Australasian Transport Research Forum 2023 Proceedings
29 November – 1 December, Perth, Australia
Publication website: http://www.atrf.info

Uncovering the determinants of shippers' willingness to shift from road to rail freight transport

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Abstract

Traditionally, agri-food shippers have preferred road transport to move their commodities from the point of production to the point of consumption. However, road transport's environmental and economic impact have become increasingly apparent, especially following the just-ended COVID pandemic. As such, a growing interest in inducing a modal shift in the freight movement from road to rail freight has increased exponentially. This shift can potentially influence the existing modal split, as rail transport offers lower carbon emissions, reduced road congestion, and lower transportation costs. Various factors influence the mode choice decisions of freight shippers, and modellers consider these factors within the perceived utility these shippers are assumed to maximise. However, this perceived utility varies for different shippers, even for the same commodity type, resulting in shippers choosing different modes for different freight trips. In this study, we look at revealed modal shift choice behaviours by estimating a discrete choice model to understand the key factors that induce modal choice. The estimated mode choice model applies a revealed preference data of import and export movement to and from one of the major Australian ports. The model estimation results show that shipments' weight, distance, rail mode accessibility and monetary value are highly relevant to modal shift choices. Specifically, the higher the monetary value of commodities such as agricultural and livestock products, the less likely shippers will use rail. Moreover, distance, weight, and mode availability play a crucial role in the mode choice behaviour of shippers. For example, longer distance increases the likelihood of using rail compared to road, and heavier commodities such as coal products are more likely to be shipped by rail than by road.

Keywords: Revealed Preference data, Freight mode choice, import and export, Container movement, freight transportation

1. Introduction

Technological advancements and improved logistics practices have significantly changed global distribution channels in recent years. The rise of e-commerce, for example, has led to increased demand for parcel shipping and last-mile delivery services. At the same time, automation in distribution centres and warehouses has improved speed and efficiency in order fulfilment. As a result, freight transportation and movement have substantially increased worldwide. Regardless of these changes, road transport remains the dominant mode of freight transportation, representing more than 40% of tonne-kilometres transported globally. This

mode share is significantly larger than that of rail freight (24%), coastal shipping (16%), inland waterways (13%) and pipeline (7%), according to (OECD & International Transport Forum, 2022). In Australia, truck traffic is expected to surge by 25% over the next decade, primarily consisting of short-haul trips made up of truck trips less than full truckloads and increased empty runs coupled with smaller consignments(Transport and Infrastructure Council & Council of Australian Governments, 2019).

As the focus on reducing greenhouse gas emissions grows, there is an increasing need to shift freight transport to alternative modes with less or zero environmental externalities and move towards cost-effective door-to-door transport solutions to address climate change concerns. As such, there is a need to understand the behaviour of shippers concerning their mode choice between Road and Rail and investigate which policies would have a higher potential to induce modal shifts within the agri-food supply chains. In achieving this, governments worldwide have introduced policies and set goals to encourage modal shifts from Road to Rail. For example, the Australian Government aims to increase the share of rail freight at Port Botany by 28% (Government New South Wales, 2018).

Policies encouraging shippers to choose alternative freight transport modes must fulfil shippers' logistical requirements and fit into their supply chains. Policymakers must understand the underlying rationale behind these decisions to ensure that behaviour-sensitive policies are introduced. Shippers often prefer road transport due to its accessibility (Comi et al., 2014), speed and flexibility (Sakai et al., 2017), reliability (de Bok et al., 2022), and smaller consignments and irregular shipment size (Delle Donne et al., 2023). Although rail freight is cheaper per transported tonne-kilometre, the extra costs of loading and unloading and first and last-mile delivery often add costs to the shipper's logistics systems. Rail transport is often limited by routing and terminal location inaccessibility, lack of flexibility in scheduling, transhipment cost and risks (Ballis & Golias, 2001).

Furthermore, infrastructure capacity constraints, lengthy transit times and limited integration with other modes of transport often make it difficult for shippers to switch from Road to Rail (Rosell, Codina, and Montero, 2022). In Australia, the rail network is often not directly connected to the berth at the portside via an on-dock rail system design. Moreover, the freight rail services share infrastructure with the passenger rail services. As passenger services are often prioritised, freight services encounter delays and restricted schedules. This results in the freight rail being the least preferred transport mode for time-sensitive commodities such as agricultural products and foods.

