DECISION MAKING PROCESS AND FACTORS AFFECTING TRUCK ROUTING

Published in Freight Transport Modeling, Ben-Akiva M, Meersman H. and van de Voorde E., eds.,
Emerald, pp. 239-255, 2013

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ABSTRACT

This research studies the decision-making process and the factors that affect truck routing. The data collection involved intercept interviews with truck drivers at three rest area and truck stop locations along major highways in Texas, Indiana and Ontario. The computerized survey solicited information on truck routing decisions, the identity of the decision-makers, the factors that affect routing and sources of information consulted in making these decisions. In addition, Stated Preferences (SP) experiments were conducted, in which drivers were asked to choose between two route alternatives. A total of 252 drivers completed the survey, yielding 1121 valid SP observations.

This data was used to study the identity of routing decision makers for various driver segments and the sources of information used both in pre-trip planning and en-route. A random effects logit model was estimated using the SP data. The results show that there are significant differences in the route choice decision making process among various driver segments, and that these decisions are affected by multiple factors beyond travel time and cost. These factors include shipping and driver employment terms, such as the method of calculation of pay and bearing of fuel costs and tolls.

INTRODUCTION

Trucks are the dominant mode of freight transportation in the US. In 2009, trucks carried freight at a value of 9.5 billion dollars, which is about 65% of the value of freight transported by all modes. The total annual highway miles driven by trucks have increased by 109% between 1980 and 2008 (Schmitt and Sprung 2010). This growth rate is higher compared to that of general road traffic. The highway transportation system has not grown at a comparable rate. Its total route length has increased by only 5% during the same period (Schmitt and Sprung 2010). This discrepancy contributes to increased congestion, energy consumption and degradation of the environment and traffic safety.

Understanding the behavior of road users is critical in order to develop measures to improve the performance of transportation networks. However, while there have been numerous studies of the relevant passenger travel behaviors, the research on truck routing choices is limited.

Toll road operation is a useful example to demonstrate the need to better understand truck routing behavior. Heavy trucks are critically important for toll roads because of their importance in generating revenue. Bain and Polacovic (2005) found that trucks account for 10% of traffic flow on toll roads, but generate 25% of the revenue. In many cases, the use of toll roads, after they opened, was lower than originally forecasted, with an over-estimation of traffic by 20-30% in the first five years of operation. Furthermore, forecasting errors for truck traffic were larger compared to those for light vehicles (Prozzi et al. 2010). This uncertainty, often over-forecasting flows and revenue, contributes to increased risks in the development of toll roads. Thus, better understanding of trucks' route choices is important to improve toll road use forecasts. It may also help road operators design measures that would make toll roads more attractive to trucks.

This research studies the decision-making process and the factors that affect truck routing. The remainder of the paper is organized as follows: the next section reviews previous studies that addressed truck routing behavior. Then, the survey that was developed to collect data on truck routing decisions is presented. The following sections present analysis of the data and the route choice model that was estimated with the SP data. Finally, a conclusion is presented.

LITERATURE REVIEW

Most studies of truck route choice behavior are value of time (VOT) studies, which consider the tradeoff between travel time and cost. Zamparini and Reggiani (2007) conducted meta-analysis of 46 previous studies on truck VOT. They found a mean VOT of $20/hour with a coefficient of variation of 0.66. Some of the differences among VOT values could be explained by the geographic location of the study, the GDP of the country where it was conducted and the shipping mode (five of the studies addressed rail transport). Wynter (1995) found wide variability also in VOT of French carriers. A lognormal distribution of VOT, with a coefficient of variation of 0.69, was fitted to SP responses from 408 fleet managers. The study also found that the mean VOT increases linearly with the trip length and varies considerably among various commodity types. Kawamura (2000) found even higher variability in VOT among carriers in California in the context of toll lanes. He estimated a lognormal distribution of VOT with a mean of $23/hour and a coefficient of variation of 1.37. Smalkoski and Levinson (2005) found a wide range of VOT among carriers in Minnesota, from $21/hour to $78/hour, depending on the type of facility being served. They found statistically significant higher VOT for for-hire carriers compared to private fleets ($60/hour and $42/hour, respectively). In contrast, Bergkvist (2001) found that the VOT of Swedish shippers is higher for private carriers compared to for-hire ones. With respect to trip length, Bergkvist found higher VOT for short trips (less than 3 hours) compared to longer ones. This result contradicts that of Wynter (1995). De Jong (2000), in a study of UK carriers, also found differences between the VOT of for-hire and private carriers. However, the results depended on the way the scenarios were presented: VOT were lower for private fleets in abstract scenarios, but higher in scenarios defined in a route choice context. Miao et al. (2011) recognized the importance of the specific conditions relative to the delivery schedule. They estimated VOTs between $26/hour to $68/hour, depending on the geographic location (Wisconsin and Texas) and on the relations to the scheduled arrival time. In addition, they found higher VOT for drivers for private carriers compared to owner-operators and for-hire drivers, and for drivers paid by miles compared to other drivers. As expected, drivers who paid the tolls themselves were less willing to use toll roads.

