Mode and Carrier Choice in the Quebec City - Windsor Corridor: A Random Parameters Approach

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Paper presented at:

The 6th Triennal Symposium on Transportation Analysis (TRISTAN VI)
10-15 June 2007
Phuket Island, Thailand

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Abstract

The Quebec City-Windsor corridor is the busiest and most important trade and transportation corridor in Canada. The transportation sector is the second largest contributor to greenhouse gas (GHG) emissions in the country. Governments around the world, including Canada, are considering increased mode share by rail as a way to reduce transportation emissions. Evaluating the potential of freight mode shift as a means to reduce transportation emissions requires rigorous analytical models that can predict the effect of government policy on mode split.

This paper presents the findings of a random parameters mixed-logit model of shipper carrier choice in the Quebec City-Windsor Corridor. The model itself was developed using the results of a stated preference survey undertaken in the fall of 2005. The survey was designed explicitly to evaluate shipper preferences for the carriage of intercity consignments, and particularly for their preferences for carriers that contract the services of rail companies to carry these shipments via rail. A fixed parameters approach suggests that shippers are very mistrustful of using rail to move their consignments and suggests that increasing rail's share of freight faces tremendous challenges. This result is not entirely consistent with shipper interviews conducted during survey development that suggested some shippers might prefer rail for environmental-public relations reasons. A random-parameters approach was adopted to test whether preference variation across respondents would be able to explain this inconsistency. This random-parameter analysis suggests that there is some variation in shippers' preferences for the use of intermodal transportation. In particular, the model suggests that for 20% of shippers, knowledge of a carrier's use of rail has a positive effect. This appears to be the first attempt at a random parameter approach in the freight choice literature.

1 Introduction

Canada, like many countries, is searching for ways to decrease its greenhouse gas (GHG) emissions. One method considered to reduce them in freight transportation is to increase the proportion of freight transported by rail rather than road. Evaluating the potential for government policy to be used to move more freight to rail requires realistic analytical and empirical models of mode choice. This paper describes a random-parameters model using a mixed-logit formulation of carrier choice using a stated preference dataset of shippers in the Quebec City - Windsor Corridor of Canada.

It begins with background information on the transportation sector in Canada, its contribution to overall GHG emissions, and some information on intermodal freight transportation in Canada. A literature review of mode choice modeling is followed by a description of the development and design of the SP study. Afterwards, the main results of the survey, including a description of the shipper choice model are presented and concluding remarks made.

2 Freight CO_2 Emissions in Canada

The transportation sector is the second largest GHG-contributing source in Canada, producing around a quarter of all emissions. Freight's GHG contribution stands at around 10% of overall Canadian emissions, with road freight making up more than half of these emissions and rail freight around 10%. At the same time road freight's contribution to emissions is increasing while rail's contribution has been declining. Measured in tonne-kilometres (t-km), road climbed from 24% to 37% of landbased freight mode share between 1990 and 2003 (Transport Canada (2004)). Also road transportation is thirteen times less GHG efficient than rail, with road GHG emission intensity in 2000 being 264 grams CO_2 equivalent per tonne-kilometre shipped, compared to 20 for rail (Environment Canada (2004)).

3 The Quebec City - Windsor Corridor

The Quebec City-Windsor corridor (hereafter referred to as 'the Corridor') is the strip (more or less 100-kilometre-wide) that hugs the Canada-United States border for roughly 1,100 kilometres between Quebec City, Quebec and Windsor, Ontario (see Fig. 1).

Quebec and Ontario are the two most populous provinces of Canada containing roughly half its population. The Corridor is home to 85 percent of the populations of Quebec and Ontario, and the location of 3 of the 4 largest Canadian cities. It is also the industrial heartland of the country (Environment Canada (2002)). Due to this concentration of industry and population, it is the busiest and most important trade and transportation corridor in Canada.

The Montreal-Toronto section forms the busiest segment of the Corridor. Along this corridor by 1997 road had captured 65% of freight tonnage com-

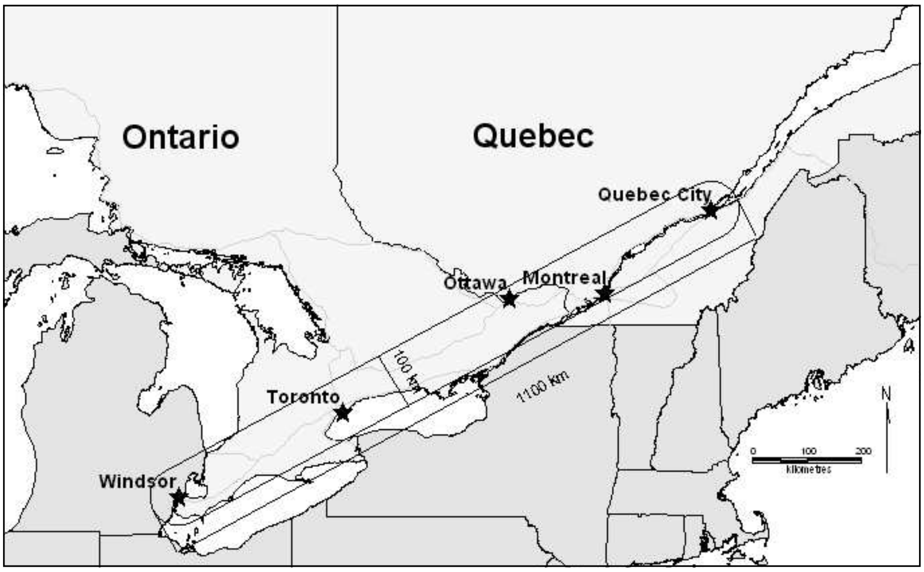


Figure 1: The Quebec City Windsor Corridor

pared to rail's 35%, a much higher share than in the country as a whole, and up from 60% in 1990 (Delcan Corporation and A.K. Socio-Technical Consultants (1999)). The importance of this corridor for transportation and its domination by trucking has important implications for understanding the potential to increase rail mode-share and reduce freight emissions both in this corridor and the country as a whole.

