Original Article

Understanding mode choice decisions: A study of Australian freight shippers

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Abstract This research article examines the Australian domestic freight transport market, focusing on the decision-making process by which cargo interests and their agents make mode choice allocation decisions between land-based transport and coastal shipping. It evaluates the willingness to pay (WTP) for various attributes of modal options on specific transport corridors. Such understanding lays the groundwork for being able to assess the likely impact of changes to transport prices arising from the introduction of carbon pricing or other regulatory factors. Reporting the results of a stated choice experiment, this article identifies and quantifies freight shippers' preferences for components of services offered by freight transport providers across modes with distinct characteristics (that is, mixes of speed (transit time), frequency of departure, reliability (two measures) and cost) in three corridors. There are seven variables examined: frequency, transit time, freight distance, direction (headhaul/backhaul), reliability as measured by delivery window, reliability as measured by delay and price offered by the operator. The article concludes by providing guidance on what trade-offs are relevant in shippers' choice of mode on the specific corridors under investigation in a more complex mode choice model than explored in previous research. It also examines what will likely happen if price rises as a result of carbon pricing regulation.

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Introduction and Background for the Research

North American studies indicate that by studying freight distance, traffic volume, congestion, the availability of secondary ports and whether there is a competing rail corridor, coastal (short sea) shipping opportunities can be identified (see Bendall and Brooks, 2011, for a detailed review of North American studies). The impact of road congestion on transit time and cargo delivery delay has been identified as a key element in North American truck versus shipping mode choice allocation (Brooks and Trifts, 2008). In the North American market, however, the trade-offs between rail and sea options are poorly understood and there have been few corridors on which to test mode choice criteria; generally it has been concluded that cargo interests using trucks would switch to rail intermodal services rather than short sea shipping, wherever rail operates in the corridor under study (MariNova Consulting Limited, 2005).

In the Australian context, there is a belief that coastal shipping is only competitive in corridors exceeding 2200 road km, while under 1500 km the road mode will dominate the market with rail succeeding in the over 1500 km market (Commonwealth of Australia, 2006). However, as noted by Bendall and Brooks (2011), there does not appear to be any empirical research behind these statements to test the validity of this argument. Given the considerably shorter distance found in the North American mode allocation study by Brooks and Trifts (2008), and the finding by Puckett *et al* (2011) that shippers will pay for frequency of service, we believe that a mode choice study that examines the trade-offs between price, transit time, frequency and reliability over different corridor distances and mode options is a necessary input to making sound regulatory and policy choices in the Australian freight market. As mode choice is seldom an all-or-nothing decision but involves risk mitigation through route and mode allocation, this research contributes to the larger mode choice field by using an allocation experiment to explore the mode trade-offs made.

In their study of Australian coastal shipping, Bendall and Brooks (2011) concluded that land-based modes of transport were well developed in Australia and the growing share of traffic held by rail services provided a clear competitor to any coastal shipping operator seeking to introduce a service. In key coastal shipping corridors, more than four intermodal trains a day were in service, and the 'rail industry is working hard to increase its intermodal volumes'. Given that the coastal shipping mode is the most environmentally friendly mode of transport, their study concluded that 'empirical evidence on modal choice and allocation to mode decisions by cargo interests' was needed and that 'It is here that the greatest contribution of future research may be made'. Hence, this article is motivated to provide an understanding of mode choice decisions in the Australian context so that appropriate transport and environmental policy may be developed.

This article reports the results of a Stated Choice Experiment (SCE) and its subsequent analysis. The experiment is administered to managers in charge of shipping goods between Australian cities in three corridors. It is designed to gauge managers' preferred allocations of their cargo across modal alternatives, including road freight, rail freight and short sea shipping (both domestic and foreign carrier). The study identifies and quantifies freight shippers' preferences for components of services offered by freight transport providers across modes with distinct characteristics (that is, mixes of speed (transit time), frequency of departure, reliability (two measures) and cost) in three corridors where there is or could be competition between the modes. This will help to identify corridors over which more environmentally friendly modes (that is, rail and sea) may be competitive with road freight, informing transport policy and investment decisions that currently lack this information.

Development of the Study Variables

Over the last 10 years, there has been considerable interest in converting those who transport their goods by land-based modes of trucking and rail to the use of coastal shipping as a means of mitigating greenhouse gas emissions. In spite of the significant rhetoric in support of short sea shipping by governments, the conversion of buyers of freight transport services from trucking and rail to short sea shipping has not lived up to expectations. There have been numerous studies within North America looking at what is necessary to make a short sea shipping service work (for example, MariNova Consulting Limited, 2005, 2009; Cambridge Systematics Inc., 2007; CPCS Transcom, 2008; Kruse and Hutson, 2010) and government findings that US freight interests are reluctant to use short sea shipping (GAO, 2005). Likewise, there have been numerous case studies in Europe (for example, Paixão and Marlow, 2002; García-Menéndez *et al*, 2004) but few have provided help in understanding what it takes to convert buyers to this mode. Recently, Australia has been identified as a test bed for understanding modal switching, given that its regulatory environment is less restrictive than the North American one. Bendall and Brooks (2011) concluded that the country was ripe for a modal switching study that examined cargo shippers' trade-offs in making a modal choice on routes where coastal shipping might work.

Studies in North America have found that there are several factors necessary for coastal shipping to work. One of these is freight distance. Freight distance is a key factor in determining whether coastal shipping is a viable alternative when compared with truck or rail alternatives in North American studies. There have been successful coastal shipping operations in markets of longer distance, but on shorter distances of < 1000 nautical miles, time and conditions favour the road mode. Brooks and Trifts (2008) found that shipping could only be competitive with trucking in corridors under 1000 nautical miles in certain circumstances, like the longer road route around the Bay of Fundy. An example of a shorter distance niche market would be the Hudson River ferry where trailer on barge has enabled repositioning of freight in the highly congested New York City urban environment (Shabe, 2011).

