Chapter 1
Redeveloping the Strategic Flemish Freight Transport Model

Stefan Grebe, Gerard de Jong, Dana Borremans, Pieter van Houwe and Hans-Paul Kienzler

1.1 Introduction

The Flemish authorities use a strategic freight model to forecast the demand for freight transport in the future and to support the decision making process for large infrastructure investments. In addition, the estimated truck matrix is input for the Flemish strategic passenger transport model.

The freight model is a classical four-step traffic model with several additions. One of the additions is a time-period choice model, which takes into account shifts from peak periods to off-peak periods due to congestion and allows for instance simulations of policies with congestion charges during peak hours. Another extension is a module for the use of logistical hubs (by mode).

Recently, a new version of the freight model (version 4.1.1) has been developed. In this paper we will discuss the Flemish freight model version 4.1.1 with a main focus on the mode and vehicle type choice. We discuss the model structure, the cost functions, the results of logit model estimations and present the elasticities. Furthermore, we briefly discuss the time-of-day choice model.

S. Grebe (✉) · G. de Jong
Significance, The Hague, The Netherlands
e-mail: grebe@significance.nl

G. de Jong
ITS Leeds, Leeds, UK

D. Borremans
Verkeerscentrum, Department MOW, Flemish Authorities, Antwerp, Belgium

P. van Houwe
MINT, Mechelen, Belgium

H.-P. Kienzler
Prognos, Basel, Switzerland

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1.2 Model Description

The model starts with the application of production and attraction multipliers on socio-economic data (for future year these are forecasts themselves) for each zone. The model uses 518 zones within Belgium and 96 larger external zones in Europe. Given the productions and attractions per zone, the distribution is modelled by using a gravity model.

Mode choice and vehicle type choice are integrated in one model and are estimated simultaneously. The mode and vehicle-type choice part of the model considers three road vehicle types, three train types and ten inland waterways (IWW) vessel types as direct and intermodal transport modes. Air transport and short sea shipping are not modelled. To compensate for this, the zones hosting harbors or airports attract and produce the amounts of cargo that is shipped further away in reality.

There are three separate network assignments: for IWW transport, for rail transport and for road transport (the latter takes place simultaneously with the assignment of the cars in the strategic passenger transport model).

Goods are distinguished in 20 product groups (NST 2007 classes) following the classification system for transport statistics by the Economic Commission for Europe by the United Nations. For three of the commodities (NST 15, 18 and 20) no data is available and no model can be estimated. Table 1.9 in the Appendix gives an overview of the classification of goods per NST class. During the estimations and the model calculations the commodities are treated independently. In this way, different demands for the different product groups can be taken into account and different trends between them are incorporated correctly.

1.3 Mode and Vehicle Type Choice

1.3.1 Model Specification

The mode choice and the vehicle-type choice are integrated within one model. An overview of the structure and the alternatives is shown in Fig. 1.1. The three modes are road, rail and inland waterways. The latter is split further into direct and intermodal transport. On the lowest level are the different vehicle types. For rail and the two IWW branches substitution between specific alternatives is taken into account by including nesting coefficients. For road transport a deterministic model is estimated, due to lack of observations on road vehicle type at the OD level.

In the estimation process, first multinomial logit (MNL) models have been estimated per NST class. The probability P_i of each alternative i can be calculated from the utilities U_i

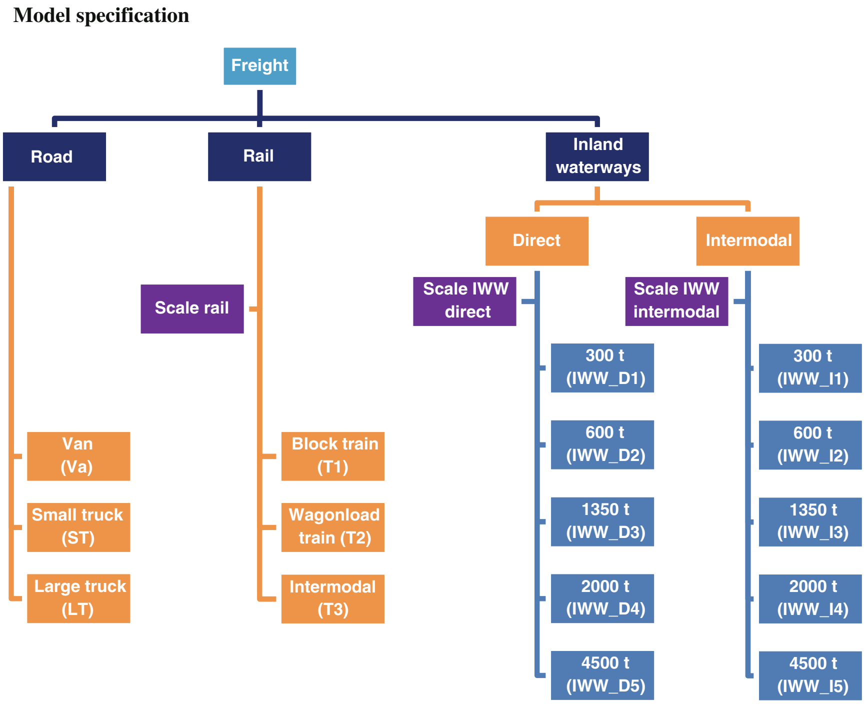

Fig. 1.1 Schematic overview of the mode and vehicle-type choice model

$$P_i = \frac{e^{U_i}}{\sum_{j=1}^{n} e^{U_j}}.$$

The utility function U_i consists of two terms, the observed utility component $\tilde{U}_i$ and the random (or error) term ε_i: $U_i = \tilde{U}_i + \varepsilon_i$.