4 Premium-intermodal

The focus of this research was intermodal transportation that could compete directly with truck-only freight transportation in the Corridor. Premium-TOFC was the only competitive intermodal configuration. It refers to railway service configurations that prioritize on-time reliability (through scheduled services and short loading and unloading times), minimize damage risk (through the use of smooth-ride technologies), and provide service schedules that allow carriers to provide the same services to their clients as truck-only services (Canadian National Railway (2000) and Canadian Pacific Railway (2004)).

These services are referred to as premium-TOFC because they both involve carrying truck trailers as opposed to marine or domestic containers. Both Canadian National Railway (CN) and Canadian Pacific Railway (CP) introduced premium-TOFC services in the Corridor at the turn of the 21st century. Service has been provided between various combinations of the main Corridor destinations (Chicago, Montreal, Toronto and Windsor), but has been for the most part abandoned by CN, while CP continues to provide service between Montreal and Toronto. As a result, the CP service, called Expressway, was used as the 'model' configuration during the study and survey development.

While premium-TOFC was used as the model of a service that could compete directly with trucks, the survey should not be seen as a study of the potential of only premium-TOFC services, but rather of the potential for premium-intermodal services more generally.

5 The Shipper Survey

5.1 Stated Choice Methods

This section draws on Louviere et al. (2000) and Hensher et al. (2005). In general, Stated Choice Methods involve the use of specially designed surveys in which respondents express preferences by choosing an outcome from a set of alternatives which has been generated according to a particular experimental design. This type of survey is also referred to as a choice-based conjoint survey in the marketing literature. Each survey question provides a hypothetical, yet realistic set of alternatives, including the relevant information needed to choose one. Once the experimental choice sets have been designed and respondent choices elicited, the resulting Stated Preference data are analyzed using discrete choice statistical methods to produce estimates of, among other things, the probabilities of respondents choosing particular alternatives under various circumstances and choice options.

Stated Preference (SP) data is distinguished from revealed preference, or RP, data. The latter represent the world as it is. In the context of mode choice, it includes information about the actual shipment choice that a firm has made (e.g. cost, time, type of freight, etc.). It also includes information of the alternatives that were not chosen.

Although RP methods are intuitive, SP methods (and data) can help to overcome the limitations of RP data. First, because all the information relevant to the choice of interest is provided to the respondent, the informational burden is lower for the respondent, and there is no possibility for measurement error in the explanatory variables. Another benefit is that respondents do not need to provide information that might be considered competitively sensitive. Second, by design explanatory variables do not suffer from high correlation. Third, SP surveys can present respondents with choices that resemble current choices, as well as hypothetical future settings. As a result of these benefits, an SP approach was taken for this survey.

Recently, there have been numerous freight SP studies reported in the literature (Wigan et al. (2000),Vellay and de Jong (2003), Fowkes and Tweddle (1988), Shinghal and Fowkes (2002), Norojono and Young (2003) and Fridstrom and Madslien (2001)). SP freight studies can be classified along two important dimensions: how shipping mode is incorporated in the survey, and who the respondents are.

In some of these, choice is between different carriers within the same mode (Wigan et al. (2000), Fowkes and Tweddle (1988), Fridstrom and Madslien (2001)), so-called within-mode studies. In others (Vellay and de Jong (2003), Shinghal and Fowkes (2002) and Norojono and Young (2003)), mode is included explicitly and respondents are asked to choose between alternative modal configurations for their shipments. These are referred to as between-mode choice surveys.

The appropriate sampling frame of respondents to survey requires a bit of background. Shipping decision-makers are generally classified into three categories: shippers, receivers and carriers. Shippers are the agents that have a shipment that needs to be delivered. The receiver is the agent to whom the shipment is destined. Carriers are the agents (trucking company, rail company, etc.) that actually move the shipment from the shipper to the consignee. These categories are not necessarily mutually exclusive. For example, it is possible for shippers to own their own equipment and deliver their own goods, so-called private shippers. Shippers who hire others (carriers) to ship their goods are referred to as 'hire and reward' shippers or shippers using for-hire carriers: referred to here as "end-shippers." It is also possible for receivers to organize shipments. In this case, receivers can be thought to behave as shippers.

Potentially two agents decide about using intermodal services: shippers and carriers. Generally the latter decides, since the carrier organizes the movements of consignments from end-shipper to receiver. So, while one might think end-shippers are indifferent to how their shipments are carried, provided they arrive in good condition and on time, carrier decisions about using intermodal services will ultimately be constrained by shipper preferences. In effect the end-shipper can be seen as the true backstop for the demand for intermodal services.

This is the reasoning behind the end-shipper survey used here. As a result, while many previous mode choice studies, e.g. Vellay and de Jong (2003), have looked at private- as well as end-shippers, this study focused exclusively on the former. It was designed to establish whether a carrier's use of intermodal services would affect the end-shipper's choice of carrier.