In Europe, the most successful services in the Marco Polo case studies have included shipping distances of greater than a 1-day truck driving distance. For example, one of the most successful services has been determined by the European Commission (2011) to be the Ro-Ro Past France service, a freight ferry service sailing between Bilbao in northern Spain and Zeebrugge in Belgium. At a subsidy of €6.8 million, the project is expected to remove 8.4 billion tonne-kms of traffic off the congested highways of northern France, resulting in an environmental benefit of €211 million. While incurring a marginally longer sea distance (677 nm or 1254 km at 1.85 km/nm) with a 2 days sailing time at 14 nmph against a road distance of a little more than 1200 kms (driving time a little over 12 hours), the road distance is above the single day driving limit and, with mandated rest periods, the two routes are within a competitive 2-day range with respect to time. Whether they compete successfully depends on port handling times at each end and the commitment made to the buyer of the service for the price charged. While this is claimed as a success, the project pilot period is still underway and there is no available documentation to substantiate whether the switching would have occurred without the subsidy provided. In other words, the confirmation of success in this corridor demands a close look at the realised price for the service and the modal preferences of buyers on the corridor.

In the Australian context, the Commonwealth of Australia (2006) and Meyrick and Associates (2007) have argued that coastal shipping is only competitive in corridors of more than 2200 road kilometres. This assumption has not been tested and, as already noted, services have operated in shorter corridors. Therefore, in this study we examine three corridors and have set a variable of freight distance to be tested as one factor in identifying mode choice outcomes. The question will be one of identifying if there is a willingness to accept coastal shipping at a lower price on freight distances of < 2200 km, such as Melbourne–Brisbane and Brisbane–Townsville, both of which are < 2200 km.

Related to this is the issue of transit time. Paixão and Marlow (2002) concluded, for example, that European short sea shipping is perceived as slower than truck while Brooks *et al* (2006) noted that the Boston–Halifax sea leg of a service would have an advantage, given that the land distance was sufficiently longer to offset the time loss at sea. For just-in-time (JIT) services, it may not be about the distance but about the elapsed transit time for the goods. While the two variables are likely related, the study needs to separate responses for cargo that has a JIT specification from those where JIT is not specified.

The third variable that we are concerned about is frequency. In modal switching studies conducted by Puckett *et al* (2011) and Brooks and Trifts (2008), it has been demonstrated that frequency is a key factor in the rejection of coastal shipping as a viable alternative. In the second, for example, Atlantic Canadian shippers were unwilling to accept service frequencies of every 2 weeks in the I-95 corridor. A weekly service was acceptable with conditions. In revisiting the Brooks and Trifts data, Puckett *et al* (2011) found that there was significant preference heterogeneity in the sample and that shipper willingness-to-pay (WTP) for gains in service frequency could be estimated for the routes examined. Finally, recently published research by Feo *et al* (2011) uncovered a relatively small (€24 a shipment) WTP for increased frequency of departure in a European road – short sea modal switching study.

As freight flows are seldom balanced directionally, we include in the study design parameters the direction in each corridor (headhaul or backhaul) to see if that too is a factor in the study, although we consider that this too may be reflected in price given that backhaul cargoes, in practice, are often charged considerably less than headhaul cargoes.

In addition to the frequency, freight distance and direction, there is the question of reliability. Paixão and Marlow (2002) concluded that European short sea shipping is perceived as less reliable than truck. There has been very little research focused on the issue of reliability, despite its considerable importance; enough so that the International Transport Forum of the Organisation of Economic Cooperation devoted an entire workshop to the issue (ITF, 2010). Reliability and fluidity are especially important for goods that are time sensitive in reaching their destination (Eisele *et al*, 2011). High value goods with significant inventory carrying costs, as well as perishable items, need to be efficiently transported in order to help reduce risks and decrease total costs.

There have been very few studies of modal switching that have definitively identified what reliability means to buyers of freight services. Generally, an arrival or departure time within 1 day of schedule for marine transport is considered to be reliable service (Saldanha *et al*, 2009) although not acceptable when seen from a cargo owner's perspective (Leach, 2006). A window this wide is not seen in other modes.

Feo *et al* (2011) was published after this study was designed. They opted to present the reliability of maritime as a percentage different from the reliability of road. We believe that reliability is a difficult construct because it really has two components. One is the need for a JIT buyer to have his or her freight delivered within a delivery window that it is acceptable for production process inputs or retail shelf stocking. The second is the reliability required to reduce buffer stock so that inventory-carrying costs are minimised. For this study, we have chosen to collect buyer evaluations of reliability in these two dimensions. For the first, we have offered in the study design the probability that the delivery will occur within 3 hours of scheduled time. For the second, we have accounted for delay as the probability of being more than 24 hours off-schedule.

Therefore, it is important in the study design to have a constant definition across the modes, hence our decision to standardise the way reliability is defined across the modes so that allocations of cargo across the modes would be comparable, and be they more or less reliable. Reliability time also depends on the distance of the route, with longer routes having a larger buffer time for arrival and departure reliability.

One variable found to be a situational factor of relevance in the Brooks and Trifts (2008) study is the existence of road congestion. Global Insight and Reeve & Associates (2006) identified several corridors with sufficient volume to support a short sea shipping operation in North America on the basis of existing road congestion. The Institute for Global Maritime Studies (2008) also used this a key criteria in identifying suitable corridors. Examining Commonwealth of Australia (2006) traffic reports, Bendall and Brooks (2011) identified five potential corridors to be examined in a modal switching study in Australia based on traffic volumes and distance alone; they concluded that Melbourne–Brisbane, Sydney–Adelaide or Cairns–Brisbane might have promise as they are sufficiently long enough to meet distance minimums (set at a day's driving threshold), although the last may not have sufficient traffic volumes. Sydney–Perth and Melbourne–Perth do not appear to have adequate road volumes to be included in a study design but Perth–Melbourne is a significant rail corridor and so we include it as a rail–sea challenge corridor.

In this study, we have chosen three corridors as having potentially sufficient freight distance, but only one with significant road congestion (Melbourne–Brisbane), while the other two have competing rail alternatives to consider (Perth–Melbourne and Brisbane–Townsville) but less congestion. These two appear to have sufficient traffic (combining road and rail) to warrant inclusion in the study.

