

A TIME-PERIOD CHOICE MODEL FOR THE STRATEGIC FLEMISH FREIGHT MODEL BASED ON STATED PREFERENCE DATA

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1. INTRODUCTION

In transport model systems that are used in practice for forecasting and project appraisal, time period choice is usually missing. However, there is evidence, especially in passenger transport, that departure time choice is rather sensitive to changes in transport time and costs.

Transport models that do include a time-period choice are usually passenger models, such as the Dutch National Model system (LMS; see Willigers and de Bok, 2009). In freight transport time-of-day choice models are almost non-existent.

The current Strategic Flemish Freight Model (SVV) version 1.6 of the Flemish Traffic Centre does not contain an explicit time-period choice model either. But a new version of the SVV is being developed. In this version, a module will be 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). This paper describes the development of this new time-period choice module of the SVV.

It is very hard to obtain revealed preference (RP) data 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 have based the time-period choice model on new stated preference (SP) data. In the SP interviews we focussed on the receivers of goods (consignees). Industry experts and the (limited) scientific literature 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.

Firms in Flanders receiving goods by road transport were selected from company registers and called by phone to check whether they are in scope and to invite them to participate in the SP survey. The stated preference interview itself was done by computer assisted personal interviewing (CAPI). 27 pilot interviews were carried out, followed by a main survey of 175 firms. These were stratified by type of firm (manufacturers, wholesalers/warehouses and retailers) and by transport distance class for the typical transport that serves as the context and reference situation for the SP experiment.

Since we are interested in shifts away from the peak, it sufficed to sample shipments that are currently transported in the (morning or evening) 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 and in the SP experiments they were asked to choose between two (hypothetical) alternative transports for this shipment. Each transport is described by the following characteristics:

- Transport time
- Transport cost
- 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.

In the statistical design the presented attribute values are derived from four attributes: transport time, transport cost, width of the delivery time window and midpoint of the delivery time window.

The SP data have been 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 is implemented in the SVV, which uses seven time-of-day periods, including a morning and an afternoon peak. The implemented time-period choice model does not include specific delivery windows, but it gives the number of transports per period, depending on travel time and costs per period. It is made consistent with observed shares for the time periods and only produces changes relative to the base distribution: the module is applied in a pivot-point fashion. For the base year, a table for the observed distribution of transport over time periods is available.

In the next section of this paper we give an overview of the present Flemish strategic freight model. In a third section, the existing literature on time-period choice models in freight transport is presented. In a fourth section, the questionnaire used and the SP experiment on time-period choice in freight are described in detail. A fifth section reports on the outcomes of the survey and the estimation results for the discrete choice models. A final section presents the module as implemented in the new SVV version.

2. THE FLEMISH STRATEGIC FREIGHT MODEL

Currently, the Flemish authorities use the strategic freight model for Flanders version 1.6 (Verkeerscentrum, 2012) for the preparation and support of the policy to take decisions 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 base year is 2004. Scenarios are available for 2008 and 2020. Different modules use different zoning systems within the study area. Some modules have a NUTS-3 zoning system in the study area, other modules have a finer zoning system that corresponds more or less to the municipalities in the study area.

The model considers road, railway and inland waterways as possible modes. Sea- and air transport are not considered.

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 version of the model produces robust and reliable results, but there is a need for further development, such as an update of the base year and new scenario forecasts. Furthermore, a new module for time-period choice, that takes into account the congestion, has to be developed, as well as smaller improvements of the assignment module for rail transport.

Last but not least, a better integration of the freight model and the passenger transport models (both the Flemish regional model and the smaller-area provincial traffic models) is needed. The fourth generation strategic passenger transport models and the strategic freight model of Flanders will form one family: the strategic transport models of Flanders. Therefore, the next version of the strategic freight model of Flanders will also be called a fourth generation freight model ('version 4.1').

3. TIME-PERIOD CHOICE MODELS IN FREIGHT TRANSPORT

Considerable literature exists on time of day models, that explain the choice when to travel, 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), that 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. 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, Hess et al., 2007). 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 (Significance, 2011). 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). Examples of time-of-day choice models in freight transport are Halse et al. (2010) for Norway and Significance et al. (2013), but these are 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 the carriers did not increase their rates or only by a small amount as a response to the toll, and also because these additional costs

for the receivers were clearly outweighed 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). 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.

A somewhat different policy is described in Holguín-Veras et al. (2006). This concerns a toll on the bridges and tunnels to New York levied by the Port Authority of New York and New Jersey (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 daytime delivery (defined here as 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.

4. THE SP-SURVEY

For the new module for the time-period choice, we carried out a stated preference (SP) survey. It is paramount that the SP questions refer to an actual situation and that attribute levels are varied around current values for that attribute. 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, the experiment needs to be customised for each respondent.

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. 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 also is available for giving explanations).

