A TIME-PERIOD CHOICE MODEL FOR ROAD FREIGHT TRANSPORT IN FLANDERS BASED ON STATED PREFERENCE DATA

Abstract
This paper presents one of the first models explaining the choice of time-period in road freight transport. Policies that would shift some fraction of the trucks from peak to earlier and later periods will contribute to the reduction of congestion. Therefore there is an increasing interest in modelling the time-period sensitivity of road freight transport to changes in travel time and cost by period. The model developed here is based on a stated preference survey among receivers of goods in Flanders and was implemented in the strategic freight transport model of the Flemish authorities.

Key words: time-period choice, departure time choice, scheduling, road freight transport, stated preference.

1. INTRODUCTION

Considerable literature exists on time of day models, which explain the choice when to travel (e.g. in the morning peak, before it, after it) using different discrete time periods. Most of the literature refers to passenger transport (e.g. de Jong et al., 2003; Börjesson, 2008; Koster, 2012). Especially in the academic literature, models for departure or arrival time choice are often based on the scheduling model (Vickrey, 1969; Small, 1982), which represents the trade-off between travel time on the one hand and arriving further away from one's preferred arrival time (PAT) on the other hand. Many travellers, especially for work trips, would prefer to arrive in or shortly after the morning peak, but this would lead to long travel times because of congestion in the peak.

In model systems that are used for forecasting and project appraisal (through cost-benefit analysis), time period choice is usually missing and the allocation to time periods is done using fixed time-of-day fractions. However, there is evidence, especially in passenger transport, that departure time choice is rather sensitive to changes in time and transport costs (often more than mode choice; see de Jong et al., 1998; Hess et al., 2007a,b). There are some practical transport passenger transport models that include a choice model for time period choice, such as the Dutch National Model system LMS (Daly et al., 1990; Willigers and de Bok, 2009; Significance, 2011) or TRESIS (Hensher, 2008) for Sydney. These models usually do not implement a full scheduling model with preferred arrival times (especially because data on PATs are very hard to obtain). An exception is the SILVESTER model for Stockholm (Kristofferson, 2011).

In freight transport model studies for transport authorities, time-of-day choice models are almost non-existent. Many freight transport models produce forecasts for a full year as the time dimension and do not consider time scheduling at all. However, freight transport models that include network assignment (especially for road), and especially model systems where the assignment of trucks takes place together with that of cars, need to consider the allocation to time-of-day periods. As in passenger transport, this is then done using fixed fractions.

Car traffic is often heavily peaked and could be spread more evenly over the day if the right incentives were in place. Road freight transport is considerably less peaked than car traffic. This has to do with the fact that freight does not have to arrive at the work starting time, but can be delivered as long as the receiver is open (though a carrier will often have to serve multiple destinations within a single time window). Also carrier firms and shippers with own account transport have an incentive to use their vehicles during the whole day, to reduce the fixed cost per kilometre driven. Nevertheless, there are many trucks on the road during the morning and afternoon peak and congestion could be reduced by shifting not only cars but also trucks to periods before and after the peaks. Transport authorities therefore are interested in learning about the sensitivity of road freight transport in terms of shifts away from the peaks as a result of changes in the level of congestion and possible new transport policies involving road user charges that are higher during the peaks than off-peak.

This paper presents a model for time-period choice of receivers in road freight transport, to be used as a component in the Strategic Flemish Freight Model (SVV). This is a practical freight transport forecasting model used by the Flemish government for the preparation and support of decision-making on large scale infrastructure projects for rail and inland waterways and for the calculation of a truck matrix for the Flemish strategic passenger transport models. The network and zoning system of this transport model contains most of Europe. The study area itself is the Flanders region (the Northern half of Belgium), the base year is 2004. Scenarios are available for 2008 and 2020. The model considers road, railway and inland waterways as possible modes. This model is based on a classical four-step traffic model, but with several additions, such as a (relatively straightforward) logistic module and a vehicle type choice model.

The current SVV does not contain an explicit time-period choice model. But in the new version, a module is implemented that determines how many road freight vehicles will depart earlier/later in response to increasing transport times (i.e. congestion) and/or increasing transport costs (e.g. road user charging that is differentiated by time-of-day). As such, it is one of the first time-period choice models in freight transport in the world.

In the next section of this paper, the existing literature on time-period choice models in freight transport is presented. In the third section, the questionnaire used and the SP experiment on time-period choice in freight are described in detail. The fourth section reports on the outcomes of the survey and the estimation results for the discrete choice models. After this, section 5 presents simulation results from this new model. A summary and conclusions are provided in section 6.

2. TIME-PERIOD CHOICE MODELS IN THE FREIGHT TRANSPORT LITERATURE

Some (larger) firms in freight transport and logistics use optimisation methods and software for scheduling their trips on a specific day. It might be possible to base a time-period choice model on the literature on scheduling within a firm. However, the transfer from individual firms to entire regions or countries is all but straightforward, whereas these private sector models also do not focus on congestion and peak-charging. We decided to restrict the literature review to studies that refer to entire cities, regions or countries.

Examples of time-of-day choice models in the sense of scheduling models in freight transport can be found in Halse et al. (2010) for Norway and Significance et al. (2013), but these were studies to derive values of time and reliability in freight transport, not studies to develop practical freight transport forecasting models.

In the past decade, experiments and model simulations were carried out in New York City concerning policy measures to shift road freight vehicles delivering during the day to delivery during the evening or night (Holguín-Veras, 2008; Holguín-Veras et al., 2006, 2007, 2008, 2012; NCFRP, 2013; Ozbay et al., 2006). Most of the analyses were done by the Renselaer Polytechnic Institute, Rutgers University and Cambridge Systematics. The day was usually defined as between 07:00 h. and 18:00 h., and evening/night as the complement. Policy measures that directly affect the costs borne by the receivers of the goods turned out to be much more effective than tolls with a higher tariff during the day, because most carriers did not increase their rates (only 9% increased the truck rate) or only by a small amount as a response to the toll, and also because these additional costs for the receivers were clearly outweighted by the additional costs of staying open longer. This is an important policy conclusion.

