DISTRIBUTION AND MODAL SPLIT MODELS FOR FREIGHT TRANSPORT IN THE NETHERLANDS

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1. INTRODUCTION

The Netherlands has a tradition of using mathematical models in policy and decision making in transport (and other sectors). In an effort to improve the information provided to policy makers and to maximise the added value of the existing instruments and available knowledge and data, the Dutch Ministry of Infrastructure and the Environment decided to work towards a new freight transport model. The first step in the building process is a basic model called BASGOED ("BAS" stands for "basic" and "GOED" means "good"). This model is meant as fundamental corner stone for an incremental building process leading to a modular, transparent and flexible set of instruments for policy making in the area of freight transport.

For this purpose, BASGOED has been designed as a basic model, satisfying the basic needs of policy making, based on proven knowledge and data that will also be available in the future. BASGOED therefore makes use of those modules and data from the existing SMILE+ model (Bovenkerk, 2005), that are suitable for the new set-up. This is the case for the Economy Module which provide transports flows in tonnes by commodity type generated and attracted in each zone. New models have been estimated and implemented for distributing these flows to origin-destination pairs and for determining the modal split (road, rail and inland waterways). These two new models are presented in this paper.

Section 2 of this paper discusses the policy context in which BASGOED will operate. Conditional on this a freight transport model development strategy ('roadmap') was developed, which will be described in section 3. Here we distinguish between a model that could be developed relatively quickly (BASGOED) and all sorts of longer term model developments. The structure of the overall model and the role of the submodels for distribution and modal split are sketched in section 4. Section 5 contains a description of the data used in BASGOED. The distribution model and the modal split model are discussed in detail (inputs and outputs, specification and estimation results) in sections 6 and 7 respectively. After this, the elasticities from

BASGOED are reported in section 8, and discussed on the basis of a comparison with the literature (using recent international overview studies of freight transport elasticities). Finally, section 9 provides a summary of the paper and conclusions.

2. POLICY CONTEXT

2.1 Models for policy making
Strategic transport models play a crucial role in the complex realm of policy and decision making in the Netherlands. The government uses strategic transport models to simulate traffic flows on future traffic networks. The applications are very diverse; for example to determine the effects of building new roads or adding lanes to existing roads, to determine funding levels for ports, or to estimate the required size of a new lock. Moreover, national transport policy is often addressed, including issues such as tolling, cleaner vehicles, and fuel taxes.

Another application of model output is the estimation of impacts on the environment of policy measures already selected, such as the estimation of the required number and size of sound baffles for a new road section.

Freight transport modelling is an important component within strategic transport models. Estimates of freight flows are essential for policy making. It concerns estimations at different geographical levels, under different scenarios of future development, with prediction horizons of 10 to 40 years. Based on expected economic growth, the future demand is estimated, often followed by an estimate of the corresponding traffic.

2.2 Recent developments
During the previous decade, the suitability of the existing strategic transport models for policy purposes has become a increasingly controversial issue. In order to establish the need for improvements, the Netherlands Institute for Transport Policy Analysis (KiM), at the request of the Mobility directorate-general of the Ministry of Infrastructure and the Environment, conducted a study in 2009. The aim of the study was to analyse how strategic traffic models are currently used in policy processes and to provide recommendations for improving current models.

KiM concluded in the study that the current strategic transport models do not meet the needs of policy makers in the Netherlands: "If traffic models are to remain usable in the years ahead, we must improve them, ensure they are of a higher quality, and present the model results in better ways."

In an effort to improve the information provided to policy makers and to maximise the value of the existing instruments and available knowledge and data, Rijkswaterstaat[1] and TNO[2] developed jointly a so-called roadmap. The roadmap is in essence, the strategic research and development agenda of the Ministry towards an improved set of both passenger and freight transport models in the Netherlands. Section 3 of this paper contains a description of the roadmap for freight transport models.