The error term follows the extreme value distribution type 1 (Gumbel) and will not be further discussed in the rest of this paper. The observed utility consists of an alternative specific constant $\mathrm{ASC_i}$, a number of coefficients c_i times continuous variables K_i and d_i coefficients times dummy variables $D_i (= 0 \vee 1)$

$$\tilde{U}_i = \mathrm{ASC}_i + c_i \cdot K_i + d_i \cdot D_i.$$

The problem of a classical MNL model is that it does not take into account correlations between alternatives, which are very often present in reality. Nested logit models take the substitution between specific alternatives into account. The nesting coefficient describes the correlation between the alternatives. The coefficient has a value between 0 and 1. A value outside this range is not consistent with utility maximization and indicates a problem with the estimated model. A coefficient of 1

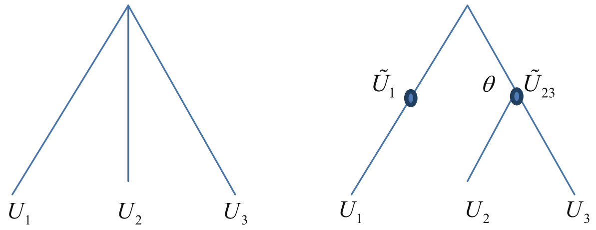

Fig. 1.2 Example of a simple MNL model with 3 alternatives (*left*) and a nested logit model (*right*). Θ is the nesting coefficient

means no correlation and 0 full correlation between the alternatives. A schematic comparison of a MNL model without nesting and a nested model is shown in Fig. 1.2.

In a nested model the probability for an alternative with utility H within a nest with m alternatives is calculated with a similar formula as in the MNL model.

Within a nest the probability of each alternative compared to the *m* alternatives is calculated analogously to a MNL model

$$P_{<i|A,k>} = \frac{e^{H_i/\theta}}{\sum_{j=1}^{m} e^{H_j/\theta}}$$

with H_i the observed utility component, Θ the nesting coefficient and k the number of alternatives on the higher level. The probabilities one level higher in the decision tree with n alternatives are calculated with

$$P_{A,k} = \frac{e^{G_k+\theta_k \cdot L_k}}{\sum_{l=1}^{n} e^{G_l+\theta_l \cdot L_l}}$$

with G_k the utility term of the top level and the "logsum"-term within the nest

$$L_k = \ln \sum_{i=1}^{m} e^{H_i/\theta}$$

The probability of alternative *i* is the product of the probabilities of the two levels

$$P_i = P_{A,k} \cdot P_{<i|A,k>} .$$

For more details about nested and MNL models see (Train 2003).

In the Flemish freight model only utilities on the lowest level are estimated. This means that in the formulas above $H_i = \tilde{U}_i$ and $G_k = 0$. By multiplication of all utilities with all nesting coefficients in the model, costs and times have the same meaning for all alternatives.

1.3.2 *Data on Transport Flows and Costs*

For the modes and vehicle types the distances and travel times between Origin-Destination (OD) pairs are estimated by skimming each of the three networks. The results are level-of-service files per vehicle type that contain per OD pair distance, travel time, (road charge) and accessibility. For intermodal transport the travel times and travel distances are given for both modes. All zones are accessible by road transport, but not all zones can be reached by rail and IWW. If an alternative is not available, it is excluded during the estimation process.

Furthermore, OD matrices for the base year 2010 have been constructed based on data from available transport statistics. These are aggregate data (zonal level) which are split in the 20 NST classes. For rail and IWW this information is available for all vehicle types. For road transport only a national vehicle type split is available. Therefore, a deterministic road vehicle-type choice model was built and calibrated to match the overall shares per vehicle type. Based on the costs the best vehicle per OD-pair is chosen. The method will be discussed in the next section.

The cost functions used in the mode and vehicle-type choice model include transport-time dependent cost, transport-distance dependent cost, toll fees, resting periods, as well as costs for loading, unloading and transshipment. The general formula is:

$$Costs = \tilde{\alpha} + \beta_1 \cdot t_1 + \gamma_1 \cdot d_1 + \tilde{\Delta} + \beta_2 \cdot t_2 + \gamma_2 \cdot d_2 + \varepsilon.$$

- $\tilde{\alpha}$ is the sum of the loading costs α_1 in the origin zone and the unloading costs α_2 in the destination zone. We assume that loading and unloading costs are equal and only depend on the vehicle type. As time and distance costs scale linearly, threshold effects are also incorporated in the costs for loading and unloading.
- β_1 and γ_1 are the time and distance dependent costs for rail or IWW. They are multiplied with the transport time t_1 and transport distance d_1 with one of these modes. The times and distances are vehicle type dependent.
- $\tilde{\Delta}$ are the transshipment costs for intermodal transports. In the model the assumption is made that these costs have to be paid once if the origin or destination zone is a harbor and otherwise twice. This implies that non-harbor zones require pre- and post-carriage by road transport.
- β_2 and γ_2 are the time and distance dependent costs for road transport (either direct or serving as access to and egress from rail or IWW). They are multiplied with the transport time t_2 and transport distance d_2 with this mode. Road user charges ε can add to the transport cost of the road shipment. The distances and times are vehicle type dependent.

