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# An empirical analysis of mode and route choice for international freight transport in Ireland

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# An empirical analysis of mode and route choice for international freight transport in Ireland

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## Abstract

In this paper we analyse the transport mode and route preferences of Irish manufacturers/exporters when shipping goods to Continental Europe. We use an efficient discrete choice experiment to model the impact of various transport attributes on the final Irish manufacturers' choice of shipping mode/route. In particular, we consider the decision to be made between two routes; one in which goods are shipped to the continent via the UK landbridge and the other in which goods are shipped direct to the continent without UK passage. Generally, these two routes are associated with contrasting levels of service in terms of reliability. The degree to which exporters are willing to make trade-offs in terms of variation in service attribute is of particular interest in this study, as it is envisaged that increased congestion and emissions levies within the UK are likely to reduce the competitiveness of the UK landbridge option, and increase demand on the direct service route. Results from this study contribute to the understanding of the demand for international freight transport services in Ireland to continental Europe and will assist in estimating the potential impact of road-freight taxation on the logistics competitiveness of the export sector in Ireland.

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Author Contact Details: Benjamin Breen, SEMRU, NUI Galway, Email: benjamin.breen@nuigalway.ie

## 1. Introduction and motivation

In recent years, the significance of the road-freight transport industry for traffic congestion and environmental sustainability has been increasingly highlighted [1,2]. Environmentally, increasing public and political awareness of the link between climate change and human consumption of fossil fuels has increased pressure on governments to pursue policies that reduce CO2 emissions nationally and internationally [3,4]. Ideally, civilisation could reduce fossil fuel usage through the development of cheaper, less polluting alternative forms of energy production. While this is to some extent occurring [5,6], society is a long way from developing alternative energy sources that will replace fossil fuels to the extent required to sufficiently reduce CO2 emissions [7,8]. As a result, governments often employ forms of fossil fuel taxation, which naturally has a severe impact on fuel intensive sectors such as the road-freight transport industry. The issue of traffic congestion, while less controversial, is nonetheless problematic for municipalities and leads to slower travel speeds, longer trip times and increased vehicular queuing. While a host of solutions to overcome traffic congestion exist, taxation is also relied upon as a primary combative measure [9]. While such measures may be effective in reducing traffic-congestion and CO2 emissions, they nevertheless increase the cost of distributing manufactured inputs and outputs, which has knock on effects for economic activity [10].

In Ireland, the road haulage industry was made up of 77,000 registered good vehicles in 2013 which were responsible for transporting 109 million tonnes in goods, travelling 1.26 billion kilometres to do so [11]. The dedicated heavy goods vehicle (HGV) component of the sector (that is vehicles with an unladen weight of at least 10 tonnes) accounted for 20.7 % of registered vehicles but was responsible for 88.5% of total activity in terms of tonne-km [11]. It is these latter operators that provide the bulk of product distribution services to Irish manufacturers, both exporters and importers, and whom are most significantly impacted by congestion and carbon emissions taxation.

In April 2014, the UK government introduced a road user charge for HGVs for the use of its road network. This is a road user charge of up to £1,000 a year or £10 a day and applies to lorries weighing more than 12 tonnes using UK roads. UK-registered

HGVs will pay the road user charge for the same period and in the same transaction as they pay for vehicle excise duty (VED i.e Motor Tax). Foreign-registered vehicles can pay the charge either daily, weekly, monthly or annually. There are associated reductions for UK-registered HGVs in the amount of VED that is payable. This is intended to mean that the vast majority of UK-based hauliers will pay no more than at present (Department for Transport, 2014).