The above-mentioned studies do not present elasticities for changes in transport cost on time period choice. We made some tentative calculations on the basis of the outcomes of the American research (also making additional assumptions, e.g. on the distribution of traffic over the day in the base case and the magnitude of the transport costs; these calculations are available from the authors upon request). This results in period-specific transport cost elasticities for a shift from day to evening/night between -0.2 and -1, where the latter value does not apply to the effects of a toll during the day but to a subsidy to receivers of the goods for receiving deliveries during the evening/night.

Holguín-Veras et al. (2006) also describes a somewhat different policy. This concerns a toll on the bridges and tunnels to New York levied by the Port Authority of New York and New Yersey (PANYNJ). In 1997 an electronic toll system (E-ZPass) was introduced for cars and lorries, initially without a differentiation between time periods. In 2001 there was a change in the tariffs, which made the toll somewhat lower during the non-peak part of the day (and considerably cheaper during the night) than in the peaks for holders of electronic passes (which includes most of the lorries). The effects reported were in line with those calculated and reported for New York above.

Further experience with the choice between day or night-time delivery was gained when the PierPASS was introduced in California (Holguín-Veras, 2008). This is a fee paid by the owners of the goods (thus not the carriers) of $50 per '20 ft equivalent' container and $100 per '40 ft equivalent' container for delivery in the period 03:00 – 18:00 h.) to the ports of Los Angeles and Long Beach. The revenues of this 'traffic mitigation fee' were used to compensate the additional labour costs to keep the terminals open longer. The resulting daytime fee elasticity is about -0.5.

The model developed by Hunt and Stefan (2007) includes a time period choice model (five periods of the day) in freight transport estimated on RP data with period-specific constants (ASCs) and zonal attributes (usually not significant) for Calgary, Canada. In a later calibration only three period ASCs were recalibrated. Within each of the periods there is a choice of tour start time (in continuous time), but this is done through Monte Carlo simulation. The duration of the stop also comes from a Monte Carlo process.

Hensher and Puckett (2008) carried out a stated preference experiment in Sydney, Australia, in an interactive setting where both carriers and their clients were interviewed to make inferences about decision-making in the supply chains. They found that for receivers of goods the key variables were the price to be paid and the time of delivery of the goods.

Ellison et al. (2015) interviewed 62 Australian (mainly urban) freight operators asking how they would organise their deliveries under a number of hypothetical scenarios. They investigated the responses of the operators to two different government policies: a low emission zone (which applies all day) and a congestion charge (which applies from 07:00 h. to 18:00 h.). The data were analysed by estimating latent curve models (a form of structural equations modelling) for the use of toll roads, the number of routes to complete the delivery task, emissions standard and class of the vehicles used and departure time. For the latter choice, the respondents (being carriers, not receivers) had to take the time windows of the receivers as given and could only change departure time within these constraints. The paper does not give quantitative impacts of policy simulations on departure time choice.

3. THE SP-SURVEY

It is very hard to obtain revealed preference (RP) data (=data on observed choices) on transport time and cost by time-period of the day: these variables are difficult to measure directly, and transport times and transport costs are highly correlated. Furthermore, the transport costs vary only little over time periods since almost nowhere road user charges vary with time-of-day. Therefore, we based our time-period choice model for freight transport in Flanders on new stated preference (SP) data (=data on hypothetical/experimental situations).

In the SP interviews we focussed on the receivers of goods (consignees). Industry experts and the (limited) scientific literature (see section 2) tell us that they usually determine the delivery windows of the goods, and that carriers are bound by the choices that the senders and receivers make. The influence that the carrier might have on time period choice can be included through the transport costs function.

The recruitment and the SP interviews were carried out by GfK Belgium. Firms selected from existing company registers were called by telephone to check whether they were in scope (i.e. receiving goods delivered by road transport that takes place in the peaks), to determine in which segment they belonged (see below) and to ask whether they would be willing to participate in the SP survey. Within the firm we asked to interview the logistics manager, purchase manager or (in smaller firms) the director. The SP interviews were carried out as computer-assisted personal interviews (CAPI): the interviewer visited the firms at their premises, taking a laptop. During the interview, both the interviewer and the respondent looked at the screen of the laptop, where the questions were displayed, and the interviewer also read out the questions and typed in the answers (and was also available for giving explanations).

It is paramount that the SP questions refer to a situation that the respondent actually experienced, and that attribute levels are varied around current values. For freight this is even more important than for passenger transport, because in freight transport there is considerably more heterogeneity between the transports (shipments) than in passenger transport. Consequently, respondents were asked to describe a recent transport with a delivery in or just after a peak. This transport was taken as the context of the SP experiment. The attribute levels presented in the SP were pivoted around the actual attribute values.

Since we are interested in shifts away from the peak, if sufficed to sample shipments that are currently transported in the (morning or afternoon) peak. So in the interview we asked the respondents to describe a recent road-based shipment that was transported (at least partly) during a peak period.

The attributes for the SP experiment were selected on the basis of the literature and the policies that the SVV should be able to cope with (impacts of congestion and the possible introduction of tolls differentiated by time period). Each transport was described by the following attributes:

1. Transport time;
2. Transport cost;
3. Width of the delivery time window;
4. Location of the delivery time window in time.

The last two attributes determined the start and end of the delivery time window: this is the timeframe within the receiver wants the shipment to arrive at its final destination. This window was presented to the respondents as can be seen from the example choice situation in Figure 1.