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[1] Agency within the Dutch Ministry of Infrastructure and the Environment responsible for the execution of public works projects
[2] Netherlands Organization for Applied Scientific Research

2.3 First step towards incremental improvement

The first step as described in the roadmap for freight transport models is a basic model, a fundamental corner stone for an incremental building process. This process aims at to a modular, transparent and flexible set of validated instruments for policy making in the area of freight transport.

For this purpose, BASGOED has been designed to meet the basic needs of policy making. These needs concern both the content of the information demand as well as the way the results get presented and explained.

In order to meet these needs, it has been necessary to go "back to basics". Based on proven knowledge and data that is expected to be available in the future, BASGOED makes maximum use of those elements of the existing SMILE+ model[3] that are suitable for a new set-up. This set-up consistently focuses on:
  o transparency of through- and outputs
  o results that can be explained well (intuitive, logical, plausible).

New core modules had to be developed and implemented for BASGOED. One of them is the Distribution Module, distributing the transport flows in tonnes among origin-destination pairs. The second one is the Modal Split Module, which determines the modal split between road, rail and inland waterways. These two new modules are the main subject of this paper.

3. THE ROAD MAP FOR FREIGHT TRANSPORT MODELS

In order to develop a strategic view of the development of a new generation of national transport models, two road maps[4] were developed that identified and linked long and short term development trajectories for passenger and freight transport models. The expected gains of this approach are twofold. Firstly, gains related to model contents will include a better focus of the research community on a limited number of model development issues and an improved insight into the (short or long term) use of state of the art models. Secondly, a process-type gain is that model development will become much more a collaborative activity between the R&D community and the governmental agencies using and applying models. This could speed up innovation at lower costs. In this section we will summarize the outcome for freight modelling. We refer the interested reader to (TNO, 2009) for a detailed description of the road maps for passenger and freight transport models and (Tavasszy et al, 2010) for a report on the broader governance context within which the road mapping process was organised.

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[3] The most important reused module of SMILE+ is the Economy Module which provides the expected growth in transports flows in tonnes by commodity type generated and attracted in each zone, for a given future economic scenario.

[4] We use the term road map in the context of planning by analogy with technology road mapping. Road maps are used in many industries to align technological development and user needs; moreover, road maps serve as a means of communication for identifying potential consequences of choices (implicit or explicit) on critical aspects, such as technology platforms and architectures, standards and norms.

The new simple model for freight transport, presented in this paper, is the starting point of the road map. It is based on the conventions of four step transport demand modelling, with a focus on the modes road, rail and inland waterways. Although this model is a step back from the earlier SMILE+ model in terms of the ability to study complex freight policy questions, it promises to be less costly in maintenance and more transparent in its operation. Using the roadmap for extensions of the model, its development can proceed in a stepwise and controlled manner. Seen from the perspective of the simple model, the purpose of the road mapping process was to identify the main model extensions needed and possible. A summary of the result are listed in the table below:

Table 1: Summary of main development challenges in the road maps

Theme	Knowledge Development	Database Development	Model Development
1. Accounting for different Vehicle types	Vehicle stocks Choice of vehicle type	Light Goods Vehicles Shipment sizes	Vehicle type choice
2. Spatial and economic effects of transport improvements	Trade patterns	Regional accounts Regional I/O tables	Dynamic regional indirect effects
3. International linkages: trade and ports	Port choice factors	Port performance data Transport statistics	Port choice Trade models
4. Inventory and transport logistics	Logistics choices	Inventory locations Transport chains Shipment sizes	Mode chains Inventory choice Trip generation
5. Reliability	Effects on logistics re-organisation	Value of Reliability Network reliability	Multiclass dynamic assignment Logistics choices Modelling network reliability
6. Air and pipeline freight demand models	flow composition (descriptive)	Flow statistics, detailed	Basic demand models
7. Effect of (changes in) freight transport on congestion	Improved structural models for route choice and departure time choice	Passenger car equivalents values Route data	Multiclass dynamic assignment
8. Hazardous materials	Trip generation	Transport statistics	Risk models

Note that this table already indicates some of the limitations of the simple model. Extending the model would be necessary on the short term to allow treating day to day questions. This could involve new research but also the linking of existing models to the road map.