VOT studies are very limited in that they only consider travel time and cost and ignore the effects of any other factors. The wide range of freight VOTs across studies or within one study for various segmentations suggests that additional factors affect routing decisions. However, few studies linked truck route choices to other factors beyond time and cost. Small et al. (1999) showed that carriers in California were highly sensitive to late schedule delays. When accounting for the schedule delay, the travel time itself was not significant in predicting route choices. Knorring et al. (2005) found that long-haul truckers are willing to trade an increase of 1% in their travel distance for a speed gain of 0.4 mph in situations in which they have a choice between a route passing through a metropolitan area and a bypass route. Hyodo and Hagino (2010) found an effect for the road type, in addition to tolls and travel times, on truck route choices in Japan.

In the context of toll alternatives, Hunt and Abraham (2004) found that the attributes of travel time, toll cost, primary road type (freeways or surface streets) and the probability and magnitude of delays had significant effects on truck route choices in SP data collected in Montreal, Canada. The value of delay they estimated was greater than the VOT. Wood (2011) studied the factors that affect toll road usage. In most cases, only familiarity with the scenario described in the question (i.e. tolled turnpike, bypass road or bridge) was associated with an increased willingness to pay tolls. Prozzi et al. (2009) conducted a survey of carriers in Texas on their use of toll roads in the state. The main reasons to use toll roads that respondents provided were time savings and reduced congestion. Some respondents also noted better road quality, safer travel and shorter distances. The main reason to avoid toll roads was the price.

These studies suggest that the not only travel time and cost, but also risk of delays, the delivery schedule constraints and the ultimate bearer of costs affect route choices and can help explain some of the large variability in estimated VOT values. Studies related to the choice of carrier service (e.g. Jovicic 1998, Kurri et al. 2000, Bolis and Maggi 2001, Fuller et al. 2003, de Jong et al. 2004, Danielis et al. 2005, Fowkes and Whiteing 2006) also show the importance of the risk of delays and late deliveries to shippers and that the value placed on these attributes varies for different shipments, such as truckload (TL) or less-than-truckload (LTL), and by commodity types and values.

SURVEY

Data on the decision-making process related to truck routing and the factors that affect it, was collected using a computerized survey was developed. The survey included two parts. The first part collected information on the routing decision making for the shipment they were transporting at the time of the interview. In addition, information on the driver and carrier characteristics, the contractual or employment terms for the driver (i.e. basis for calculation of compensation and terms related to the costs of fuel and tolls) was collected.

The second part included a Stated Preferences (SP) experiment. Respondents were asked to choose between two hypothetical route alternatives. The alternatives were defined by the values of the factors shown in Table 1. The SP questions were developed around two typical toll road scenarios:

- Bypass scenario: A choice between an urban freeway passing through the downtown of a metropolitan area and a bypass alternative, which has longer distance, but less congested and so may be faster. The bypass may also be tolled.
- Turnpike scenario: For a long section of a trip passing through a rural area, a choice between a tolled highway and a free parallel road, which offers a lower design level (e.g. includes signalized intersections).

With both scenarios the questions were set in the context of a future trip with the same origin, destination and delivery (or pick-up) schedules as the one the drivers were transporting at the time of the interview. A design with 40 cases in ten blocks of four cases was developed using the AlgDesign package in R (Wheeler 2004). This procedure uses Fedorov's algorithm applied to a randomly selected subset of the possible set of candidate cases to obtain the D-optimal design and blocking. Each respondent was randomly assigned with one block for each scenario. Thus, each respondent was presented with a total of eight cases.