Figure 1. Example of a choice situation

	Option A	Option B
Transport time	2 h.	2 h 30 min.
Transport cost	€ 100	€ 80
Delivery time window	14:00 – 15:00	13:00 – 13:30

Reliability of transport time was not included as an attribute, because including this would ask quite a lot from the SP presentation (Tseng et al. 2009) and the analysis. This would put too much burden on this survey. Consequently it was made very clear to the respondents that reliability did not vary between any of the alternatives presented.

Each attribute had five possible levels, except for the width attribute, which only had three levels.

1. The transport time varied around the transport time of the typical transport TT. The five levels were:

   TT × 0.75, 0.90, 1.00, 1.10, 1.25

   in which TT is the off-peak transport time of the typical transport as described by the respondent. Transport times of choice alternatives for which the available window required a transport (partly) during the peak were increased by 40% to both simulate existing congestion and encourage trading between the peak and off-peak alternatives;

2. Transport cost varied around the transport cost of the typical transport TC:

   TC × 0.65, 0.80, 0.90, 1.00, 1.15

   Note that by having different pivot factors for cost and time, we are probing more levels of the values-of-time. The pivot factors used for time and costs were based on the literature (especially literature on the value of travel time changes in freight transport such as described in de Jong et al., 2014).Transport costs of choice alternatives for which the available window required a transport (partly) during the peak were increased by 25%;

3. The width of the delivery time window varied typically between 30 minutes, 1 hour or 2 hours;

4. For the time location of the delivery time window we offered typically:
   - one alternative with a window starting two hours before the peak
   - one alternative with a window ending just before the peak
   - one alternative with a window starting at the beginning of the peak
   - one alternative with a window ending at the end of the peak
   - one alternative with a window sufficiently later than the peak such that transport could be made fully outside the peak.

   We did not offer any alternatives with windows opening directly after the peak, since that could lead to confusion on whether the transport was during the peak or not. The exact opening and closing times of the windows were modified according to legal restrictions and thinkable future opening times. Table 1 shows the delivery window for each combination of the third and fourth attribute in case of a morning peak delivery, assuming there are no (legal) restrictions on the delivery times.

Table 1. Delivery window depending on the levels of attribute 3 and attribute 4 (morning peak delivery, no legal restrictions on the window).

		Attribute 3: Width of the window		
		Level 1	**Level 2**	**Level 3**
Attribute 4: Time location of the window	**Level 1**	05:00 – 05:30	05:00 – 06:00	05:00 – 07:00
	Level 2	06:30 – 07:00	06:00 – 07:00	05:30 – 07:00
	Level 3	07:30 – 08:00	07:30 – 08:30	07:00 – 09:00
	Level 4	09:00 – 09:30	08:30 – 09:30	07:30 – 09:30
	Level 5	09:00+TT – 09:30+TT	09:00+TT – 10:00+TT	09:00+TT – 11:00+TT

Binary choice is the form of choice experiment that puts the smallest burden on respondents. However in this case, the numbers of attributes and levels are too large and the target number of respondents is too small for a full experimental design. An orthogonal 5x5x5x3 design contains 25 alternatives, which can be combined into 12 choice pairs (deleting one alternative each time). Twelve binary choice questions is a reasonable amount for a respondent during a face-to-face interview, therefore we decided that each respondent would be asked to make twelve choices. Note that since we do not have any hypothesis on the respondents 'preferences, we also do not have any prior expectations on dominant alternatives, so no choice pair was a priori disregarded .

We created 15 different sets of twelve choice pairs (each time deleting another alternative) So, each set was to be seen by about 10 respondents. Each design was folded randomly, but such that each attribute level occurred about the same number of times over all sets. The correlation between the attributes over all sets was always less than 0.031, so very close to orthogonality.

A pilot was carried out first, containing 27 interviews with receiving firms. This was followed by the full survey of 175 successfully completed interviews. The total number of completed interviews therefore is 202.

Specific quotas were defined on the basis of two characteristics: the type of receiver and distance band. These quota are meant to ensure that we will have enough respondents/observations in each segment to estimate at least a simple linear model with a few coefficients. The target number of interviews and the number actually completed are in Table 2. All specified targets were met.

Respondents with transports that took more than four hours were excluded, as were transports with implausible values on key attributes, especially on transport costs, speeds or delivery time intervals. 44 respondents were thus excluded from further analysis. This is a normal loss rate and such a loss was taken into account when setting the quota. These exclusions did not impact the characteristics of the design: the correlation between the design attributes remained low (less than 0.034) and the balance between the occurrences of all attribute levels (within 5%) was not disturbed. The correlations between the attribute levels that were actually shown are slightly higher (less than 0.056), except for the correlation between time and cost which is 0.25 due to the default 40% increase in transport times and 25% increase in transport costs during the peaks.

Table 2. Number of Interviews by type of receiver and distance band

Type of receiver	Survey target	Survey realisation	Sample used for analysis
Producer	50	59	44
Retailer	50	86	62
Wholesale, warehousing, distribution	50	57	52
Total	150	202	158

Distance band	Survey target	Survey realisation	Sample used for analysis
<= 50 km	70	91	72
51-150 km	50	78	65
151+ km	30	33	21
Total	150	202	158

The models in the next section will be estimated on 158 respondents, 151 of which described a recent transport that (partly) took place in the morning peak and 7 (partly) in the afternoon peak. This also implies that it will probably not be possible to estimate coefficients that are specific to the afternoon peak; coefficients such as those for transport costs and time will not distinguish between morning and afternoon peak (we did estimate a period-specific coefficient for the afternoon peak). The relatively small fraction of observations for deliveries in the afternoon peak (relative to the morning peak) is consistent with the frequency distribution of the delivery times for the incoming transport of the interviewed firms (see Figure 2).