Finally, there is the question of how to model government initiatives that would work to reduce environmental impact. While Macintosh (2007) found that modal switching from land-based modes to coastal shipping would be unlikely to be effective or efficient as a greenhouse gas mitigation strategy, we see that it is all a matter of incentive pricing. Furthermore, García-Menéndez *et al* (2004) investigated a road versus short sea discrete choice and found that the choice of sea transport by cargo interests was more sensitive to changes in road prices than to changes in shipping costs. They concluded that a substitute for an eco-tax could be a subsidy to the sea transport, as road does not bear its full environmental costs. This research was further endorsed by later findings by Feo *et al* (2011) who concluded that value of time, reliability and frequency are needed if governments are to make policy decisions about road pricing schemes, like Ecobono, to induce modal shift. Therefore, we have altered prices in the experimental design to reflect carbon pricing of fuel should the government decide such a policy was worth considering.

In summary, there are seven variables at play in the design of this choice experiment. These are frequency, transit time, freight distance, direction (headhaul/backhaul), reliability as measured by delivery window, reliability as measured by delay, and price offered by the operator. In the end, we have concluded that WTP will capture the environmental costs should government decide to impose a form of carbon pricing or road pricing mechanism to encourage modal switching.

Empirical Methodology

We identified a SCE as our best approach toward capturing the key behavioural measures that might induce freight mode shift under either carbon pricing or the introduction of new short sea shipping services in Australia. Fundamentally, SCEs enable analysts to quantify preferences under hypothetical mixes of alternatives and specifications of those alternatives (that is, attribute levels) that are not present in the market. This is critical in this application, given a lack of both price signals relating to carbon emissions abatement (for example, carbon taxes or carbon prices) and short sea shipping alternatives for the corridors in consideration within the study. We further identified a computer-based (with personal interview) survey instrument as our preferred SCE approach, due to the ability of a computer-based survey both to allow choice menus to be tailored to respondents' experience with respect to prices and transit times, and to capture and store survey data accurately and efficiently. The personal interview component is strongly preferred due to the need to ensure that respondents can make informed choices within an instrument and series of tasks that may be unfamiliar to them.

Feo *et al* (2011) offer a contemporary confirmation of the merit of such an approach, through a stated choice study of preferences for trucking versus short sea shipping in the Spanish market, comparing preferences for high-value cargo versus low-value cargo within individual modes. Our study follows the behavioural framework of Brooks and Trifts (2008), in which mode choice is not a binary decision, but rather involves the issue of proportional allocation across modal alternatives. Consistent with Feo *et al* (2011) characteristics of the cargo are tested as key influences on preferences for modal alternatives.

For example, perishable cargo is assumed to promote relatively strong preferences for modes offering higher reliability and speed; this relationship is testable within our approach, through an analysis of mode choice allocations with respect to cargo characteristics.

The remainder of this section outlines the components of the SCE and its experimental design, along with the econometric approach for analysing the resulting choice data.

Design of the State Choice Experiment

The primary objective of the SCE are to capture data enabling us to improve our understanding of how shippers purchase freight transport services in Australia, with a focus on competition between road, rail and short sea shipping along three key corridors: Perth–Melbourne, Melbourne–Brisbane and Brisbane–Townsville. These three corridors represent distinct origin–destination pairs for headhaul and backhaul services, involving different physical and temporal characteristics, costs and levels-of-service, the mixes of which could impact relative intermodal competitiveness considerably. Furthermore, the research has two specific policy-centred objectives. First, the research examines the potential competitiveness of the introduction of short sea shipping services (including the distinction between Australian-flag and foreign-flag vessels), which would likely involve unique relative benefits across the six origin–destination pairs in the study. Second, the research aims to evaluate the potential impacts of different degrees of carbon taxes, which would cause changes in the relative costs of each mode through a relatively larger impact on road transport, with its higher level of carbon emissions.

To achieve these objectives, we tested background questions and choice menus both to represent shippers' decision-making settings and to capture shippers' preferences within our hypothetical mix of modal alternatives under carbon pricing. The information and wording seeding the SCE was pre-tested and piloted among industry stakeholders to enable the development of an appropriate and effective survey instrument that helps to answer key policy questions including the extent to which: (i) shippers are sensitive to trade-offs between door-to-door price and level-of-service attributes such as transit time, reliability (in terms of both on-time performance and significant delay) and frequency of departure; (ii) constraints on delivery windows influence these sensitivities; (iii) perishability of the cargo influences these sensitivities; (iv) intermodal competitiveness varies across each origin–destination pair; and (v) preferences for short sea shipping alternatives vary with respect to not only cost/level-of-service trade-offs, but also to whether the alternative is a domestic-flag or foreign-flag vessel.

The background questions preceding the stated choice menus in the survey instrument were designed to quantify the scope and type of operations for each shipper, experience along the corridors in the study, and the nature of cargo with respect to its perishability and any relevant delivery time windows. Respondents are first asked to indicate whether their firm is (or is part of) a multinational organisation, along with the specific role they play in shipping freight (that is, manufacturer, wholesaler/distributor, retailer, freight forwarder, all with or without owning their own trucking operations).

Respondents are then asked to indicate their experience shipping freight between each of the origin–destination pairs in the study, across a series of three screens (one for each corridor). For each of the three corridors, respondents are asked to indicate whether they ship goods along the corridor, and the frequency (if any) of shipping activity along the corridor. This information is not only valuable for investigating variations in preferences (for example, those with higher frequencies of shipping activity along a corridor may have important differences in sensitivities to cost or levels-of-service to those with lower frequencies of shipping activity), but also enables the ensuing choice menus to focus on one specific origin–destination pair with which the respondent has current freight experience. The specification of the unique origin–destination pair represented within all of the choice menus for a given respondent is made in a screen following these three corridor-centred screens. If the respondent has experience with one origin–destination pair, the choice menus are seeded with this pair by default; if the respondent has experience with two to six pairs, the respondent and interviewer select one of the pairs to seed the choice menus; this enables the interviewer to ensure adequate responses are received across the three corridors.

Respondents are then asked to indicate the proportion of shipments that involve delivery windows of: <3 hours, between 3 and 24 hours and more than 24 hours. This information too is carried forward into the choice menus, by representing the (stated) proportion of shipments that involve a delivery window of 3 hours or less. On the same screen, respondents are asked to indicate the distribution of cargo values for their shipments. Once an origin–destination pair has been selected, respondents are prompted to indicate whether they have experienced particular values for the freight rate and total transit time for shipments between the origin and destination for both road and rail transport. If the respondent indicates values on the screen, these values are carried forward as base levels within the choice menus. If the respondent is unsure about any of these values, they can leave the fields blank; in such cases, the base values are specified as industry averages collected during the survey design process.