Because of this, the form of survey instrument was most similar to a within-mode end-shipper survey of freight service choice such as that undertaken by Wigan et al. (2000). The main difference is that the current study includes not only standard carrier and shipment attribute information, but also information on whether the shipment would be carried by rail on a portion of the trip. We refer to this type of study as a carrier choice study.

5.2 Survey Development, Population and Design

5.2.1 Survey Development

An initial literature review of stated preference freight studies was undertaken to establish the attributes used in previous studies. Initial interviews with potential respondents involved asking about factors affecting the shipper's choice of carrier, employing the commonly used attributes drawn from other studies as a guide. Shippers were also asked what information was necessary to be able to choose between carriers, and what the realistic ranges of attribute values were. Particularly knowledgeable respondents in the Montreal area were asked whether they would be interested in participating in a focus group relating to the design of the survey.

Altogether, five hundred and fifty phone calls were made to two hundred and twenty seven companies. Sixty-five interviews were undertaken and six people agreed to attend the focus group. One person actually attended the focus group. As a result, it was decided to undertake individual interviews in person. This turned out to be a good approach, and all of the six people who had agreed to participate in the focus group and one other respondent, were interviewed. Once these interviews were completed, the survey instrument was developed. It was web-based and designed using Sawtooth Software's SSI Web. SSI Web is designed for the development of choice-based conjoint (CBC) studies to be hosted on the internet. It integrates functionality to produce factorial designs at the same time as being a flexible web survey editor.

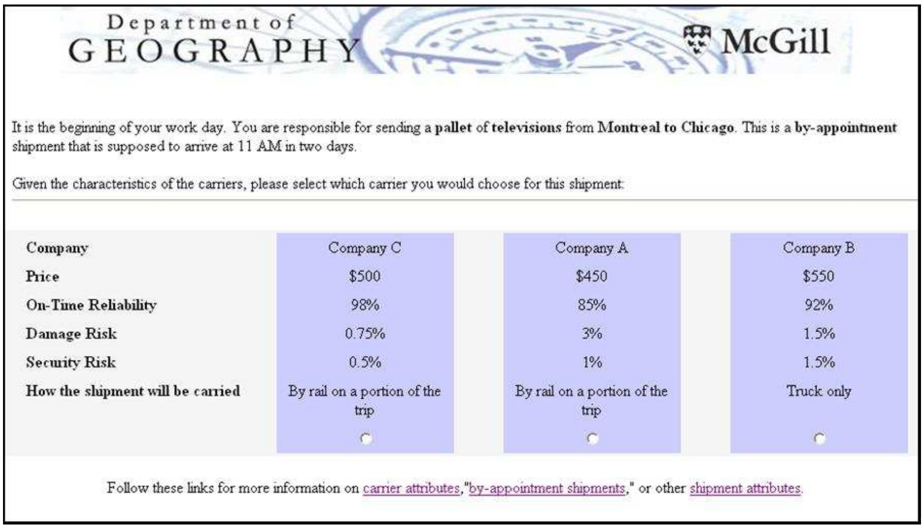
A preliminary version of the survey was tested by asking for comments from respondents interviewed in the first stage of development, as well as various other knowledgeable informants either in the field of freight transportation or in web-based surveys. Based on comments received, the survey was finalized and launched.

Survey respondents were contacted by a firm specializing in telephone market research. The responsibilities of the firm were to contact the companies in the list provided to them; determine if there was a shipping manager; conduct a preliminary interview to ensure the company was indeed within the survey population; and to ask the shipping manager to participate in the study. If the individual agreed, the firm was sent an invitation e-mail with a link to a URL and a password by which the individual could be associated with his/her responses. Follow-up calls were made if respondents who had agreed to take the survey did not complete it.

Once a survey was completed, the answers were downloaded from the survey host site (also Sawtooth Software) and after some automated manipulation and preparation, the data were ready to be analyzed.

5.2.2 Survey Population

The survey population included all Corridor end-shippers which were either manufacturing facilities with more than 50 employees, or wholesalers and retailers that were either head offices or single locations with more than 50 employees at that location and all third party logistics companies. Third party logistics companies (3PLs) organize shipments on behalf of other companies. The firm's shipping manager was the target respondent. The list of companies used for the survey was Dun & Bradstreet's Million Dollar Database (MDDI) of all companies in Ontario and Quebec with more than $1 million in sales or more than 20 employees. In total, 7,229 companies fell into this population.



Department of GEOGRAPHY McGill

It is the beginning of your work day. You are responsible for sending a **pallet of televisions** from **Montreal to Chicago**. This is a **by-appointment** shipment that is supposed to arrive at 11 AM in two days.

Given the characteristics of the carriers, please select which carrier you would choose for this shipment:

Company	Company C	Company A	Company B
Price	$500	$450	$550
On-Time Reliability	98%	85%	92%
Damage Risk	0.75%	3%	1.5%
Security Risk	0.5%	1%	1.5%
How the shipment will be carried	By rail on a portion of the trip	By rail on a portion of the trip	Truck only

Follow these links for more information on carrier attributes, "by-appointment shipments," or other shipment attributes.

Figure 2: A Sample Question from the Survey

5.2.3 Survey Design

The survey took the form of what is called in the literature 'contextual stated preference' or CSP survey (e.g. Wigan et al. (2000)). In fact, there were two surveys, one in English and the other in French, reflecting the primary mother tongues of respondents. The surveys had two parts. The first described the purpose of the survey, as well as describing how the survey was intended to be completed. In addition, some information thought relevant to post analysis was sought. In particular, respondents were asked: if any of their carriers use intermodal services and whether this influenced their choice of carrier; the proportion of their shipments that fell into one of six shipment categories divided by value and fragility; the proportion of their shipments that were 'by-appointment,' and finally the proportion of their shipments that were truckload and less-than-truckload shipments.