In the telephone recruitment and the first part of the CAPI interview, we asked questions about a recently received transport. This observed transport forms the context of the SP experiment. The attribute levels presented in the SP are pivoted around the actually observed attribute values.

Twelve binary choice situations are presented in the SP experiment. These look like the example below.

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

These numbers are derived from four attributes that define each alternative.

1. Transport time (five levels)
2. Transport cost (five levels)
3. Width of the delivery time window (three levels)
4. Location of the delivery time window in time (five levels, offering both peak and off-peak options, conditional on the current arrival time and constrained by the legal requirements on delivery times).

An orthogonal 5x5x5x3 design contains 25 alternatives, which can be combined into 12 choice pairs (deleting one alternative each time). We created 15 different designs (each time deleting another alternative). Each design is folded (randomly, but such that the occurrence of each attribute level is equal over all sets). Each respondent is asked to make all 12 choices in a particular choice set. So, each choice set is seen by about 10 respondents.

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.

Quota were defined on the basis of two characteristics: the type of receiver and distance band. The target number of interviews and the number actually completed for these attributes are in Table 1. All specified targets were met.

Table 1. Number of Interviews by type of receiver and distance band

Type of receiver	Target	Realisation
Producer	50	59
Retailer	50	86
Wholesale, warehousing, distribution	50	57
Total	150	202

Distance band	Target	Realisation
<= 50 km	70	91
51-150 km	50	78
151+ km	30	33
Total	150	202

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. The models in the next section will be estimated on 158 respondents, 151 of which had an observed transport that (partly) took place in the morning peak and 7 (partly) in the afternoon peak.

5. ESTIMATION RESULTS

Logit discrete choice models were estimated on the SP data, using the Alogit and Biogeme software. We started the estimation with a linear additive utility function for the 151 morning peak respondents 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 also tried logarithmic and Box-Cox specifications for costs and time and found that the best model (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 time (up to 60 minutes, for longer times, the time coefficient is equal to 0).

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. In the transport costs that the receivers pay and that are of substantial importance in the estimation, a component for time-dependent costs is already included. So the time coefficient that we estimated here measures the additional effect of transport duration on the receiver's disutility. 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 does not want to see a somewhat extended transport duration. This gives trade-offs between delivery time and transport costs, between delivery time and transport time and between time and costs. The latter is a value of time, which is

additive with respect to the value of time that is implied by the transport costs function of the carrier.

After this, we added the observations for the afternoon peak and included interactions with the type of receiver and distance band. The model was estimated both using the standard logit model and using the Jackknife (see Cirillo et al., 2000) to correct for the fact that we have repeated observations for the same respondent (and thus dependence between error terms). Both types of estimation results for the preferred model are in Table 2.

Table 2. Estimation results (standard and Jackknife) for the preferred model for time period choice

Name	Before Jackknife			After jackknife	
	Value	Robust t-test	t-test	Value	t-test
CostBoxCox $(=(\text{cost}^\lambda - 1)/\lambda)$	-1.22	(-4.78)	(-5.43)	-1.180	(-3.21)
λ	0.359	(7.66)	(9.09)	0.352	(5.03)
Log(time) if time < 60 min	-1.04	(-2.26)	(-2.22)	-1.043	(-2.18)
Width of delivery window	0.00107	(1.01)	(0.99)	0.001	(1.06)
<u>Time period constants:</u>					
1900_0459_D1_T1	-1.84	(-2.96)	(-3.52)	-1.636	(-1.55)
1900_0459_D1_T23	-1.85	(-7.42)	(-7.88)	-1.788	(-4.37)
0500_0659_D1_T23	-0.902	(-5.00)	(-5.03)	-0.879	(-2.92)
0700_0859_D1_T23	0.376	(2.29)	(2.19)	0.377	(1.85)
1900_0459_D2_T1	-0.979	(-2.50)	(-2.26)	-0.952	(-1.83)
0500_0659_D2_T1	0.514	(2.25)	(2.22)	0.510	(1.31)
0500_0659_D2_T23	-0.997	(-5.47)	(-5.60)	-0.963	(-2.87)
1900_0459_D2_T23	-2.88	(-9.32)	(-9.64)	-2.775	(-5.36)
1900_0459_D3_T1	-1.4	(-2.90)	(-3.16)	-1.334	(-1.79)
1900_0859_D3_T23	0.788	(2.31)	(2.33)	0.778	(1.50)
1600_1859	-0.625	(-1.83)	(-1.69)	-0.633	(-1.13)

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.

For the model “before Jackknife” two t-ratios are presented. The first (“robust t-test”) is the t-ratio based on robust variance-covariance matrix, that already corrects for “non-severe mis-specification error related to the postulated distribution for the error terms” (Bierlaire, 2009). This t-ratio therefore already partly corrects for the unjustified assumption of independent error terms. The second t-ratio is the ordinary t-ratio. This one can be compared to the t-ratio after Jackknife. For the “after Jackknife” results we do not present robust t-ratios.