Given increasing road-freight costs arising out of increased congestion and emissions taxation, the issue of transport route and mode substitutability becomes an increasingly important factor. This is especially true for Ireland, an island nation with a strong exporting presence with the rest of Europe. A significant quantity of Irish road freight to and from continental Europe transits between core distribution hubs such as the Netherlands, Belgium and West Germany [12]. The vast majority of this cargo ships through UK landbridge via RoRo shipments [12]. This transport mode minimises the transport distance made up of time at sea, and primarily relies on UK road infrastructure and the availability of frequent crossings between Ireland and the UK and the UK and continental Europe. However, as road-freight costs increase, services providers may be compelled to increasingly seek less road-reliant transport options when shipping goods to and from continental Europe, specifically, through the use of direct shipments between Ireland and Continental Europe. While doing so may potentially reduce shipment costs, there are other service attributes about which service consumers are concerned. In today's global world, where manufacturing processes are international and manufactured inputs and raw materials must arrive according to strict deadlines, factors such as frequency, transit time, delivery reliability and cargo damage are of key concern. Key questions arise. For example, what is the capacity of the Irish port infrastructure and is it sufficient to provide realistic alternatives to the UK landbridge transport mode and route? If not, is the development of such infrastructure economically viable? Which would be the funding mechanisms? What are the likely changes in service attributes (such as price, transit time and reliability) if hauliers increasingly offer alternative modes and routes of shipment to their customers? Finally, how are these customers, those shipping goods into and out of Ireland, likely to respond changes in these key attributes? It is this latter question we are concerned with in this study, specifically, we want to investigate the exporter's willingness to accept (WtA) and willingness to pay (WtP) in response to changes in the attributes considered in the study

As pointed out by some authors [13,14], the modelling for freight transport demand has evolved significantly over the last few decades, from the use of aggregate models based on global data of shippers and shipments, to the use of more sophisticated disaggregated models based on individual data. A shift in focus to behavioural models that analyse service demand has occurred rapidly in the passenger transport literature and to a lesser extent in the freight-transport literature given the challenging nature of data collection in this field [14]. The use of stated preference (SP) techniques makes up a good number of these recent studies. This paper makes particular use of the approach of [14] in order to estimate a discrete choice model the can be used to determine the elasticity of demand for alternative freight transport routes between Ireland and continental Europe.

This paper presents preliminary results from a stated preference survey of Irish exporters based on an efficient discrete choice experiment. We analyse Irish exporters' preferences for the attributes of the alternative transport modes and routes, namely, the UK landbridge route versus the direct route to Continental Europe.

Through this approach, we attempt to understand the responsiveness of Irish exporter choices to the changes in key freight-transport attributes and from this information, to understand the willingness of Irish exporters to tolerate some of the less competitive features of direct shipping services to Continental Europe given the superior costs structure of that mode to the UK landbridge option.

This research contributes to the literature on freight transport demand analysis and represents a tool for informing policy initiatives, commercial opportunities and the necessary infrastructural investment needed to tailor Irish maritime freight transport services to the needs of its users, in this case, the exporters.

## 2. Data, experimental design and fieldwork

This study is concerned with the analysis of the demand for international maritime freight transport services in Ireland. The aim of the research is to obtain empirical evidence of on the determinants of mode and route choice between the two alternatives: “use of the UK landbridge” and “use of a direct route” on maritime freight export shipments from Ireland to Northern continental Europe –France, Belgium, The Netherlands and Germany. The population under study is Irish exporters that use or have used in the past the UK landbridge to ship their goods to the above European destinations. The population was also narrowed by ruling refrigerated shipments out of the sample since these have very different timeline requirements and costs, and would not be comparable to the rest of the sample. As earlier noted, this route accounts for 90% of ro/ro freight movements with Continental Europe.

One of the main critical issues in freight transport modelling is to identify the decision maker, whether this is the shipper, the freight forwarder or the transport service provider. In our case of study, a reasonable argument can be made that it is road hauliers and freight forwarders that ultimately make the decision of transport route and mode [15]. However, in recent years, rising fuel costs, taxation and the highly competitive nature of the sector have reduced margins in the freight-transport sector. As a result, it is likely that continually rising costs will begin to be shifted onto exporting customers. As the impact of changes in service attributes start to be felt by Irish manufacturers, their preferences and attitudes become increasingly important to consider given that they end up conditioning the route finally chosen by the transport provider. Moreover, by surveying exporters themselves a larger sample size is possible.