The second part of the survey was the actual CSP, involving 18 questions for each respondent (see Fig. 2). For each question, the respondent was asked to choose between three alternative carriers in the context of a particular shipment, whose details were described. The information provided was the origin and destination, when the shipment was to arrive, whether the shipment was 'by-appointment,' whether the shipment was of high or low value, whether the shipment was fragile or perishable, and the size of the shipment (truckload or LTL). Information on value and fragility was not provided explicitly, but rather through the type of commodity that was being shipped. For example, televisions were the shipment used to represent high value, fragile goods.

With respect to carrier attributes, after the literature review, initial interviews and survey testing, it was decided that five attributes would be used. These were: cost, on-time reliability, damage risk, security risk and whether the carrier would send the shipment by rail for a portion of the journey. Unlike many SP freight surveys, time required for shipping was considered an attribute of a shipment and not a carrier. The reason is that from discussions with shippers it was established that shipping times on this corridor were basically standardized (e.g. a Montreal-Toronto shipment is 'overnight'). As a result, shipping time was not generally a characteristic upon which carriers were chosen since all carriers would offer the same shipping times.

Realistic shipping cost estimates were arrived at using the Freight Carriers Association of Canada and the North American Transportation Council (FCA-NATC) Rating System - Version 3. These estimates were adjusted on the basis of advice from the person responsible for the Rating System in Canada, and checked for realism by shippers contacted during survey development and testing.

The cost attribute, based on the interviews, was given a maximum difference between carriers of 20%. The attribute itself had 3 levels (low, medium and high) with the medium cost being the cost estimate arrived at by the method described above. That is, the highest cost was 10% higher than the estimated shipment cost and the lowest 10% lower. Cost in actual dollars was presented to the respondents. Based on economic and logistics theory it was hypothesized that as relative cost increases, the probability of choosing a carrier would decrease.

The other continuous attributes also had three levels. The values assigned to them based on interviews were as follows: on-time reliability ranging from 85% to 98%; damage risk varying from 0.5% to 3% (LTL shipments had higher damage risks associated with them) and security risk varying from 0.5% to 1.5%. On-time reliability was defined as the proportion of shipments that the carrier delivered that were on time. Damage risk was defined as the proportion of shipments delivered by the carrier that suffered from damage. Security risk was defined as the proportion of shipments delivered by the carrier that suffered from theft. Based on economic and logistics theory as well as previous studies, the likelihood of choosing a carrier was hypothesized to increase with on-time reliability and to decrease with damage and security risk.

The last attribute was whether the carrier would send the shipment by rail on a portion of the journey. Whereas in previous studies separate modes have been characterized as separate alternatives, it was decided that in this study it would be considered as an attribute of the carrier. The reason for this was that in interviewing shippers it seemed that for the most part shippers were not very concerned with the mode of transport of their shipments provided they arrived on time and in proper condition. One did note, however, that some shippers might find a benefit for public relations or environmental reasons to use intermodal shipping. The shipper in question did use an intermodal service for just this reason. It was therefore decided to include the variable to test whether the fact that a carrier used rail would affect a shipper's choice of carrier.

It was unclear what the effect of shipment mode should have on choice of carrier. Based on the business press (see e.g. Luczak (2005) for a recent example) that routinely reports discontent with rail service, as well as the observed rapid increase of road transportation, it was considered likely that identification of a carrier as an intermodal carrier would have a negative effect on carrier choice. Given this ambiguous evidence for the effect of shipment mode on carrier choice an *a priori* hypothesis for the sign of the intermodal variable was not obvious. This was part of the justification for choosing a random parameter approach (see Section 6.1) to model estimation.

The factorial design of the surveys was not a traditional fixed fractional factorial design. Traditional fixed factorial designs can employ a single version of the questionnaire that is seen by all respondents. Sometimes respondents are divided randomly into groups, with different groups receiving different 'blocks,' or versions of the survey. Each of the blocks contains a subset of the questions in the fractional factorial design. For example, if the fractional factorial design contained thirty questions with different unique attribute value combinations, three different survey versions (ten questions each) might be distributed to respondents. In this study, a 'random' factorial design was used with each of the eight versions of the survey having a different factorial design with 300 different sets of questions. The algorithm (part of SSI Web) used for choosing the attribute value combinations ensures jointly the orthogonality (maximizing the efficiency of estimation), balance (that each attribute value is shown an equal number of times) and minimal overlap (each attribute value is shown as few time as possible in a given choice task) of values. It also takes into consideration previous designs that are made so that the same designs are not produced more than once. While this type of design is not necessarily 100% efficient, as is often the case with fixed factorial designs used in choice-based conjoint analysis, in this context, with such a large number of responses they were expected to be 100% efficient. Moreover, these designs allow the flexibility of estimating higher order effects (Chrzan and Orme (2000), Sawtooth Software (2005)).

6 Survey and Model Results

The survey occurred between mid-August and early December 2005. All companies in the list sent to the marketing firm were contacted (7,229). Of these companies, 680 agreed to participate. In the end, completed results were obtained for 392 respondents. Respondents came from all of the industries in the initial survey in the approximate proportion of the original company list, with roughly two-thirds from manufacturing and a quarter from wholesalers and retailers. Third party logistics companies were, however, slightly underrepresented at around 6% whereas there were around 10% in the entire company list. The respondents represented a relatively large spectrum of establishment sizes with the smallest being a 3PL of only a few employees and the largest an electronics wholesaler with 1,400 employees. Before presenting the model results, a brief description of the random parameter mixed-logit model used in the analysis follows.