4. OVERALL MODEL STRUCTURE

The structure of the simple freight model is based on the four step freight modeling approach, which includes (see e.g. Ortúzar and Willumsen, 2011):
- freight generation: the yearly volumes (weight) of freight produced and consumed;
- distribution: the transport flows between these regions;
- modal split, resulting in the flows between regions by mode;

- traffic conversion and assignment, describing the number of vehicles on the network.

Figure 1 indicates how this architecture was implemented. We explain the outline of this overall approach below; the next sections will develop the characteristics of the model in more detail.
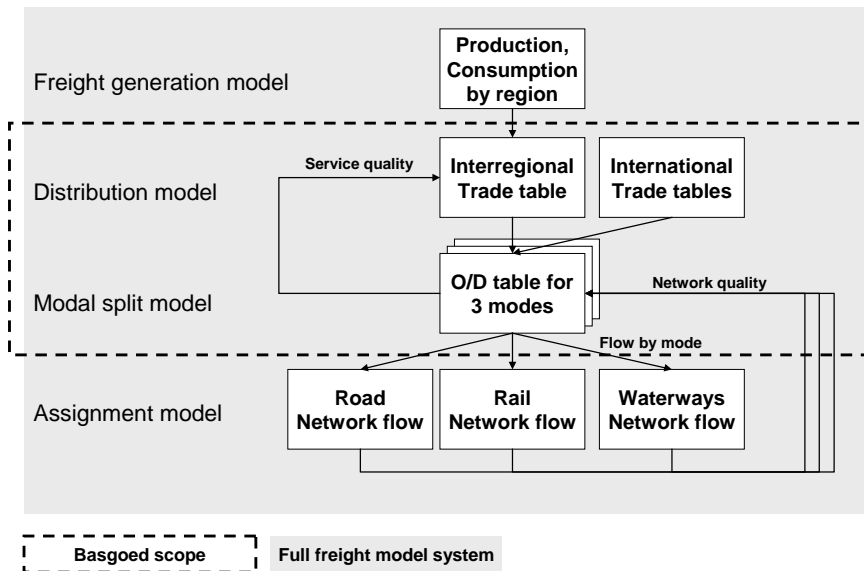

Figure 1: Architecture of the BASGOED model system

Existing models were used for the freight generation and assignment stages. The freight generation model is the input-output based framework as used in SMILE+ for translating economic scenarios in regional freight production and attraction forecasts (domestic and import/export). The same geographic level of detail was kept in the model, i.e. 40 regions within the Netherlands (NUTS3) and 29 in the rest of the world. International trade tables not including the Netherlands as origin or destination are also produced by this model, however not using the same I/O framework but based on exogenous trade and transport tables. The traffic conversion and assignment stage is covered by the existing assignment models for passenger transport (the National Model System owned by Rijkswaterstaat), rail (the Routgoed model owned by ProRail, the Dutch railway infrastructure provider) and inland waterways (BIVAS, owned by Rijkswaterstaat). The commodity classification used is NSTR-level1 (10 commodity groups).

In between these stages are the distribution and modal split models. Together, these replace the earlier modules for distribution, inventory logistics and multimodal transport of SMILE+. The main change with respect to the previous architecture of SMILE+ is that inventory chains and multimodal chains are neglected. As these modules are the main exponent of the move towards simplification of the Dutch freight model system, jointly they were called BASGOED (where BAS abbreviates BASIC and GOED stands for "freight" or "good"). The modal split model is fed by the underlying assignment models to provide measures of transport costs and times between regions.

As the assignment models have substantially more detailed zoning systems, baseline flow tables are matched at the aggregate (NUTS3) level. For prediction purposes, a growth factor method (pivot point analysis) is used. The model is run for a baseline and a future situation. Growth factors are derived for the O/D tables by mode, expressed in tons moved yearly. These growth factors are applied to the flow tables that are input for the detailed assignment models; after this assignment of new flows can be done.