The surveys were implemented on Apple iPad tablets using the iSurvey application (iSurvey 2012). Questions were read to participants, responses were recorded by the interviewer. Participants were not compensated. The survey was administered on several days between February and June 2012 to drivers at rest areas and truck stops on or near three highway corridors:

- I-35 near Salado, north of Austin, Texas
- Ontario Highway 401 near Ayr, west of Toronto, Canada
- Lake Station on the west end of the Indiana Toll Road.

The collected data set includes responses from 252 drivers (118 in Texas, 53 in Ontario and 81 in Indiana) and 1121 valid SP choices.

Table 1 Factors and their levels in the SP experiment

Scenario	Factors	Levels
Bypass	Difference in travel distance (miles)	5, 10, 15, 20
	Difference in expected travel time (min.)	0, 10, 20, 30
	Frequency of delays that exceed 30 min (in 10 trips)*	0, 1, 1, 2 (bypass - v1) 0, 1, 2, 4 (bypass - v2) 0, 2, 4, 6 (downtown -v2)
	Toll amount ($)	0, 5, 10, 15
	Toll payment method	Cash, Electronic
	Toll bearer	Driver, Other
	Toll reimbursement method (if applicable)	Pre-paid, Reimbursed
Turnpike	Difference in travel distance (miles)	-20, -10, 0, 10, 20
	Difference in expected travel time (min.)	0, 15, 30, 45, 60
	Toll amount ($)	10, 15, 20, 25, 30
	Toll payment method	Cash, Electronic
	Toll bearer	Driver, Other
	Toll reimbursement method (if applicable)	Pre-paid, Reimbursed
	Free road type	2 lane undivided, 4 lane divided

* In the first version of the SP experiment, drivers were asked to report delay probabilities that they have experienced for the downtown route and to use these in their SP responses. They were only given the values for the bypass alternatives. Later, they were given values for both alternatives.

RESULTS

The results presented below are derived from the responses in all three locations. For some items, there were differences (questions were added) between the questionnaires used.

Therefore, the sample sizes relevant to each analysis differ.

Sample composition

75% of the drivers in the sample are hired drivers. Within these, 56% worked for for-hire carriers and 19% for private fleets. The remaining 25% are owner-operators (OO). 78% of the drivers were transporting truckload (TL) shipments when they were interviewed. . 10% were less-than-truckload (LTL) shipments and 12% were either parcels, empty trips or others. Most trips (72%) did not involve any special shipping service. 16% involved temperature control and 5% involved shipment of Hazmats. Overall these figures are consistent with figures published by the Census Bureau (USCB 2002).

Table 2 Employment terms

Characteristic		**Overall** (N=252)	**Hired** (N=192)	**OO** (N=64)
Pay calculation method	Book miles	47%	48%	38%
	Actual miles	12%	14%	6%
	Hours	12%	15%	3%
	Others	29%	23%	53%
Bearer of fuel costs	Company	69%	92%	5%
	Driver - partially	15%	2%	54%
	Driver	16%	7%	41%
Bearer of toll costs	Company	74%	89%	24%
	Driver - partially	2%	68%	50%
	Driver	16%	5%	14%
	Other/no answer	8%	3%	56%
Electronic toll tag	With tag	65%	68%	50%
	Without tag	35%	32%	50%

Some aspects of the driver's employment terms, especially those related to compensation and bearing of various costs, may affect routing decisions. The employment terms for the overall sample and for the hired and OO segments are summarized in **Table 2**. The majority of drivers are paid a fixed amount for a specific trip, which does not depend on their routing. Most commonly, drivers are paid by book miles. The only two payment calculation methods in which that relate to the actual travel time and distance are drivers paid by hours (12%) and to lesser extent drivers paid by actual miles (12%). Some hired drivers are paid by actual miles or hours (14% and 15%, respectively). These methods are less frequent for OOs (3% and 6%, respectively). The terms are very different for hired drivers and OOs with respect to fuel and toll costs. For 92% of hired drivers, but only 5% of OOs, the company is responsible for fuel costs. The situation with respect to toll is similar. 89% of hired driers, but only 24% of OOs reported that their company is fully responsible for tolls. OOs are also less likely compared to hired drivers (50% and 68%, respectively) to have electronic toll collection (ETC) tags.