6.1 A Random Parameters Mixed-logit

This subsection draws mostly on Train (2003), and in some parts on Hsiao (2003) and Kennedy (2003). The workhorse for the vast majority of discrete choice modeling is the conditional multinomial logit (MNL). Most people will be familiar with the MNL and so its description is kept short.

According to the random utility framework, the decision-maker (indexed n) will choose the alternative (indexed j) yielding the highest utility (U_{nj} in Equation 1). While the decision-maker unconsciously knows his own utility function, the researcher does not. The researcher can only observe the choice made and some characteristics of the alternatives and the decision-maker. The researcher can specify a function using the observed characteristics and choice outcomes to produce estimates of what is called representative utility, or the deterministic portion of utility. This is represented by V_{nj} in Equation 1. The deterministic portion of utility is generally represented as a linear combination of alternative and decision-maker characteristics, as can be seen in Equation 2, where the observable characteristics are represented by xs.

$$U_{nj} = V_{nj} + \epsilon_{nj} \ \forall_j \tag{1}$$

$$U_{nj} = \beta' x_{nj} + \epsilon_{nj} \ \forall_j \tag{2}$$

At the same time, there are aspects of utility that the researcher cannot observe and which are considered to make up an 'error' term denoted as ϵ_{nj}. Knowledge of the error term allows the researcher, with the information from the deterministic part of the utility, to make probabilistic statements about the decision-maker's choice. The assumption about the distribution of the error term determines the model that results. In the case of the MNL, the errors are assumed to be independently and identically extreme value distributed (iid). This assumption allows for the derivation of the well-known, closed-form expression of the MNL (Equation 3). P_{ni} is the probability that individual n chooses alternative i.

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_{j=1}^{J} e^{\beta' x_{nj}}} \tag{3}$$

The formulation implies, among other things, that preferences are constant across individuals (βs are fixed across individuals) and that errors are not correlated across observations. These consequences are not only limiting from a behavioural perspective, but are also often likely not to hold in reality. The use of a mixed-logit model can obviate these limitations by allowing for random taste variation, as well as for correlation across observations. These characteristics of the mixed-logit make it particularly attractive in the context of panel data, i.e. data that are composed of several responses from the same individual.

To show how the mixed-logit can overcome these limitations, the first step is to rewrite Equation 2 to further decompose utility to include another random term as well as multiple observations for the same person.

$$U_{njt} = \alpha' x_{njt} + \beta_n' z_{njt} + \epsilon_{njt} \ \forall j \quad (4)$$

Here αs represent fixed (across individual) coefficients for for variables x_{njt} and β_ns are random coefficients with zero means for variables z_{njt}. Note that the utilities are also now indexed across t - this represents the multiple observations for each individual. The β_ns are fixed for an individual across his choices. When x_{njt} and z_{njt} overlap (i.e. some variables enter both x_{njt} and z_{njt}) the coefficients of these variables are considered to vary randomly with mean α and the same distribution as βn around the means, with the remaining error term ϵ_{njt} being iid. It is possible to estimate a choice model including this extra flexibility by using the logit model while at the same time integrating out some the random part of utility. In the context of panel data, where preferences are allowed to vary across individuals, but not across the choices of the same individual, we get the following choice probabilities:

$$\mathbf{L}_{n\mathbf{i}}(\beta) = \prod_{t=1}^{T} \left[\frac{e^{\alpha' x_{nit} + \beta_n' z_{nit}}}{\sum_{j=1}^{J} e^{\alpha' x_{njt} + \beta_n' z_{njt}}} \right] \quad (5)$$

Since the ϵ_{njt} is iid, Equation 5 represents the probability of an individual making a sequence of choices $\mathbf{i} = i_1, ..., i_T$ conditional on β. The unconditional probability is the integral of this product over all values of β:

$$P_{n\mathbf{i}} = \int \mathbf{L}_{n\mathbf{i}} f(\beta) d\beta \quad (6)$$

The mixed-logit, takes its name from the fact that the first part of the function ($\mathbf{L}_{n\mathbf{i}}$) is the standard logit, and $f(\beta)$ is the mixing function. Intuitively, this model can be estimated in the following way: starting values of the coefficients are chosen and a draw of β is taken from its distribution and the logit formula is calculated for each choice of a given individual. The product of these logits is taken. This is repeated over many draws (here 1,000) of β and the results averaged. This process is continued until the likelihood function is maximized, resulting in the final estimated model coefficients. This is the technique that was used to estimate the random parameters mixed-logit model presented below.

BIOGEME was used to estimate this model. BIOGEME is a statistical package designed specifically for discrete choice estimation. It is capable of estimating many different types of discrete choice models, including models requiring the use of simulation techniques for solving integrals for which closed form solutions do not exist. It was designed by Prof. Michel Bierlaire of the Ecole Polytechnique Fédérale de Lausanne, in Lausanne, Switzerland. BIOGEME is free and can be downloaded on the internet.

6.2 Descriptive Results

Before presenting statistical modeling results, it is useful to present a descriptive analysis of the collected data. This helps to provide the reader with a better understanding of the variables in the model. To begin with, we present summary statistics on the explanatory variables available from the survey. Table 1 presents a summary of the carrier attributes used in the survey.

