search does not end with the identification of an incentive that may have an important impact; rather, we should also strive to understand the context to which the incentive would be applied.

Lastly, influence between freight travel decision makers is a critical force to understand when evaluating how freight is carried. Freight travel choices may be the result of one or many interactions between decision makers, each with one’s own objectives, constraints and relative influence. This influence may vary with respect to the freight travel attribute
in question (e.g., cost, travel time, reliability) and the context of the transaction (e.g., goods characteristics, contractual relationship between parties). To understand how a given consignment may be carried, it is imperative to understand both which types of decision makers may interact over which attributes, and the specific nature of these interactions.

Consider a case where overall traffic volumes in a city are expected to rise by a particular level, resulting in a decreased level-of-service for the traffic network (with some degree of uncertainty before taking freight responses and further feedback effects into account). To accurately predict new network equilibria, analysts would need to properly seed behavioural models with respect to group-level (i.e., supply chain) responses to the change in traffic demand. That is, interactions between decision makers with varying relative influence over different attributes affected by the change in traffic demand lead to a group-level response. Models that abstract from these interactions may not properly represent the resulting changes in freight travel behaviour.

This paper is an effort to: (1) identify powerful tools and approaches that have been developed recently in this regard; (2) consider what areas may need to be covered to yield further gains in our understanding of freight-related decision making; and (3) propose some empirical tools and approaches that could help cover those areas. To this aim, we now turn to a three-part section on promising developments in freight travel behaviour research. The section was not designed as an exhaustive review of relevant freight behaviour research. Rather, it is a review of applications and frameworks that may be particularly well suited to evolving empirical and policy challenges in the area of freight travel behaviour. Developments in micro-simulation techniques and land-use modelling, freight strategy and policy empirics, and negotiation are considered in the section, along with a discussion of important steps forward based upon these developments.

The paper then turns to a spotlight on three related behavioural research techniques that will be applied to freight travel behaviour research in an effort to improve our understanding of freight transport decision making with both a short- and long-term strategic focus. These techniques will also be developed with the goal of improving our empirical toolkit for further applications involving freight and group decision-making, in general. Finally, the discussion concludes by considering how the advances and potential tools discussed in this paper relate to empirical and policy challenges ahead.
2 KEY DEVELOPMENTS IN FREIGHT TRAVEL DECISION-MAKING RESEARCH

2.1 Micro-Simulation and Land-Use Modelling

The cornerstone of freight travel research may well be the physical modelling of freight movements. The role of behavioural modelling within this effort is to link market-driven behaviours with the physical movements of heavy goods vehicles. That is, it is one goal to represent the physical role of trucks within a traffic network, but it is another to incorporate factors that determine how freight is carried within physical models.

The starting point for replicating freight travel patterns has commonly been some variant of tools used within similar applications for replicating passenger travel patterns (Hunt and Stefan, 2007; Liedtke, 2009). For example, information on shares of total traffic originating and terminating in a given area is calibrated within models to estimate flows of vehicles across a network; physical freight models can adjust these calibrations with respect to information on commodity flows, converting data from one metric of interest (e.g., weight or monetary values of cargo) to another (e.g., consignments) to further improve estimations of freight travel within a network. The sophistication of this general approach can be improved through addressing the presence of logistics and transport functions in the allocation of flows to modes and trips within modes (Liedtke, 2009).

Such an aggregate-level approach can abstract from information on why freight may be carried, what may determine responses to particular mixes of levels-of-service, and the role that competing transport service providers and logistics firms can play in freight travel choices. This may not be highly critical within a strict objective of representing freight flows, but these weaknesses do come to play when analysing scenarios involving new policies and cost/level-of-service mixes. Indeed, Hunt and Stefan point out that expanding origin-destination matrices to replicate freight flows is a flawed approach due to a lack of policy response capability.

Recent research, including de Jong and Ben-Akiva (2007), Hunt and Stefan (2007) and Liedtke (2009) has made important strides in addressing these shortcomings through an agent-level focus that incorporates behavioural factors governing freight travel choices. Central to a disaggregate approach is the ability to simulate freight travel (at whatever focal unit of analysis) such that the resulting simulated population-level activity represents status quo freight travel activity and is plausibly sensitive to behavioural influences of interest (e.g., new policies, changes in infrastructure).

de Jong and Ben-Akiva (2007) propose a detailed, behaviour-driven micro-simulation model of logistics activity that accommodates the determination of shipment size and preferences for the use of transhipment points (i.e., consolidation and distribution centres). This model represents a powerful, policy-sensitive module within a broader freight model that accommodates commodity flows on the whole. The model disaggregates commodity flows to firm-to-firm flows, and then simulates logistics choices including shipment size, the use of transhipment points, modal split (by vehicle...
type) and loading unit type; the simulated decisions are derived through a cost minimisation function. The resulting outputs are origin-destination flows, with the twist that transhipment points including ports and airports are also considered as origins and destinations. de Jong and Ben-Akiva note that most freight models presently abstract from logistics activities, which is an important omission, given that consolidation at distribution centres is a key strategy in urban freight distribution.

de Jong and Ben-Akiva note that this shipment-based approach abstracts from modelling tours, which opens the door for the potential to combine this approach with the tour-based approach taken by Hunt and Stefan. Hunt and Stefan’s model uses Monte Carlo simulation techniques to designate the attribute profile for each simulated tour. By simulating individual tours to match aggregate tour levels for an area, and interacting this activity with information on fleet allocation and market conditions (e.g., population, employment and transport supply), the model is capable of generating useful outputs for policy analysis and forecasting.

Acquiring sufficient data to reflect logistics activity is no small task, to be sure. To include logistics activity effects in the de Jong and Ben-Akiva model (or in a hybrid format with the Stefan and Hunt model), data are required on individual shipments (including spatial patterns, goods characteristics, modal characteristics, size and frequency of shipments, the use and location of terminals and transhipment points, and the role and location of ports and airports) and transport and logistics costs for feasible alternatives. Furthermore, the Stefan and Hunt approach presently rests on assumptions made with respect to the nature of transactions and interactions across decision makers. There is a role here for researchers to undertake research to provide behavioural information to supplant the assumptions present in the current form of the model.

Liedtke (2009) also takes a disaggregate approach, simulating market interactions that determine logistics functions, which in turn condition the flow of commodities. Although computationally-intensive, this group-level approach is a promising development that allows for testing of behavioural adaptations to changes in the marketplace, such as a motorway toll tested via simulation. Changes in shipment size and shifts to new freight transport providers and vehicle types are accommodated in the model along with the simulation of tour characteristics and route choice.

Liedtke’s model acknowledges directly the role that interactions across decision makers play in determining freight travel behaviour. Liedtke points out that, whilst some simulation-based disaggregate models include optimisation with respect to mode choice and generalised costs, these are optimisations on the transport demand side; however, relative influence is commonly held by shippers and receivers (i.e., those who set constraints that may restrict the degree of optimisation available). Ultimately, interactions between shippers, receivers and carriers result in group-level transport activity that can be divergent from what would be predicted when analysing freight transport service demand and supply separately. Liedtke notes that failing to account for interactions between shippers and receivers directly within a model may result in upward biases of demand elasticities of transport time and cost.
When considering relevant interactions in freight travel decision making, it is also important to consider interactions between freight stakeholders and the physical structure of the transport, commercial and residential networks related to the generation and satisfaction of freight travel demand. Hesse and Rodrigue (2004), Zhang et al. (2005) and Woudsma et al. (2008) offer powerful approaches and arguments in this regard. As Hesse and Rodrigue (2004) explain, increasing flows of freight impact interdependencies across modes of production and distribution. Indeed, they argue that the nature of freight distribution has evolved to the point where freight transport is not merely a derived demand, but rather it plays a functional role in the interdependency between goods distribution and materials management.

The role of physical distribution networks has been overlooked in urban studies according to Hesse and Rodrigue; not only is the opportunity set of distribution alternatives a critical factor in determining urban goods movement behaviour, but the opportunity set itself will also change as policies and constraints change. This is an important point, especially when viewing freight travel behaviour from a strategic perspective. If the point is generally true, current analyses of urban goods movement can already be off the mark through abstracting from physical distribution network structures. Consider the relevance of de Jong and Ben-Akiva’s work on incorporating logistics structures within freight models to reinforce the value of this information.

Beyond the immediate relevance of physical distribution structures, abstracting from these structures becomes an even greater impediment to successful planning or accurate policy analysis at a strategic, long-term level. The types of analysis that may be most relevant from a long-term or strategic perspective would centre on changes in policies and constraints. For example, analyses of changing carbon constraints and significant travel demand management strategies are fundamental shifts in policies and constraints that could impact both physical distribution structures themselves, along with the relative benefits of the alternatives that they represent to freight transport decision makers.

Continuing within the realm of micro-simulation techniques, Zhang et al. (2005) demonstrate an agent-based simulation approach to estimate interdependencies between multiple infrastructure networks, including freight, private travel and data. Decisions within the freight network are made under an assumption of Cournot-Nash behaviour, where decision makers coordinate quantities demanded and produced under the prevailing market price until equilibrium is reached. Corresponding with this market-level activity, individual decision makers are simulated to optimise choices over, amongst other things: demand and production plans, routing plans, shipping costs and travel (dis)utility. The ability of the model to incorporate interactions across multiple infrastructure networks reveals the potential for urban transport models to improve their predictive power through internalising interactions across land-use patterns, production and distribution networks and the public transport infrastructure.

Woudsma et al. (2008) consider the relationship between land use and urban transport networks with a focus on behaviour within the logistics sector. The behavioural link
considered in the study are the effects that transport system costs (representing accessibility) have on land use patterns of logistics firms. They explicitly identify the complexities of incorporating spatial influences and outcomes into models of freight behaviour; clustering of land types is likely to lead to spatial autocorrelation in land use data, for example.