The data used in the estimation process were provided by exporters of non-refrigerated goods to Northern Europe. Specifically, the preliminary results presented in this paper are the result of 18 face-to-face interviews across Ireland, providing a total of 180 observations.

The surveying method took the form of personally organised interviews with a professional in each company’s logistic or supply chain department in charge of managing the transport shipments. Interviews ran for approximately 20 minutes using a laptop. The survey participant was guided through the survey questions, which were displayed in Qualtrics online survey software. Each surveyed company provided information about their representative consignment shipped to Continental Europe through the UK landbridge. Companies were selected by a simple random sample provided by a number of organisations including the Irish Exporters Association and Enterprise Ireland.

The questionnaire was structured into four sections:

- A first section was designed to obtain general information about the characteristics of the company and its logistic dimension;
- A second section was designed to collect information on the characteristics of the reference shipment in terms of the key attributes defined for the study.
- A third section included questions to determine the importance of the attributes defining the transport service, as well as the level of quality perceived;
- A fourth section involved the collection of the decision-maker's preferences in an SP experiment.

In-depth interviews were carried out with exporters and freight transport service providers to understand the current composition of the transport demand and supply in the transport corridors under study. This provided the research team with information to identify the main service attributes and the initial service attribute levels to be presented to participants in the choice experiments. Attributes and levels considered in the SP choice experiment are in Table 1.

Table 1: Attributes and levels considered in the SP choice experiment

| Attribute | Definition and unit | Alternative A (Landridge UK) | Alternative B (Direct) |
|---|---|---|---|
| **Cost** | ▪ Cost of the IRL port - EU port transport section<br>▪ Euros/Shipment | Catalogue of 30 possible cost levels | -30%, -20%, -10%, +10% |
| **Transit time** | ▪ Transit time between the IRL port and the EU port<br>▪ Hours | 16 | +8 hrs, +20 hrs, +32 hrs |
| **Probability of delays** | ▪ Probability of suffering a significant delay.<br>▪ Percentage | 5 | -2 percentile points, current level, +2 percentile points |
| **Delays duration** | ▪ Hours of delay with respect to the initially agreed delivery time. | 5 | - 2 hrs, current level, + 5 hrs |
| **Service frequency** | ▪ Waiting hours with respect to the preferred departure hour. | 4 | +8 hrs, +20 hrs, +32 hrs |

The data collection regarding the SP choice experiment was carried out in two phases. First, two pilot exercises were conducted for a sample of 15 companies, which allowed for the estimation of preliminary models to obtain parameter priors required in the construction of the final choice experiment. Providing as much realism as possible for the respondent was a source of concern in the experimental design phase. To achieve this, the Cost variable is selected from a catalogue of 30 possible cost levels according to the actual cost reported by the interviewee. This resulted in 30 individual choice experiments being constructed for the study. N-gene software (ChoiceMetrics, 2009) was used to build the efficient designs for a multinomial logit specification. With regard to the levels used for the level of service attributes, these are kept fixed for all shipments. Based on the information obtained from the two pilot exercises and the in-depth interviews with exporters and freight transport service providers, it was found that there was a similarity in the levels of service offered by the various landbridge transport providers along the corridor under study. Therefore, the level of cost is the only attribute that varies across respondents in the SP experiment.

This efficient design approach is based on the idea of minimising the determinant of the asymptotic variance–covariance (AVC) matrix of models estimated on data collected using the designs. This is essentially a way of minimising the standard errors in the model, therefore obtaining more reliable parameter estimates. A popular format for this approach is to minimise the D-error, i.e. the asymptotic variance matrix which is based on the second derivatives of the log-likelihood function. One of the major advantages of the D- efficient design is that it allows analysts to attain more reliable estimates in the face of a small sample size [15].