Table 1: Summary Statistics of Explanatory Variables

Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Cost(ln)	7074	6.49	0.68	4.91	7.59
On-time Reliability	7074	91.67	5.31	85	98
Damage Risk	7074	1.45	0.85	0.5	3
Security Risk	7074	1	0.41	0.5	1.5
Shipment Distance	7074	968	376	555	1462

Table 2 presents the frequency of shipment characteristics of the shipments presented to the respondents of the survey. As can be seen, respondents were presented with almost equal numbers of questions associated with each of the different shipment characteristics considered in the survey. Altogether, three types of explanatory variables were available for survey analysis: respondent information (see Sections 5.2.2 and 6), carrier attribute data and shipment data.

6.3 Model Results

Two models are presented. The first is the standard conditional logit model (Table 3) and the second is the mixed-logit model (Table 4). A preliminary analysis of this data is presented in Patterson et al. (Forthcoming). The standard logit model is provided mostly for comparison with the mixed-logit model, as well as for completeness. The rest of the discussion focuses on the mixed-logit model. See Table 5 for a reminder of variable units of measurement used in the models.

The models presented (in Tables 3 and 4) were arrived at by testing down from a more general to these more specific models. Altogether three different types of variables were tested in model development. First, carrier attributes included cost, on-time reliability, damage and security risk and the variable indicating the shipment as intermodal. *A priori* expectations for these variables were explained in Section 5.2.3.

Second, shipment and shipper attribute interactions with carrier attributes were included, e.g. interactions between cost and shipment type dummy variables, such as by-appointment, high-value or perishable goods. Based on total logistics cost theory (see e.g. Ballou (2004)) the following effects of shipment type on carrier choice were expected. High-value, fragile and perishable goods are subject to high inventory costs. High-value goods have higher inventory costs simply because of their high value (through opportunity costs), but might also be subject to higher inventory costs as a result of security related costs. Fragile goods have higher inventory costs because they need to be handled more carefully. Perishable goods are subject to high inventory costs because they can

Table 2: Summary Statistics of Shipment Characteristics

Value	**Frequency**	**Percent**	**Cumulative Frequency**
High-value Fragile	3464	49%	49%
Low-value Fragile	3610	51%	100%
Total	7074	100%	
Fragility	**Frequency**	**Percent**	**Cumulative Frequency**
Non-fragile	2244	32%	32%
Fragile	2451	35%	66%
Perishable	2379	34%	100%
Total	7074	100%	
Distance	**Frequency**	**Percent**	**Cumulative Frequency**
555 km	2267	32%	32%
864 km	2409	34%	66%
1,462 km	2398	34%	100%
Total	7074	100%	
Appointment Type	**Frequency**	**Percent**	**Cumulative Frequency**
By-appointment	3618	51%	51%
Not by appointment	3456	49%	100%
Total	7074	100%	

easily go bad, but also because they often require specialized equipment (e.g. refrigerated warehouses). As a result of these higher inventory costs, one would expect that carrier choice would be less sensitive to transport cost as firms are willing to pay more to have them shipped more quickly or carefully to reduce inventory costs.

Another type of shipment interaction tested was between shipment distance and carrier attributes. Based on standard transportation economics (see e.g. Wilson (1980) for his discussion on the elasticity of transportation demand) shipment distance was expected to increase shipper sensitivity to cost. Anecdotally, through telephone and in-person interviews, it seemed that shippers thought intermodal options were more interesting at longer distances. As a result, the distance-intermodal interaction was hypothesized to be positive. Since shippers normally assume rail transportation to be less expensive, this could be explained by increased sensitivity to transportation cost as distance increases, as described above.

Shipper attributes interacted with carrier attributes included the interaction of shipper size and geographical information with carrier attributes. For example, shipper size (represented by the number of employees) was interacted with carrier attributes. There were no *a priori* hypotheses about the effect that

Table 3: Conditional Logit Model

Variable	Coefficient	Std. Error	P-value
Cost(ln)	-3.83	0.60	0.00
Cost(ln)*Distance	-2.08	0.51	0.00
Cost(ln)*By-appointment	1.53	0.38	0.00
Cost(ln)*High-value	1.34	0.39	0.00
Cost(ln)*High-value*3PL	3.64	1.07	0.00
On-time Reliability	0.10	0.01	0.00
On-time Reliability*Distance	-0.02	0.01	0.00
On-time Reliability*By-appointment	0.04	0.01	0.00
On-time Reliability*Perishable	0.05	0.01	0.00
Damage Risk	-0.37	0.03	0.00
Damage Risk*Fragile	-0.18	0.05	0.00
Damage Risk*3PL	0.25	0.08	0.00
Security Risk	-0.14	0.04	0.00
Intermodal	-0.83	0.09	0.00
Intermodal*Distance	0.20	0.09	0.03
Intermodal*Ontario Shipper	-0.44	0.08	0.00
ASCs			
ASC1	0.47	0.04	0.00
ASC2	0.51	0.04	0.00
Number of observations:	5670		
Init log-likelihood:	-6229.13		
Final log-likelihood:	-4660.85		
Likelihood ratio test:	3136.56		
Rho-square:	0.25		
Adjusted rho-square:	0.25		
Final gradient norm:	4.12E-03		