For direct trips the equation simplifies:

$$Costs = 2 \cdot \alpha_{1,2} + \beta_{1,2} \cdot t_{1,2} + \gamma_{1,2} \cdot d_{1,2}(+\varepsilon).$$

The cost functions are determined based on data from studies in Scandinavia, the Netherlands and Belgium. In addition to the determination of the $\alpha, \beta, \gamma, \Delta$ and ε special attention has been given to also determine the shares of fuel, taxes, personal, insurances and other important contributions to the total costs per hour and per km. This is important in the forecast of future years and for the simulation of policy effects (Table 1.1). An overview of the unit cost inputs per ton is given in Fehler! Verweisquelle konnte nicht gefunden werden.

The capacities and the cost indicators take the average load factors into account. All costs have to be paid for integer numbers of vehicles, wagons or containers. For road transport the minimum shipment size is one truck. For (wet en dry) bulk ships it is the capacity of a ship. For container ships and intermodal rail transport costs are per containers of 12 tons. Carriage trains have a minimum shipment size of 20 ton (one wagon) and for block train only whole trains can be booked. Note that for intermodal shipments (IWW and rail) the road transport part is exclusively with heavy trucks (with containers) in the model.

For IWW the model distinguishes direct and intermodal shipments. For intermodal shipments the cost indicators of container ships are applied. For direct transport, the assumption is made that all NST classes except 2, 7 and 8 are dry bulk goods. For the other three classes we assume a mixture of wet and dry bulk with percentages of 50 % (NST 2), 75 % (NST 7) and 100 % (NST 8) wet bulk.

1.3.3 Deterministic Road Transport Model

For road transports five vehicle types are considered (the three that are in Fig. 1.1, but with container and non-container for small and large trucks). However, the information which vehicle is used for specific ODs is lacking (which is required to estimate a logit model). Therefore, the choice of the road-vehicle-type is estimated using a deterministic model. Based on the transport costs the cheapest vehicle is chosen for each OD pair and NST class. To match the fraction of containerized and non-containerized transports an intermediate step is introduced.

The amount of containerization per NST class is deduced from the Dutch BasGoed (Significance, NEA en DEMIS (2010)) in which the containerization is determined for 10 NSTR classes. Under the assumption that the amount of containerization is the same in both countries the containerization can be approximated for the 20 NST classes (see Table 1.2).

For small and large trucks the container-type and the non-container type are merged into a single vehicle type each. Thus, the deterministic model is estimated for three vehicle types only: vans, small trucks and large trucks. For small and large

grebe@significance.nl

Table 1.1 Overview of the cost indicators (in Euro per ton) for 2010 in the cost functions of all transport modes in the freight model

	Category	Capacity	β	γ	α	$\tilde{\Delta}$
Road	Van	1.5	20.087	0.086	14.400	14.400
Road	Small truck	12	3.128	0.019	2.700	2.700
Road	Small truck (co)	12	2.954	0.019	2.167	1.500
Road	Large truck	27	1.741	0.014	1.481	1.481
Road	Large truck (co)	27	1.656	0.014	1.541	0.970
IWW	dry bulk	600	0.163	0.004	0.800	
IWW	Wet bulk	600	0.171	0.004	1.000	
IWW	Container	600	0.120	0.004	0.600	
IWW	Dry bulk	1350	0.090	0.002	0.700	
IWW	Wet bulk	1350	0.111	0.002	0.800	
IWW	Container	1350	0.071	0.002	0.500	
IWW	Dry bulk	2000	0.075	0.002	0.654	
IWW	Wet bulk	2000	0.095	0.002	0.754	
IWW	Container	2000	0.060	0.002	0.454	
IWW	Dry bulk	4500	0.058	0.001	0.600	
IWW	Wet bulk	4500	0.077	0.001	0.700	
IWW	Container	4500	0.047	0.001	0.400	
IWW	Dry bulk	9000	0.038	0.001	0.600	
IWW	Wet bulk	9000	0.050	0.001	0.700	
IWW	Container	9000	0.031	0.001	0.400	
Rail	Carriage	501	0.898	0.021	1.500	
Rail	Intermodal	765	0.598	0.014	1.500	
Rail	Blok train	765	0.598	0.014	1.435	

The two vehicle types with the addition (co) are trucks with containers

Table 1.2 Average containerization per NST class for road transport

NST	% Cont	NST	% Cont	NST	% Cont	NST	% Cont
1	2.9 %	6	5.1 %	11	6.8 %	16	6.8 %
2	1.5 %	7	1.6 %	12	6.8 %	17	6.8 %
3	1.2 %	8	2.5 %	13	6.8 %	18	–
4	4.5 %	9	2.2 %	14	3.1 %	19	6.8 %
5	4.3 %	10	4.3 %	15	–	20	–

trucks the costs depend on the amount of containerization per NST class δ_{NST} and are calculated as:

$$Costs = \delta_{NST} \cdot Costs_{Container} + (1 - \delta_{NST}) \cdot Costs_{No-Container}.$$

Fig. 1.3 Overview of driving times (*light grey*) and resting times (*dark grey*) for road transport. For shipments longer than 24 h the pattern repeats

In the mode and vehicle choice model congestion is not considered as freight transport takes place only to a small extent during peak hours. Much more important to consider during mode choice are the mandatory rest periods for truckers. In the model they are added to the transport times for road-shipments longer than 270 min. Figure 1.3 gives an overview of the implemented resting periods. In the calculation of the time-dependent costs the short breaks of 45 min are considered, the long breaks during the night are not.