5. THE DATA USED

Three types of data were used to build BASGOED: transport data, transport cost data and network information.

5.1 Transport data
A harmonised transport data base for the Netherlands is constructed for the Dutch Ministry of Infrastructure and the Environment on a regular basis. This is based on data from Statistics Netherlands, supplemented with data from other organisations (such as carriers and foreign statistical agencies). The basic datasets are available for the transport modes road, rail and inland waterways and contain several important features which are important for modelling purposes or policy analysis. For the datasets a harmonised coding scheme is applied, this allows to create a single transport data file which is the input for BASGOED. Notably harmonisation is relevant for: a) the regions of origin and destination in the Netherlands and in other countries, b) commodity groups, c) handling type classification (container, dry bulk, liquid bulk and general cargo). The tonnes transported are registered as gross tonnes. At present the most recent base year is 2004. It is most likely that the base year will be updated in the coming year. The present BASGOED model contains the surface transport modes road, rail and inland waterways within the Netherlands and in relation with foreign countries. In Duijnisveld et al., (2010) it is explained that for future extension of the model the TRANS-TOOLS datasets will be used for transport in relation with surrounding countries of the Netherlands.

5.2 Transport cost data
Besides the above described transport database, the Dutch Ministry of Infrastructure and the Environ also regularly commissions a study into the cost of transport from the user perspective. This is called the comparison of costs of modes of transport (in Dutch Vergelijkingskader Modaliteiten; VKM). The key figures are the average variable, fixed, loading and unloading costs, the average load, average load factor and the percentage of loaded trips. In the VKM these are broken down by vehicle type, appearance and direction (domestic / international). These key figures are linked to the transport database, and then a weighted average is determined for each of these key figures based on the average weight transported by each mode. In this way a cost per tonne transported is obtained for each mode.

5.3 Network information
Besides the transport volumes and unit transport costs also transport networks of the different modes are used. These are obtained from lower level models. The road network is obtained from the Dutch National Model System LMS, the inland waterway network from the BIVAS model, the rail network from ROUTGOED. For obtaining

information for foreign countries the TRANS-TOOLS networks are used and combined with the previous three mentioned networks. By obtaining a harmonised set of networks the distances and transport times between the regions can be determined. When this is combined with transport cost information, then for each mode the transport costs can be calculated for each origin and destination region. The result is the input for the modal split model.

6. THE DISTRIBUTION MODEL

6.1 Model specification, input and output
The purpose of the distribution model is to produce an origin-destination (OD) matrix for the forecast year. The input of this model is the OD matrix of the base year, the total incoming and outgoing flows per zone in the forecast year, and the level of service (logsums) per OD relation (all per commodity type).

The distribution model works by calculating growth factors per OD relation. Using a gravity model, temporary OD matrices are generated for both the base year and the forecast year. From these temporary matrices the growth factors can be calculated, and then applied to the actual base year OD matrix.

At its core, a gravity model is fairly simple. It needs the total incoming and outgoing flows per zone and the impedances per OD relation as input. The logsums which are derived from the transport costs per mode are not directly used, since they can be both positive and negative. Also a higher logsum yields a lower resistance. To obtain a useful impedances the maximum logsum is calculated. From each logsum this maximum is subtracted, and then multiplied by -1. These impedances are transformed into starting values using a distribution function. Generally, a higher impedance results in a lower starting value. A doubly-constrained matrix balancing procedure is applied to the starting values so that a matrix is generated that corresponds with the row and column totals.