Routing decision-maker

In identifying the routing decision makers, a distinction was made between pre-trip route planning and en-route adjustments. In the route planning phase, drivers may be assigned a route or choose on their own. An assigned route may be mandatory, or a recommended one that they can ask for approval to change or freely choose another one. Drivers that choose their routes may be required to do so from a set of pre-approved alternatives, get their chosen route approved, or be to make their own choice. En-route drivers may not be allowed to change routes at all, may ask and be assigned a new route, or they may change their route on their own freely or after getting approval for the change. **Table 3** shows the distribution of responses for both planning and en-route decision-making for the overall sample and various segments within it.

Table 3 Planning and en-route routing decision-making by driver and shipment type

			Driver type		**Shipment type**	
		Overall (N=153)	**Hired** (N=114)	**OO** (N=39)	**TL** (N=119)	**LTL** (N=16)
Planning	Assigned - must follow	16%	20%	5%	16%	25%
	Assigned – approval	2%	3%	0%	1%	6%
	Assigned – freely	8%	11%	0%	9%	13%
	Choose - alternatives	7%	10%	0%	7%	6%
	Choose - approval	2%	3%	0%	2%	0%
	Choose - freely	65%	54%	95%	65%	50%
En-route	Not allowed	3%	3%	0%	1%	6%
	Reassigned	1%	1%	0%	1%	0%
	Approval	12%	16%	0%	13%	19%

	Freely	85%	80%	100%	85%	75%

The majority of drivers report that they are responsible for routing decisions. At the planning stage 65% of drivers were free to choose their own routes. Only 16% were assigned a route that they had to follow. While en-route, drivers have even more flexibility to change their routes. 84% reported that they could change their routes freely. Only 2% cannot change at all or will be reassigned a route by their company. This result indicates that drivers have substantial responsibility in managing their routes. OOs, almost always, decide their own routes, both at the planning stage and en-route. In contrast, only 53% of hired drivers freely choose their own routes. The rest experience different levels of supervision, with 21% taking required follow routes assigned to them. Still, 96% of hired drivers can change their routes while driving, either freely (80%) or after obtaining approval. Drivers carrying LTL shipment play lesser roles in deciding routes. Only 50% of LTL drivers choose their own route freely, compared to 65% of TL drivers. At the other extreme, 25% of LTL drivers must follow an assigned route, as opposed to only 16% of TL drivers. While the sample size for LTL is rather small, these patterns are consistent in all decision-making options. Similarly, 85% of TL drivers may change their route freely while driving, compared to only 75% of LTL drivers.

Table 4 shows the routing decision-makers for various driver segments in terms of the bearing of fuel and toll costs and the method of pay calculation. Drivers may be fully, partially or not at all responsible for the cost of fuel and tolls. Drivers that are fully or partially (e.g. receive surcharges) responsible for the cost of fuel overwhelmingly have the right to choose routes on their own. Drivers that are not responsible for fuel costs at all are more restricted in their routing. Only 53% can choose their routes freely. 20% are assigned routes that they must follow. 81% can change their route while driving, compared to almost all drivers that pay for fuel themselves. A similar pattern is observed for toll costs. 89% of drivers that are fully or partially responsible for tolls select their own routes, and 100% can freely change their routes while driving. In contrast drivers freely choose routes, pre-trip and en-route only in 57% and 82% of the cases, respectively, when they are not responsible for tolls. With respect to the method used to calculate the drivers' pay, the other category, which combined payment options that are unrelated to routing (i.e. fixed amounts or depending on the load weight, value or the freight charges) have the highest level of freedom in choosing their routes (81% pre-trip and 91% en-route). Drivers paid by hours, whose pay depends the most on routing decision had the least flexibility in making decisions (47% and 71% for pre-trip and en-route, respectively).