An integral functional force when considering transport policies and land use is the vector of response lags for different stimuli, according to Woudsma et al. (2008). That is, different transport elements that influence land use (and vice versa) operate at different, difficult-to-identify lags. Hence, gaining an understanding of the specific time scales at which different feedback effects operate is crucial. For example, it may be well understood that households and firms may form, change membership, relocate and dissolve fairly quickly under different factors, and that freight demand and travel patterns can adjust quickly to market structures, whilst infrastructure tends to change at a much slower rate. As Woudsma et al. put succinctly, infrastructure tends to last longer than the people or things that use it. Yet, identifying specific feedback lags between changes in infrastructure or its quality and land use and transport demand remains an important challenge.

2.2 Freight Travel Empirical and Policy Studies

The true utility of freight modelling is not only in the ability to represent freight activity as it currently stands, but also in the opportunity to investigate potential freight activity and its impacts under various policies or states of the world of interest. Leading research from the past few years in this area includes multiple studies from Holguín-Veras and colleagues, Regan and Golob (2005), Anderson et al. (2005), Danielis and Marcucci (2007), Fowkes et al. (2004), Fowkes (2007), Browne et al. (2007) and Rich et al. (2009). These studies cover key interrelated empirical areas including influence across interdependent decision makers, constraints set by interdependent decision makers, the potential for policies such as road pricing and tax incentives to achieve desired results subject to the effects of agent interdependency, how to link sustainability objectives with urban logistics policies and strategies, how to identify and account for what truly matters to freight travel decision makers, and how different urban areas are targeting policies to improve outcomes relating to freight travel.

Holguín-Veras et al. (2007a,b) set out a brilliant framework for investigating the impacts of potential freight management policies in New York. The game-theoretic framework considers the choice of time of travel for freight shipments, whilst considering the relative influence and vulnerability of shippers and carriers with respect to the policies. Hence, the model reflects the economic nature of interdependent decision making that determines when urban goods movement takes place. Some policies considered impact shippers, some policies impact carriers, and some policies impact both; interactions between sensitivities to the policies and the relative influence that shippers and carriers hold yield the ultimate group response to the policies.
This is a highly appealing framework that should be expanded to examine policies that have longer-term implications. For example, this approach could be applied to group responses to changes in land-use patterns, new restrictions on asset use (e.g., vehicle emissions zones and time restrictions) and large shifts in cost structures under carbon constraints. Indeed, Holguín-Veras et al. (2007) support the importance of studying interactions explicitly through experimental applications; long-term planning and large shifts in market fundamentals are both areas to which an analysis of such interactions would be well applied.

A study of the impacts of time-of-day pricing at the Port Authority of New York and New Jersey (Holguín-Veras et al., 2006b) showed that only around one-fifth of carriers changed their behaviour under time-of-day-based charges, and that less than one-tenth of carriers passed on charges to their customers. The charges did, however, lead to behavioural changes outside of facility usage; of those that did change behaviour, almost half used the change in conditions to improve their productivity. Holguín-Veras (2006a) confirms that road pricing may have a limited impact on the temporal distribution of freight. This is primarily due to the temporal constraints set by shippers, along with a limited capability of transporters to pass along the charges. Even in cases where shippers would bear the charges, the charges would tend to be small relative to the operational expenses of extending delivery windows.

This is a critical finding that dismisses the validity of a standard approach toward pricing – that is, that charges to carriers would lead to a shift in travel behaviour based upon some assumed price sensitivities of carriers. Rather, agent interdependence makes the standard approach false, in that there is no clear trade-off between charges and time of travel at the effective group level; carriers, who are sensitive to the charges ceteris paribus, may struggle to use the charges as a meaningful signal to other group members due to influence structures, and may further struggle to optimise time of travel due to delivery time constraints set by group members.

Holguín-Veras et al. (2007b) note that the propensity to include passing charges to customers is likely due to the balance of power between shippers and carriers. The role of shippers in setting constraints to behavioural adjustments to policy measures was highlighted further by Holguín-Veras et al. (2007b), in that over two-thirds of carriers in the study that did not change their behaviour under the charges were simply unable to due to delivery time restrictions set by customers.

The willingness of receivers to accept off-peak deliveries is imperative for a successful attempt to shift goods movement out of peak travel times. To encourage receivers to accept deliveries off-peak, financial incentives (e.g., tax breaks) need to be sufficient to overcome the operational expenses of extending or shifting delivery windows. The subset of stakeholders that are most likely to take on off-peak deliveries are those with relatively low marginal costs of accepting deliveries outside of peak times; Holguín-Veras et al. (2007b) suggest areas with large densities of freight activity are the most promising in this regard. Specifically, both facilities that receive large volumes of deliveries (e.g., shopping centres, government offices), which could handle centralised deliveries for
multiple recipients, and neighbourhoods that receive a large proportion of freight destined for a broader geographic area are likely to have relatively low marginal costs of shifting some deliveries off-peak. Scale economies would drive this opportunity, due both to carriers’ potential to consolidate off-peak deliveries and receivers’ potential to share the marginal costs of accepting off-peak deliveries.

Holguín-Veras et al. (2007b) also identify promising areas for future research building from their framework. Most generally, they argue that it is important to gain a deeper understanding of the decision making processes under potential freight-related policies; an approach similar to that taken by Holguín-Veras et al. (2007b) applied to a range of relevant candidate freight-related policies would certainly qualify. They also note that it is important to consider the role of the spatial distribution of receivers, which could be a powerful extension relating back to the models incorporating land-use and physical distribution in the preceding sections. Lastly, they argue that there is a need to develop discrete choice models that consider interactions amongst decision makers; there has been progress in that area, including within the area of freight travel, which will be discussed in the following sections.

Silas and Holguín-Veras (2009) confirm the findings of Holguín-Veras et al. (2007a,b) through behavioural microsimulation techniques. This is an interesting hybrid between the microsimulation techniques used within broad network equilibrium models discussed above and revealed- and stated preference techniques used in other empirical studies. In a follow-up study, a tax deduction provided to receivers of goods for accepting off-peak deliveries and time-of-day tolls with higher toll levels during peak periods were tested through simulation models based upon the preferences elicited in the study by Holguín-Veras et al.

Silas and Holguín-Veras created a synthetic population of carriers and receivers to test the potential impacts of these policies. The simulation technique begins with the random selection of an industry segment (e.g., wood and lumber); a carrier is then selected randomly from within the segment’s population. The selected carrier is assigned a number of stops, at which point a corresponding number of receivers is selected. This defines the set of receivers towards which the target policy is tested within the simulation. The carrier’s behaviour is simulated to be a function of the decisions made by the receivers, based upon estimated delivery cost differentials across peak and off-peak periods.

Within the microsimulation, the utility receivers derive from peak and off-peak delivery alternatives is estimated to yield a probability of enacting a given distribution strategy. A random probability is then generated, and if this value is exceeded by the estimated probability of choosing an off-peak delivery strategy, the simulation designates that delivery as occurring in off-peak hours. This is repeated throughout the sampled set of receivers and applied across different magnitudes of policies (e.g., for different levels of tax incentives).
The carriers’ behaviour is simulated to be a function of their own delivery costs conditioned upon the simulated strategies of receivers, which act as a binding constraint on the set of time-of-travel alternatives. The location of receivers forms a further constraint on the trip-chaining alternatives available to carriers within the simulation. Carriers are assumed to agree to shift to off-peak deliveries if the corresponding delivery costs are lower than the case when all receivers accept peak-hour deliveries only.

The simulation revealed some interesting implications, including the scope of impact one may expect to observe under tax incentives for receivers. A $10,000 tax break to receivers in exchange for accepting off-peak deliveries was simulated to lead to a 15 to 20 percent shift in deliveries outside of the peak. Tolls were not simulated to have much impact on when goods are carried, however. This confirms the behavioural relationships identified by Holguín-Veras et al., in that power structures in freight transport transactions do not tend to allow carriers to influence when goods are delivered when faced with time-of-day-related tolls.

One freight policy that could reduce the negative impacts of road freight on other road users is the establishment of shared-use freight terminals in metropolitan areas. Regan and Golob (2005) conducted a survey of freight stakeholders in California to gauge factors influencing the demand for such terminals, in an effort to increase our understanding of the role that the public sector should play (if any) in the development these terminals. The economic benefits of the terminals could include: enabling carriers to shift travel to off-peak hours; offering a means of transferring portions of consignments more efficiently across vehicles for travel within urban centres without the need for purchasing or managing urban warehouse facilities; enabling less-than-truckload carriers to consolidate consignments and hence increase load factors; improving the level-of-service experienced by drivers with respect to amenities such as opportunities for resting; and featuring useful information technology to allow operators to communicate effectively with their organisations and to receive information on the state of the traffic network.

Whilst previous research has identified some of these benefits, Regan and Golob made the important contribution of focussing on the preferences of carriers with respect to the use of shared-use freight terminals. That is, although it has been established that these terminals could serve a useful function, there was little behavioural information relating to the potential users of the terminals to guide any planning or investment processes. Regan and Golob make the important distinction that, contrary to initial research on shared-use freight facilities, these terminals would be likely to serve as de-consolidation centres (i.e., shifting cargo from larger vehicles to smaller vehicles) rather than consolidation centres. This is due to evolutions in logistics practices such as just-in-time strategies that focus on responsiveness as opposed to returns to scale from consolidation.

The survey used by Regan and Golob specifically prompted managers of carriers whether their organisations would have any use for freight facilities near urban centres that provided space for consolidation and de-consolidation activities and internet access. This is a critical question, and one that could be built upon in further research. For example,
stated choice experiments could be used to identify preferences for particular features or configurations of shared-use urban freight terminals; this information could guide decisions on both whether to invest in the development of such terminals, and what specific amenities to offer at a particular site. Indeed, Regan and Golob cite a need to pursue this information, including identifying willingness-to-pay measures for these facilities. Information on willingness-to-pay – especially under various charging mechanisms – could then be used to guide the process of setting charges in areas where public good concerns (e.g., air pollution abatement) are not significant enough to justify investment; stated preference techniques are particularly well-suited to this goal. Regan and Golob also suggest the use of simulation techniques to improve our understanding of the benefits that would be offered by these facilities.