At this point, the instrument transitions into the central choice task by describing the context and content of the choice task. Respondents are asked to

Part 2: Making Transport Choices

An example of a choice scenario is given below:

You are re-evaluating your mode options from Perth to Melbourne for your shipments this month. You have recurring shipments of non-bulk cargo (a shipping container or truckload equivalent) of 20 tonnes for delivery on this corridor. 2% of these shipments involve perishable items, and 0% of these shipments must reach the destination within 3 hours of the scheduled delivery time.

Given the attributes for the mode service offerings in this corridor, how much of 100% of your cargo would you allocate to each of the modes?

After entering the first three values, the fourth value will be calculated automatically to ensure that the values add up to 100%.

	Truck	Rail	Coastal Shipping (Australian Flag)	Coastal Shipping (Foreign Flag)
Freight Rate	$6000	$3500	$2500	$2700
Total Transit Time	4 Days, 18 Hours	3 Days, 12 Hours	6 Days	6 Days
Departures per Week	25	18	2	2
Percentage of Shipments Arriving within 3 Hours of Schedule	75%	70%	70%	60%
Percentage of Shipments Arriving over 24 Hours after Schedule	5%	8%	20%	15%
I would allocate the following percentage of my cargo to these modes:	0 %	0 %	0 %	100 %

Back	Next

Figure 1: Practice choice menu screen.
Source: Authors.

assume that they must allocate proportions of their shipping activity along the origin–destination pair specified, for delivery to a warehouse, factory or retail outlet within 50 km of the port. Each of the alternatives (road, rail, short sea with domestic carrier, short sea with foreign flag) are specified in terms of door-to-door price of transport (that is, the freight rate), total transit time in days and hours, frequency of departures (per week), percentage of shipments arriving within 3 hours of schedule and percentage of shipments arriving more than 24 hours after schedule.

The specific choice task is described as follows: ‘You are re-evaluating your mode options from [origin] to [destination] for your shipments this month. You have recurring shipments of non-bulk cargo (a shipping container or truckload equivalent) of 20 tonnes for delivery on this corridor. [Percentage indicated in background screens] of these shipments involve perishable items, and [Percentage indicated in background screens] of these shipments must reach the destination within 3 hours of the scheduled delivery time.

‘Given the mode service offerings in this corridor, how much of 100 per cent of your cargo would you allocate to each of the modes?’

The interviewer guides the respondent through the use of a practice game, before the respondent goes on to make decisions on the eight choice sets with which he/she has been presented. An illustration of the practice game is found in Figure 1.

The choice task then begins in earnest, with respondents stating their preferred allocations across the modal alternatives for eight unique choice sets, each of which offer different mixes of costs and levels-of-service. This choice data represents the central information analysed within discrete choice models to yield behavioural measures relating to preferences for each mode as functions of cost/level-of-service trade-offs, and characteristics of corridors, firms and cargo. The survey instrument concludes with a brief series of attitudinal questions, and the opportunity for respondents to state their opinions on shipping and greenhouse gas emissions, and on the potential value of integrated short sea shipping alternatives.

We now turn to a discussion of the experimental design process, which specified the particular attribute level mixes across alternatives for each choice set in the survey instrument.

Experimental design

A serious constraint in a SCE approach to studying preferences in freight is difficulties in sourcing a large sample size. Indeed, in this application, we are limited by constraints of both feasibility (that is, the potential to recruit appropriate respondents) and financial concerns (the cost per computer-aided personal interview), restricting our expected sample size to 100 respondents or fewer. As such, we were motivated to extract as much meaningful information as possible from each respondent, subject to the practicality of time per interview. Consistent with a previous freight study in Sydney (see Puckett *et al*, 2007 and Puckett and Rose, 2010 for details), we opted to generate a *d*-efficient experimental design to reduce the standard errors associated with attribute parameters that we would expect to observe in our discrete choice models of the choice data, relative to standard orthogonal designs for a given sample size (for example, Bunch *et al*, 1994, Bliemer and Rose, 2010).

Efficient designs, including our preferred approach of *d*-efficiency (for example, Carlsson and Martinsson, 2003), use prior information on the preferences of respondents and expected attribute levels to generate the mixes of attribute levels across alternatives in each choice set presented to respondents, with the specific goal of producing choice models with more precise parameter estimates than in models calibrated with respect to data from experimental designs that do not incorporate prior information (for example, orthogonal or random designs). A *d*-efficient design, therefore, is expected to produce models with smaller standard errors for a given sample size. This is of particular importance when facing sampling constraints, as in this application; an efficient design can achieve models with a desired level of precision at a lower sample size than orthogonal designs, increasing the likelihood of obtaining meaningful empirical results without recruiting hundreds of respondents.

The prior information on attribute base levels used to seed the design was found through interviews and consultation with expert advisors, tested against BITRE (2008, 2009, 2010), where applicable. These values were tested with industry experts to confirm that the numbers were reasonable. For short sea services, consultation with six expert advisors and a potential coastal shipping operator revealed ranges of potential market offerings; representative values were selected within these ranges and likewise confirmed through pilot testing to ensure that the numbers were reasonable. Attribute base levels from the headhaul origin–destination pair with the highest level of mid-range attribute levels and closest values between road and rail (Melbourne to Brisbane) were chosen to seed the generation of the design, which was specified in terms of percentage deviations from the base levels (with the exception of frequency of service), and hence applicable to all origin–destination pairs and any respondent-specified values for road and rail prices and transit times.

The range of attribute levels (that is, percentage deviations from the base levels) to appear across the choice alternatives was selected to be representative of the potential variation in outcomes that could be observed under carbon pricing and the addition of short sea shipping services over time. These impacts and ranges were hypothesised to be different across modes (for example, prices for road freight services should experience higher variability due to a relatively larger burden through carbon taxes), resulting in the following ranges of attribute levels across alternatives, as shown in Table 1.