During the second phase of the SP choice experiment, currently underway, a web-based survey exercise is being carried out by the research team. Respondents are presented with 12 choice scenarios, with a binary choice to be made by the survey participant in each case. Alternative “A” reflects the company’s current transport choice in terms of mode/route (use of the UK landbridge) and Alternative “B” reflects the transport mode/route corresponding to the use of a direct route. Because alternatives are unlabelled during the choice experiment, respondents are not made aware that they are selecting an alternative consistent with the UK landbrige (“A”) or the direct shipping to Europe (“B”). This paper presents the preliminary results from this second phase.

## 3. Methodology

Discrete choice models provide a useful analytical capacity in situations where individuals choose between a set of mutually exclusive, exhaustive and finite alternatives [16] such as those companies face in shipment decision making. They are usually developed in a random utility model (RUM) framework in which utility, though unobservable, is assumed to be maximised by the choices that individuals make, each potential alternative having a positive, negative or zero implication for an individual’s utility. For individual $n$, faced with a set of $J$ alternatives, the analyst can specify,

$$j \in U_{nj} \subseteq U, j = 1, \ldots, J.$$

where $j$ is a specific alternative, $U_{nj}$ is the utility derived from the $n^{th}$ individuals choice $j$, and $U$ is the utility derived from the universal set of alternatives. As there are aspects of individual $n$'s utility which is unobservable, the utility of individual $n$ from choosing alternative $j \in U_{nj}$ is defined,

$$U_{njt} = V_{njt} + \varepsilon_{njt}$$

where $V_{njt}$ is the observable part of $U_{njt}$ at time $t$ and $\varepsilon_{njt}$ represents the unobservable component of $U_{njt}$, i.e., these terms represent the systematic and stochastic components of $U_{njt}$ respectively. The analyst then assumes any individual chooses the alternative with the highest connoted utility, that is, individual $n$ chooses alternative $i \in U_{nj}$ if and only if,

$$U_{nit} > U_{njt} \forall j \neq i$$

The joint density of the random vector $\varepsilon_n = \{\varepsilon_n 1, \dots, \varepsilon_n J\}$ is written $f(\varepsilon_n)$. This description of the stochastic component of utility allows one to make probability statements about an individual's prospective choices. Thus the probability that individual $n$ chooses alternative $i$ at time $t$ can be written,

$$P_{nit} = Prob(U_{nit} > U_{njt} \forall j \neq i)$$

$$= Prob(V_{nit} + \varepsilon_{nit} > V_{njt} + \varepsilon_{njt} \forall j \neq i)$$

$$= Prob(\varepsilon_{njt} + \varepsilon_{nit} < V_{nit} + V_{nit} \forall j \neq i).$$

As the probability that each random term $\varepsilon_{njt} - \varepsilon_{nit}$ is below the observed quantity $V_{nit} - V_{njt}$, the distribution can be described as cumulative, and given the density $f(\varepsilon_n)$, it can be written as:

$$P_{ni} = Prob\left(\varepsilon_{njt} - \varepsilon_{nit} < V_{nit} - V_{njt}\right)$$

$$= \int_{\varepsilon} I(\varepsilon_{njt} - \varepsilon_{nit} < V_{nit} - V_{njt}) f(\varepsilon_{nt}) d\varepsilon_{nt}$$

where $I(.)$ is the indicator function equal to 1 when the expression in parenthesis is true, and 0 otherwise. This representation of the cumulative probability distribution is a multidimensional integral over the density of the unobserved portion of utility, $f(\varepsilon_{nt})$. The specification of the probability distribution can be altered by making different assumptions about the distribution of the unobservable component of utility, which in turn leads to different types of discrete choice models. The specification and underlying assumptions about the distribution are of critical importance, because they influence the means by which the probability that individual $n$ will choose alternative $i$ is calculated, and therefore the accuracy of the analyst's predictions.