Table 4 Planning and en-route routing decision making by employment terms

		Driver bears fuel cost			Driver bears tolls			Pay calculation method			
		No (N=118)	Partly (N=23)	Yes (N=18)	No (N=32)	Partly (N=4)	Yes (N=24)	Book miles (N=66)	Actual miles (N=20)	Hours (N=17)	Others (N=53)
Planning	Assigned - must follow	20%	9%	6%	12%	0%	8%	21%	20%	23%	9%
	Assigned - approval	3%	0%	0%	3%	0%	0%	1%	0%	12%	0%
	Assigned - freely	12%	0%	0%	16%	0%	4%	18%	5%	6%	0%
	Choose - alternatives	9%	0%	0%	6%	0%	0%	5%	15%	12%	6%
	Choose - approval	3%	0%	0%	0%	0%	0%	2%	0%	0%	4%
	Choose - freely	53%	91%	94%	63%	100%	88%	53%	60%	47%	81%
En-route	Not allowed	3%	0%	0%	3%	0%	0%	2%	5%	6%	2%
	Reassigned	1%	0%	0%	0%	0%	0%	1%	0%	0%	0%
	Approval	15%	4%	0%	9%	0%	0%	14%	10%	23%	7%
	Freely	81%	96%	100%	88%	100%	100%	83%	85%	71%	91%

Sources of information

Information about the sources of information that drivers use when planning their routes and the way they learn about delays on their routes while driving was also collected. Drivers were asked to rate the frequency at which they use various information sources on a 5-point scale. Drivers mainly base routing choice on their own prior experience. All drivers indicated that they rely on it at least half the time. Maps and navigation systems are also useful sources (62% and 65%, respectively use it at least half the time). En-route, other drivers are the most frequent source of information (72% use it at least half of the time). The company is not perceived as a significant source of information at any stage. Only 27% and 18% receive information from it at least half of the time, pre-trip and en-route, respectively.

Table 5 Sources of information used in making routing decisions

		Never 1	Seldom 2	Half 3	Usually 4	Always 5	Avg.	Std.
Planning	Prior experience (N=11)	0%	0%	9%	73%	18%	4.1	0.5
	Navigation (N=58)	26%	9%	20%	21%	24%	3.1	1.5
	Map (N=58)	29%	9%	17%	21%	24%	3.0	1.6
	Other drivers (N=11)	18%	46%	9%	27%	0%	2.5	1.1
	Company (N=11)	37%	36%	18%	0%	9%	2.1	1.2
En-route	Navigation (N=146)	53%	7%	6%	13%	21%	2.4	1.7
	Highway Radio (N=146)	40%	8%	15%	20%	17%	2.7	1.6
	Other drivers (N=148)	21%	7%	16%	28%	28%	3.3	1.5
	Company (N=149)	67%	15%	8%	6%	4%	1.7	1.1
	No information (N=149)	21%	21%	23%	22%	13%	2.9	1.3

Factors that affect route choices

Respondents were also asked about the frequency at which several factors affect their routing decisions. Four factors were considered: travel time predictability, availability of parking locations, fuel stations that the driver can use and the effect on fuel consumption. The results are presented in Table 6. Drivers were most concerned with having fuel stations that they could use (88% at least half the time), followed by having predictable travel times (84%) and by being able to find truck parking (81%). In contrast, the effect of the route on fuel consumption did not factor in their responses. None of the respondents stated that they consider it usually or always.

Table 6 Factors that affect routing decisions

	Never 1	**Seldom 2**	**Half 3**	**Usually 4**	**Always 5**	**Avg.**	**Std.**
Predictable Travel Time (N=57)	9%	7%	9%	24%	51%	4.0	1.3
Parking (N=58)	12%	7%	17%	17%	47%	3.8	1.4
Fuel Stations (N=58)	7%	5%	10%	16%	62%	4.2	1.2
Fuel Consumption (N=11)	46%	27%	27%	0%	0%	1.8	0.8

ROUTE CHOICE MODEL

The SP data was used to develop truckers' route choice model. A utility function is associated with each alternative:

$$U_{int} = V_{int}(X_{int}, \beta_n) + \alpha_i \varepsilon_n + \varepsilon_{int} \quad (1)$$