The objective of this study is the in-depth analysis of the modal shift behaviour of shippers from a purely behavioural perspective by focusing on the actual choices of these shippers. To estimate modal shift potential, (Brogan et al., 2013) identified two approaches: market segmentation methods and mode choice models. Although market segmentation is widely used due to its simplicity, most researchers do not consider capacity constraints, diversification of real-world systems or the impact of modal shift policy interventions. To address these challenges, (Pani et al. 2021; Soto et al., 2021) adopted the market segmentation approach to study tailored incentives and policies to encourage sustainable transport choices.

Recent researchers have adopted mode choice models. Mode choice models survey individual shippers' preferences and help estimate model elasticities and predict modal shifts, often using discrete choice models, while offering more depth to policy analysis. Ma, Yu and Liu (2020a) utilised a nested logit model to model a joint travel mode considering travel time choice in

urban areas using disaggregate models. As with disaggregate freight modelling, this research was characterised by data imbalances, leaving out key variables. Building on existing nested logit models, Wen and Koppelman (2001) adopted the generalised nested logit model to provide higher flexibility in estimating substitution or cross-elasticity between alternatives in the mode choice decisions of shippers.

A few studies have looked at the freight mode shift in Australia, such as Ghaderi, Cahoon, and Nguyen (2015), who identified impediments to the modal shift from Road to Rail for non-bulk freight and cited the need for greater integration due to infrastructural inefficiencies in current rail transports. Wijeweera, To, and Charles (2014) corroborated this finding by showing that the availability and accessibility of alternative modes affect the choice of shippers' and how shippers respond to policies aimed at shifting mode choices. Schrobback, Irannezhad, and Prato (2023) found that only 30% of shippers were willing to shift from road to sea and that for shippers' the value of time was a key attribute for which they were willing to pay. Moreover, Brooks et al. (2012) looked at the interplay of tradeoffs that affected the decision-making process of shippers between land-based transport (Road and Rail) and coastal shipping and looked at the effect of introducing carbon pricing policies on the decision of shippers to shift mode.

These studies adopt Stated Preference (SP) Surveys to examine modal shift behaviour. However, whether these research findings mirror real-life decisions by shippers and receivers is still in question. Stated Preference (SP) data is affected by a lack of realism, subjective perception of the laboratory settings and abstractness of the choice simulation (Vacca et al., 2019) In countering this, researchers have adopted Revealed Preference (RP) data, which provides data on the actual observed decisions and choices of these Shippers in the past.

This study explores the mode choice behaviour of shippers by using data acquired from one of the significant Australian ports while exploring the factors that these shippers consider when making mode choice decisions. The utilisation of revealed preference data serves to mitigate inherent biases often associated with SP experiments. These biases encompass the participants' response burden, strategic response bias, and, notably, the divergence between SP participant's perceptions and the realities of an actual choice situation (Collins et al., 2012) Consequently, the participant's perceptions might deviate from real-life choice scenarios. They might not encompass all the factors influencing their behaviour in a genuine context.

Therefore, there is a pressing need to investigate and understand the behaviour of shippers towards policies aimed at increasing modal shifts, how these behaviours inform their mode choice decision and which attributes and factors within these policies could promote modal shift. Such information is essential for policymakers and other stakeholders in the freight transport industry. This study examines individual' shippers' behaviour regarding modal shift policies and identifies the factors influencing their decisions. As such, this research seeks to answer the following research questions:

1. How can freight mode decisions vary across shipment sizes, values, and commodity types?
2. How do various shippers behave towards policies aimed at increasing modal shifts?
3. What are the critical attributes that can promote modal shift?

This study tests the effects of several determinants of mode choice behaviour, such as distance, mode availability, weight, and AUD value of the commodity. It adopts a binary logit model,

and this study sought to understand the contribution of each factor in resulting in shippers preferring one mode to another.

As this paper is abridged, it is organised as follows: Chapter 2 provides a brief description of the data used, followed by the presentation of preliminary results and discussions of the model in section 3, then the future direction of the research is outlined in section 5 and conclusive remarks provided.

2. Data

In this study, we used Revealed Preference (RP) data of actual individual import and export container movements from/to one of the significant Australian ports collected in 2017. The data covers 43,560 individual freight movements, including commodity type, origin and destination postcode and timestamp, weight, shipment value (AUD), and transport mode.
The population studied in this study are importers and exporters who handled freight in 2017 from and to one of the major Australian ports. This port accounts for over $31.3 Billion of trade annually. One key goal of this port is to shift freight from Road to Rail by inducing a modal shift. As such, a study focused on understanding the mode choice behaviour of shippers utilising that port is relevant.