A not trivial choice in the deterministic model is the trip frequency. The OD matrix contains the flows of goods between zone pairs in the base year. This corresponds to a trip frequency ω equal to 1. Per NST class there are many zone pairs where several shippers and receivers are situated. For most of them the trip frequency will be higher than once per year. Both effects are arguments for a higher trip frequency. Counteracting this is consolidation of shipments from different zones. By comparing the amount of ton kilometers per vehicle type in Belgium (see Table 1.3), the optimum trip frequency is determined. It is 2.6 for national transports and 1.04 for international transports. After the calibration the determined and observed shares per vehicle type are in good agreement (Federale Overheidsdienst Economie, ADSEI 2010).

Taking into account the containerization per NST class, the rest times and the trip frequencies, the costs for the three vehicle types can be calculated for each OD pair. Per vehicle type also the minimum number of vehicles is determined. The total costs are the product of the costs per vehicle and the minimum number of vehicles (integer number) required. For each OD pair the cheapest type is chosen and its price is used in the logit model.

1.3.4 Estimation Results

The logit model is estimated with the ALOGIT software. In the estimations process observations are weighted by their shipment size. To normalize all shipments are normalized by the average shipment size per NST class (see Table 1.4).

Table 1.3 Observed and modelled distribution (after the calibration) of freight in ton kilometers transported in vans, light and heavy trucks for national and international shipments

Mode	Observed		Deterministic model	
	National (%)	International (%)	National (%)	International (%)
Van	0.5	0.0	0.82	0.08
Light	5.5	1.0	4.45	0.91
Heavy	94.0	99.0	94.73	99.01

Table 1.4 Average flow of goods per OD pair and NST class

NST	Ton per transport	NST	Ton per transport
1	203.9	10	381.9
2	143.6	11	104.1
3	258.9	12	97.5
4	187.9	13	24.8
5	46.5	14	109.9
6	119.4	16	47.1
7	268.9	17	39.9
8	189.8	19	31.0
9	321.5	Average	159.9

The model includes a cost term that consists of the monetary transport costs and shadow costs to account for the transport time that is related to the commodities (e.g. for interest on the capital in transit, deterioration, safety stock). For the transport time different valuation estimates have been tested and compared. In the final model the transport time is valuated with 10 % of the transport costs for non-containerized goods and 20 % for containerized goods, which means that transport time is valuated as shadow costs of 10 of 20 % respectively (Significance et al. 2013).

In the model cost coefficients are estimated for road, rail, direct IWW and intermodal IWW. The utilities of all alternatives have the structure

$$\tilde{U}_i = \mathrm{ASC}_i + \mathrm{cc}_i \cdot \left(\frac{C}{TonTot} + 0.1 \cdot \frac{C}{TonTot}\right) + D_i^{\mathrm{int}} + D_i^{\mathrm{Hav}},$$

with ASC the alternative specific constants, cc the cost coefficients, C the transport costs and TonTot the size of the transport. $\mathrm{D}^{\mathrm{int}}$ is a dummy for international transports and $\mathrm{D}^{\mathrm{Hav}}$ the dummy for trips to harbor zones. The 0.1 in the formula is a 0.2 for containerized shipments. As reference category road transport has been chosen. Therefore, the ASC for road transport has been fixed to zero.

An overview of all results is given in Table 1.5. The model contains individual cost coefficients for road, rail plus direct and intermodal IWW transport. All cost coefficients have negative values. The absolute values for road transport are the smallest, for rail transport in the middle and for IWW transport the largest. This is in agreement with our expectations. In addition, significant dummy coefficients have been found for international IWW and rail transports and transports by rail to or from harbor zones.

Different patterns of substitution between different modes were tested by specifying different nesting structures and testing whether the nesting coefficients were significant. Per NST class zero, one or two nesting coefficients are estimated.

Table 1.5 Overview of the estimated coefficients of the final model

File	NST01.F12	NST02.F12	NST03.F12	NST04.F12	NST05.F12	NST06.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Observations	275389	156103	233731	274571	220612	267109
Final log (L)	−69989.2	−92727	−208866.9	−49407.1	−88370.8	−116294.7
D.O.F.	20	16	20	20	7	18
$\text{Rho}^2(0)$	0.845	0.675	0.605	0.892	0.7	0.78
$\text{Rho}^2(c)$	0.083	0.124	0.134	0.102	0.088	0.06
Estimated	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
Scaling	1	1	1	1	1	1
ASC_Road	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_Rail1	−25.11 (−13.6)	−8.097 (−56.2)	−9.367 (−88.4)	−97.36 (−4.4)	−2.004 (−120.4)	−5.487 (−5.1)
ASC_Rail2	−27.93 (−13.6)	−10.15 (−57.6)	−10.71 (−88.6)	−98.70 (−4.5)	−2.998 (−186.3)	−6.989 (−5.1)
ASC_Rail3	−34.42 (−13.6)	−13.63 (−55.1)	−13.42 (−82.7)	−101.1 (−4.6)	−4.174 (−150.6)	−9.883 (−5.1)
ASC_IWW_D1	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_I1	0 (*)	0 (*)	−12.51 (−28.3)	0 (*)	0 (*)	0 (*)
ASC_IWW_D2	−14.09 (−13.8)	−5.712 (−42.5)	−4.274 (−99.7)	−60.63 (−4.5)	0 (*)	−13.98 (−5.0)
ASC_IWW_I2	−21.99 (−16.0)	0 (*)	−7.124 (−51.6)	−135.1 (−4.4)	0 (*)	0 (*)
ASC_IWW_D3	−12.45 (−13.6)	−2.214 (−32.7)	−2.336 (−76.1)	−43.68 (−4.5)	0 (*)	−7.054 (−5.1)
ASC_IWW_I3	−16.87 (−13.9)	0 (*)	−4.715 (−45.9)	−98.48 (−4.4)	0 (*)	−7.206 (−5.0)
ASC_IWW_D4	−14.16 (−13.8)	−2.176 (−33.2)	−2.561 (−80.9)	−59.29 (−4.5)	0 (*)	−7.780 (−5.1)
ASC_IWW_I4	−18.94 (−15.2)	0 (*)	−4.173 (−41.8)	−152.7 (−4.4)	0 (*)	−4.593 (−3.6)
ASC_IWW_D5	−13.77 (−13.8)	0.8681 (15.9)	−1.203 (−40.4)	−49.80 (−4.5)	0 (*)	−11.71 (−5.1)
ASC_IWW_I5	−14.54 (−12.6)	−0.5718 (−0.2)	−3.891 (−41.3)	−172.4 (−4.3)	0 (*)	−3.963 (−3.1)
InternRail	1.540 (6.8)	0.8425 (12.5)	2.305 (43.0)	10.08 (4.1)	−0.2126 (−13.7)	−0.8602 (−5.0)
InternIWW	4.401 (13.2)	−1.309 (−25.2)	2.506 (73.8)	21.12 (4.4)	0 (*)	1.030 (4.4)