Importantly, Regan and Golob found that many firms that would stand to benefit relatively highly from such facilities (i.e., organisations other than private carriers, who may be more likely to specialise in point-to-point full truckload operations) demonstrated some measure of demand for the facilities. Regan and Golob used an ordered probit model in their search for determinants of demand for shared-use urban freight terminals, and found that demand was relatively high amongst long-distance carriers, carriers acting as part of an intermodal service (i.e., connecting to rail terminals), and carriers that are early adopters on information technology and advanced distribution techniques such as third-party logistics services.

Moving to a more normative approach, Browne et al. (2007) offer an excellent comparison of freight policies in London and Paris that involve several policy measures that should be of high research importance. The policies in Browne et al. include changing loading and unloading access, setting incentives for the use of cleaner trucks, and encouraging shifts to alternative modes. These policies are aimed at, amongst other things, the goals of improving freight transport efficiency (a vital goal for economic growth under increasing transport demand and constraints) and mitigating environmental impacts of freight (also vital in meeting emissions targets).

Specific policies of particular interest include the Low Emissions Zone in London, the use of urban consolidation centres, efforts to change vehicle access times, and driver and customer training aimed at improving efficiency at loading and unloading points. The comparison of the battery of policies chosen in each city highlights common approaches (at least in Western Europe) with respect to influencing freight travel behaviour and efficiency; most notably, governments in London and Paris appear to acknowledge the need for a multi-faceted approach to encourage changes in behaviour that can benefit society whilst yielding some positive economic benefits to compensate the adoption of new technologies and freight distribution strategies.

Anderson et al. (2005) offer a thorough empirical framework for analysing potential impacts of sustainability-driven policies on freight transport providers in the United Kingdom. The study merged information from travel surveys and in-depth interviews first to develop a picture of urban freight distribution in three urban areas, and then to examine how operations, costs and environmental outcomes may be influenced through
policy measures including road pricing, vehicle emissions zones, vehicle weight restrictions and access restrictions. Anderson *et al.* established a relational database to specify causal linkages in freight distribution activity for sampled firms, leading to the ability to test the effects of changes in policy on freight vehicle travel characteristics (e.g., shifts in time of day of travel, shifts in vehicle kilometres travelled by vehicle type, operating cost, pollutant emissions) based upon information gained from in-depth interviews.

Low emissions zones were shown to have a potentially small impact on the structure of freight travel activities, but could have a large impact on pollutant output. Compliance costs (i.e., acquiring lower-emissions vehicles) were shown to be a potential obstacle for some firms, however. Larger firms with national operations have additional flexibility by being able to shift higher-emissions vehicles to areas without LEZs, offering these firms a competitive advantage. Congestion charging was shown to offer a potential benefit in improved travel time sufficient to offset daily charges for some firms up to a point; hence, to gain support amongst freight transport providers, such charges may need to offer a reasonable time savings relative to the charge. Vehicle weight restrictions may have a broad range of impacts, as reflected by the heterogeneity in the sample; some sampled firms have a relatively large proportion of larger vehicles in their fleets, leading to considerable shifts in travel patterns, high compliance costs and increases in pollutant emissions depending upon the coping strategies that such firms would adopt (e.g., sending two smaller trucks to carry a load that one truck would carry otherwise). Lastly, changing time restrictions could have a broad range of effects depending upon the change specified; compressing delivery windows would lead to increased congestion-related costs and emissions, whilst expanding delivery windows would offer both benefits in terms of travel efficiency and extra labour costs.

Rich *et al.* (2009) take an important practical approach to modelling values of time across alternative modes and commodity types. Whilst the approach is not directly behavioural in nature, the method allows the analyst to uncover behavioural information from aggregate-level commodity flow data. Rich *et al.* analyse commodity flow data by creating representative agents within a weighted logit framework that allows one to disentangle decision makers from the commodities being carried. That is, there is no consensus on the appropriate unit of analysis relating to shipments, and can vary by mode, commodity and area (de Jong and Ben-Akiva, 2007).

Decoupling decision makers from commodities allows one to estimate values of time by weight and commodity group. The modelling approach centres on an assumption that heterogeneity, although important, can be controlled for at the commodity level, due to market segmentation effects influencing who carries what. Conversely, spatial heterogeneity is assumed to be a highly important conditioning factor, in part due to the presence or absence of modal alternatives.

The weighted logit model estimated by Rich *et al.* produces elasticities with respect to travel cost and travel time across modes and commodity groups (weighted by tonnes carried), along with value-of-time estimates (euros per tonne per hour) across commodity
groups. The estimates demonstrate significant heterogeneity in each of these dimensions; this heterogeneity may have been obscured through standard stated or revealed preference studies due to conflation of modal and shipment size effects (i.e., different modes tend to involve significantly different shipment sizes). Furthermore, modelling directly with respect to origin-destination matrices enables the analyst to include accurate behavioural information with respect to spatial effects that may be absent from a stated or revealed preference study.

This discussion of key recent empirical work concludes by highlighting three studies that focus on empirical and econometric techniques to account for what matters to freight travel decision makers when estimating policy outputs such as willingness-to-pay measures. Fowkes et al. (2004) applied an adaptive stated preference experiment to shippers, carriers and third party logistics operators to gauge sensitivities to different temporal dimensions of the level-of-service of the road network: the value of delay time, the value of arrival time spread, and the value of schedule delay. This is an important contribution, in that it not only recognises heterogeneity in preferences across classes of freight travel decision makers, but it also recognises that reliability is a multidimensional construct that can have different implications for different types of stakeholders. The value of delay time measures the willingness-to-pay to avoid additional travel time on the network, the value of arrival time spread measures the willingness-to-pay to mitigate uncertainty in the time of arrival at a destination, and the value of schedule delay measures the willingness-to-pay to avoid delays in undertaking a trip.

Fowkes et al. show that, on average, travel time savings are the most valuable to stakeholders on a minute-by-minute basis, with a mean value of over one pound per minute, compared to mean values of around 85 and 66 pence per minute saved relating to arrival time spread and schedule delay, respectively. Significant heterogeneity in preferences was found across transport role (i.e., own account versus third-party logistics carrier versus third-party logistics client), just-in-time or quick-response strategy status, trip distance, goods type, intermodal options, the ability to transport goods at night, and location of operations; however, for almost all subsets of freight transport scenarios in the study, the general relationship across willingness-to-pay measures held. Still, the value of arrival time spread was found to be importantly linked to trip length; shorter trips appear to be much more sensitive to arrival time uncertainty, due in part to an increased likelihood of needing to use extra vehicles to provide a given level-of-service.

Fowkes (2007) followed the 2004 study by applying an adaptive stated preference experiment to confirm that thresholds matter for shippers with respect to different components of freight travel times, including the overall duration of tours, variation in travel times, and lateness of arrival. The paramount finding is that threshold effects made small improvements in travel times and reliability of negligible value to some carriers; however, shippers of some commodities are notably sensitive to small changes in travel times and reliability. This is an important finding, by confirming that improvements in travel quality offered by infrastructure investments will be overvalued using standard techniques unless the improvements are large enough to truly matter to decision makers.
This is confirmed by Danielis and Marcucci (2007), who highlight the importance of challenging a view that variations in attribute levels in alternatives impact decisions linearly. They adapt Swait’s (2001) framework to examine the importance of threshold effects in attribute levels comprising freight shipment alternatives. Their findings are important and intuitive: whilst (generally small) changes in some attribute levels have a negligible effect on choice probabilities, shippers demonstrate break points for some attributes beyond which alternatives become either wholly unacceptable or unacceptable in the absence of considerable compensation through other attributes. By accommodating this behaviour within econometric models, estimated sensitivities are significantly different to those found under a standard linear model.

2.3 Negotiations over Freight Travel Characteristics

Interactions between freight travel decision makers involving non-coincident preferences require some negotiation mechanism to resolve these differences in preferences. That is, if two or more decision makers do not share a preference for a particular strategy for moving freight, it is necessary for these decision makers to negotiate some outcome (which could include impasse). This may be a straightforward concept in itself. However, there may be much to learn about both the general nature of negotiations over freight travel characteristics and the likely outcomes within these negotiations across decision making settings. This is especially important when considering potential policy changes and future states of the world, due to the lack of real-market experience with negotiations involving such cases.

Going back as far as Rinehart (1989), we can see a need for greater insight to freight-travel-related negotiations. Rinehart argues specifically that it is important to understand the elements of the negotiation process and their application by shippers and carriers. To that end, applied research must examine negotiation behaviour within sampled groups. Rinehart approaches this area from the perspective that this information would be critical for negotiators; furthermore, it is critical for transport researchers and policy makers to gain insight into potential interdependent transport choices and their underlying processes, as well, a notion supported by Ramsay (2004), who states we need to improve our understanding of the negotiation process in freight itself.

Recent freight-related methodological research by Ramsay (2004) and Krause et al. (2006) identifies concepts that are of considerable empirical relevance for freight travel behaviour research. Ramsay focuses on the disconnection between the inter-company interaction literature (see Ramsay for a thorough review), which considers collaborative outcomes within which multiple parties can generate increased net benefits, and the general negotiation literature, which tends to centre on a competitive, zero-sum perspective. To push a familiar analogy, whilst the general negotiation literature tends to look into ways in which organisations may compete to maximise their share of the pie, the inter-organisational literature may acknowledge the validity of concepts such as cooperative bargaining in a discussion of how firms can work together (at least for some portion of the negotiation process) to increase the overall size of the pie. Ramsay places a
particular focus on the importance of examining the extent to which customers are resistant to cooperative negotiations with suppliers.

Whether the non-cooperative model is a representative view of negotiations over freight travel characteristics is an empirical issue, and not one that should simply be assumed. It could be most productive to look into this issue and why particular degrees of (non-)cooperation may be observed in freight travel negotiations. Ramsay cites risks of information exchange as one motivation firms may have to avoid acting collaboratively within negotiations. Productive interactions (i.e., negotiations that may lead to some resolution) tend to involve the disclosure of some information, either explicit or implicit, along multiple dimensions, including: (1) preferences regarding the specification of a transaction; (2) details of one’s organisation; and (3) details relating to external market forces. Interactions leading toward beneficial cooperative outcomes may require the disclosure of information along each of these dimensions. If firms choose to maintain a non-cooperative approach, they retain the option to keep information obscured, strategically-timed or distorted.