3. Model specification

3.1 Model for predicting the behaviour of shippers

In this study, we estimate a model to investigate the modal shift behaviour of shippers. For this research, we utilise a binary logit model under discrete choice methods to analyse the data as it better simulates the behaviour of shippers towards policy measures. As it is based on a probabilistic framework, it ensures a more realistic modelling of human behaviour than a deterministic model, as individuals often make choices with uncertainty and varying preferences (Cramer, 1999) The details of the multinomial logit models are well summarised in many sources, such as (Anas, 1981; Lee et al., 2018) The binary logit model estimates preferences for multiple attributes, such as cost, reliability, time, and sustainability, likely influencing shippers' modal choice decisions. We estimate mode choice models under the assumption that decision-makers are utility maximisers. The binary logit model is in the form:

$$P_n(i) = \frac{\exp(V_{in})}{\sum_{j=1}^{k} \exp(V_{jn})} \quad (1)$$

Where:
$P_n(i)$ = probability of shipper n choosing mode I,
V_{jn} = utility derived by individual n from mode j,
K = number of available modes of transportation

Hence, the utility by a shipper n from mode j, V_{jn}, is derived as a linear function of the explanatory variables as follows:

$$V_{jn} = \beta_{0j} + \beta_{1j}X_{1n} + \beta_{2j}X_{2n} + \cdots + \beta_{nj}X_{qn} \quad (2)$$

Where:
β_{0j} = Alternative Specific constant for mode j,
β_{1j} , β_{2j}, ….., β_{nj} = Coefficients associated with explanatory variables
X_{1j} , X_{2j}, ….., X_{nj} = Explanatory variables for shipper n
Q = number of explanatory variables included in the model

In designing mode choice models for freight movement, an extensive evaluation of the observed data and the efficiency of the whole model system is essential. The parameters reviewed for the modal choice behaviour of shippers were assessed as follows: Availability of mode (i.e., rail or road, or rail and road, rail only, road only), Distance from origin to destination, weight (commodity type * weight in tons), the AUD value of the freight (commodity type * Customs value AUD) of the commodity. The coefficients were estimated using the maximum likelihood estimation method, and only the statistically significant variables with a 95% confidence interval were kept in the model.

3.2. Results and discussion

The estimation results are presented in Table 1.

The literature suggests that rail is the least preferred mode choice for shippers (Tavasszy & de Jong, 2021). Estimating an alternative specific constant for rail corroborates this with a negative value of -13.7, which captures the unknown and unobserved variables contributing to lowering the likelihood of choosing rail. Distance for many shippers is a crucial factor considered when choosing a mode. This model considers the natural log of the distance from the place of origin to the destination to improve the model's performance by reducing the influence of extreme values and making the relationship between variables more interpretable (Greene, 2009). The results indicate that the longer the distance, the higher the probability that shippers will use rail.

In choosing between rail and road, the value of the commodity plays a significant role in positively influencing the mode choice; for agricultural, forestry and livestock products with a low shipment value, shippers can choose to ship by rail as a loss in these products does not result in high loss. For commodities with high shipment value, such as household items and machinery, shippers most likely prefer roads for shipping these commodities. Sakai et al. (2017) corroborate these findings by pointing out that safety and reliability are essential in mode choice decisions for many shippers. Shippers are far more likely to choose modes perceived as safe for high-value shipments.

Moreover, the weight of the commodity shows a statistically significant influence on the mode choice. For commodities such as food, dairy, fruit, and beverages, increasing the shipment size increases the likelihood of using rail, as the coefficient was estimated as 0.0538 with a highly significant robust t-test value of 7.57, which corroborates the findings of Delle Donne et al. (2023), who iterated the convenience of road transport for freight with smaller consignments and irregular shipment size.

Finally, the significance of rail mode accessibility is shown to significantly affect the choice of these shippers with a positive coefficient of 9.45, corroborating the findings of (Comi et al., 2014), who highlight the need for infrastructural development and alternative mode subsidies to increase the mode share of environmentally safe modes such as rail.