Comparing both sets of estimates makes clear that the coefficient values do not change much, but that the t-ratios usually decline when using the Jackknife.

The time and cost coefficients have the expected sign and are significant after Jackknife. 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 is not needed for policy simulations; we decided to leave it in the model.

The preferred period is the morning peak or the period between the peaks. Only for products at medium distances there is a slight preference for the period just before the morning peak.

For the choices in and around the morning peak we 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).

6. APPLICATION OF THE ESTIMATED MODEL

The preferred model will be implemented in the SVV version 4.1. This is work in progress. In order to get an idea about the sensitivity of time period choice to changes in time and costs, the preferred time period choice model (after Jackknife) 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. The table below gives the actual distribution for trucks, based on traffic counts (row 1) and the predictions of the preferred model applied to the sample of firms (row 2). After this, we determined period-specific correction factors (see in Table 4) by re-estimating the time period constants to represent the period fractions in the traffic count data and predicted again applying the preferred model with the correction factors on the sample (row 3), and obtained a good match with the traffic counts.

Table 3. 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%
Model prediction (uncorrected)	4.3%	23.2%	42.2%	30.3%	60.4%	32.0%	7.6%
Model prediction (corrected)	11.8%	22.4%	21.7%	44.1%	53.8%	27.1%	19.1%

Table 4. Correction factors (need to be added to the time period constants)

Time period	Correction
00:00 - 04:59	0.685
05:00 - 06:59	-0.4625
07:00 - 08:59	-1.094
09:00 - 11:59	0
12:00 - 15:59	0
16:00 - 18:59	-0.0543
19:00 - 23:59	1.073

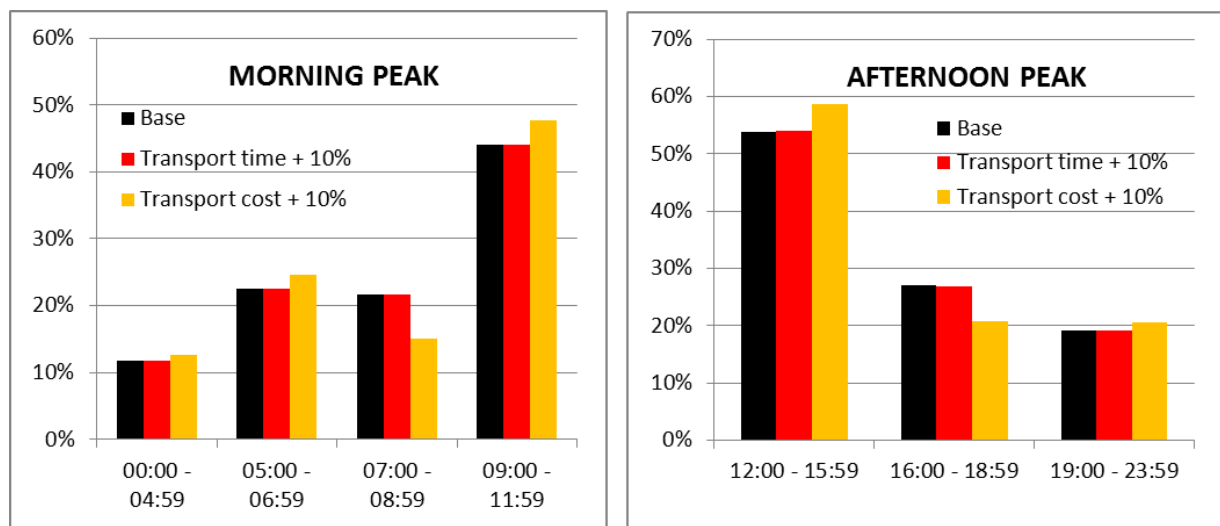
Two ‘policy’ simulations were carried out using the corrected model:

1. all transport times in morning and afternoon peak become 10% longer;
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 21.66% (also see Figure 2). The implied transport time elasticity of the number of transports in the morning peak is therefore -0.02. For the afternoon peak this is -0.08. This very low sensitivity of receivers of goods for transport time changes corresponds with what was discussed in the previous chapter: 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.

The sensitivity to a transport costs change is much larger (also see Figure 2): increasing the peak transport costs by 10% reduces the morning peak share to 15.09%. 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 -3.05 for the morning peak and -2.34 for the afternoon peak.

Figure 2. Modelled impact of changes in transport time and cost in the peaks



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 chapter 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 a plausible 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.

7. SUMMARY AND CONCLUSIONS

Submodels for the choice of time period are lacking in practically all freight transport forecasting systems. 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 that takes place in the peaks and calibrated to reproduce the observed time distribution.

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 -0.1), which we think are plausible. 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).

The new time-period choice model for road freight transport will be implemented as a component of the new Strategic Flemish Freight Model version 4.1.

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