This leads to a consideration of a hybrid model, which makes strong behavioural sense: the cooperative-competitive approach. Ramsay considers this approach, which involves two distinct stages. In the first stage, interdependent agents cooperate to identify non-zero-sum gains that could be made through some course of action. In the second stage, the parties attempt to secure a target share of the gains. There is a danger to those sharing information in the collaborative stage, as this information can be exploited in the competitive stage. Specifically, the disclosure of information in the collaborative stage can lead to losses of control, power, tactical flexibility and image. These are all justifiable concerns for firms in competitive markets.

Ramsay also cites a characteristic of negotiations that is of direct relevance to empirical studies involving stated preference methods: log-rolling. Log-rolling is a common competitive negotiation tactic, which involves trading off concessions over bundles of issues. Specifically, agents may offer concession over attributes of an offer that are of relatively lower importance to the outcome. Ramsay notes that this is not a deceitful practice; indeed, it is intuitive to begin one’s concession with attributes of lower (dis)utility. However, a successful compromise may require hidden preferences to ensure a satisfactory level of concession from another party. By making the preferences of one’s organisation apparent in the collaborative stage, one may give another agent sufficient information to manipulate counter-offers in the competitive stage such that the agent is able to secure a larger portion of the gains under negotiation than in the absence of this information.

This is relevant empirically, in that stated choice experiments involve trade-offs across alternatives that consist of fixed attribute bundles. Hence, whilst it may be empirically attractive and advantageous to consider alternative means of specifying negotiation-centred empirical instruments (see Section 3.3 for further details), there is a behavioural justification for employing variants of stated preference experiments in studies of freight-related negotiation settings. Such experiments could be used to test many concepts,
including attitudes regarding information exchange in reaching compromises in collaborative or joint collaborative-competitive negotiations.

Krause et al. (2006) focus on two economic concepts relating to negotiations in supply chain relationships that are similarly important for empirical applications: reservation prices and aspiration prices. A reservation price, or more generally, reservation utility is the minimum acceptable price or utility level sufficient for a decision maker to agree to a resolution. The reservation utility levels for each interdependent agent within a negotiation lead to a bargaining space over which a resolution could be expected to be observed; that is, each agent’s reservation utility serves as an endpoint defining the range of outcomes that could form a satisfactory outcome for the group. Another factor influencing the bargaining space and potential equilibria within it is the aspiration price or utility, which is the best outcome a decision maker could expect to realise within a negotiation.

Kristensen and Garling’s (1997a) interpretation of aspiration utilities as an agent’s expectation of another party’s reservation utility is supported by Krause et al. This is indeed a hypothesis in consistent preferences and expectations approaching the other party’s reservation price: Why would one expect to obtain an outcome that the other party wouldn’t find acceptable (i.e., when the aspiration price is worse for the other party than that party’s reservation price), and why would one not expect to obtain an outcome that the other party would find acceptable (i.e., when the aspiration price is equal to the reservation price)? The expectations forming the aspiration price may be influenced by information revealed during the negotiation, however, most notably the opening offer (Kristensen and Garling, 1997b).

Taken together, these concepts form a useful basis for empirical analyses of group decision making relating to freight travel. Just as Krause et al. examine stated reservation prices versus aspiration prices in negotiation settings, further empirical analyses of freight-related negotiations could yield valuable information about both freight decision makers’ preferences and influence within relevant interactive settings for current and future market scenarios. This information could be obtained by analysing group equilibria (and cases of non-agreement) as functions of initial offers and counter-offers within stated preference and alternative frameworks (see sections 3.2 and 3.3 for further discussion).

The importance of initial and feedback effects between reservation and aspiration utilities in such analysis is clarified by Krause et al. The bargaining space can be expected to yield Nash equilibria within the convergence of each party’s aspiration zone, which is the space between one’s reservation utility and aspiration utility (White and Neale, 1994). Interestingly, White and Neale point out that the size of this zone – and hence the size of the Nash-equilibrium-producing bargaining space – may influence the level of aggression and concession displayed by negotiators throughout the negotiation; this is an interesting and testable hypothesis for freight decision-making groups. Krause et al. (2006) consider the further impacts that the size of the aspiration zone may then have on the probability of reaching any resolution at all; that is, the size of each party’s aspiration zone influences negotiation behaviour and hence influences the probability that some resolution is
reached. This confirms the merit of searching for determinants of group choice equilibrium in freight negotiation settings, including a focus on initial offers and counter-offers.

Krause et al. note that an important behavioural distinction between reservation and aspiration utility levels is that reservation levels would tend to be private (indeed, highly guarded) information, whilst aspiration levels may be made quite explicit, for example through opening offers. This could be obscured through deception, however (e.g., making an opening offer that is greater than the aspiration level in an attempt to improve the final outcome above what would be found under a less ambitious opening offer, making a false statement relating to a minimum acceptable outcome). Ultimately, reservation and aspiration utility levels may serve as reference points that represent the goals and expectations of relative power held by each party. As negotiations are carried out, new information is revealed that may impact these reference points. Freight researchers have the opportunity to identify the role of these reference points and how they impact group decision-making outcomes in freight negotiation settings, which could be highly significant when seeded within an analysis of potential new policies and constraints.

3 EMPIRICAL TOOLS FOR THE NEXT GENERATION OF FREIGHT TRAVEL BEHAVIOUR APPLICATIONS

In this section, the discussion turns to a focus on tools that may offer opportunities for further development of our ability to represent current and potential freight travel decision making settings and their underlying behaviour. Although a clear bias in the preference for these tools must be acknowledged here (i.e., the author is developing these tools with colleagues), the tools represent the directions that freight travel behaviour research is currently taking and can continue to expand toward as the opportunities and needs relating to this research evolve. That is, the empirical approaches discussed in this section support the aims and frameworks presented in the previous section through an expanded capability to capture critical information relating to the preferences of freight travel stakeholders.

Four empirical developments will be discussed here. The first is an econometric and experimental technique for capturing richer information on what matters to stakeholders, by eliciting information about the strategies used by respondents to process the information presented to them in stated choice experiments. Continuing in the area of stated choice experiments, this section addresses two alternative methodologies outside of standard, independent survey techniques: stated choice experiments for interdependent decision makers, and experiments that allow for respondents to alter attribute levels within their control to create new alternatives or counter-offers. The section then concludes with a discussion of potential experimental approaches outside of a stated choice framework.
### 3.1 Attribute Processing Strategies

As discussed in the previous section, work by Fowkes (2007), Fowkes et al. (2004) and Danielis and Marcucci (2007) represents important research into identifying what truly matters to freight travel stakeholders. Whilst the research of Fowkes and colleagues centres on identifying how preferences relating to time vary across temporal dimensions and Danielis and Marcucci consider cutoffs in attribute levels that establish relevance in decision-making settings, a further avenue to pursue relates to how respondents in stated choice experiments process the information presented to them.

Puckett and Hensher (2008, 2009) explore this by conditioning models of interdependent carrier and shipper freight travel behaviour on respondents’ stated attribute processing strategies (APSs). Within an interdependent stated preference survey, Puckett and Hensher prompted respondents to indicate whether they ignored or aggregated each attribute for each alternative on offer in the choice sets they faced; whilst any attributes could be ignored, only those with a common metric (i.e., time, trip-related costs) could be designated as combined into an aggregate measure. The stated APS information was used to calibrate collected choice data through a series of data transformations. Firstly, the marginal utilities of ignored attributes were specified as zero within the alternative where they were ignored. Secondly, the marginal utilities of individual attributes that formed part of an aggregate within an alternative were also set equal to zero. Thirdly, aggregate explanatory variables were introduced for cases where aggregation took place; where these aggregates were not made, the marginal utility for the aggregate was set equal to zero.

This series of transformations yields the capability of estimating choice models that account directly for the stated APS behaviour of respondents. That is, if respondents indicated that a particular attribute for a particular alternative did not play a role in their choice, this approach allows the resulting choice model to acknowledge that behaviour by assigning a marginal utility of zero to that attribute for that alternative. Likewise, if respondents indicated that it was only the aggregate level of attributes along a particular dimension that mattered to them for a particular alternative, the resulting choice model is able to acknowledge that behaviour by estimating the marginal utility for that particular aggregate (i.e., the marginal utilities across components of the aggregate are equivalent).

This technique avoids the misspecification bias that would ensue by treating all attributes in all alternatives as though they mattered to respondents despite their indications otherwise. Specifically, the approach enables choice models both to estimate marginal utilities based upon the subset of alternatives in which attributes make a given non-zero impact on the choices made, and to represent the subset of cases where each attribute along a given dimension had an equivalent impact on the choices made. Indeed, in the study by Puckett and Hensher, attributes were ignored at important rates (ranging from six to twelve percent of the time for carriers, depending upon the attribute) and aggregated at surprising rates (well over half of the time for both time and cost measures).
The main motivation behind this technique is that any stated choice design may provide information that is either behaviourally irrelevant or cognitively burdensome for some respondents. The standard assumption of passive bounded rationality – that all attributes are considered fully and uniformly across decision makers and choice tasks – may not accurately represent the manner in which respondents actually process the information presented to them. This is particularly applicable to freight travel behaviour studies, in that one may expect to observe both significant heterogeneity in decision-making roles, influence and preferences for decision makers both within and across industry and commodity segments; this heterogeneity may lead to a greater propensity for a given choice setting to include some information that is either ignored or aggregated (or indeed dealt with some other alternative way) than in independent passenger travel settings. The relevance of this approach is supported by DeShazo and Ferro (2004), who propose the need to accommodate APS behaviour if one is to mitigate the misspecification bias that would arise under an assumption of passive bounded rationality.

The econometric analysis in Puckett and Hensher (2008, 2009) reveals important distinctions between the implications resulting from models with and without APS information. Weighting total travel times across free-flow and slowed-down conditions, the analysis showed that a model with an assumption of passive bounded rationality yielded a mean estimate of the value of travel time savings of almost fifteen percent greater than that within a model accounting for respondents’ stated APS behaviour. Furthermore, within an APS-conditioned model, the APSs of respondents revealed considerable segmentation effects with respect to sensitivities to travel time. Those who aggregated time measures demonstrated a significantly lower sensitivity to travel time than those who differentiated between free-flow and slowed-down time; this effect is particularly clear within slowed-down time, where those who attended to slowed-down time demonstrated much higher sensitivities to congested conditions than the non-APS mean value.