(continued)

Table 1.5 (continued)

File	NST01.F12	NST02.F12	NST03.F12	NST04.F12	NST05.F12	NST06.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
HarborRail	5.283 (12.4)	−1.531 (−23.0)	2.617 (50.3)	21.19 (4.3)	0.5161 (36.1)	1.142 (5.0)
cc_Road	−0.09306 (−12.8)	−0.1354 (−43.6)	−0.1286 (−62.1)	−0.2872 (−5.6)	−0.04490 (−76.2)	−0.1086 (−5.1)
cc_Rail	−0.05573 (−7.9)	−0.1323 (−29.1)	−0.08025 (−29.8)	−0.1694 (−11.3)	−0.07660 (−65.7)	−0.1610 (−5.1)
cc_IWW_D	−0.4522 (−13.7)	−1.066 (−46.3)	−0.5832 (−72.8)	−5.026 (−4.6)	0 (*)	−1.172 (−5.1)
cc_IWW_I	−1.540 (−11.7)	−3.432 (−5.3)	−0.7038 (−49.8)	−4.139 (−4.1)	0 (*)	−2.096 (−4.8)
Theta_IWW_I	0.6734 (14.7)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	0.4269 (5.1)
Theta_IWW_D	0.3291 (38.0)	0.3574 (63.3)	0.4905 (99.4)	0.5811 (37.6)	1.000 (*)	1.000 (*)
Theta_Rail	1.000 (*)	1.000 (*)	1.000 (*)	0.09426 (4.6)	1.000 (*)	1.000 (*)

File	NST07.F12	NST08.F12	NST09.F12	NST10.F12	NST11.F12	NST12.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Observations	168950	250690	264028	248535	229675	201072
Final log (L)	−80577.3	−183076.1	−99886.4	−155781.1	−99952.1	−125041.1
D.O.F.	21	18	19	19	14	15
$Rho^2(0)$	0.668	0.707	0.807	0.626	0.754	0.604
$Rho^2(c)$	0.103	0.057	0.079	0.041	0.062	0.15
Estimated	16-Jan-15	14-Jan-15	16-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
Scaling	1	1	1	1	1	1
ASC_Road	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_Rail1	−12.83 (−5.3)	−6.500 (−73.7)	−4.903 (−35.1)	−3.799 (−24.3)	−3.316 (−3.8)	−1.969 (−111.2)
ASC_Rail2	−16.14 (−5.3)	−7.668 (−74.3)	−5.578 (−35.1)	−5.032 (−24.3)	−4.388 (−3.8)	−2.741 (−141.8)

(continued)

Table 1.5 (continued)