For all models, the empty container (Com10) variable was excluded as it resulted in insignificant results. Freight value for mining, coal, limestone, metallic ores, nonmetallic minerals (Com2), Metallic and machinery products, primary and fabricated metal products, electronics, electrical machinery, transport equipment (Com3), Light industrial products, textiles, leather (Com5), food, dairy, fruit, beverages, tobacco, seafood (Com7) were excluded as its results were insignificant. For freight weight estimations, the results for Agricultural, forestry, fishery and livestock products (Com1), Metallic and machinery products, primary and

fabricated metal products, electronics, electrical machinery, transport equipment (Com3), Wood and paper products, lumber or wood products, pulp, paper or allied products, printed matter (Com6)and Coal products, rubber or plastic products, clay, concrete, glass, and stone products were insignificant and as such were removed.

Table 1: The Binary mode choice estimation

		Freight Value			Freight weight		
	Variables	Value	Rob. Std. err	Rob p-value	Value	Rob. Std. err	Rob p-value
Commodity type	Agricultural products	10.30	1.05	0.00	0.02	0.01	0.00
	Mining	0.00	0.00	0.00	0.00	0.02	0.01
	machinery products	0.00	0.00	0.00	0.00	0.00	0.00
	chemical products	-2.89	0.71	0.00	0.07	0.07	0.01
	textiles	0.00	0.00	0.00	0.04	0.01	0.00
	craft products	-15.6	4.40	0.00	0.05	0.01	0.00
	perishable food	0.00	0.00	0.00	0.00	0.01	0.00
	Household materials	0.95	0.18	0.00	0.00	0.00	0.00
	construction materials	-3.94	0.91	0.00	0.07	0.01	0.00
Variable	Alternative Specific constant_rail	-13.70	1.57	0.00			
	Distance	0.36	0.04	0.00			
	Rail mode accessibility	9.45	1.56	0.00			
Statistics	No of parameters	14					
	Final log likelihood	-2680.88					
	Akaike Information Criterion	5389.77					
	Bayesian Information Criterion	5508.19					

4. Conclusion & future direction of research

The fundamental goal of this abridged paper is to provide preliminary results to a modal shift behaviour model, which is aimed at providing beneficial information to policymakers and transport planners. The proposed model shows that inducing modal shift needs a closer look at several key factors as it is receptive to several parameters. Consequently, these parameters can be used to estimate the impact of changes in these features or to analyse how particular policy changes affect modal shifts.

A lack of alternate mode choices, such as rail, was a considerable deterrent to shippers shifting from Road to Rail. Moving forward, there is a pressing need for transport planners to invest in improving rail infrastructure and services. This will significantly improve the mode share of rail transport. Moreover, the safety and reliability of rail services are a pressing concern for many shippers, especially high-value goods. To induce modal shifts, improving the dependability and safety associated with rail freight movement by providing real-time tracking services and visibility is critical to increasing rail share.

To conclude, the result of this research serves as a steppingstone for future research into modal shift and policies introduced to induce modal shift. It is suitable as an analytical foundation for modelling the mode choice behaviour of shippers and informing policymakers in making behaviour-sensitive policies successful at inducing modal shifts.

5. Future research

This present research is being expanded in several ways. Firstly, it looks at the mode choice behaviour of shippers in response to the introduction of hypothetical new modal shift policies, specifically:

i. Heavy truck tolls and pricing (HTTP) with fossil fuel taxation (FT),
ii. Marginal tax on CO2 emissions (MTCE),
iii. Subsidising or reducing rail prices (RRP) and Improving Rail Service Quality (IRSQ)

These policies will be presented to the shippers to consider their preferences under different scenarios, as they are responsible for choosing how and when goods will be shipped. The responses provided by these businesses will allow us to calculate how many and which of them would be willing to shift their mode of choice due to these policies.

Also, to effectively formulate and implement such policies, gathering comprehensive behavioural insights, often acquired through surveys based on Stated Preference (SP) choice experiments, is crucial. To this effect, this research aims to design an individual-specific choice experiment aimed at agri-food import and export firms. This individual-specific choice experiment will be based on the historical choices of these respondents gained from Revealed Preference Data. This is aimed at providing more realism to our survey results.

Finally, future studies based on this model will consider the effect of multimodal choices apart from Road and Rail to encompass sea transport. It can also consider inter-mode transport for different legs of the freight journey as, most often, shippers use different modes for different transport legs.

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