A relevant policy-related example of these segmentation effects is revealing. If a policy were able to reduce slowed-down travel time for a given trip by 30 minutes, the standard (non-APS) model estimates a mean value of A$41.89 for this time savings. However, when taking respondents’ APSs into account, a savings of 30 minutes of slowed-down time is valued at A$9.68, A$18.83, A$42.27 and A$89.21 for those who aggregated both times and costs, times only, costs only, and neither times nor costs, respectively. There may be many ways to interpret this result, but combined with the larger mean estimates of travel time savings in general resulting from the standard model, the evidence may suggest that the benefit to carriers of the road pricing mechanism analysed in the study may have been overstated in the standard model. Some very large potential benefits to a small proportion of the sample appear to have been averaged out across the sample in the non-APS model. This implies that the choice whether to account for APS behaviour in a study could directly impact the policy implications resulting from the study, as the theory suggests.
Importantly, the impacts of accounting for APS behaviour within the study were bi-directional. Whilst the non-APS model yielded higher mean estimates of the value of travel time savings relative to the APS model, the non-APS model yielded lower mean estimates of the value of reliability gains (i.e., the value of a percentage point increase in the probability of a truck reaching its destination on-time). For all APS segments within the sample, improvements in reliability were valued more highly than in the non-APS model, on average. In this case, a separate effect relating to the capability of the model to isolate instances where and how attributes were attended to may be driving the differences in valuation.

Ultimately, the results from the APS model capture a range of choice-related processes. Different APS segments of the sample demonstrated divergent preferences when faced with time-cost trade-offs. This is intuitive, in that those who attend to specific element of a trade-off may have a different sensitivity to those who either do not differentiate between that element and its metric relative or ignore the element altogether.

Interestingly, APS behaviour was found to have systematic links with contextual effects such as professional experience, spatial and temporal constraints on deliveries, and decision-making structures (i.e., which decision makers had influence on how and when a truck travels), whereas those contextual effects themselves did not reveal the same extent of preference heterogeneity. An important implication of this is that APS behaviour may be a powerful means of segmenting samples relative to using socio-economic characteristics. Whilst the state of practice involves explaining heterogeneity in preferences via contextual effects, the observed APS behaviour of respondents may offer a stronger proxy for otherwise unobserved sources of preference heterogeneity. Hence, APS behaviour represents rich information with respect to the underlying preferences of respondents that may offer a bridge between the contextual effects correlated with preferences and the decision-making behaviour of respondents that is driven by these preferences.

This evidence supports the use and development of techniques to capture information on the way that respondents process the information presented to them in experimental settings, along with expanded econometric methods for incorporating this information. Important steps to take in the development of this approach include identifying efficient mechanisms for prompting respondents for APS information, establishing effective APS information to seek, and expanding econometric techniques to accommodate this information more effectively. The potential complexity and heterogeneity present in freight travel decision-making settings makes this a particularly relevant tool for improving our knowledge relating to the preferences of freight travel stakeholders, who may not be likely to attend to all information presented to them uniformly in such settings.
3.2 Choice Experiments for Interdependent Decision Makers

Stated choice experiments have considerable merit in analyses of travel behaviour, especially in applications to non-market valuation and changes to opportunity sets (i.e., changes in infrastructure or policies). However, standard stated choice experiments abstract from any elements of influence across interdependent decision makers. Such influence may be of critical importance in freight travel behaviour, where shippers, carriers and receivers may interact over a range of factors relating to the movement of goods. An appealing stated choice method to estimate influence measures is the use of interactive agency choice experiments (IACEs), developed by Hensher (Brewer and Hensher, 2000). IACEs involve an iterative technique by which interdependent respondents have the opportunity to amend their stated preferences within choice menus based on the preferences of other members of their sampled group. The observed process of preference revision enables the analyst to quantify the effects of interactivity whilst maintaining the desirable empirical properties of discrete choice data obtained through stated choice experiments.

Unfortunately, it may be infeasible, especially within freight travel behaviour studies, to conduct an IACE with a satisfactory sample size due to the high level of resources required, including difficulties in matching agents for the simultaneous participation of sampled groups. Not only is it difficult to secure the participation of pairs of real-market or representative freight stakeholders within an experiment that requires feedback between the respondents, but it can also be difficult to identify the appropriate stakeholders in a timely manner in the first place. The administrative obstacles of IACEs within a freight transport context are not limited to the feasibility of sourcing appropriate respondents, however. IACEs require more time and effort in evaluating each choice set than standard choice experiments, due to the process of observing the choices of sampled group members, choosing whether to amend one’s preferences, and repeating this process until either consensus or impasse is reached. This restricts the analyst’s ability to capture final choice observations relative to standard choice experiments, necessitating a large sample size relative to such experiments, which can be financially, temporally or practically prohibitive.

Given the potential difficulty in establishing a sufficiently large sample of decision-making groups for a fully-specified IACE, and recognising that one is typically limited to a few choice set treatments within IACEs, representing the nature of interaction without having to interact agent pairs in data collection is an appealing empirical approach to parameterising a group-choice model system. The inferred influence and integrative power (IIIP) model, and its initial application, the minimum information group inference (MIGI) method, were established to accomplish this goal by offering a means of inferring group-choice outcomes within an administratively less burdensome empirical application (for researchers and respondents) relative to IACEs (Hensher et al., 2007; Hensher and Puckett, 2008). IIIP experiments are capable of securing a larger sample of respondents acting independently within a group-choice setting that can be coordinated ex post, each of whom can be given more choice sets to evaluate in the experiment relative to IACEs.
Similar to an IACE, IIIP experiments are framed in terms of an interactive setting, within which respondents are asked to indicate their preferences amongst the given alternatives. Specifically, IIIP experiments prompt respondents to indicate how they would rank the alternatives if they had to attempt to reach agreement with the other member(s) of a sampled group. Importantly, the ranking process includes the option of denoting an alternative as unacceptable, to avoid inferring agreement outcomes that would not likely be observed under direct interaction. Although we do not contend that IIIP is preferable to the direct observation of interactions amongst interdependent decision makers, we suggest that IIIP represents a means of gaining meaningful inference with respect to group decision-making when other interactive methods are infeasible.

Whatever approach one adopts, the preferences of the agents of interest in choice studies are those associated with the final choice outcome of either choice agreement or impasse. Choice agreement provides the most relevant preference information pertaining to markets, in that new joint strategies can only be implemented under adequate agreement. Non-agreement outcomes do provide useful information in two ways, however. In cases where impasse would lead to maintaining the status quo, it is reasonable to infer that the effective group choice would be the status quo; in cases where some new group strategy must be chosen (i.e., the status quo is not a feasible outcome), non-agreement outcomes can be analysed to infer causes of non-agreement.

The empirical process for IIIP centres on a sequential procedure in which the experiment is first offered to a class of decision maker that is able to provide the relevant contextual information to seed the resulting choice menus. Within a freight application involving carriers and shippers, the appropriate class of decision makers to begin the process with was carriers, who were able to provide details of revealed-preference freight trips that formed the basis for the choice menus viewed by carriers and shippers. The identical choice sets faced by members of a sample group in this first stage of the process are then administered to other members of the sampled group. The choices made for each identical choice set are then coordinated across group members within the analytical stage to project group choice outcomes.
The interactive inference approach does not capture the real-market interactive agency structure directly within the stated choice experiment. Rather, the choice experiment uses the ranked independent preferences of each agent in a group, in concert with the stated willingness of each group member to accept each alternative as a group outcome. This information is used to estimate group preferences and power structures in two stages. Firstly, group choice outcomes are inferred using a choice coordination algorithm; the purpose of the choice algorithm is to replicate, as parsimoniously as possible, the process of preference revision that occurs within an IACE in the absence of directly-observed interaction between respondents. Secondly, individual preference parameters are carried forward into a group choice model, in which estimates of relative power over each attribute on offer are estimated to explain the factors leading toward group choice equilibrium.

The motivation for this methodology is that the empirical insight that really matters may only be each agent’s reaction to the perceived action of other agents in a real-market or representative group. If true, respondents could participate at a time of their own choosing, independent of others in the sampled group, making data collection more effective. Similar results may then be achieved through having agents in a sampled group responding in a simulated setting to those when the group interacts directly. If the experiment is designed effectively, each of the respondents in a particular choice setting could state their preferences whilst yielding sufficient information about the influences of other agents in the group.
The group choice coordination algorithm is an element within IIIP that can be improved upon to increase the inferential power of the analysis. In MIGI analysis, the group choice coordination algorithm is the least restrictive. Within models of concession by a focal agent type, the algorithm projects the group choice outcome as the first preference of the other agent type (in the case of two-agent groups; this could be reversed in larger groups to focus on concession toward a focal agent without changing the behavioural implications) if the focal agent stated a willingness to accept the alternative as a group choice outcome, otherwise the group choice is specified as either the status quo (if plausible) or as an alternative non-agreement outcome. By comparing the implications of group choice outcomes across models of concession for each agent type, we are able to estimate a bargaining space consistent with the approach taken by Krause et al. (2006).

Consider a case where two agents \(q\) and \(q'\) in a group face three alternatives, \(A\), \(B\), and \(C\). If both agents find \(A\) and \(B\) acceptable as a group choice outcome, but not \(C\), it is reasonable to restrict the bargaining space for the agents to those two alternatives. And hence, if the agents’ first preferences do not coincide (i.e., one prefers \(A\) and one prefers \(B\)), it appears both wasteful to ignore the opportunity to restrict the bargaining space in this way, and incorrect to assume that no choice agreement would be made (as under an analysis of first preferences alone). In MIGI analysis, \(A\) is projected as the group choice outcome when analysing concession by agents of the class to which \(q'\) belongs, whilst \(B\) is projected as the group choice outcome when analysing concession by agents of the class to which \(q\) belongs. Estimating and comparing the results from the two resulting concession models yields inference on the broadest stated range of influence-driven outcomes that respondents indicate could occur within a direct interaction, which is a direct representation of the bargaining space (constrained to the set of alternatives on offer).