The problem is to find the right specification of the distribution function. For this particular transport model, many different function specifications were attempted. The choice was between one, or a combination of the following:

- Negative exponential function
- Negative power function
- Cross-border impedances
- Endogenous intrazonal impedances

The general form of the distribution function is as follows:

$$r_{ij} = \exp(-\alpha \cdot (c_{ij} + G_{ij})) \cdot (c_{ij} + G_{ij})^{-\beta} \tag{1}$$

Here r_{ij} is the resulting starting value for the impedance between zone i and zone j, α the parameter of the negative exponential part of the function, β the parameter of the negative power part of the function, c_{ij} the generalized cost or impedance per OD relation, and G_{ij} the added cross-border impedance per OD relation. The impedances c_{ii} can be replaced by intrazonal impedances d_i, which

are estimated within the model as additional parameters. G_{ij} are estimated in a similar way, but these are added to the original impedances c_{ij}.

The tonnes from region i to to region j can then be specified as:

$$T_{ij} = p_i \cdot q_j \cdot r_{ij}$$ (2)

Here p and q are the production and attraction parameters that follow from the doubly-constrained matrix balancing procedure.

Estimating the distribution function is done using the Newton method. Only the base year data is needed. Given a certain choice of function and parameters, the gravity model produces a new matrix that can be compared to the actual matrix. The fit is quantified using the coefficient of determination R², where a higher coefficient means a better fit. The Newton method works by calculating the gradient at a certain point in the parameter space. The gradient shows in which direction the parameters should be moved to increase R². Eventually an optimum is found. This optimum is most likely a local one, as the parameter space is very large. To get as close as possible to the global optimum, a grid search is used before application of the Newton method. With this grid search a good starting point can be found.

The form of the distribution function and its estimated parameters are different per commodity group. This is because some commodities are more likely to be transported over longer distances than others.

6.2 Estimation results
The results of the estimation are summarised in the following table. Per specification, ten functions are estimated (one for each commodity group). This results in an average R². A function is unstable when its shape is non-intuitive, or when one or more of its parameters take on an extreme value. In this case non-intuitive means that the function is increasing, which means that the estimated flows are higher for higher impedances.

Table 2: Overview of specifications tested and key results

specification					result	
number	α	β	G	d	Avg. R²	Unstable functions
1	x				0.615	1
2		x			0.608	1
3	x	x			0.618	1
4a	x	x	fixed		0.627	3
4b	x	x	variable		0.638	3
4c	x		variable		0.615	1
4d		x	variable		0.625	2
5a	x			fixed	0.724	1
5b	x			variable	0.815	1
6	x	x	variable	variable	0.831	0

The effect of the cross-border impedances proved to be fairly insignificant. As it is a national freight transport model, the cross-border transport flows are relatively small, and the amount of cross-border transport is fixed. Therefore the impedances only have a small effect on the overall picture. And since the specifications with cross-border impedances add a large number of parameters, the small improvement in R^2 was not worth it.

However, the endogenous intrazonal impedances drastically improved the fit. The existing impedances did not accurately reflect the size of the intrazonal flows. It was clear that these impedances would have to be estimated endogenously.

Specification 5b was chosen for each of the commodity groups, except for NSTR4, which had one unstable intrazonal parameter. Specification 1 was chosen instead for this commodity group. The estimated α per commodity group are in Table 3.

Table 3: Main estimation results for selected specification for the distribution model

NSTR	α	R^2
0	1.602	0.680
1	0.912	0.771
2	2.752	0.978
3	1.363	0.945
4	0.887	0.984
5	0.539	0.637
6	1.462	0.855
7	0.969	0.670
8	2.148	0.817
9	1.016	0.815
Avg.		0.815

7. THE MODAL SPLIT MODEL

7.1 Model specification, inputs and outputs
The specification of the cost functions is primarily based on the cost functions in SMILE+. The following figure shows the transport chain for rail and inland waterway transport and the cost components. The mode choice model in BASGOED does not include advanced multi-modal transport chains or logistical decisions, but it uses simplified transport chains. Principal design characteristic is that it uses the (assignment) results of the existing uni-modal transport models as input, and furthermore logistical decisions involving shipment size or transfer costs at terminals are not included in full.