Discrete choice models that arise from different assumptions about the probability distribution include the multinomial logit, nested logit, mixed logit, and probit. All of these models are suited to different real world applications. With respect to the multinomial logit, there is a closed form solution, due to the fact that one of the core assumptions of the model is that the unobserved portion of utility is independently and identically distributed (iid). This contrasts starkly with the probit for example, where $f(.)$, is assumed multivariate normal, or the mixed logit, where one assumes the unobserved portion of utility comprises a part that follows any distribution that the analyst wishes and a part that is iid extreme value. This means that for both of these specifications, the integral has no closed form solution and is evaluated numerically through simulation. The best choice of assumptions about the probability distribution, i.e. the best discrete choice model to be used in a particular case, depends upon the physical circumstances of the system being analysed.

## 4. Preliminary estimation results

This study presents preliminary results from a number of discrete choice models estimated using the data obtained from the discrete choice experiment [1][17]. The objective is to analyse the importance of the identified service attributes on the final transport mode/route choices made by Irish exporters. Under the assumption of linear utility, the following model is estimated:

[1] Version 2.3 of BIOGEME (Bierlaire's Optimistion Toolbox for General Extreme Value Model estimation) was used in the estimation process.

$$U_{landbridge,n} = \beta_1 COST_{landbridge,n} + \beta_2 TIME_{landbridge} + \beta_3 DELM_{landbridge} + \beta_4 DELP_{landbridge} + \beta_5 WAIT_{landbridge} + \mu_n + \varepsilon_{landbridge,n}$$

$$U_{direct,n} = \beta_1 COST_{direct,n} + \beta_2 TIME_{direct} + \beta_3 DELM_{direct} + \beta_4 DELP_{direct} + \beta_5 WAIT_{direct} + \varepsilon_{direct,n}$$

where $U_{landbridge,n}$ *and* $U_{direct,n}$ represent the utilities of using the UK landbridge and the direct option respectively. Preliminary estimation results for model MNL1 show the expected sign for attributes COST (transport cost), TIME (transit time), DELM (Delay Duration) and WAIT (service frequency). Previous research has suggested that the service reliability variables in terms of delays/punctuality may be difficult to estimate [18]. For this reason, the discrete choice experiment was designed to collect data for two variables measuring reliability. The first variable is defined in terms of percentage (DELP: Variation (%) with respect to the level of average delay offered by the reference alternative) and the second variable is defined in terms of magnitude (DELM: Hours of delay with respect to the agreed delivery time). Results from the preliminary models show a counterintuitive sign for DELP, although not significant. In turn, the DELM variable shows a negative sign, which is consistent with the general perception of the impact of this variable. According to our preliminary results, companies included in our sample will only be valuing the magnitude of the delays, while the percentage of shipments affected by those delays would be of low importance. Preliminary estimation results are presented in Table 2.

Table 2: Preliminary estimation results

| ***Attributes*** | ***Estimate (t-test)*** | | | | | |
|---|---|---|---|---|---|---|
| | ***MNL1*** | | ***MNL2*** | | ***MNL3*** | |
| *ASC_LB* | *-1.69* | *(-1.24)* | *-2.01* | *(-1.46)* | *-1.72* | *(-1.26)* |
| COST | -0.00387 | (-5.51) | -0.00423 | (-6.06) | -0.00397 | (-6.2) |
| DELM | -0.255 | (-2.84) | -0.276 | (-3.16) | -0.254 | (-2.82) |
| *DELP* | *0.0752* | *(0.46)* | *0.557* | *(0.86)* | - | - |
| TIME | -0.0919 | (-2.44) | -0.0989 | (-2.62) | -0.0912 | (-2.43) |
| WAIT | -0.0835 | (-2.42) | -0.120 | (-2.92) | -0.0846 | (-2.45) |
| CO_COST | - | - | 0.000147 | (0.35) | - | - |
| CO_DELM | - | - | -0.0452 | (-0.29) | - | - |
| CO_DELP | - | - | -0.546 | (-0.81) | - | - |
| CO_TIME | - | - | -0.833 | (-11.81) | -0.817 | (-12.85) |
| CO_WAIT | - | - | 0.0369 | (1.51) | - | - |
| Nº OBS: | 180 | | 180 | | 180 | |
| R-ADJ: | 0.287 | | 0.267 | | 0.34 | |
| LOG-LIK | -83.004 | | -80.413 | | -84.86 | |
| Nº PARAMETERS | 6 | | 7 | | 6 | |