This simple choice coordination algorithm and corresponding series of concession models were chosen as a parsimonious approach to accommodating the uncertainty in group choice outcomes when the first preferences of agents in a sampled group do not coincide. However, a more restrictive approach could certainly prove useful. For example, the preference rankings of respondents could be interacted with one another through simulation techniques that incorporate respondents’ independent preferences. This could be especially productive in cases where respondents are not willing to concede toward the first preference of another group member, but are willing to concede toward an alternative that is less preferred by the other member; in such cases, looking at concession toward first preferences alone would obscure some available information on concession and hence influence within sampled groups. Another useful development could include expanding the specification of preference rankings to represent relative support for compromises under different negotiation scenarios. One such approach could include the respondent indicating one’s first preference, and also indicating under what circumstances any of the other alternatives are acceptable (e.g., the second-most preferable alternative is acceptable regardless, the third-most preferable alternative is only acceptable if the decision maker(s) are compromising, as well).
The econometric modelling structure for the concession models centres on the projected group choice based upon the focal decision-maker type’s willingness to concede toward the preferences of the other agent(s) in the sampled group. In the two-agent case, a choice amongst three alternatives (1, 2 and 3) would be used to calibrate the following choice model:

\[
U_{11} = \alpha_{11} + (\tau_{qk} * \beta_{qk})' * x_{1k} + (((1 - \tau_{qk}) * \beta_{q'k})' * x_{1k} + \varepsilon_{11} \\
U_{22} = \alpha_{22} + (\tau_{qk} * \beta_{qk})' * x_{2k} + (((1 - \tau_{qk}) * \beta_{q'k})' * x_{2k} + \varepsilon_{22} \\
U_{33} = \alpha_{33} + (\tau_{qk} * \beta_{qk})' * x_{3k} + (((1 - \tau_{qk}) * \beta_{q'k})' * x_{3k} + \varepsilon_{33}
\]

where \( U_{jm} \) is the estimated utility the group \( g \) derives from the joint choice of alternative \( j \) by agent \( q \) and alternative \( m \) by agent \( q' \) in simulated group interaction \( gp \). \( \alpha \) represents an alternative-specific utility component for the joint choice alternative, \( \tau_{qk} * \beta_{qk} \) represents a vector of the product of relative influence measures for a focal agent type and the independent marginal utility derived by \( q \) for attribute \( k \) in \( j \), \( x_{jk} \) represents the vector of levels of each \( k \) present in \( j \), \( ((1 - \tau_{qk}) * \beta_{q'k})' \) represents a vector of the product of relative influence measures for the other agent \( (1 - \tau_{qk}) \) and the independent marginal utility derived by \( q' \) for \( k \) in \( m \), \( x_{mk} \) represents the vector of levels of each \( k \) present in \( m \), and \( \varepsilon_{jm} \) represents the unobserved effects for the joint choice alternative.

As the power measures for agents \( q \) (\( \tau_{qk} \)) and \( q' \) (\( 1 - \tau_{qk} \)) sum to unity for each attribute \( k \), comparisons of influence across agent types are straightforward. If the two power measures are equal for a given attribute \( k \) (i.e., \( \tau_{qk} = (1 - \tau_{qk}) = 0.5 \)), then group choice equilibrium is not governed by a dominant agent with respect to attribute \( k \). In other words, regardless of the power structure governing other attributes, agent types \( q \) and \( q' \) tend to reach perceptively fair compromises when bridging the gap in their preferences for \( k \). If the power measures are significantly different across agent types (e.g., \( \tau_{qk} >> (1 - \tau_{qk}) \)), then \( \tau_{qk} \) gives a direct measure of the dominance of one agent type over the other with respect to attribute \( k \); as \( \tau_{qk} \) increases, so does the relative power held by agent type \( q \) over \( q' \) for \( k \).

For example, the power measures may reveal that one agent type tends to get its way with regard to monetary concerns, whereas the other agent type tends to get its way with regard to concerns for levels of service. These relationships can be examined further within subsets of agent groups (by decomposition of the random parameter specification of \( \tau_{qk} \)), in order to reveal deviations from the inferred behaviour at the sample level that may be present for a particular type of relationship.

One direct empirical advantage of this technique is securing a relatively large sample for the estimation of independent preferences of decision makers. In the application in Hensher et al. (2007) and Hensher and Puckett (2008), the MIGI experiment yielded key policy measures including values of travel time savings for free-flow and slowed-down
conditions for carriers (with a mean sensitivity to slowed-down conditions of approximately twice as large as to free-flow conditions), along with values of reliability gains (i.e., values of percentage point increases in the probability of a truck reaching its destination on time) for carriers and shippers, with shippers demonstrating particularly strong sensitivities to on-time arrival probabilities. Still, the paramount contribution of the technique is the capability of estimating the range of cooperative outcomes that could be observed within group decision-making settings, consistent with the bargaining space discussion in Krause et al. (2006). In the freight application, models of concession by shippers and carriers were compared to infer the range of power structures that are likely to be observed for interactions relating to variable road user charges.

The experiment showed that power in shipper-carrier dyads is multidimensional, with shippers dominating some attributes, carriers dominating others, and shared power over the remainder. For example, carriers appear to hold strong power with respect to on-time reliability and variable charges (i.e., even in cases where carriers would concede toward the preferences of shippers, carriers’ preferences relating to on-time reliability and variable charges would tend to be preserved). Hence, policy measures centred on the implementation of variable road-user charging and changes in reliability are likely to impact freight travel behaviour most directly through the influence of the preferences of carriers.

Conversely, shippers appear to hold strong power over transit time and the freight rate. Hence, policy measures that would influence travel time on the road network would likely impact freight travel behaviour most directly through the preferences of shippers, who would also use their power to control related changes in the freight rate. Lastly, standard operating costs for freight travel (i.e., fuel cost) was an attribute over which both shippers and carriers demonstrated a willingness to accommodate the preferences of their partners.

Overall, MIGI analysis of variable road user charges in Sydney showed that shippers and carriers appear willing to cooperate with each other to adjust the parameters of their freight travel behaviour strategies to achieve outcomes that are favourable to both sides. Whilst carriers could dominate decisions relating directly to variable charges, carriers may be willing (and indeed motivated) to achieve improved travel times and changes in operating costs that could benefit shippers both directly and indirectly.

The initial application of IIIP and MIGI to the study of freight travel behaviour under variable road-user charges confirms the power in alternative approaches to representing agent interdependency both in general and specifically within a freight transport context. Extending the technique to allow more complex representations of preference revision and concession could be an important advance of the empirical toolkit in applications relating to the strategies enacted by interdependent freight stakeholders.
3.3 Endogenous Attribute Levels

Whereas independent and interdependent choice experiments involve trade-offs across fixed bundles of attribute levels, some decision-making settings involve the choice amongst alternatives described by a set of attribute levels that can be altered by one or more interdependent decision makers. That is, in some negotiation settings, participants are free to propose mixes of attribute levels that can be varied (e.g., price, level-of-service characteristics) in an effort to establish cooperation or power in the process of determining a group choice outcome. Within a freight context, for example, shippers and carriers may negotiate freight travel parameters such as delivery time windows, with each having significantly different initial offers.

In such cases, the added flexibility to amend the attribute level mix corresponding to an alternative is tantamount to the presence of a superset of alternatives that forms the true bargaining set that could be generated from a starting set of market or proposed alternatives. This is important, not only because of the direct behavioural relevance of capturing negotiation processes, but also because of the potential for there to be points within the bargaining set that are more satisfactory group choice outcomes than any initial set of alternatives on offer. In real markets, there may be low barriers to reaching these points. However, in choice experiments involving interdependent decision makers, if the traditional stated choice method does not allow for feasible movements to these points, the method is potentially limiting in making inferences about the behaviour of agents; hence, the method may limit the ability to make appropriate projections of behaviour in related settings.

The direct implication of this is that cases of non-coincident preferences reflect uncertainty not only in group choice outcomes over a fixed set of alternatives, but also in what feasible group choice outcomes could be preferable beyond the fixed set. Continuing with the three alternative example from the previous section, if two agents would find alternatives A or B acceptable, yet differ in the first preference, the real market could feasibly allow the agents to amend the attribute level mixes of either of the alternatives (say, change A to become A’, which takes on some of the characteristics of B, or more similar characteristics to B) to yield a new alternative (A’ in this case) that offers greater joint utility than either A or B. Such gains in joint utility are not theoretically limited to Pareto improvements; rather, it is feasible that interdependent decision makers could identify new alternatives that improve utility for each member of the group relative to the (constrained) best alternative originally on offer.

Stated endogenous attribute level (SEAL) analysis has been proposed as an empirical means of addressing this gap (Hensher et al., 2007). SEAL was created specifically as a tool for analysing preferences within freight negotiations, although its application is not technically limited to freight. SEAL analysis begins as a traditional stated choice experiment in which the levels of the attributes are determined experimentally using proven experimental design techniques for determining exogenous attribute levels (e.g., d-optimal designs – see Rose and Bliemer, 2008; Kanninen, 2002). The resulting initial
choice sets faced by members of a sampled group are identical in form to a standard choice set. However, the SEAL experiment allows respondents to adjust endogenous attribute levels when the first preferences of group members do not coincide.

Consider a simple choice set with three alternatives A, B and C, with two attributes classified by the analyst as exogenous (i.e., they cannot be adjusted by respondents): travel time and damage rate. Along with these exogenous attributes, there are two endogenous attributes in each alternative: on-time arrival rate (which, given the set of exogenous constraints, could feasibly be satisfied by the carrier by taking the required measures), and the freight rate. The initial attribute levels could be functions of revealed preference information specified by respondents, along with their positions on the minimum and maximum levels of the attribute they believe could feasibly be offered; this latter information could be utilised to set the upper and lower bounds of the endogenous attributes. If each member of a sampled group prefers the same alternative within a choice set, no further information is required to establish the group choice outcome. If respondents’ first preferences do not coincide, the SEAL experiment moves into its extended phase.