Figure 3 shows the distribution of the respondents over the key survey dimensions: transport time, transport cost, transport costs per hour and mean speed. The average transport took 2 hours and 4 minutes for a distance of 85 kilometres at a mean speed of around 40 km/hour. The average transport costs were € 107 or € 55 per hour.

Figure 2: Distribution of the incoming transports by hour of the day (based on an unweighted average over 202 receiving firms of their answers to the question about all their incoming transports)

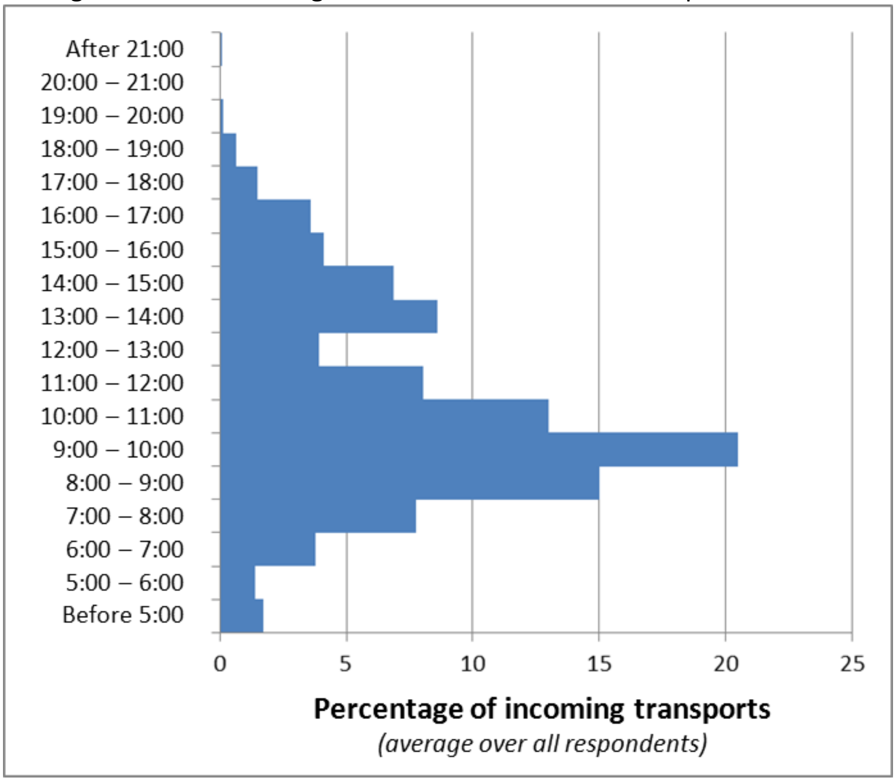
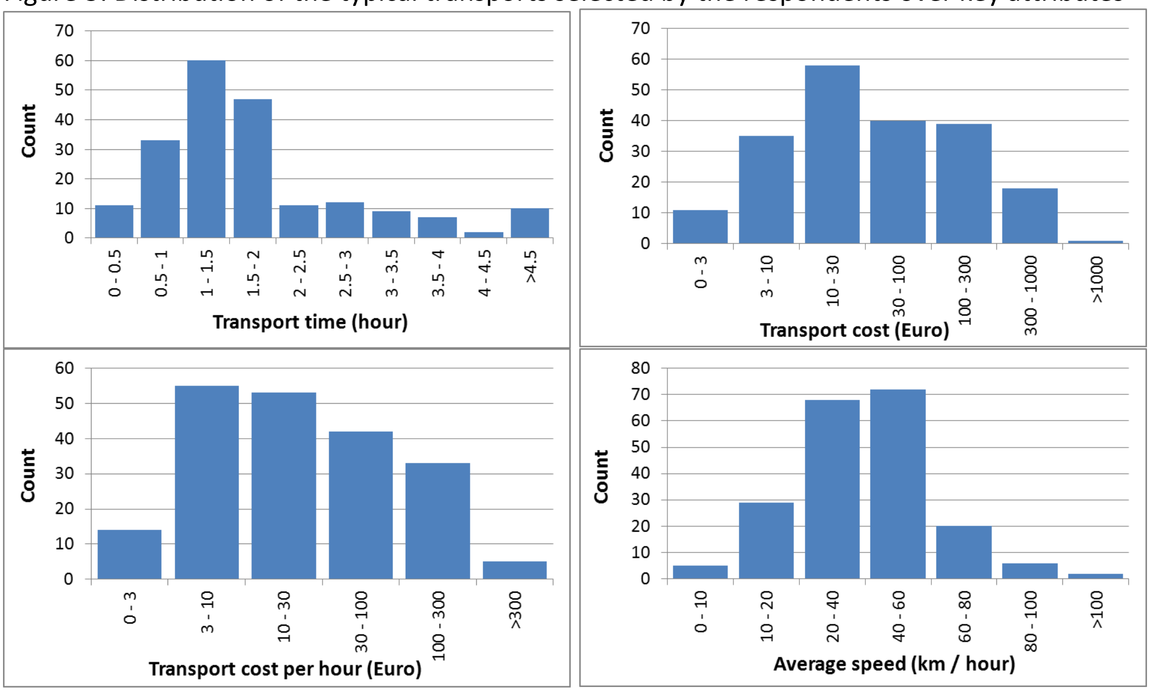


Figure 3: Distribution of the typical transports selected by the respondents over key attributes



4. ESTIMATION RESULTS

The SP data were used to estimate discrete choice models that explain the trade-offs between transport time, cost and earlier/later transports. This provides the basis for the time-period choice module that was implemented in the Strategic Flemish Freight Model, which uses seven time-of-day periods, including a morning and an afternoon peak. Logit models were estimated using the Alogit and Biogeme (Bierlaire, 2003) software.