File	NST07.F12	NST08.F12	NST09.F12	NST10.F12	NST11.F12	NST12.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
ASC_Rail3	−22.60 (−5.3)	−10.38 (−72.2)	−7.148 (−34.8)	−8.369 (−24.4)	−6.344 (−3.8)	−4.126 (−123.3)
ASC_IWW_D1	−10.31 (−5.1)	0 (*)	0 (*)	0 (*)	−14.18 (−4.7)	0 (*)
ASC_IWW_I1	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D2	−10.47 (−5.3)	−4.299 (−89.0)	−5.576 (−48.4)	−9.062 (−26.4)	−15.09 (−4.8)	0 (*)
ASC_IWW_I2	2.421 (1.2)	−11.78 (−28.3)	−1.528 (−3.4)	−20.62 (−12.0)	0 (*)	0 (*)
ASC_IWW_D3	−1.931 (−5.0)	−3.069 (−75.5)	−4.278 (−41.0)	−7.621 (−23.3)	−10.99 (−3.8)	−2.946 (−61.0)
ASC_IWW_I3	2.550 (1.4)	−7.419 (−31.2)	−4.354 (−8.0)	−14.74 (−15.3)	0 (*)	−0.8200 (−7.1)
ASC_IWW_D4	−2.452 (−5.1)	−3.081 (−79.8)	−3.977 (−37.3)	−8.194 (−25.9)	−11.70 (−4.2)	−2.203 (−56.5)
ASC_IWW_I4	−2.684 (−1.5)	−9.643 (−33.5)	−2.745 (−6.0)	−16.48 (−15.4)	0 (*)	3.255 (60.6)
ASC_IWW_D5	4.323 (5.3)	−1.553 (−46.4)	−3.725 (−42.5)	−7.669 (−24.4)	0 (*)	−1.058 (−34.3)
ASC_IWW_I5	−6.126 (−3.5)	−5.345 (−26.7)	−0.8786 (−2.2)	−15.27 (−15.7)	0 (*)	4.271 (84.6)
InternRail	0.2285 (1.7)	0.1395 (4.2)	0.4618 (16.8)	−1.429 (−21.7)	−0.5841 (−3.7)	−0.3324 (−17.2)
InternIWW	−2.836 (−5.3)	0 (*)	−0.1630 (−4.1)	−1.747 (−13.1)	−5.571 (−3.6)	−0.7909 (−40.7)
HarborRail	−2.507 (−5.2)	0.8848 (27.9)	1.516 (31.9)	0.8522 (19.5)	0.8282 (3.7)	0 (*)
cc_Road	−0.1220 (−5.3)	−0.02492 (−29.6)	−0.04757 (−29.9)	−0.09695 (−24.6)	−0.07789 (−3.7)	−0.01900 (−34.6)
cc_Rail	−0.1033 (−5.1)	−0.01958 (−16.7)	−0.03777 (−20.4)	−0.1073 (−23.0)	−0.1247 (−3.7)	−0.03124 (−33.1)
cc_IWW_D	−1.960 (−5.3)	−0.4238 (−59.4)	−0.2638 (−25.3)	−0.3779 (−23.6)	−0.04960 (−2.2)	−0.2932 (−38.1)
cc_IWW_I	−4.213 (−5.3)	−0.6024 (−20.7)	−1.133 (−14.4)	−0.5089 (−6.0)	0 (*)	−0.8211 (−91.6)
Theta_IWW_I	0.2770 (5.3)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Theta_IWW_D	0.7381 (68.3)	0.5082 (79.2)	0.8011 (35.5)	0.4052 (24.8)	0.6153 (3.8)	1.000 (*)
Theta_Rail	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)

(continued)

Table 1.5 (continued)

Observations	NST13.F12	NST14.F12	NST16.F12	NST17.F12	NST19.F12
Final log (L)	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
D.O.F.	TRUE	TRUE	TRUE	TRUE	TRUE
Observations Final log (L) D.O.F. Rho^2(0)	NST13.F12 VrachtModel TRUE 153914	NST14.F12 VrachtModel TRUE 238610	NST16.F12 VrachtModel TRUE 175107	NST17.F12 VrachtModel TRUE 174826	NST19.F12 VrachtModel TRUE 189694
Rho^2(c)	−47506.3	−149214.4	−122599.9	−60910.3	−93221.3
Estimated	7	19	17	7	16
Scaling	0.671	0.66	0.619	0.655	0.737
ASC_Road	0.14	0.088	0.168	0.107	0.13
ASC_Rail1	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
ASC_Rail2	1	1	1	1	1
ASC_Rail3	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D1	−0.8534 (−36.0)	−7.181 (−50.8)	−5.570 (−35.7)	−1.360 (−67.8)	−1.314 (−74.0)
ASC_IWW_I1	−2.455 (−117.8	−8.941 (−51.4)	−8.711 (−38.3)	−2.565 (−136.1	−2.572 (−155.6)
ASC_IWW_D2	−3.568 (−99.1)	−12.21 (−50.7)	−12.94 (−37.8)	−3.765 (−116.9	−3.733 (−131.4)
ASC_IWW_I2	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D3	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_I3	0 (*)	−6.138 (−60.2)	−2.948 (−25.9)	0 (*)	−3.151 (−46.2)
ASC_IWW_D4	0 (*)	−14.55 (−18.7)	0 (*)	0 (*)	0 (*)
ASC_IWW_I4	0 (*)	−3.915 (−47.6)	−0.6739 (−8.0)	0 (*)	−1.649 (−36.1)
ASC_IWW_D5	0 (*)	−3.330 (−16.7)	5.436 (22.5)	0 (*)	−2.095 (−7.9)
ASC_IWW_I5	0 (*)	−3.885 (−47.4)	−2.907 (−30.5)	0 (*)	−1.540 (−30.8)
InternRail	0 (*)	−6.428 (−25.7)	8.068 (30.0)	0 (*)	0 (*)

(continued)

Table 1.5 (continued)

Observations	NST13.F12	NST14.F12	NST16.F12	NST17.F12	NST19.F12
Final log (L)	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
D.O.F.	TRUE	TRUE	TRUE	TRUE	TRUE
InternIWW	0 (*)	−3.045 (−38.5)	0 (*)	0 (*)	−1.699 (−27.2)
HarborRail	0 (*)	−2.279 (−12.7)	12.54 (35.9)	0 (*)	−1.269 (−5.3)
cc_Road	−0.2298 (−11.2)	0.8343 (19.3)	−0.3640 (−6.0)	−0.2179 (−11.8)	−0.1915 (−11.8)
cc_Rail	0 (*)	0.1790 (3.8)	−1.744 (−21.9)	0 (*)	−0.8982 (−20.6)
cc_IWW_D	0.1482 (7.7)	2.200 (40.0)	−0.4334 (−7.6)	0.3794 (22.5)	0.3510 (23.7)
cc_IWW_I	−0.03393 (−59.5)	−0.06251 (−39.6)	−0.06911 (−31.3)	−0.04064 (−64.9)	−0.04324 (−81.6)
Theta_IWW_I	−0.07170 (−60.7)	−0.07476 (−32.2)	−0.1271 (−31.2)	−0.07788 (−61.3)	−0.08366 (−76.7)
Theta_IWW_D	0 (*)	−0.5087 (−46.0)	−1.018 (−41.6)	0 (*)	−0.3163 (−48.4)
Theta_Rail	0 (*)	−1.068 (−32.3)	−2.698 (−37.3)	0 (*)	−0.6184 (−16.2)
Observations	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Final log (L)	1.000 (*)	0.3983 (53.1)	0.3157 (40.2)	1.000 (*)	1.000 (*)
D.O.F.	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)