In this phase, respondents are given the opportunity to take the alternative they would most like to use to build a counter-offer, and then each adjusts the levels of the endogenous attributes and continues to do so with feedback and revision in the goal of reaching a consensus outcome. For example, the experiment could offer one respondent the opportunity to build a counter-offer out of one of the alternatives, adjusting the levels of the endogenous attributes within the alternative consistent with the ranges specified by the respondents (e.g., select alternative A, raise the freight rate by $100 and raise the on-time arrival rate by 5 percent). If this is acceptable to all as a group choice outcome, the process is concluded; otherwise, another respondent in the group is given the opportunity to form one’s own counter-offer. The process repeats itself until either a consensus can be reached, or impasse is reached (either through a maximum number of iterations, or through a respondent indicating that a compromise is not feasible).

The final group equilibrium responses and attribute levels would be the most critical information relevant to the estimation of the related discrete choice models. However, respondents could be prompted to indicate their order of preference amongst some or all of the counter-offers during the simulated negotiation process. This could expand the set of useful choice data gained from the experiment considerably above a comparison of final choices versus initial offers or penultimate offers.

The analyst can hypothesise a range of logical relationships amongst counter-offers; these relationships can be exploited to reveal additional information about the behaviour of respondents. For example, each counter-offer made should yield a greater utility to that decision maker than the preceding offer made to the decision maker. If this holds, which appears reasonable (otherwise the decision maker would accept the offer rather than create a counter-offer), adjacent offer pairs can be examined in at least two dimensions: (1) the direct utility difference between the alternatives in these pairs; and (2) the evolution of these offer pairs as the experiment progresses. The ability to capture a
A dynamic process of preference revision and concession across endogenous attributes could form a powerful development relative to either static preference rankings (as in standard stated choice experiments or IIIP) or iterative choices across fixed attribute bundles (as in IACEs).

A further development in this area could be combining the negotiation-centred focus of SEAL with the empirical practicality focus of IIIP to avoid similar administrative obstacles as under IACEs. A simulation method could be used to replicate the negotiation behaviour of real-market or representative partners of respondents. That is, rather than matching agents directly for participation in a SEAL experiment, respondents could participate in isolation. In such cases, algorithms could be used to prompt respondents with simulated counter-offers from decision-making partners. Within a given experiment, the simulation algorithm could start fairly simply, by being seeded with prior information on the preferences of that type of decision maker, along with stated information from the respondent with respect to expectations of the other decision maker’s preferences or bargaining behaviour. The algorithm would use this information to adjust counter-offers in response to the evolving counter-offers made by the respondent; prior information could also be used to reach trigger points at which the simulated participant would accept an offer (to allow at least some of the respondents’ offers to be accepted).

Most importantly in this scenario, the algorithm could be updated as the survey progresses, incorporating observed negotiation behaviour of each class of respondent in the sample. That is, the set of useful prior information would grow within each experiment, allowing for improvements in the simulated behaviour of respondents’ decision-making partners. Indeed, subsequent studies could build upon the observed behaviour in preceding SEAL experiments, leading to a more effective empirical technique over time.

3.4 Simulated Panels

The tools discussed up to this point in this section have centred on refinements and expansions within a stated choice framework. It is worth acknowledging that whilst stated choice is a powerful tool in analyses of changes in policy, it need not be the only tool utilised by researchers in this area. One area where different tools may have particular merit is in an analysis of long-term strategic behaviour. Whilst stated choice may be able to capture important behavioural information under a given scenario, there may be little to nothing relating the choices made by respondents with potential consequences of these choices. Other approaches may be able to be tailored to represent consequences of chosen strategies, which could serve the joint benefits of reinforcing the motivation to make informed choices in experimental settings and capturing information on the ways in which decision makers adjust to a range of outcomes as they relate to decision makers’ expectations.

Research in progress (Puckett and Greaves, 2009) is testing a method to achieve this through a simulated panel approach for freight transport providers. Simulated panels centre on an interactive simulation game, in which respondents are given hypothetical
scenarios based upon respondents’ real-market experience (which is behaviourally similar to stated choice) and asked to offer their preferred strategy (which is again similar to stated choice if there is a countable set of alternatives, or is similar to SEAL if there is a large set of alternatives including endogenous attributes). The central premise of the panel element deviates from a stated choice or SEAL approach, in that the game involves the simulation of time effects. Rather than simply asking respondents what they would do if a new policy were enacted, the game builds upon respondents’ stated strategies to test how respondents would respond under different outcomes as time progresses.

For example, a respondent may indicate that she would prefer to shift a certain proportion of the vehicle fleet to activities in new locations under a low emissions zone. The game could then simulate an outcome of this strategy after a certain amount of time (e.g., that costs and revenues changed by a certain amount after one year under the new strategy, and that industry peers had enacted a certain set of strategies with corresponding outcomes) and then prompt the respondent to indicate whether she would like to amend the strategy in light of this information. Not only can the game carry this line of simulated activity over a given time frame of reference (e.g., every year for ten years), but also could test a range of outcomes for each simulated point in time (e.g., prompt for strategy revision under a relatively beneficial outcome after one year, and prompt for strategy revision under a relatively detrimental outcome after one year). The resulting (simulated) behavioural information could test both learning effects and sensitivities to positive and negative deviations from expectations under uncertain states of the world.

Furthermore, the scenarios can be represented in a format that is different to stated choice menus and SEAL negotiation menus. For example, the current freight study will use a map-based interface to prompt respondents to indicate preferred changes in distribution activity across space, time and vehicle class under target policies such as low emissions zones. This is a rich, multidimensional representation of the behavioural elements underlying the strategies enacted by respondents in the simulation. The level of multidimensionality is likely limited to some extent due to concerns of cognitive burden or time limits; however, this approach could demonstrate important advances in representing behavioural information in meaningful ways under complex decision-making settings.

The real-market data used to calibrate the simulated panel instrument can come from a range of sources; for freight travel settings, GPS data in conjunction with driver and manager surveys appears to have considerable promise. GPS data can be incorporated into the simulation game to reveal observed travel patterns relating to sampled organisations’ business activity, and can aid in specifying the scope of business activity forming the basis of the analysis. Managers and drivers could supplement the GPS data through revealing information relating to the spatial and temporal distribution of an organisations’ freight-related travel by vehicle class, attitudes toward target policies and attitudes toward and responses to the potential behaviour and preferences of shippers under target policies.
This approach to data collection builds upon the empirical method of Anderson et al. (2005), which also centred on a joint vehicle use-personal interview survey. Whereas the study by Anderson et al. involved the use of driver diaries, we prefer a focus on GPS for capturing vehicle-specific travel data. Collecting this data via GPS could be advantageous, in that it: (1) may enable one to collect data on both more vehicles and more trips per vehicle due to a lower respondent burden relative to paper-based surveys; (2) allows one to import vehicle travel data directly into the central computer-aided personal interview (CAPI) survey instrument to represent the real-market travel behaviour of an organisation’s vehicles that was observed during data collection; and (3) allows one to develop automated means of coding vehicle travel data spatially and temporally for subsequent analysis, mitigating the risks of reporting and transcription error.

Collecting data on more vehicles and more trips per vehicle offers a clear direct advantage: by capturing information on a wider scope of truck movements relative to what would be captured under a standard travel diary, one would be better able to represent rich descriptions of sampled organisations’ commercial travel behaviour behaviourally within a survey instrument and econometrically. This is of considerable value in both the estimation of pollutant output and subsequent stages of behavioural change. Furthermore, because GPS data should be richer than diary data for each trip captured in a survey, GPS data would reveal spatial, temporal and traffic condition information for each trip that a paper diary would either omit altogether or include with important degrees of subjectivity, inaccuracy or aggregation. In addition, by importing GPS data directly into the CAPI survey instrument, respondents will face experimental scenarios that are represented more faithfully to real-market conditions, aiding in the task to specify the spatial and temporal distribution of their freight travel activity and anchoring the subsequent hypothetical policy-based scenarios in reality by offering a real-market reference point.

The GPS and survey data would form the behavioural basis for the analysis by creating a status quo profile of freight vehicle activity across space and time (as defined by the spatial and temporal units of analysis, such as aggregate zones and daily time periods). The subsequent policy-based scenarios would then prompt respondents to indicate how their organisations may deviate from the status quo through strategies such as shifting vehicles across space and time, replacing vehicles with more fuel efficient or lower-emitting vehicles, consolidating shipments onto a lower volume of vehicles, changing the companies with which one conducts business, and shifting to other business activities, taking into account constraints set by other interdependent decision makers (e.g., delivery time windows and minimum levels-of-service).

There are many candidate econometric frameworks that may be suitable for the analysis of respondents’ stated strategies. The primary elements that must be accounted for to quantify the central behavioural information present in the data are spatial and temporal sensitivities across vehicle classes to new policies both upon enactment of the policies and as experience under the policies grows subject to (simulated) realised outcomes.
Simultaneous equation and discrete choice frameworks are of particular interest here and could be mutually reinforcing.

Moving to the CAPI questionnaire, which will be administered to managers of freight transport companies, the survey instrument will first prompt respondents to offer information on the nature of their organisations’ freight transport activity. The data needs of the study centre on commercial, spatial and temporal dimensions. Commercially, we are interested in the types of business relationships that correspond to the organisation’s freight activity (i.e., vehicle kilometres of travel under spot contracts, ongoing contracted relationships with influential partners, and ongoing relationships with partners with little or no influence on how the organisation moves freight), the types of goods that the organisation carries (i.e., general type and value), the split of vehicle kilometres of travel by vehicle type, and the freight rate that the organisation receives (i.e., above, at or below market average) under each relationship structure.