Where, U_{int} is the utility of alternative (route) *i* to individual *n* in choice experiment *t*. V_{int} is the systematic part of the utility function. X_{int} and β_n are the explanatory variables in the utility function and the corresponding parameters, respectively. ε_n is an individual-specific error term. α_i is the corresponding parameter for alternative *i*. ε_{int} is a generic error term. The error terms are assumed to be independently and identically drawn from a Gumbel distribution. Under these assumptions, the predicted probability that driver *n* chooses route *i* in experiment *t* is given by:

$$P_{nt}(i|\beta_n, \varepsilon_n) = \frac{\exp(V_{int}(X_{int}, \beta_n)}{\sum_{j=1}^{J} \exp(V_{jnt}(X_{jnt}, \beta_n)} \quad (2)$$

Where, $J = \{1, 2\}$ is the set of alternatives.

The utility parameters are defined as individual-specific in order to capture the heterogeneity in tastes within the driver population. In the model estimation, a random coefficients approach is used and the distributions of these parameters in the population are estimated (Ben-Akiva et al. 2008). In the current model, two coefficients are assumed to be distributed in the population: the coefficients of the toll amount and of a toll dummy (which takes value of 1 if the road is tolled and 0 otherwise). The coefficients will be formally defined below. Both are assumed to follow log-normal distributions:

$$ln\beta_{Toll,n} \sim N(\beta_{Toll}, \sigma^2_{\beta_{Toll}}) \tag{3}$$

$$ln\beta_{TollD,n} \sim N(\beta_{TollD}, \sigma^2_{\beta_{TollD}}) \tag{4}$$

Where $\beta_{Toll,n}$ and $\beta_{TollD,n}$ are the coefficients of toll amount and toll dummy for individual *n*, respectively. β_{Toll} and β_{TollD} are the corresponding mean parameters of the lognormal distributions. $\sigma_{\beta_{Toll}}$ and $\sigma_{\beta_{TollD}}$ are the corresponding standard deviations.

Table 7 defines the variables that were used in the final model specification. The specification includes variables that capture carrier/driver characteristics (TollCompany and Hourly), shipment attributes (Temp), and route attributes (Urban downtown/ Rural freeway, Travel Time, Toll, and Risk of Delay).

Table 7 Definitions of variables used in the estimated model

Variables	Definition
Downtown	Downtown constant: 1 if downtown route in bypass scenario, 0 otherwise
Free	Free route constant: 1 if free route in turnpike scenario, 0 otherwise
Time	Travel time (hours)
Toll	Toll amount (2012 US$)
TollDummy	Toll road dummy: 1 if the route involves tolls, 0 otherwise
Delay	Number of trips with delays that exceed 30 minutes (out of 10 trips)
TollCompany	Toll paid by company: 1 if company is responsible for tolls, 0 otherwise
DelayHourly	Number of trips with delays that exceed 30 minutes (out of 10 trips) if driver is paid by the hour, 0 otherwise
DelayTemp	Number of trips with delays that exceed 30 minutes (out of 10 trips) if shipment is temperature controlled, 0 otherwise

The utility functions given by:

$U_{int} = \beta_{downtown} + \beta_{free} + \beta_{time}\text{Time}_{int} + \beta_{toll,n}\text{Toll}_{int} + \beta_{tollD,n}\text{TollDummy}_{int}\big(1 +$

$\beta_{tollcompany}\text{TollCompany}_{int}\big) + \beta_{delay}\text{Delay}_{int}\big(1 + \beta_{delayHourly}\text{DelayHourly}_{int} +$

$$\beta_{DelayTemp}\text{DelayTemp}_{int}) + \alpha_i \varepsilon_n + \varepsilon_{int} \quad (5)$$

The model was estimated with BIOGEME (BIOGEME 2012) and using simulated maximum likelihood with 5000 Halton draws. The model estimation results are presented in **Table 8**.