The Theta coefficients are the nesting coefficients. t-ratios are given within brackets

1.3.5 *Time and Cost Elasticities*

Time and cost elasticities have been calculated using the estimated model. This has been done by increasing the transport time or the transport costs in one of the three modes (road, rail, IWW) with 10 % and keeping the rest constant. In the calculations of the cost elasticities only the real cost are increased and not the 10 or 20 % of the time valuation. By comparing the mode shares (in ton and ton kilometers) before and after the adjustment the elasticities are calculated

$$\sigma = \frac{N_{(+10\,\%)} - N}{N \cdot 10\,\%},$$

with N the number of ton or ton kilometer. The results are displayed in Tables 1.6 and 1.7. The cross elasticities are calculated for all NST classes. Due to the huge amount of elasticities we have chosen to present the full set of own and cross elasticities only for one commodity (NST 1) as an example (Table 1.6) and own elasticities for all commodities (Table 1.7).

The time elasticities are (in absolute value) smaller than the price elasticities as the costs also include non-time dependent costs (e.g. fuel) which are larger than the 10/20 % increase of the costs for the time elasticities. Averaged over all commodities the elasticities are for road transport −0.13 for time and −0.21 for costs, for rail −0.47 and −0.91 and for inland waterways −1.01 and −1.44 respectively.

Table 1.6 Time and price elasticities including all cross elasticities for NST 1 per ton and ton kilometer

NST	Type		IWW		Rail		Road	
			Price	Time	Price	Time	Price	Time
1	WE	ton	0.04	0.02	0.00	0.00	−0.02	−0.01
1	SP	ton	0.05	0.04	−0.18	−0.08	0.39	0.25
1	BV	ton	−0.61	−0.41	0.00	0.00	0.22	0.13
1	WE	ton * km	0.05	0.04	0.01	0.00	−0.05	−0.03
1	SP	ton * km	0.06	0.04	−0.30	−0.15	0.76	0.50
1	BV	ton * km	−0.77	−0.58	0.00	0.00	0.42	0.27

Table 1.7 Time and price elasticities for all NST classes per ton and ton kilometer

NST	Type	IWW		Rail		Road	
		Price	Time	Price	Time	Price	Time
1	ton	−0.77	−0.51	−0.39	−0.18	−0.03	−0.02
1	ton * km	−0.99	−0.75	−0.61	−0.32	−0.08	−0.05
2	ton	−0.82	−0.44	−0.81	−0.34	−0.18	−0.10
2	ton * km	−0.92	−0.58	−1.07	−0.53	−0.52	−0.34
3	ton	−0.64	−0.37	−0.53	−0.22	−0.15	−0.08
3	ton * km	−0.77	−0.53	−0.69	−0.35	−0.40	−0.26
4	ton	−1.12	−0.65	−0.41	−0.18	−0.02	−0.01
4	ton * km	−1.67	−1.20	−0.63	−0.33	−0.05	−0.03
5	ton			−0.57	−0.27	−0.02	−0.01
5	ton * km			−0.76	−0.40	−0.05	−0.03
6	ton	−2.18	−1.30	−0.96	−0.44	−0.16	−0.10
6	ton * km	−3.11	−2.33	−1.47	−0.76	−0.41	−0.26
7	ton	−0.65	−0.35	−0.69	−0.30	−0.18	−0.11
7	ton * km	−0.86	−0.57	−0.95	−0.48	−0.49	−0.32
8	ton	−1.00	−0.58	−0.47	−0.21	−0.09	−0.05
8	ton * km	−1.59	−1.20	−0.73	−0.38	−0.23	−0.15
9	ton	−1.23	−0.68	−0.55	−0.25	−0.07	−0.04
9	ton * km	−1.81	−1.32	−0.83	−0.43	−0.36	−0.23
10	ton	−1.24	−0.83	−0.48	−0.22	−0.27	−0.17
10	ton * km	−1.73	−1.33	−0.70	−0.36	−0.66	−0.43
11	ton	−0.53	−0.30	−0.99	−0.45	−0.20	−0.12
11	ton * km	−0.79	−0.61	−1.50	−0.78	−0.47	−0.30
12	ton	−1.55	−0.83	−0.64	−0.29	−0.12	−0.07
12	ton * km	−2.06	−1.26	−0.99	−0.51	−0.25	−0.16
13	ton			−0.95	−0.42	−0.16	−0.09
13	ton * km			−1.35	−0.70	−0.30	−0.19
14	ton	−1.13	−0.67	−0.49	−0.22	−0.11	−0.06
14	ton * km	−1.48	−1.07	−0.73	−0.38	−0.30	−0.19
16	ton	−1.46	−0.77	−0.72	−0.32	−0.13	−0.08
16	ton * km	−2.08	−1.32	−1.10	−0.57	−0.25	−0.16
17	ton			−1.00	−0.45	−0.18	−0.11
17	ton * km			−1.47	−0.76	−0.36	−0.23
19	ton	−1.75	−1.08	−1.01	−0.45	−0.18	−0.10
19	ton * km	−2.43	−1.87	−1.50	−0.78	−0.37	−0.24