We started the estimation with a linear additive utility function and obtained significant coefficients for transport costs, delivery window width and a number of period-specific constants (using the mid-point of the transport in time), but not for transport time. We tried logarithmic and Box-Cox specifications for costs and time and a number of interaction variables (attributes of the firm and the transport) to account for observed heterogeneity. Both for MNL and mixed logit (ML) models , we found that the best specification for non-container transport (78% of the observations), in terms of fit and in terms of significant coefficients for costs, time and period constants, was one with Box-Cox formulation for cost and a logarithmic formulation for time (up to 60 minutes, for longer times, the time coefficient is equal to 0). The Box-Cox parameter λ is significantly different for goods with a low and a high value density. For container transports (22% of the observations), the time specification is the same as for non-container, but the cost specification is logarithmic.

The outcome that, for a large part of freight transport, the receivers of the goods do not place any value on transport time is quite understandable. The transport costs that the receivers pay contains (for a discussion on transport costs functions see NEA et al., 2003):

- A transport distance dependent component (e.g. fuel costs);
- A transport time dependent component (e.g. wage costs for the lorry drivers, depreciation of the vehicle);
- Loading and unloading costs.

Therefore, a component for time-dependent transport costs is already included in the transport costs used in the model. The estimated cost coefficient shows that transport costs are of substantial importance. So, the time coefficient that we estimated here measures the additional effect of transport duration on the receiver’s disutility (de Jong and Ben-Akiva, 2007, de Jong et al., 2014). For transports above one hour, the transport durations (given the transport costs and the delivery time window) are not of importance. This only matters for short durations: for goods that usually are underway only a short while, the receiver dislikes a longer transport time. This gives trade-offs between delivery time and transport costs, between delivery time and transport time and between time and costs. The latter is the value of travel time changes, which is additive with respect to the value of travel time changes that is implied by the transport costs function of the carrier. Our finding that transport costs and time of delivery are the main variables explaining the choices of the receivers is consistent with the outcomes of Hensher and Puckett (2008).

Table 3. Estimation results (MNL and panel mixed logit) for the preferred model for time period choice

Variable	MNL		Panel mixed logit			
	Value	**Robust t-test**	**Value**	**Robust t-test**	**Standard deviation**	**Robust t-test**
(Random) coefficients:						
CostBoxCox (=($cost^{\lambda}$-1)/λ) NCT	-1.507	(-4.0)				
or:	−exp(0.410)	(1.6)	−exp(-0.689)	(-1.0)	1.233	(3.6)
Log(cost) CT	-12.57	(-7.4)				
or:	−exp(2.532)	(18.7)	−exp(3.163)	(9.3)	1.854	(6.4)
Coefficients:						
λ NCT low value goods	0.296	(5.3)	0.557	(3.4)		
λ NCT high value goods	0.203	(2.8)	0.468	(2.0)		
Log(time) if time<60 min; 0 else	-1.035	(-2.2)	-1.054	(-2.3)		
Width of delivery window	0.001	(1.0)	0.002	(1.4)		
Time period constants:						
1900_0459_D1_T1	-1.793	(-3.0)	-1.620	(-1.8)		
1900_0459_D1_T23	-1.782	(-7.4)	-2.252	(-4.3)		
0500_0659_D1_T23	-0.889	(-5.0)	-1.072	(-2.9)		
0700_0859_D1_T23	0.322	(2.0)	0.449	(1.9)		
1900_0459_D2_T1	-1.014	(-2.6)	-0.851	(-1.3)		
0500_0659_D2_T1	0.546	(1.9)	0.612	(1.5)		
0500_0659_D2_T23	-0.964	(-5.5)	-1.226	(-3.6)		
1900_0459_D2_T23	-2.714	(-9.6)	-2.931	(-5.5)		
1900_0459_D3_T1	-1.168	(-2.9)	-1.111	(-2.9)		
0500_0859_D3_T23	0.874	(2.3)	1.032	(1.6)		
1600_1859 PM	-0.655	(-1.9)	-0.355	(-0.7)		
Goodness-of-fit						
Number of observations	1896		1896			
Final Loglikelihood value	-952.5		-867.1			
$Rho^2(0)$	0.271		0.340			
$Rho^2(c)$	0.275		0.340			

Where:

Reference period: 9:00-16:00 h.

D1, D2, D3: distance bands : 0 – 50 km, 51 – 150 km, 151+ km respectively;

T1, T2, T3: type of receiver: producer, retailer, wholesaler respectively;

CT: containers (22%); NCT: non-containers (78%);

PM: for choices around the afternoon peak (all other time period dummies: for choices around the morning peak)

Low and high value goods: value density below and above 10,000 euro per tonne (each around 50%).

Table 3 shows the estimation results for a MNL model, and a mixed logit model that also accounts for unobserved heterogeneity in the cost coefficients.[1] For the mixed logit model we assumed the lognormal distribution for the coefficients (which has the advantage that the coefficients are restricted to one side of zero) and we applied a panel specification (assuming a respondent-specific error term) to correct for the bias that might results from having multiple choices from the same respondent.[2] We used 1000 pseudo-random draws and we verified that the final estimates are not sensitive to the number of draws.

We tested models with an alternative-specific constant for the left-hand side alternative, which could capture lexicographic or irrational responses to some degree, but this coefficient was not significant. The impact of the presence or absence of this coefficient on the other model coefficients was negligible. We decided to keep all alternative-specific constants referring to the periods, regardless of their significance, but to drop the insignificant left-hand side alternative-specific constant, because there is no a priori behavioural explanation for this coefficient.