Table 8 Estimation results

Parameters	**Estimated values**	**t-statistics**
Downtown	-1.29	-5.90
Free	-0.965	-2.79
Time	-0.874	-2.84
Toll - mean	-4.56	-5.26
Toll – standard deviation	1.53	2.37
Toll dummy	-0.565	-0.98
Toll dummy – standard deviation	0.430	1.31
Toll dummy – company	-1.08	-19.4
Delay	-0.0227	-0.67
Delay – hourly pay	0.123	3.07
Delay – temperature controlled	-0.204	-1.85
$\alpha_{downtown}$	0.976	4.11
α_{free}	1.13	4.65
$\sigma_{Toll,TollD}$	-2.11	-2.62
Number of observations:	1121	
Number of individuals:	143	
Number of Halton draws:	5000	
Final log-likelihood:	-630.86	
Rho-square:	0.188	
Adjusted rho-square:	0.170	

Overall, the estimated values of the parameters are in agreement with prior expectations. As expected, the signs for the coefficients of travel time, tolls and delays are all negative.

These imply that increases in the values of these variables for a specific route alternative reduce the utility of that route and the probability that it will be chosen.

The constants in the model capture the preference of drivers to the specific types of routes described in the two experiment scenarios. In both cases they imply preference to higher quality and level of service roads. The constant for the downtown route in the urban bypass scenario is negative. This implies that, everything else being equal, drivers prefer the bypass route to the downtown route. Similarly, the negative constant for the free route in the rural highway alternative implies that, everything else being equal (including zero tolls), drivers prefer the toll route.

The coefficients of the toll cost and the toll dummy variables were estimated as random parameter with log-normal distributions. The estimated distribution of the toll cost parameters is given by:

$$\ln \beta_{toll,n} \sim \mathcal{N}\left(\beta_{Toll}, \sigma^2_{\beta_{Toll}}\right) = \mathcal{N}(-4.56, 1.53^2) \tag{6}$$

Similarly, the estimated distribution of the toll dummy parameters is given by:

$$\ln \beta_{tollD,n} \sim \mathcal{N}\left(\beta_{TollD}, \sigma^2_{\beta_{TollD}}\right) = \mathcal{N}(-0.565, 0.43^2) \tag{7}$$

The toll dummy variable is also interacted with a dummy variable for the case that the company (and not the driver) is responsible for the toll cost. The estimate value for this variable is -1.08. This means that the negative impact of the toll road on the route choice when the driver is responsible for the toll cost is reversed when the company is responsible for the toll cost.

Other characteristics of the shipment and employment terms were interacted with the delay variable. The compensation for drivers that are paid by hours may increase when they experience delays on their trips. The estimation results show this effect, as they were much less sensitive to the risk of delays on the route. In contrast, drivers that were transporting temperature-controlled goods, were more sensitive to travel delays. This may reflect the higher time-sensitivity that may be associated with these shipments (often perishable) or the higher energy costs of keeping the required temperatures.

The estimated parameter values suggest significant trade-offs among travel time, the use of toll roads, toll costs and the frequency of delays. The estimation of random toll coefficients leads to a distribution of toll values of time. The value of time (VOT) for the mean toll coefficient is 30 $/hr. This value is consistent with figures reported in the literature. However, the range of VOT is wide with values from 30 $/hr and 235 $/hr between the first and third quintiles. This wide range reflects two extreme attitudes of drivers that were observed in the sample. On one extreme, one group stated that they will not use toll roads in any case. At the other extreme, drivers stated that they will always use the fastest route disregarding any tolls they may incur.

The wide range of attitudes towards toll roads is also apparent when considering the toll road dummy variable. This variable captures the attitude towards using the toll road itself, regardless of the toll amount. Drivers that pay for the tolls themselves, at the first quartile of the distribution would be willing to accept a 29 minutes additional travel time in order to avoid a toll road (before considering the toll cost itself). Drivers at the third quartile would be willing to accept additional 52 minutes of travel time to avoid the toll road. As noted above, this behavior is reversed when the driver is not responsible for the toll costs. In this case drivers are willing to incur additional travel times between 2 minutes (1st quartile) and 4 minutes (3rd percentile) in order to use the toll road.

Two characteristics of the shipment and employment terms were found to affect the disutility associated with the risk of unexpected delays: drivers that are paid by the hour favor delays compared to other drivers. Drivers that transport temperature controlled shipments are more sensitive to the risk of delays. Other drivers are insensitive to delays, willing to trade-off only 2 minutes of travel time for a 10% reduction in the risk of delays that exceed 30 minutes. Drivers paid by hours are willing to accept 7 minutes longer travel times in order increase their risk of travel delay by 10%. While this result is not expected, it should be noted that the pay for these drivers increases when they are delayed in traffic. In contrast, drivers with temperature-controlled shipments are willing to increase their travel times by 16 minutes to reduce their risk of delays by 10%. This may reflect higher time sensitivity of these goods (perishables) and the additional energy cost for refrigeration associated with travel delays.