The cost functions include link costs and access/egress costs. The link costs (link-based costs) in BASGOED are calculated from the time and distance for the available modalities on the OD pair.

The access/egress costs (between the centroids of zones and the network access points) for rail and inland waterway transport are calculated from the average time and distances from all freight trips in the national transport model within the region to the access point. Road transport does not include freight transfer at terminals, so no additional access and egress costs are included. For some commodity groups, access or egress costs are excluded because the transport in these commodities typically takes place through direct access. Direct access at the origin and destination side has been applied for NSTR-level1 groups 2, 3 and 4 (mining, oil.
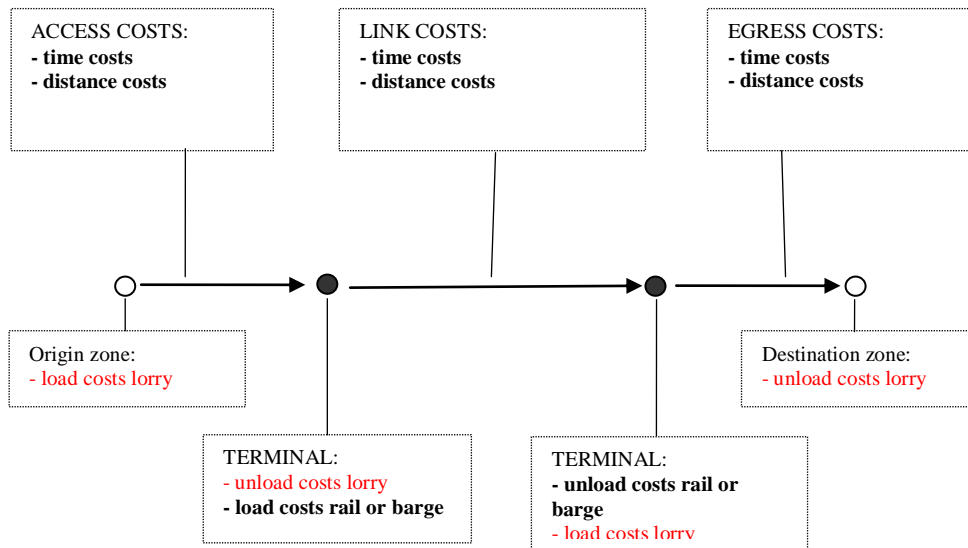

Figure 2: Rail and inland waterway transport chain as represented in BASGOED.
(cost components in bold are included; in red are excluded)

and ores). Commodity group 6 (construction materials) is assumed to have direct access at the origin. In addition to mode specific time and distance costs, the mode choice model also includes mode-specific constants and some other commodity-specific attributes such as degree of containerization. The time and distance costs are based on unit costs from the VKM (see section 5.2). The cost function that resulted from the specification analyses and that is chosen for implementation, includes a cost parameter for the time- and distance costs and a separate time parameter for the capital costs. The cost function for transporting one tonne of goods of commodity g between origin i and destination j by mode v, is specified as:

$$V_{ijvg} = \beta_{tc} \cdot \left(d_{ijv} \cdot T_v + t_{ijv} R_v \right) + \beta_t \cdot t_{ijv} + MSC_{iv} + MSC_{jv} + CONT_{ijg} + INT_{ijv} \tag{3}$$

With:

β_{tc} : cost parameter for time- and distance costs;

β_t : time parameter for the capital costs of the goods during transit;

d_{ijv} : distance by mode v between region i and j;

t_{ijv} : time by mode v between region i and j;

T_v : distance unit costs for mode v;

R_v : time unit costs for mode v;

MSC_{iv}, MSC_{jv} : regional mode specific dummies for origin region and destination

$CONT_{ijg}$: OD and commodity specific containerisation degrees;

INT_{ijv} : mode specific border penalty for transport with international origin or destination.