Table 4: Random Parameter Mixed-Logit Model

Variable	Coefficient	1% Increase	10% Increase	Std. Error	P-value
Cost(ln)	-4.72	-4.588	-36.229	0.69	0.00
Cost(ln)*Distance	-2.29			0.59	0.00
Cost(ln)*By-appointment	1.59			0.44	0.00
Cost(ln)*High-value	1.62			0.45	0.00
Cost(ln)*High-value*3PL	4.46			1.26	0.00
On-time Reliability	0.12	1.13	3.35	0.01	0.00
On-time Reliability*Distance	-0.03			0.01	0.01
On-time Reliability*By-appointment	0.05			0.01	0.00
On-time Reliability*Perishable	0.06			0.01	0.00
Damage Risk	-0.44	0.64		0.03	0.00
Damage Risk*Fragile	-0.22			0.05	0.00
Damage Risk*3PL	0.29			0.09	0.00
Security Risk	-0.17	0.85		0.04	0.00
		EXP(b)			
Intermodal					
Coefficient	-1.15	0.32		0.15	0.00
Std. Deviation	1.34			0.08	0.00
Intermodal*Distance	0.31			0.11	0.00
Intermodal*Ontario Shipper	-0.58			0.19	0.00
ASCs					
ASC1 (Coeff.)	0.61	1.84		0.07	0.00
ASC1 (Std. Error)	0.90			0.07	0.00
ASC2 (Coeff.)	0.62	1.87		0.07	0.00
ASC2 (Std. Error)	0.83			0.07	0.00
Number of observations:	5670				
Number of individuals:	315				
Init log-likelihood:	-6229.13				
Final log-likelihood:	-4339.01				
Rho-square:	0.303				
Adjusted rho-square:	0.30				
Final gradient norm:	6.07E-04				

shipper size should have on carrier attribute coefficients. With respect to geographical characteristics, the intermodal variable was interacted with shipper distance from existing Expressway railheads, calculated as straight-line distance; whether the shipper was located between these railheads; and whether the shipper was located in Ontario.

Distance between the shipper and existing railheads, and location between them were hypothesized to have a negative affect on the likelihood of choosing an intermodal carrier. There was no expectation for the signs of the coefficients interacting carrier attributes with the Ontario locational dummy.

The third type of variable included were interaction terms between the first two types of variables and 3PL carriers. Industry information about respondent companies in the MDDI database allowed the identification of companies that organize shipments on behalf of other companies. 3PLs are playing a growing role in transportation logistics and as a result there was interest in whether they behave differently than other carriers who organize their own shipments. 3PLs are very understudied in the literature, particularly with respect to how their preferences might differ from other shippers in terms of carrier or mode choice. As a result, there were no *a priori* hypotheses about the signs that the direct 3PL variables would have.

Variation across respondents was partially controlled for through shipper and shipment interactions with carrier attributes. At the same time, there was interest in testing whether even after having controlled for this variation there might be unidentifiable random variation across respondents. As a result, variation in preferences across respondents for the carrier attributes was also tested for using the mixed-logit. The final global model is presented in Table 4.

Overall, the results are quite reasonable: each of the direct carrier attribute coefficients is significant and has the right sign. Increases in cost, damage risk and security risk decrease the probability that a carrier is chosen, while an increase in on-time reliability increases the probability of choosing a carrier. Inclusion of the random terms in the mixed-logit shows an important increase in the likelihood ratio index suggesting an improved explanatory power relative to the standard logit model.

Because the cost variable is in natural logarithms, the coefficient of -4.72 suggests that a 1% increase in cost would result in a 4-5% decrease in the odds that a carrier would be chosen, and a 10% increase would decrease the odds

Table 5: Units of Measurement for Continuous Variables

Cost: Natural logarithm of $CAD (Range: 4.9-7.6)
On-time Reliability: % of shipment on-time (Range: 85%-95%)
Damage Risk: % of shipments suffering from damage (Range: 0.5%-3%)
Security Risk: % of shipments suffering from theft (Range: 0.5%-1.5%)
Distance: km(000s) between shipment origin and destination (Range: 0.555-1.462)

by 36%. This figure is in the range of other similar studies. In Fridstrom and Madslien (2001) 'shipment level' model they report an estimate of -2.21 (half the magnitude of our estimate), whereas Wigan et al. (2000) report coefficients from -0.049 to -0.298. The latter are based on nominal figures (i.e. the explanatory variable for cost is expressed in dollars and not natural logarithms). When the present model is rerun with cost in nominal terms, the estimated coefficient, -0.004, is much lower than their estimates. Cost was not found to be randomly distributed.

The 0.12 coefficient for on-time reliability suggests a similarly strong effect on carrier choice as cost. Its value suggests that if a carrier's on-time reliability were to improve by 1%, the odds of choosing that carrier would increase by 13% and would increase more than three times with an increase of 10%. In more intuitive terms, supposing the initial likelihood of a carrier being chosen were one half, a 10% increase in on-time reliability would improve its likelihood of being chosen to 70%. It is less straightforward to compare this coefficient with other studies, since they have tended to quantify on-time reliability in terms of percentage late as opposed to percentage on-time. Nevertheless, the estimate obtained seems reasonable and indicates extremely high sensitivity to on-time reliability in the choice of carrier. On-time reliability was not found to be significantly randomly distributed.

The damage risk coefficient, -0.44, indicates an increase of 1% in damage risk would decrease the odds of choosing a carrier by about a third. This would reduce a probability of 50% to about 40%. The coefficient is within the range of other studies with Fridstrom and Madslien and Wigan et al. reporting coefficients of -0.25 and ca. -500 respectively. The extremely large coefficients reported in Wigan et al. likely has partly to do with a stricter definition of damage risk. At the time of writing and due to long calculation time it was not possible to establish whether damage risk should have a random distribution.

While other studies have not reported on security risk, the coefficient reported here, -0.17, seems reasonable. An increase of 1% in security risk will reduce the odds of choosing a carrier by 15%. This would result in a decreased probability of choosing a carrier from an initial probability of a third to a quarter. Security risk was not found to be significantly randomly distributed.