1.4 Time Period Choice

The time period choice is modelled in a special module within the strategic Flemish freight transport model. It determines how many road freight vehicles adjust their departure due to congestion or increased travel costs (e.g. road charge depending on the period of the day). To determine the size of these effects a stated preference (SP) experiment has been designed and carried out by interviewing the receivers of goods (consignees). They were asked to describe a recent shipment that was at least partly transported during the morning or the afternoon peak. The presented alternatives varied in transport time, transport costs, the midpoint and the width of the delivery window. The data is used to estimate discrete choice models. The best fitting model was a model with a Box-Cox formulation for costs and a logarithmic description of times up to 1 hr and a time coefficient of zero for longer times.

The results are used to build a time-of-day-model with seven periods (including the morning and the afternoon peak). The model is calibrated with data of the base year and forecasts changes in the future. The model is described in detail in (de Jong et al. 2014).

To show the sensitivity of the model to policy changes two simulations have been carried out on the population-reweighted sample of receivers. In the first all transport times during morning and afternoon peak are increased by 10 % and in the second all costs during these periods become 10 % higher. The effects of the policies are shown in Fig. 1.4.

In the basis case 21.7 % of all transports are during the morning peak (07.00–09.00 a.m.). An increase of the transport time decreases this share to 21.66 %. The corresponding elasticity is thus −0.02. For the afternoon peak (04.00–07.00 p.m.) the elasticity has a value of −0.08.

Increasing the costs by 10 % has a much larger effect on the time choice. The share during the morning peak decreases to 15.09 % corresponding to an elasticity of −3.05 (−2.34 for the afternoon peak).

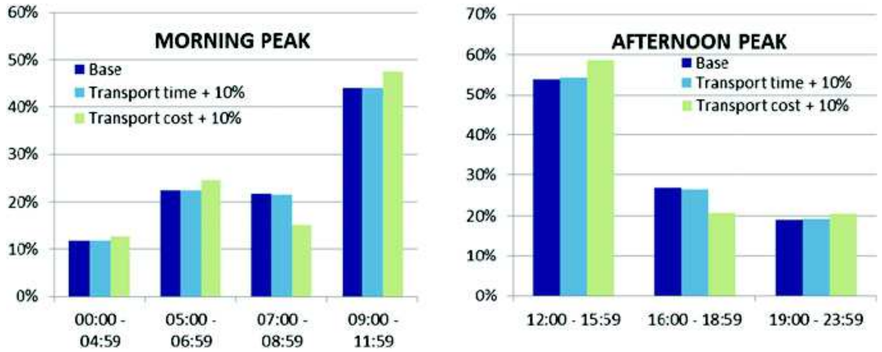

Fig. 1.4 Modelled impact of changes in transport cost and time during the morning peak (*left*) and during the afternoon peak (*right*) (de Jong et al. 2014, colors adapted)

grebe@significance.nl

1.5 Conclusion

The Flemish strategic freight model version 4.1.1 is more than an update of the strategic freight model version 1.6. The new version includes a nested logit model of mode and vehicle-type choice as well as a model for time-period choice (on top of also containing a logistics module, which was adopted from the previous version).

For the modal estimation a calibrated deterministic model for road transport has been developed. The mode and vehicle-type choice is estimated with nested logit models for 20 commodities. The coefficients have reasonable values and can be used to forecast the traffic demands for freight transport in Belgium.

By comparing the elasticities with results from literature (see Table 1.8) we find good agreement for the road and rail elasticities (price and time). For IWW the observed elasticities are higher than in the NODUS model and in the Dutch BASGOED.

The time period choice is almost not sensitive to increases in transport time but very sensitive to cost changes.

Table 1.8 Comparison of the average elasticities determined in this study and other studies from literature

	Price elasticities			Time elasticities		
	IWW	Rail	Road	IWW	Rail	Road
NODUS model (RAND Europe 2002)	−0.76					
(Significance en CE Delft 2010)		(−0.8 to −1.6)				
(Significance en VTI 2010)			−0.40			
(Significance, NEA en DEMIS 2010)	−0.28	−0.87	−0.50	−0.30	−0.23	−0.18
This study	−1.44	−0.91	−0.21	−1.01	−0.47	−0.13

For this study the average is determined by weighting the elasticities of each commodity with the amount of ton kilometers

Appendix

Table 1.9 Overview of the 20 commodities used in the Flemish freight model

NST	Description
1	Products of agriculture, hunting, and forestry; fish and other fishing products
2	Coal and lignite; crude petroleum and natural gas
3	Metal ores and other mining and quarrying products; peat; uranium and thorium
4	Food products, beverages and tobacco

(continued)

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Table 1.9 (continued)

NST	Description
5	Textiles and textile products; leather and leather products
6	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
7	Coke and refined petroleum products
8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel
9	Other non-metallic mineral products
10	Basic metals; fabricated metal products, except machinery and equipment
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
12	Transport equipment
13	Furniture; other manufactured goods n.e.c.
14	Secondary raw materials; municipal wastes and other wastes
15	Mail, parcels
16	Equipment and material utilized in the transport of goods
17	Goods moved in the course of household and office removals; baggage and articles accompanying travelers; motor vehicles being moved for repair; other non-market goods n.e.c.
18	Grouped goods
19	Unidentifiable goods
20	Other goods n.e.c

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