This cost function was preferred because first of all it simulated all time related costs as accurate as possible through the time unit costs and the time parameter for capital costs. Furthermore, by applying the unit costs from VKM, consistency is provided with existing approaches (SMILE+ and VKM). Finally, the model specifications for this cost function led to the best model fit and significant and plausible parameter values across all commodity groups.

On particular OD pairs the market share of rail or inland waterway transport for a commodity is zero. An aggregate market share model as implemented in the mode choice model of BASGOED, is not well capable of explaining these 'zero' shares out of the time and cost data. Therefore, the modal split model applies an availability condition when predicting the market shares by mode. Rail and inland waterway transport are only included in the choice set if it has an observed market share larger than zero.

Cost functions following other structures were tested in the specification analysis. In this analysis the optimal cost function was determined by evaluating the statistical fit of the model (final log likelihood), the significance and plausibility of parameters, the implicit elasticities calculated to the model and the RMSE between the observed and simulated mode shares. Ultimately this has led to the selection of the above mentioned cost specification.

In one variant, the cost function included a separate cost parameter (for distance costs) and a time parameter (for all time dependent costs, including capital costs). This structure gave a less accurate representation of the influence of time in the cost function and therefore was not preferred. Another form that was tested was based on exogenous values of time. The values of times were used to calculate generalised costs, by adding the time costs to the distance costs. This approach was not selected, because it is based on values of times and unit distance costs from different sources and is therefore less consistent.

Time and costs by transport mode are not sufficient to explain the market shares by transport mode on OD pairs. The regional dummies are included to take into account unobserved differences in regional accessibility by transport modes. In an alternative specification corridor dummies were used instead of origin and destination dummies, to correct for unobserved quality differences on specific corridors. However, these corridor dummies were less efficient in improving the goodness-of-fit compared to the regional dummies.

7.2 Estimation results

The following tables present the estimation results by commodity groups. The estimation results show the statistics of the overall model, such as the number of observations (available mode alternatives across all OD pairs) and the final log

likelihood, and it presents the estimated parameters and associated t-values. The presented models only include parameters that are statistically significant.

The cost parameters are significant and have a plausible sign (negative) for all commodity groups. The time parameter for the capital costs was significant and plausible (negative) for all commodity groups, except NSTR3 (oil). The mode-specific constants are captured with regional mode-specific dummies for origin- and destination regions. These are not included in this overview, but can be found in (Significance et al, 2010).

Table 4: Estimation results for modal split model for NSTR0 to NSTR4

File	NSTR0 Agriculture		NSTR1 Foodstuffs		NSTR2 Mining		NSTR3 Oil		NSTR4 Ores	
Observations	759		784		252		620		454	
Final log (L)	-15093.3		-23940		-11833.5		-12624		-7193.8	
D.O.F.	89		94		35		60		66	
Rho²(0)	0.424		0.499		0.594		0.699		0.797	
Rho²(c)	0.257		0.396		0.155		0.489		0.597	
Scaling	1		1		1		1		1	
INT_IWW[1]	-0.1689	(-4.3)	-0.6807	(-19.5)	0	(*)	0	(*)	0.3046	-3.4
INT_Rail	0	(*)	-5.915	(-14.0)	0	(*)	0	(*)	0	(*)
CONT_IWW	0	(*)	-3.738	(-24.4)	-12.96	(-14.4)	0	(*)	-17.74	(-20.5)
CONT_Rail	0	(*)	-12.07	(-5.6)	-153.6	(-11.3)	0	(*)	2286	-2.4
CONT_Road	0	(*)	0	(*)	0	(*)	0	(*)	0	(*)
….	The mode specific dummies by destination and origin region are not shown here									
Time	-2.09E-04	(-10.9)	-6.32E-04	(-33.8)	-1.09E-04	(-9.0)	0	(*)	-6.02E-04	(-11.5)
Cost	-0.07247	(-16.3)	-0.1821	(-40.4)	-0.1342	(-20.2)	-0.3054	(-59.8)	-0.284	(-22.7)