The coefficients for the continuous variables in the model seem quite strong and reasonable. The most remarkable result, however, is the value of the intermodal coefficient, -1.15. It implies that the odds of choosing a carrier that uses intermodal services is reduced by two thirds. If for example the probability of choosing a particular carrier were one half, knowing that a carrier used intermodal services would reduce its probability of being used to a quarter. The coefficient for the variance of the intermodal coefficient is highly significant - even at the 1% level of significance. This suggests that the variance of the intermodal variable should be included in the estimation. Its value of 1.34 implies that there is taste variation for intermodal shipments, and in particular that for 80% of respondents an intermodal carrier has a negative effect on carrier choice. What is interesting is that this also implies that for 20% of respondents, it has a positive effect. This result might be an artefact of the breadth of the distribution but lends support to the notion that some shippers have a positive impression of rail. This would seem to reconcile the ambiguous evidence of shipper impressions of rail referred to above in Section 5.2.3.

Moreover, the size of the intermodal coefficient is somewhat larger in the mixed than in the MNL (as are the other coefficients). This is expected and explained by the reduction in the variance of the error in the mixed-logit model because of including the random error terms in the estimation.

The coefficients ASC1 and ASC2 are the alternative specific constants. They represent the location of a particular alternative relative to the others. ASC1 is the alternative specific constant identifying the first (or left-most alternative in a choice task). ASC2 identifies the second choice task. Both of these suggest that respondents were more likely to choose the first and second alternative as compared to the third. In fact, the odds of choosing the first and second alternatives relative to the third were 84% and 87% higher, respectively.

In the final mixed-logit model, in addition to the five carrier attributes, there were another 10 shipment and shipper interaction variables. There are three significant distance interaction terms: cost, on-time reliability and the intermodal variable. The cost-distance interaction coefficient implies for example, that for a shipment between Montreal and Chicago, the coefficient on the interaction between cost and distance implies that price sensitivity on this shipping route would be -5.98: 50% higher than the cost coefficient by itself. Shippers are not only price-sensitive, but they become even more price-sensitive as the distance (and cost of the shipment) increases - what we expect based on transportation demand theory. Also of interest, the interaction between distance and the intermodal variable suggest that shippers seem less biased towards rail for longer distance shipments. In fact, for a shipment between Montreal and Chicago, the fact that a carrier ships intermodally will reduce the odds of choosing that carrier by one half instead of by two-thirds. The interaction between on-time reliability and distance implies that shippers are less sensitive to on-time reliability as distance increases.

Statistically significant interaction terms between by-appointment and high-value shipments meet expectations with both of them being less price-sensitive and more sensitive to on-time reliability. Moreover, perishable goods are more sensitive to on-time reliability and fragile goods more sensitive to damage risk.

With respect to shipper characteristics, there are three interesting significant interactions. With respect to the geographic characteristics of shippers, Ontario shippers are even less likely to choose an intermodal carrier than other shippers. With respect to 3PLs, the two significant interaction terms suggest that they are less price-sensitive for high-value goods and less sensitive to damage risk.

SIGMA1 and SIGMA2 are simply the standard error of the ASCs. The fact that they are statistically significant simply confirms that it's appropriate to include these random terms in the estimation.

In summary, it can be said that the main carrier attributes used in the model all have important explanatory power and that their importance changes in ways conforming to expectations when taking into consideration shipment and shipper attributes. Most importantly for this research, despite a reduced bias against intermodal shipping on longer distance shipments, there remains a strong unexplained bias against using rail for shipments for the vast majority of shippers. At the same time, variance on this coefficient suggests that this is not the case for all shippers with carrier choice being positively affected for around 20% of shippers when they know a carrier is intermodal. This seems to reconcile the conflicting evidence from survey pre-interviews and the MNL specification and public perceptions of rail more broadly.

7 Model Implications

This model represents the first random-parameter model in the carrier/freight mode choice literature. As such, it is a useful tool for understanding the importance of factors affecting carrier choice. Moreover, the random-parameter approach is able to dissect and reconcile apparent market segmentation within carrier choice - the vast majority of shippers that are mistrustful of rail and a small minority for whom it may be considered an asset.

It is indeed the issue of mistrust of rail that provides the most interesting results. In particular, the coefficient estimate for carriers that use intermodal services implies that irrespective of other service attributes (cost, on-time reliability, etc.) there is a bias against the use of rail for the vast majority of shippers. That is, even if a carrier had the same cost, on-time performance, etc. as another carrier, but used intermodal services, the odds of its being chosen would be reduced by two-thirds. This can only be interpreted as a bias, because the purpose of using a factorial design of attribute values is precisely to be able to extract the influence of variables separately. I.e. it cannot be claimed that it is rail's unreliable on-time delivery that causes such a strong negative coefficient for intermodal, because on-time reliability should already be captured in the coefficient for that variable. The way attributes were presented in the survey ensures that other factors are at play in explaining the results.

This bias probably reflects general shipper perceptions of rail versus truck-only transportation services as appear in the popular or business press (see for a recent example Luczak (2005)). At the same time, the results seem to suggest that this is not the case for all shippers, since for some shippers intermodalism appears to be an asset. Based on pre-survey interviews those characteristics of rail that make it more desirable are likely related to environmental public relations concerns. What seems clear, however, is that these results suggest increasing rail's share of freight transportation in this corridor will require more than just improvements in the standard carrier attributes. It suggests that rail needs to change its reputation and possibly take advantage of those factors that some shippers find desirable.

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