We also tested interaction variables for the cost, time and width coefficients with type of receiver (producer, retailer of wholesaler), distance band, commodity type and number of employees of the receiving firms, but these were clearly not significant. This finding is most likely at least in part due to the limited sample size.

In Table 2, a number of t-ratios are below 1.96 (in absolute values), which says that these coefficients are not significantly different from zero:

- For the time period constants this is no problem, because there are no compelling reasons to assume a priori that these should be zero (i.e. equal to the reference time period constant for the period 09:00-16:00 h.).
- For the width coefficient this is no problem, because it will not be included in the model that will be implemented in the SVV (this variable is not needed for policy simulations and it's difficult to predict how it will develop in the future). We tested non-linear specifications without success. We concluded that the receivers are quite indifferent of the window size. This may be due to the fact that our windows are always two hours or less. In the end, we decided to leave it in the model presented in this paper to show this result.
- The cost coefficient in the mixed logit model seems not significantly different from zero, but this is due to the mixed logit specification with a lognormal distribution. A loglikelihood ratio test on a model without this coefficient revealed that the cost coefficient is significant.

The preferred period is the morning peak. Only for products at medium distances there is a slight preference for the period just before the morning peak. Periods before and after the peaks have different constants. In all cases, with the exception just mentioned, the period between 05:00 and 9:00 h. ('earlier') is seen as less attractive than the period after the morning peak ('later').

For the choices in and around the morning peak we also find that the period 19:00 to 05:00 h. is the least preferred period for producers (all distances) and for retail and wholesale (short and middle distances).

[1] We also tested mixed logit models with unobserved heterogeneity (taste variation) in transport time, but this increased the loglikelihood values by less than 0.1 point. Twice this value falls short of the critical value from the chi-square table (3.84 for one degree of freedom).

[2] Alternative methods for dealing with repeated measurements bias are re-sampling methods such as Jackknife and bootstrap or scaled MNL (Hensher et al., 2015).

We performed a loglikelihood ratio test and concluded that the mixed logit is significantly better than the MNL model which has two parameters less (standard deviations)[3]. Furthermore, we should keep in mind that the mixed logit model, thanks to the use of the panel specification, corrects for repeated measurements, whereas this does not happen in the MNL. As a consequence, for the MNL we should expect that the t-ratios are overstated, as often found in the literature on repeated measurements effects. The time, width and time period coefficients of MNL and mixed logit are quite similar. The cost coefficients for non-containers are very different between these two models, but this is related to the assumption of a lognormal distribution for the cost coefficients in the mixed logit model. In the next section we will calculate time and cost elasticities for both types of models so that we can compare differences in sensitivity to time and cost changes.

5. APPLICATION OF THE ESTIMATED MODEL

In order to give an impression of the sensitivity of time period choice to changes in time and costs, the time period choice model (as presented in section 4; both MNL and mixed logit) was programmed in Excel. This application uses the observed time period choices of the respondents in the survey (n=158). Of course, this sample is not representative for road freight transport on a working day in Flanders as a whole. Therefore we correct for the actual distribution of trucks over the time periods.

For this, we distinguish seven time periods per day (as in the SVV). Table 4 below gives the actual distribution for trucks based on automatic (double loop) traffic counts at 200 locations on motorways spread across the whole study area (row 1), and the predictions of the preferred model applied to the sample of firms (row 2). We determined period-specific correction factors (see in Table 5) by re-estimating the time period constants in the model to represent the period fractions in the traffic count data. Rows 3 and 5 in Table 4 give the predictions of the MNL and mixed logit models with the correction factors applied on the sample. We obtained a good match with the traffic counts (effectually we are imposing the fractions from the traffic count data).

Table 4. Observed and modelled time period fractions (%)

	Morning peak					Afternoon peak		
	0:00 – 4:59	05:00 – 06:59	07:00 – 08:59	09:00 – 11:59		12:00 – 15:59	16:00 – 18:59	19:00 – 23:59
Observed (traffic counts)	11.8%	22.4%	21.7%	44.1%		53.8%	27.1%	19.1%
MNL prediction (uncorrected)	4.3%	23.5%	41.7%	30.5%		60.7%	31.5%	7.7%
MNL prediction (corrected)	11.8%	22.4%	21.7%	44.1%		53.8%	27.1%	19.1%
Mixed logit prediction (uncorrected)	3.6%	22.2%	43.9%	30.4%		56.1%	39.3%	4.6%
Mixed logit prediction (corrected)	11.8%	22.4%	21.7%	44.1%		53.8%	27.1%	19.1%

[3] The difference between both models in the final value of the loglikelihood function is 85.4 (see Table 3). Twice this values exceeds the critical value (at the 95% confidence level from the chi-square distribution for two degrees of freedom of 5.99 by a considerable margin.

Table 5. Correction factors (need to be added to the time period constants)

Time period	Correction MNL	Correction Mixed logit
00:00 - 04:59	0.69	0.91
05:00 - 06:59	-0.48	-0.30
07:00 - 08:59	-1.08	-1.12
09:00 - 11:59	0	0
12:00 - 15:59	0	0
16:00 - 18:59	-0.03	-0.03
19:00 - 23:59	1.06	1.51

Two ‘policy’ simulations were carried out using the corrected model:

1. all transport times in morning and afternoon peak become 10% longer (given the formulation of the influence of time in the model, this is only simulated for travel times less than 60 minutes, through the time coefficient);
2. all transport costs in morning and afternoon peak become 10% higher.