Not only was road freight given a relatively high upper bound for the freight rate, but short sea shipping was also given a relatively low lower bound for the

Table 1: Attribute levels for stated choice alternatives (expressed as percentage deviations from base values, except for frequency of service)

Variable specified	*Road*	*Rail*	*Coastal shipping (domestic)*	*Coastal shipping (foreign flag)*
Freight rate	90%, 110%, 130%	95%, 105%, 115%	85%, 100%, 115%	85%, 100%, 115%
Transit time	95%, 105%, 115%	95%, 105%, 115%	90%, 100%, 110%	90%, 100%, 110%
Frequency of service (shipments per week)	30, 35, 40	15, 18, 21	1, 2	1, 2
Percentage of shipments arriving within 3 hours of schedule	90%, 100%, 110%	90%, 100%, 110%	90%, 100%, 110%	90%, 100%, 110%
Percentage of shipments arriving more than 24 hours after schedule	90%, 100%, 110%	90%, 100%, 110%	90%, 100%, 110%	90%, 100%, 110%

Source: Authors.

freight rate. This enables us to test a relatively broad range of potential relative prices across the modes, to represent different impacts of carbon pricing on the prices of freight transport services. The relatively higher range of deviations in transit time for road and rail was included to represent a relatively higher probability that these services could become slower through increased congestion, compared with the potential for current service speeds (which may be near free-flow speeds, on average) to decline substantially. The much higher service frequency for road (six to eight trips per business day) compared with rail (three to just over four trips per business day) and short sea shipping (one or two trips per week) represents the reality that road freight service is simply dominant in the potential to offer high frequencies of low volume service, and that short sea shipping is a higher volume but lower frequency option. Lastly, for all reliability measures for all modes, deviations of 10 per cent below and above the base values were specified to observe a reasonable degree of attribute level variation across the choice sets.

Finally, prior information on the preferences of shippers was required to seed the experimental design generation process. Information on preferences for this application was scarce (indeed, this is the central point of the research), but preference estimates from a related study (Puckett *et al*, 2011) and models estimated within the study were identified as the best information available for preferences for the freight rate and frequency of service. Information from that study was also applied as priors for reliability, with the extant reliability preference estimates used for on-time reliability (that is, arrival within 3 hours of schedule); with no further information available for preferences for delay, a conservative hedge of double the parameter estimate (with opposite sign) for on-time reliability was applied.

The base attribute levels, attribute level ranges and prior parameter values were then specified within the software program NGene (see www.choice-metrics.com/) to generate an optimised series of eight choice sets to be used within the survey instrument described in the preceding subsection, with the specific objective of generating lower standard errors within choice models than would be observed through the use of an orthogonal design.

Discrete choice analysis

The empirical analysis in the section 'Findings and Discussion' centres on discrete choice models of the choice behaviour demonstrated within the survey. We tested a range of advanced discrete choice models, with a focus on mixed logit and latent class, the latter allocating respondents or choice observations probabilistically to different classes in terms of common attribute preferences. These models take unique approaches to identifying the manner in which preferences of individuals may vary within a sample, relative to mean-level estimates produced by the standard empirical base case, the multinomial logit (MNL) model. The details of mixed logit and latent class are well summarised in many sources such as Hensher and Greene (2003) and Greene and Hensher (2003).

All models tested centre on the estimation of preferences driving the observed choice behaviour within a sample, estimating choice behaviour against a set of utility functions corresponding to each alternative in the choice sets within the sample:

$$U_{qj} = \beta_{qj}' x_j + \varepsilon_{qj} \quad (1)$$

where U represents the utility firm q receives from alternative j (that is, truck, rail, domestic flag short sea and foreign flag short sea), which is a function of the vector of preference parameters (β) corresponding to attributes x (that is, freight rate, transit time, on-time reliability, probability of delays of 1 day or more and frequency of shipments), and unobserved components of utility (that is, the error term, ε).

The candidate model structures vary in the specification of preference heterogeneity (that is, whether the β parameters are constant across individuals or choice observations, or whether subsets of identical preferences are specified with probabilistic allocation of individuals or respondents across these subsets) and the nature of the error term (that is, whether the error term is solely distributed independently and identically Extreme Value I, or whether there are additional, individual or choice-observation-specific forces represented within the error term). Still, each model structure shares the same goal of identifying the trade-offs made by respondents in the sample as effectively as possible.

The estimated marginal (dis)utility parameters enable us to identify key marginal rates of substitution demonstrated by respondents, with a focus on WTP measures for attributes within the study. WTP measures can be identified in discrete choice studies by dividing marginal utility parameters corresponding to attributes of interest by marginal utility parameters corresponding to monetary measures. Hensher and Greene (2003) offer a thorough analysis of values of travel time savings – a central transport WTP measure – in a mixed logit context, while within the area of freight, a useful meta-analysis of WTP measures from discrete choice studies and alternative methods is found in Zamparini and Reggiani (2007). In our previous study of shippers' preferences for truck versus short sea shipping in North America (Puckett *et al*, 2011), WTP measures for frequency improvement and transit time savings confirmed opportunities to increase market share by offering improved levels-of-service with respect to frequency and transit time.

In this research, as in the aforementioned papers, WTP measures are found by taking ratios of marginal utility parameters from discrete choice models. These parameters are conditional on the choices made by respondents (that is, the estimates represent individual-specific behaviour). To illustrate, consider a simple model resulting in estimated preference parameters of −0.5 for transit time (measured in utils per minute) and −0.2 for travel cost (measured in utils per dollar). By taking the ratio of the former estimate to the latter, one identifies a ratio of 2.5 dollars per minute of transit time, or US$150 per hour of transit time. In this study, by dividing preference estimates for transit time, reliability and frequency (measured in utils per day of transit time, utils per percentage point of reliability and utils per trip per week, respectively) by preference estimates for the freight rate (measured in utils per dollar), we obtain WTP measures for each attribute (that is, dollars per day of transit time, dollars per percentage point of reliability and dollars per trip per week). These estimates, reported and discussed in the next section, provide critical insight into the market's perceived valuation for level-of-service characteristics that could be influenced by changes in the cost, effectiveness and availability of services under carbon pricing and the availability of short sea shipping services. This is of particular relevance given both the unobserved nature of these sensitivities in the current market (that is, there may be no direct purchase option available for marginal changes in levels-of-service) and the as yet unobserved preference structure in the market under carbon pricing or the presence of short sea shipping alternatives.