The choice between the toll bypass and free downtown routes is used in order to demonstrate the effects of the tolls on route choices. Figure 1 shows the estimated probabilities of choice of the tolled bypass as a function of the toll amount for drivers in the 1st, 2nd and 3rd quartiles of the probability distribution, for the cases that the driver or the company is responsible for tolls. The figure is based on an assumption of equal travel times and delay frequencies in the two routes.

For drivers that are responsible for tolls, the introduction of tolls (at toll value zero) sharply reduces the probability that they will choose the toll road. This captures their preference to avoid toll roads. In contrast, when drivers are not responsible for the toll cost, the introduction of tolls does not affect their route choices. Further increases in the toll amounts negatively affect the probability of toll road choice in all cases.

The figure also shows the wide variability in drivers' preferences towards the toll road. The choice probabilities are much lower for drivers that are responsible for the toll cost. But, even within the same segment, and in particular for drivers who are responsible for the toll cost, there are very large differences in the toll road choice probabilities between drivers in the 1st and 3rd quartiles of the distribution (e.g. between probabilities of 0.03 and 0.62 for $50 tolls).

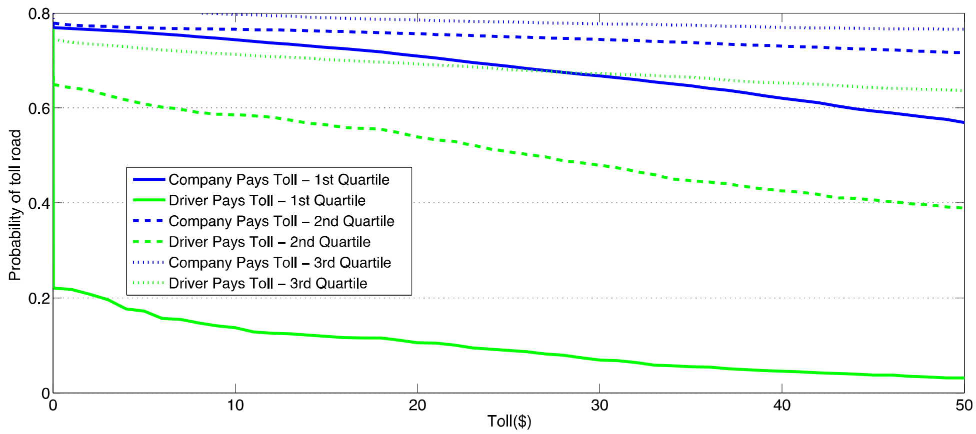

Figure 1 Effects of Tolls

CONCLUSION

This research studies the decision-making process and the factors that affect truck routing. Using data collected in intercept interviews with truck driver, the identity of routing decision makers was investigated. The results show that in most cases the driver has the power to choose routes. This is especially the case for OOs and for drivers that are responsible, even if partly, for the cost of fuel and tolls. Furthermore, the sources of information that drivers consult in making routing decisions are limited. They receive little support from their companies. The results also show that drivers consider additional factors beyond travel time and travel cost in deciding their routes. In the survey drivers mentioned travel time predictability and availability of parking and fuel stations as relevant considerations. Estimation results of an route choice model based on SP data also show that there are significant differences in the route choice decision making process among various driver segments, and that these decisions are affected by factors that include shipping and driver employment terms, such as the method of calculation of pay and bearing of toll costs. The model also showed a strong preference to avoid toll roads when the driver is responsible for the cost, but indifference to tolls when the driver is not responsible for the cost.

These findings suggest that simple VOT studies that have been used as a basis to predict truck route choices and flows, and in particular in the context of toll roads, may not be adequate. Nevertheless, the current results are based on SP data that represent simplified situations and decision protocols. In on-going work, research with GPS devices that will collect data on actual routes that driver use is being conducted.

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