In the base case 21.70% of AM transports took place in the peak. After the increase in peak transport times this becomes 21.61%. The implied transport time elasticity of the number of transports in the morning peak is -0.041 (MNL) or -0.043 (mixed logit), see Table 6. For the afternoon peak this is -0.188 (MNL) or -0.195 (mixed logit). This very low sensitivity of receivers of goods to transport time changes is due to factors that were discussed in the previous section: given that the time-dependent costs are already incorporated in the transport costs, the remaining impact of transport time on time period choice of receivers is very small. In the simulation, only a small minority of the respondents reported a transport below one hour. In the model, all other respondents are not sensitive to a time increase. This also explains why the differences between the time elasticities of the MNL and the mixed logit model are very small.

The sensitivity to a transport costs change is much larger (also see Figure 4): increasing the peak transport costs by 10% reduces the morning peak share to 15.82% (MNL) or 14.98% (mixed logit). Most of these transports shift to the period directly after the morning peak. The peak transport cost elasticity of the number of transports in the peak is -2.708 (MNL) or -3.097 (mixed logit) for the morning peak and -2.267 (MNL) or -2.685 (mixed logit) for the afternoon peak. The mixed logit model has the same time sensitivity as the MNL (the time coefficient was not made stochastic, only the cost coefficients), but it is somewhat more cost sensitive.

The finding that the sensitivity to costs is much greater than the sensitivity to time is related to the fact that we interviewed the receivers of the goods, who are more interested in what they pay (including or time-based transport costs; see section 4) than in the difference between the departure and arrival time of the transport. This is elaborated further in the conclusion section.

Table 6. Implied time and cost elasticities of time period choice by receivers of the goods

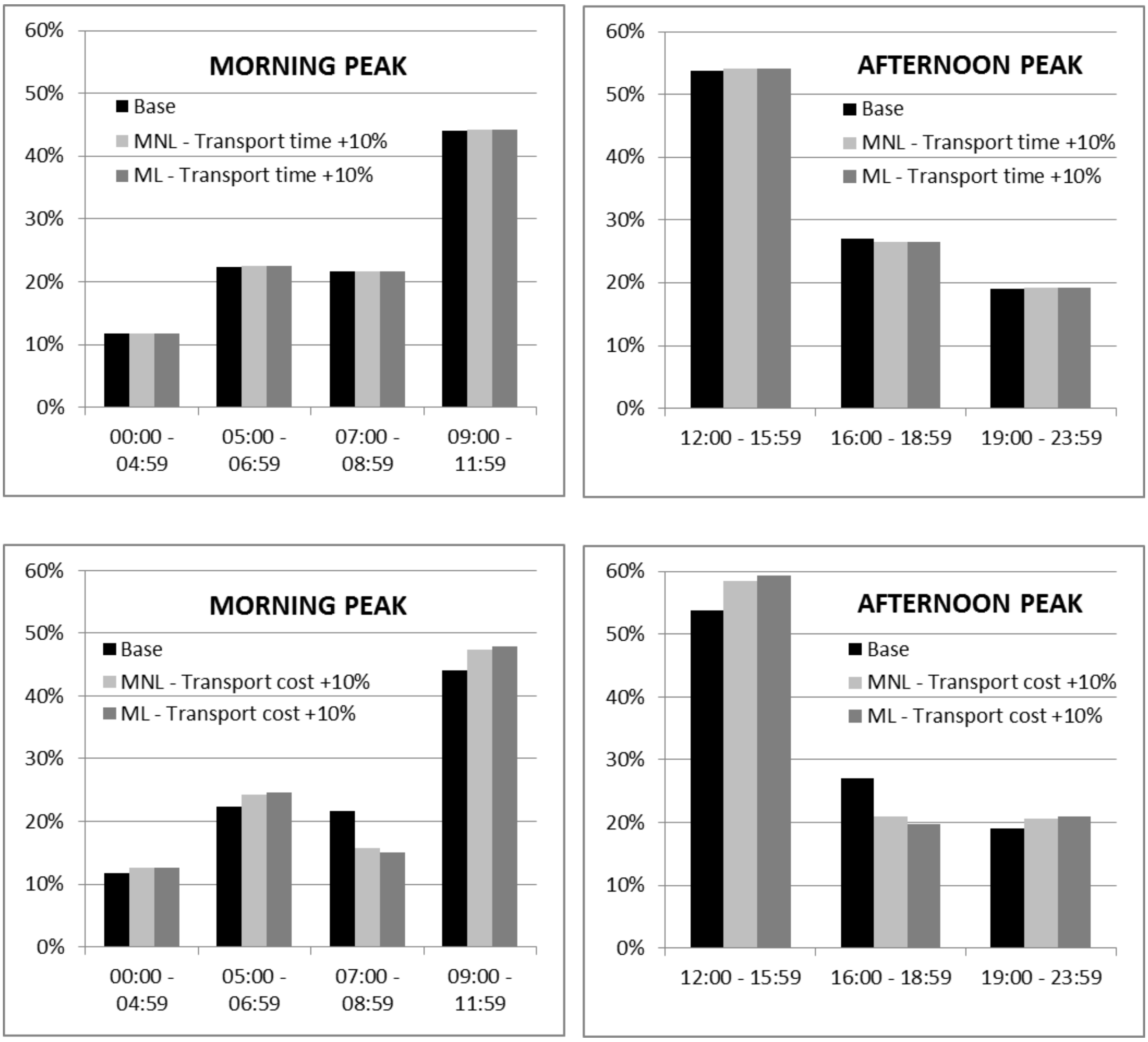
	Morning peak	Afternoon peak
Time – MNL	-0.041	-0.188
Time – Mixed logit	-0.043	-0.195
Cost – MNL	-2.708	-2.267
Cost – Mixed logit	-3.097	-2.685

Strictly speaking, for application of a model, estimated solely on SP data, not only a correction for the actual time period distribution is required, but also a rescaling of the model (changing the variance of the error component of the model). But to do this, we need to have a time period choice model for freight estimated on RP data, which is lacking. Therefore we had to assume that the scale of the SP model does not differ from that of a model estimated on RP data.