Findings and Discussion

We now turn to our initial results from the empirical survey. Our sample consists of 70 respondents representing shippers conducting activity along at least one of the three corridors within the study. After removing three observations in which respondents accidentally submitted choices prematurely, the resulting estimation sample includes 557 choice observations. Despite both the presence of three unique corridors in the study and a range of organisational roles (for example, retailer versus freight forwarder), preferences estimated within exploratory models indicated a lack of distinct classes of sensitivities within the study. This made the latent class model, which centres on the identification of groups with distinct preferences, an ineffective framework for our final model. Rather, we turned to the mixed logit model to reveal the degree of preference heterogeneity within the sample. We found that preference heterogeneity was most effectively identified with respect to the freight rate alone. The primary implication from this is that, after accounting for differences in sensitivities to

Table 2: Shipper preferences, MNL and mixed logit models (*t*-ratios in parentheses)

Attributes	*MNL*	*Mixed logit*
Mode-specific constant (rail)	−2.72653 (−3.326)***	−2.73412 (−3.838)***
Mode-specific constant (short sea)	−4.26305 (−4.355)***	−4.27865 (−4.953)***
Freight rate (mean, hundreds of A$)	−0.01670 (−4.578)***	−0.01507 (−4.474)***
Freight rate (spread parameter, hundreds of A$)	—	−0.01507 (4.474)***
Rail transit time (days)	−0.09256 (−3.326)***	−0.09055 (−1.922)*
Percentage of shipments arriving within 3 hours of schedule (rail)	0.03682 (2.765)***	0.03734 (3.168)
Percentage of shipments arriving within 3 hours of schedule (short sea)	0.03147 (2.305)**	0.03224 (2.640)***
Percentage of shipments arriving more than 24 hours after Schedule (truck)	−0.03914 (−1.592)	−0.03738 (−1.859)*
Backhaul preference for short sea	0.57697 (2.768)***	0.59028 (3.295)***
Model fit indicators		
Log likelihood at parameter estimates	−683.73	−684.94
Log likelihood with constants only	−772.17	−772.17
χ^2 (8 degrees of freedom)	176.88 (*P*-value=0.00000)	174.45 (*P*-value=0.00000)
Akaike information criterion	2.484	2.488
Number of observations	557	557

*, ** and ***represent statistical significance at the 90, 95 and 99 per cent levels, respectively.
300 Halton draws were used within the mixed logit estimation.

monetary cost across respondents, relative sensitivities to level-of-service attributes are similar across respondents. Preference heterogeneity with respect to the freight rate is modelled through a triangular distribution, with a spread parameter equal to the mean of the distribution (that is, the distribution of preferences falls linearly and symmetrically in both directions from the mean, bounded by twice the mean from below and zero from above) which resulted in the best model fit and intuitive results with respect to cost sensitivities.

Table 2 summarises the mixed logit model results, along with a comparison of results from a base MNL model with an assumption of equivalent preferences for all respondents.

The general behavioural implications for both the basic MNL and mixed logit models are the same, with the primary differences being variations in standard errors and coefficient levels, along with distributional implications within the mixed logit model that cannot be found within the MNL. Comparing the mode-specific constants within both models, it is apparent that, *Ceteris* *paribus*, road is clearly preferred to rail and both short sea alternatives (that is, all mode-specific constants are negative). The higher magnitude of the coefficient for the short sea constant indicates a stronger disutility for short sea, *Ceteris paribus*.

Interestingly, no significant improvement was added to the model when differentiating between domestic and foreign short sea services, indicating the respondents did not hold distinct preferences with respect to the flag of the short sea service, restricting comparisons with the attribute level differences between the two alternatives. Similarly, differentiating between the two short sea shipping alternatives did not improve model fit when estimating preference parameters relating to cost and level-of-service, which is intuitive (that is, after controlling for the registration of the vessel, respondents treat all ship-based dollars, hours and reliability indicators equivalently). Estimated sensitivities to the freight rate were found to be equivalent for all modes, which offers a useful common basis for comparing sensitivities to level-of-service attributes across alternatives. The estimated sensitivity to the freight rate is of particular interest within this application, in that the range of prices considered explicitly involves a range of impacts from a hypothetical carbon pricing system. Hence, the relative sensitivities of decision makers within the sample to the range of prices and mixes of levels-of-service offers useful evidence of potential sensitivities to service offerings across modes under carbon pricing. Carrying estimates from the models into decision support tools would enable the analyst to examine how carbon-pricing-specific cost changes may influence demand patterns, which is unique to the extant data on shipper preferences.

After accounting for general mode-specific influences (relative to road) through the use of alternative-specific constants for rail and the short sea (or coastal shipping) alternatives, we find distinct focal attributes influencing sensitivities in allocating proportions of shipping activity between the modal alternatives, outside of a common sensitivity to the freight rate. Allocations to road freight, which was the most preferred alternative, *Ceteris paribus* (as indicated by negative mode-specific constants for rail and short sea), are sensitive to the probability of arrivals that are delayed by 1 day or more. Conversely, allocations to rail and short sea are sensitive to the relative ability of these alternatives to provide reliable service to meet narrow delivery windows (that is, within 3 hours of schedule). Demand for rail is also sensitive to the range of transit times within the mode, which is unique among the alternatives in the study.

The behaviour implied by these results indicates an intriguing decision calculus, in which the proportional allocation of freight tasks across modal alternatives is aligned with proportional demands across the range of cost/

level-of-service trade-offs available. That is, while the study involves a range of attribute levels, and hence the nature of the trade-offs is not identical in composition across the choice sets faced by a given respondent, structural differences in the qualities of each alternative may play a large role in the allocation of freight activity across modes in the study. The ability to allocate choices proportionally may be important here, as a strict (non-representative) binary choice could be expected to lead to divergent implications. Regardless of the specification of the choice variable, the appearance of a unique subset of influential independent variables within the estimated utility functions for each alternative highlights important behaviour in relative preferences for each mode. This is supported through the inability to identify a significant sensitivity to service frequency for any mode within the study. While one may reasonably expect higher frequencies of departure to be of value, the choices of respondents were not sensitive to the range of service frequencies on offer. Hence, this indicates the presence of a multi-tiered choice calculus in which general frequencies of service (for example, high-frequency road freight, mid-frequency rail freight and low-frequency short sea freight) are considered in the allocation of cargo across modes, but where, conditional upon this choice, variations within general levels of frequency do not impact demand patterns. That is, respondents have indicated a preference for modes that include some critically high level of service frequency, without further significant sensitivities to different frequencies on either side of their perceived threshold value.