A second model is estimated (MNL2) as a soft cut-offs model (Swait, 2001), which allows for changes in the marginal utility above stated thresholds by introducing a fictitious variable for each of the attributes that takes the value of the difference between the proposed level of service and the cut-off if this value is greater than zero (the cut-off is violated) and null value if the difference is less than zero (we are below the cut-off). For the Transit Time variable, both the coefficients of the attribute and the cut-off are significant. Thus a third MNL (MNL3) model is estimated considering only significant variables. The absolute value of the cut-off parameter is over four times larger than the one obtained for the attribute parameter, which suggests that when the upper limit is reached for Alternative A (land bridge), additional increases in Transit Time are strongly penalised.

Table 3 displays the variations in the probability of choosing the direct option when faced with own and cross variations in the levels of service. According to our preliminary results, measures acting on prices are among the most effective in terms of a shift from the UK landbridge route to the direct option. There is a higher sensitivity of the direct option demand to deteriorations in the cost of the current transport alternative than to additional improvements in the cost competitiveness of direct services. For the remaining attributes, the opposite pattern is observed: the direct option probability being more sensitive to improvements in its own level of service than to deterioration in the landbridge route. Therefore, the implications for increasing road freight taxation in UK suggest that direct services from Ireland to continental Europe should increase their level of service in terms of delivery time, frequency and reliability to safeguard the competitiveness of Irish exports.

In addition to the collection of more data points, further research is needed to complete the analysis, which will provide information regarding the final sign of attribute coefficients, random taste heterogeneity and systematic taste variation. This will allow for the application of the model results into the calculation of elasticities of demand and estimates of willingness to pay.

Table 3: Variations in the probability of choosing the direct option (MNL3)

| **VARIATIONS IN THE PROBABILITY OF CHOOSING THE DIRECT OPTION** | |
|---|---|
| **UK LANDBRIDGE** | |
| Transport cost +1% | 0.589 |
| Transit time +1% | 0.102 |
| Delays duration +1% | 0.088 |
| Waiting time +1% | 0.023 |
| **DIRECT OPTION** | |
| Transport cost -1% | 0.442 |
| Transit time -1% | 0.226 |
| Delays duration -1% | 0.117 |

| | |
|---|---|
| Waiting time -1% | 0.135 |

## 5. Conclusions and further work

This paper uses experimental design techniques and discrete choice analysis to understand the responsiveness of Irish exporters to changes in key freight-transport attributes. In particular, the paper addresses Irish exporters’ preferences towards the less competitive features of direct shipping services to Continental Europe, given the superior costs structure of that mode, to the UK landbridge alternative.

In-depth interviews were carried out with exporters and freight transport service providers to understand the current composition of the transport demand and supply in the transport corridors under study. This provided the research team with information to identify the main service attributes and the initial service attribute levels to be presented to participants in the choice experiments.

Preliminary results show that the sensitivity to deteriorations in transport cost is higher for the UK landbridge transport alternative relative to additional improvements in the cost competitiveness of direct services. In contrast, the opposite pattern is observed for level-of-service attributes, where the direct option is more sensitive to improvements in its own level of service than to the deterioration in the level of service of the UK landbridge route.

The survey field work is ongoing and it will not be until completion of this work that full results can be reported.

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