The GPS data collected in the initial phase of the survey will then be demonstrated to respondents to give an indication of the types of activity that were observed. Sampled trips will be displayed on a map of the Sydney Metropolitan Area, followed by a summary of travel volumes across the zones that will form the spatial network in the econometric analysis. The task of the respondent at this point in the survey is four-fold: Firstly, respondents will be asked to specify in which zones their organisation’s freight tours originate; if there are multiple zones, respondents will be asked to estimate the proportion of overall VKT originating from each zone. Secondly, for each zone listed as an origin, respondents will be asked to estimate the proportion of VKT corresponding to travel to destinations in each zone. Thirdly, in each of the preceding tasks, respondents will be asked to indicate zones in which influential shippers operate, and the proportion of VKT corresponding to these shippers in each zone. Fourthly, respondents will be asked to indicate what proportion of trips for each origin-destination pair take place during each time-of-day segment specified in the analysis. GPS data will be used here to show respondents the distribution of travel by time of day overall and from each sampled zone as an aid.

The information gained through the approach discussed above forms the basis of comparison with behaviour under the focal policies. This behaviour can be separated into two critical time frames: immediately upon enactment of the policies, and some time after enactment of the policies (i.e., once the policies have had time to influence behaviour beyond initial adjustments). To test the immediate impacts of the policies, respondents would first be given details of a hypothetical policy. For example, in the case of vehicle emissions zone, respondents could be shown a description (with clarifying maps and images) such as follows:
Respondents would then be shown a map of their current freight transport activity as they specified, with the areas affected by the policies highlighted on the map. Respondents would be prompted to undertake their central task within the scenario: specifying how their organisation would adjust their business activity under the policy. The range of adjustments would include the choice whether and how much to shift activity across space, vehicle types and times of day, and to what degree they may change the overall volume of travel. To simplify the graphical representation of these shifts, respondents will be asked to indicate which of these general strategies their organisation would implement. The map of business activity would then be optimised to focus on the selected strategic elements, at which point respondents would be prompted to indicate the expected magnitudes of changes in freight travel. The changes would be specified one element at a time, starting from the broadest level (e.g., VKT from one origin to one destination) and progressing to finer detail (e.g., time of day of travel of the specified VKT from one origin to one destination for a specified vehicle type). The set of information gathered at this stage of the questionnaire is sufficient to estimate changes in VKT by vehicle type across the network that would occur under each policy tested at the time the policy would take effect, and to estimate the probability of observing desired reductions in VKT at the time of implementing the policy.

For each policy under consideration, respondents would be given follow-up scenarios taking place at points after the implementation of the policy (e.g., two and five years later). Within each time period considered in the scenarios, respondents would be presented with alternative scenarios representing potential outcomes under respondents’ stated preferred strategies under each policy. This range of scenarios is designed to test respondents’ long-term strategic and learning processes, in an effort to identify these forces for improved modelling of long-term policy impacts.

Consider a relatively simple case, where a respondent has indicated that a low emissions zone would result in her organisation reducing travel into the zone by 1000 kilometres per year, with travel into other zones increasing by 800 kilometres per year. In a scenario testing the impacts of the LEZ policy two years out, the respondent could be presented with a prompt such as the following:

**Policy 1: Low Emissions Zone**

In this scenario, the traffic authority has established low emissions zones (LEZs) in the highlighted areas. Within the LEZs, only trucks that meet or exceed the Euro X emissions standard will be allowed to travel. Severe penalties (e.g., a fine of $YYYY per incident) apply to violating this regulation.
Respondents would then be presented with graphical representations of their organisations’ travel activity from the first stage, in which they would have the opportunity to amend their stated strategies in light of the information within the scenario. This process would then be repeated multiple times (as determined by the experimental design) for the time period being tested with new hypothetical outcomes, followed by a similar set of scenarios at a later time period (e.g., five years after implementation).

Ultimately, the information collected in this simulated panel process enables the analyst to estimate the evolution policy impacts in an adaptable manner over the time period of interest, including capturing sensitivities to variations above or below expectations. This is an improvement over a real-market panel approach, which may be limited to observing changes in preferences as a function of observed experiences; the simulated panel approach enables the analyst to capture information over a range of feasible outcomes to improve knowledge of the adjustment strategies that individuals or organisations may enact as they learn about the effectiveness of the decisions they make under some level of uncertainty. In the case of freight-related policies, the degree of uncertainty could be considerable, and hence information on likely adjustment strategies under likely (or observed at some point in the future) outcomes would be valuable inputs into models of freight travel decision-making.

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**Scenario 1A: Two Years Later**

The LEZ has now been in effect for two years. Your organisation’s strategy in response to the LEZ to this point can be summarised as follows:

- Reduction of 1000km (20%) of travel into the LEZ
- Increase of 800km (30%) of travel to other areas

Over the two-year period, your organisation has observed the following changes:

- Freight rates for travel into the zone have risen by 8%
- Freight rates for travel to other areas have risen by 3%
- Travel times for trips into the zone have fallen by 11%
- Travel times for trips to other areas have risen by 9%
- Late arrivals for trips into the zone have fallen by 15%
- Late arrivals for trips to other areas have risen by 13%
- Costs of travel for trips into the zone have risen by 2%
- Costs of travel for trips to other areas have risen by 6%

Based on this information, what changes, if any, would your organisation make to its freight travel activity?
The primary challenges in developing the simulated panel approach for freight studies are the need to specify the scenarios in a realistic and appropriate manner, and to link the data captured in the experiment to useful econometric models. Current research by Puckett and Greaves is targeted at these challenges. In-depth interviews with representatives from freight transport companies will be carried out to align scenarios relating to transport policies with the decision-making processes central to these firms, whilst econometric frameworks will be refined to connect the information from hypothetical scenarios to policy outputs of interest.

4 CONCLUDING REMARKS

To improve our understanding of the determinants of freight travel behaviour in a meaningful way, we will need to use a range of tools and approaches. Decisions made regarding the movement of goods are governed by many important types of influences, and have many different impacts. There is hence no one area that stands out as paramount to focus our efforts; a holistic effort from researchers and policy makers appears to be an appropriate strategy for advancing our capabilities in modelling freight-related impacts on traffic networks, the economy and the environment.

Fortunately, intelligent techniques are being applied in many areas to support exactly a holistic research effort targeted at freight travel decision-making. The research discussed in this paper represents a key cross-section of the broad range of freight research developments. Decision-making processes relating to freight travel reflect the direct reasons that stakeholders would prefer to enact particular strategies – their motivations and incentives; furthermore, freight travel decision-making is conditioned by the factors leading outcomes to deviate from strategies one may expect when considering motivations and incentives in isolation – constraints and effects of interdependence across decision makers.

The advances profiled in this paper highlight the different directions being taken to account for these effects more precisely in applications relating to freight-related transport policies. In the area of network modelling, micro-simulation techniques of freight travel choices, modelling of land-use/transport network feedback effects, and accounting for physical characteristics of logistics networks have added important structural behavioural elements to models from which standard models centring on techniques such as assigning commodity flows have only abstracted. These advances account for motivations as integral as decision makers’ preferences, along with key constraints such as land-use patterns, the nature of logistics systems and restrictions set by different stakeholders having influence on a particular set of freight travel alternatives.

Furthermore, recent empirical applications have added to our understanding of the relative merit that freight-related transport policies could have in achieving desired objectives. Key empirical studies have extended the manner in which analysts account for multiple behavioural dimensions that shape how freight is ultimately carried. Parallel to advances being made in the area of network modelling, these dimensions include forces
motivating freight stakeholders to enact particular strategies, constraints that restrict a subset of potential strategies from being observed, incentives to encourage desired behaviour, and the impacts of interactivity across interdependent freight travel decision makers.

Economic growth and changes in the function of logistics networks within growing economies will support growth in the demand for freight transport. Coinciding with an increase in the freight transport task, constraints on freight transport decision-making and operations are likely to grow as well. Increased travel demand, in general, along with potential fundamental shifts in pricing structures (e.g., carbon taxes, variable road-user charging) and truck-related regulations (e.g., access restrictions by vehicle type and emissions standard) could both restrict the ability of freight transport providers to meet the demands they face and alter the preferred set of freight distribution strategies employed by carriers and shippers. The role of researchers in evaluating these potential changes to the market is significant and multi-dimensional.

There may be a need for an expansion of both the scale and scope of freight travel behaviour research centring on policy impacts. Put simply, we will need to do more, and we will need to find new ways to do it. The techniques and approaches highlighted in this paper demonstrate the remarkable capabilities present amongst freight researchers in this area. Tools being developed for analyses of network-level behaviour through an advanced understanding of the roles played by decision makers and their opportunity sets reveal a promising opportunity to analyse increasingly complex network structures with increasing accuracy. Such research will make pivotal contributions in studies of the changing impacts that freight travel demand may have on the function of road networks and logistics systems.

Supporting advances in network analyses, intelligent and targeted empirical studies such as those discussed in this paper will serve the critical goal of understanding how potential policies and changes in market structure may influence freight travel behaviour. As constraints on freight travel change, we will need to identify corresponding changes in preferences and strategies that freight travel decision makers are likely to demonstrate. Related to this, we will need to improve our understanding of how the impacts of freight-centred transport policies may align with the goals of such policies, and of the scale of indirect impacts these policies may have. The relevance of empirical studies of freight travel decision-making are by no means restricted to the empirical setting in question; each study builds upon our knowledge of central behavioural constructs underlying the potential changes to transport-, logistics- and economic efficiency we may observe under changes in policy. Hence, as freight travel demand and constraints relating to freight grow, the need for insightful empirical freight studies building upon the approaches discussed here will grow, as well.

Lastly, this paper has highlighted recent and forthcoming advances in empirical and econometric techniques to capture greater information on freight travel decision makers’ preferences and the decision-making settings within which these preferences are applied. Efforts across all freight travel research would benefit from improved confidence in
measures of what matters to stakeholders, regardless of the application in question. Similarly, expanding our knowledge of the nature of decision-making settings governing freight travel choices – both currently observed and likely to be observed under changing constraints and opportunities – will be of considerable value in freight analyses targeted at network performance, intra- and inter-organisational behaviour and transport policy, in general.

As the fundamentals conditioning freight travel choices change, and as the importance of implementing informed freight strategies grows for all stakeholders, it will become even more important to expand the scale of scope of freight travel behaviour research. It will be no less important to enhance our ability both to represent decision-making settings faithfully, and to maximise the inferential power of the information we capture across our research applications by taking advantage of empirical developments and tools targeted at these goals.

REFERENCES