Chiefly, due to the potentially limited degree to which reasonable variations in attribute levels within modes may govern trade-offs across modes, respondents indicated an intuitive sensitivity to trade-offs between cost and key threshold effects for one or more level-of-service attributes. In the case of road freight, respondents indicated a significant sensitivity to the risk of delayed shipments, which are indicative of uncharacteristically low reliability for the mode. Conversely, for both rail and short sea freight, respondents indicated a significant sensitivity to the probability of shipments meeting narrow delivery windows, which is indicative of the potential to experience a high level of reliability within modes that may be viewed as less reliable or desirable than road freight, especially within time-sensitive applications. This relationship was more pronounced for allocations to rail freight, with coefficients of larger magnitude than for short sea, indicating a higher potential to influence rail freight activity with respect to reliability in achieving narrow delivery windows. Importantly, transit time was a significant attribute specifically within sensitivities for rail freight. That is, variations in transit time did impact allocations of freight to rail, while respondents indicated no such sensitivity to transit times in other modes. This indicates that there may be an important range of rail transit times that could impact the competitiveness of the mode, while no such range of transit times was revealed for road or short sea.

One last, key influential factor in sensitivities to allocations across modes was whether the trips in question represent a headhaul or backhaul trip. Specifically, demand for short sea shipping was significantly higher for backhaul trips (that is, positive coefficient for a dummy variable representing a backhaul trip). After accounting for the mode of transport and backhaul status of trips, no further contextual effects were found to influence modal sensitivities within the sample. While further investigation is being carried out to identify further relationships influencing demand patterns within the sample, these results indicate that inertia in demand patterns across modes is a key factor to consider when evaluating the potential to shift freight demand across modes, and that this may be a general relationship rather than being specific to constraints such as requirements relating to narrow delivery windows or the relative perishability of cargo.

Comparing the log-likelihood values found for the parameter estimates to the log-likelihood values found using only alternative-specific constants offers clear support of the statistical significance of the models. This is confirmed through the χ^2 test of the significance of two times the difference between the two log-likelihood values at eight degrees of freedom (that is, the additional number of parameters in the full model relative to the alternative-specific-constants only model), which is significant at the 99.999 per cent level. Comparisons of the log-likelihood, χ^2 and Akaike Information Criterion values between the MNL and mixed logit model indicate that the added complexity within the mixed logit model (that is, the specification of a distribution of preferences across respondents with respect to the freight rate) does not necessarily add substantially to the power of the model relative to the corresponding loss of parsimony. However, the presence of a significant distribution of preferences with respect to the freight rate and the general increase in *t*-ratios for attributes within the mixed logit model both offer support for the implications of the mixed logit model. That is, while the model fit statistics do not confirm that the relatively complex mixed logit model offers gains in explanatory power, the *t*-ratios for the coefficients in the mixed logit model tend to be larger than in the MNL model.

While it is encouraging to find significant drivers of choice propensities within the initial sample, it is critical to gauge whether these estimates are meaningful. By converting the estimates to WTP measures, we are able to confirm whether the initial model offers a useful first glance at the preferences within the sample. Table 3 summarises the conditional (that is, respondent-specific) WTP estimates calculated from the parameter estimates in Table 2.

As discussed above, rail was the only mode for which respondents indicated significant sensitivities to the range of transit times present in the survey. Hence, rail is the only mode for which we can calculate the value of transit time savings

Table 3: WTP estimates

Value of …	*WTP estimate – MNL*	*WTP estimate – Mixed logit*
Transit time savings – rail (mean)	A$23.09 per hour (A$554.25 per day)	A$25.03 per hour (A$600.65 per day)
Transit time savings – rail (standard deviation)	—	A$0.51 per hour (A$12.14 per day)
On-time Reliability gains – rail (mean)	A$220.48 per percentage point increase	A$247.69 per percentage point increase
On-time reliability gains – rail (standard deviation)	—	A$5.01 per percentage point increase
On-time reliability gains – short sea (mean)	A$188.44 per percentage point increase	A$213.86 per percentage point increase
On-time reliability gains – short sea (standard deviation)	—	A$4.32 per percentage point increase
Long delay reductions – road (mean)	A$234.37 per percentage point decrease	A$247.96 per percentage point decrease
Long delay reductions – road (standard deviation)	—	A$5.01 per percentage point decrease

(VTTS), estimated at a mean of A$25.03 per hour in the mixed logit model, compared with A$23.09 per hour in the MNL model. Not only does the specification of a distribution of sensitivities to the freight rate lead to an increase in the mean estimate of rail VTTS, but it also enables us to observe a small but significant distribution of rail VTTS, with a standard deviation of 51 cents per hour. Overall, this indicates the potential for rail transport providers to receive a small premium for services that offer faster door-to-door service than competing service offerings, with some variation in preferences for faster services across organisations. Furthermore, this indicates the potential for road and short sea services to capture some demand for rail freight by improving transit time such that the difference in transit times between the modes is sufficient to impact behaviour.

However, the largest potential to receive a considerable premium for improved level-of-service was indicated through preferences for gains in on-time reliability (that is, arrival within 3 hours of schedule) and reductions in the probability of long delays (that is, arrival more than 24 hours after schedule). For both rail and short sea shipping alternatives, respondents indicated a mean WTP of over A$200 per percentage point increase in on-time reliability (mean mixed logit estimates of A$247.69 and A$213.86 per percentage point increase for rail and short sea, respectively). For road freight, reductions in the risk of shipments arriving more than a day late were valued similarly, with the mixed logit model indicating a mean WTP of A$247.96 per percentage point decrease in delayed arrivals. Hence, while structural changes intended to increase revenue through demand for higher-speed service may require significant effort for moderate gains (that is, large efforts required to streamline door-to-door processes by a matter of hours, each of which is valued at approximately A$25, on average for rail), similar gains in revenue may be found through more targeted changes focused on improving reliability (that is, optimisation to increase efficiency without improvements in speed) by marginal amounts (that is, one to a few percentage points, each of which is valued at over A$200, on average). Ultimately, the relatively high importance placed on reliability in rail and short sea shipping indicates that competitiveness in these modes hinges critically on mitigating forces interfering with meeting narrow time windows at the destination. Likewise, the central role that reliability plays within the competitiveness of road freight is reflected in a high WTP to help ensure that shipments are not delayed excessively.