There are hardly any elasticities of freight time period choice in the international literature to compare our results against, because there have been so few (model) studies so far on this topic. The only other results we are aware of come from the American studies quoted in section 3 and relate to transport costs, not time.

Our transport cost elasticities are (in absolute values) higher than the elasticities that we tentatively calculated from the American literature. In itself this is an understandable outcome, because our elasticities are about shifts away from the peaks (7:00-9:00 h. and 16:00-19:00 h.) and the American ones about shifts to the evening and night. We expect that a shift from the morning peak to the period just before or after the morning peak will be easier than a shift from day to evening/night, because the receivers will be open in these periods anyway, or will only need a small extension of the working hours. Whether our elasticities might be too high cannot be said on the basis of the available literature. But please note that our elasticities relate to a change in total transport cost. An increase in the fuel or toll costs by the same proportion will have a much smaller elasticity.

Figure 4. Modelled impact of changes in transport time (top) and cost (bottom) in the peaks based on the best multinomial logit model (MNL) and the best mixed logit model (ML)



The time period choice model has been implemented in the SVV (version 4.1). Given the better fit on the estimated data, we preferred to implement the mixed logit model. However, during the implementation phase, it became clear that this would lead to unacceptable model run times due to the need to take random draws and the repeated model calculations for each value drawn. It was therefore decided to implement the MNL time period choice model in this version of the SVV. Given the continuous increase of computational power of computers, we aim to replace this by the mixed logit model in a future version.[4] Fortunately, the sensitivities to changes in time and cost are rather

[4] This is a much more general issue than just for the SVV. Many discrete choice models in academic journals nowadays are estimated using simulation methods, but in transport forecasting models (passenger and freight) that are applied in practice, the model types used are nearly always MNL and nested logit (see for instance Hess et al., 2007b). We would like to use the mixed logit models, that often fit the data significantly better, in practice, but this is often not feasible due to the long run times that the combination of large-scale modelling and simulation methods would entail. Even without mixed logit, these large-scale models (that can use thousands of zones and many iterations between traffic demand and supply) often already have run times of 24 hours and more.. We consider the search for faster methods of model application, that would enable simulation methods, as one of the most important current challenges in discrete choice research in transport.

similar in the MNL and mixed logit models, so the inaccuracy that is caused by the implementation of a non-optimal model is limited.

6. SUMMARY AND CONCLUSIONS

Submodels for the choice of time period are absent from practically all freight transport forecasting systems in the world. This paper reported a model that yields shifts between peak periods and other periods for freight transport by road in Flanders, in response to changes in transport time and cost for each period. The model was estimated on SP data from a dedicated survey amongst 158 companies that receive goods delivered by road transport during the peaks, and calibrated to reproduce the observed time distribution.

Mixed logit models (with random taste variation in some of the cost parameters) that also correct for the panel nature of the SP data improve the model fit significantly relative to multinomial logit model. In the model applications, the time sensitivity is the same for both model types, but the mixed logit model yields somewhat stronger cost sensitivities.

When applying this new time-period choice model, we find sensitivities for changes in transport cost (elasticities between -2.3 and -3.1) and transport time (elasticities between 0 and -0.2), which we think can be explained/justified. These outcomes refer to a change in total transport cost, not just toll or fuel cost. Also please note that these results refer to measures and developments that directly influence the receivers of the goods. In case of a peak charge, levied on the firms carrying out the transports, the experience in the US suggests that, certainly in the short run, only a small fraction of the carriers (only 9% did this in the US) will include the peak charge in the prices they charge their clients. As a result of this, only a small part of the original price change will be felt by the receiver of the goods (effectively this implies that the above elasticities for receivers can be reduced by a factor of about 10 in the short run).

The above-mentioned elasticities reflect the preferences of the receivers of the goods, which are the most important decision-makers on time-period choice in freight transport. Nevertheless, the carriers may also have an influence.

One of the reasons that, even with heavy congestions in the peaks, not all goods transports take place off-peak is that (road) haulage companies want to use their trucks all times of the day. So they will also accept transports that (partly) take place during the peak, because they have trucks available in the peak. Also not all transports can be done at the time of day that would be cheapest/fastest, because the carriers do not have enough trucks to do all these transports at the same (cheap) time. Often the carriers have to do their scheduling for multiple destinations within a single time window (distribution tours). These effects can be represented in a function that gives the transport price and transport time for senders/receivers for different time periods. In the SP survey we modelled how receivers would react to different transport prices, transport times and the timing and width of the delivery time window. Transport cost functions per period are available in the SVV, now that congestion has been integrated in the model.

The research carried out has indicated that receivers of goods are willing to shift the delivery times of these goods toward periods outside the peaks, if the price that they have to pay for the transport in the peak would go up (and the non-peak prices would not). The question then is whether time-differentiated toll charges, which in first instance are paid by the carriers, will increase the peak transport costs for the receivers substantially. There is evidence in the US that this may not be the case, at least not in the short run. Policy measures that would directly influence the price the receivers pay for the transport (such as early/late delivery subsidies) would not suffer from this disadvantage and would therefore be more effective. This study also found that receivers are unlikely to move to off-peak hours simply because of increasing congestion; their time sensitivity in time period choice is very small, unlike their costs sensitivity. If the carriers would react to increasing congestion by raising their freight rates, the receivers would react much more.

The time-period choice model, but also the mode and vehicle type choice model, in this model system for Flanders are missing potentially important variables such as flexibility of the transport service offered, safety of the goods and transport time reliability. These could be included in one or more specific further stated preference surveys. Discrete choice models estimated on the SP data (possibly estimated simultaneously with current components on current data) could then also be implemented in the model system.

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