While we did not find route-specific differences, ongoing research will involve a search for route-specific variation in preferences, including an examination of differences in preferences for headhaul and backhaul services across O–D pairs.

One final related behaviour to investigate within the initial sample centres on preferences for integrated short sea shipping services. Respondents were asked to re-visit the first choice set in the survey instrument, and to indicate how their preferred allocation of cargo across the alternatives would change (if at all) if the short sea shipping alternatives included integrated, door-to-door service. A small increase in preferences for short sea alternatives was found in this case, with the mean allocation to short sea increasing from 27.2 per cent in the first choice set to 29.2 per cent when considering the first choice set again with the short sea alternatives offering integrated service (a relative increase of around 7.4 per cent). Interestingly, the presence of integrated service had a large, positive impact on domestic short sea services, with the mean allocation for Australian flag short sea service increasing from 12.7 to 17.9 per cent (a relative increase of around 41 per cent). This change represents a shift in demand away from non-short-sea and foreign flag short sea services, with demand for foreign flag services actually reducing from 14.5 to 11.3 per cent under the presence of integrated domestic and foreign flag short sea services. Ultimately, this indicates that domestic short sea providers may provide clear value above standard short sea transport, and hence could capture critical volumes of market share by placing a focus on integrated service.

Conclusions

Contribution to research

This research adds to the body of knowledge in maritime economics by examining the relative competitiveness of short sea shipping services in Australia.

Our analysis has confirmed the presence of meaningful trade-offs by shippers involving costs and perceived benefits of reducing transit time, improving on-time arrival reliability and mitigating the risk of long arrival delays. While respondents showed a general preference for established road and rail alternatives, they did identify value in obtaining increases in reliability within short sea services. Furthermore, respondents indicated interesting shifts in preferences across modal alternatives under the presence of integrated short sea shipping services. Importantly, this research places a specific focus on the role carbon pricing may play in the market in the near future, enabling tests of preferred service mixes along different Australian corridors under new cost structures impacted by carbon pricing.

This research also offers an appealing representation of reliability, allowing for the identification of unique preferences and WTP measures relating to both on-time reliability and mitigating risks of delays of 1 day or longer. This is an important contribution relative to freight studies that either ignore reliability altogether or use simplified, one-dimensional representations of reliability in settings where on-time reliability and long delay are functionally distinct drivers of service levels. The sum of these contributions expands our understanding of the degree to which short sea shipping services would be viable along Australian corridors with unique spatial, demand and expected level-of-service characteristics.

Methodologically, this research confirms the merit of using optimal experimental designs both in freight settings, in general, and in studies involving proportional choice variables, in particular. The model outputs generally had strong statistical significance and consistent behavioural implications throughout the exploratory modelling phase as new data were received. Under a standard orthogonal design, we would have expected weak statistical significance and potentially variable behavioural implications over much of the data collection process until a sufficiently large sample size was obtained. The role of the proportional choice variable was likewise essential in this study. Not only did the specification of a non-binary choice variable enable respondents to make behaviourally meaningful choices within the study, but the resulting choice models were also able to capture the presence of strong latent relative preferences for modal alternatives that may have been misrepresented through the use of a binary choice variable.

Implications for public policy and managerial practice

This study has illustrated that it is possible to evaluate the potential acceptance of a service not yet in the market through the use of discrete choice analysis. Furthermore, this study has illustrated the value of using WTP models in assessing the mode switching that may take place in the market if regulatory policy with respect to carbon pricing of transport options is imposed in future. Worldwide, those interested in the promotion of short sea shipping have, on philosophical grounds, argued that carbon pricing will induce switching without actually investigating whether this is likely to happen with existing purchasers of transport services, or if there are other factors that are at play, and the buyer is willing to pay more in the changed conditions. To use a simple example, the findings above, if put into a decision support system, indicate that a 1 per cent increase in the mean truck freight rate, due to either carbon pricing or congestion charging that are not imposed on the other modes, will result in only a 0.13 per cent decline in truck's share of the headhaul market and a 0.12 per cent decline in the back-haul market when considered at the sample mean. In the case of the headhaul market, rail acquires two-thirds of the change in share (with coastal shipping gaining one-third) but in the back-haul market they both benefit equally. Most important, the volume of traffic switching from truck, given the high preference for service frequency, is quite miniscule and implies that demand in this mode is not easily switched. This indicates that while this research provides the approach needed to evaluate proposed surcharges policy that planners might consider to induce modal switching, they may not get the effect they are seeking. The model we have developed here can be used for scenario assessment of proposed public policy tools like carbon pricing, but in the face of cargo interests committed to a particular choice, they may only provide guidance on the scale of change needed.

Given the choice of domestic or foreign flag, the research has demonstrated that the buyer of shipping services in this market will not necessarily support 'national flag' shipping through a WTP a premium price, but that the value of national flag shipping may well be tied to its ability to integrate services in the last mile, for example, in terms of meeting delivery windows and reliability requirements. This was observed through a lack of statistically significant influence on preferences for short sea alternatives with respect to the status of Australian-flag services, in concert with significant sensitivities to reliability measures. Given the current revisions planned for Australia's coastal shipping permitting regulations, this implies that public policy planners may wish to consider approaches that will assist coastal operators in integrating their services with land-based delivery in addition to any carbon pricing strategies.

In addition, this study has asked respondents for their likely allocation of business under varying circumstances. It specifically recognises that cargo allocation is a complex decision and that it is not an all-or-nothing game. By examining the issue in the context of 'splitting the business' activities by buyers, it more accurately reflects the market complexities than previous studies requiring all-or-nothing choices.

From a managerial practice perspective, this research has also demonstrated that there are WTP factors that can be exploited by rail transport providers that offer faster door-to-door service than competing service offerings and by shipping lines focusing on improvements to overall service by integrating last mile activities into the service offering. In other words, the preference for road transport has also been tied to the value placed on meeting delivery windows at the destination. For coastal shipping operators, close attention to headhaul versus backhaul markets can offer advantages in developing new services.

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