    1.   IWW=Inland waterways transport

Table 5: Estimation results for modal split model for NSTR5 to NSTR9

File	NSTR5 Basic metals		NSTR6 Construction		NSTR7 Agr. chem.		NSTR8 Chemicals		NSTR9 Miscellaneous	
Observations	481		1390		450		537		1054	
Final log (L)	-12730.4		-92124.3		-3281.2		-33730.4		-60762.8	
D.O.F.	84		102		60		95		130	
Rho²(0)	0.269		0.335		0.453		0.355		0.517	
Rho²(c)	0.266		0.316		0.441		0.261		0.409	
Scaling	1		1		1		1		1	
INT_IWW[1]	0.5568	-14.2	-0.6714	(-31.7)	-0.393	(-5.5)	0.6139	-26.7	-0.3481	(-16.8)
INT_Rail	0	(*)	0	(*)	0	(*)	-2.458	(-35.7)	-1.346	(-26.3)
CONT_IWW	-3.875	(-13.2)	1.088	-4	0	(*)	0	(*)	5.871	-119.9
CONT_Rail	-9.119	(-7.6)	-151.9	(-12.4)	-63.66	(-5.2)	2.021	-7.7	5.604	-55.5
CONT_Road	0	(*)	0	(*)	0	(*)	0	(*)	0	(*)
….	The mode specific dummies by destination and origin region are not shown here									
Time	-3.72E-04	(-29.6)	-4.57E-04	(-38.4)	-6.17E-04	(-14.0)	-3.04E-04	(-35.8)	-3.48E-04	(-58.5)
Cost	-0.05828	(-21.6)	-0.2556	(-98.7)	-0.2289	(-20.4)	-0.08938	(-50.7)	-0.02834	(-26.2)

    1.   IWW=Inland waterways transport

The mode-specific border penalties for cross border rail and inland waterway transport, were significant in some commodity groups. The degree of containerisation on an OD pair is significant for most commodity groups.

The value of time is an important characteristic for a modal split model. This modal split model has two components that each represent a part of the value of time for freight transport. First of all, the value of time for the time-dependent transport costs are represented with the time costs (staff, vehicles) that translate transport time into the associated costs. This is part of the variable 'Cost' in the Tables above. In BASGOED these values are mode-specific:

Table 6: Transport cost related values of time

Road:	2.97	€/tonne/hour
Rail:	0.41	€/tonne/hour
Inland waterway:	0.10	€/tonne/hour

These values of time are expressed in euros per tonne per hour, and are in the range of values reported in literature for road rail and inland waterways (for an overview of values of time for goods transport see De Jong, 2008).

In addition to the value of the time dependent transport costs, the model includes a time parameter for capital costs, which also contributes to the implicit value of time of the modal split model. The value of time for capital costs is calculated as the ratio of the estimated time parameter for capital costs and the estimated cost parameter. The following table shows the resulting value of times for capital costs. The value of time of capital costs is higher for commodities with higher value density, such as NSTR 5 (basic metals) and 9 (miscellaneous, but mostly containers).

Table 7: Value of time of capital costs

Valuation of capital costs: (in Euro/tonne/hour)		
NSTR0	Agriculture	0.18
NSTR1	Foodstuffs	0.21
NSTR2	Mining	0.09
NSTR3	Oil	-
NSTR4	Ores	0.16
NSTR5	Basic metals	0.38
NSTR6	Construction	0.10
NSTR7	Fertilisers	0.16
NSTR8	Chemicals	0.21
NSTR9	Miscellaneous	0.66

8. ELASTICITIES

8.1 Distribution elasticities

Elasticities are not an input to BASGOED, but can be derived as output. We calculated time and cost elasticities using the implemented distribution module, taking the following steps:

1. Determine the modal split-logsums using the implemented modal split module for the reference case.

2. Apply the distribution module with the specific set of logsums for the reference case and read the number of tkm from the output files of the distribution module.

3. Determine modal split-logsums again for a transport time and costs of some mode that is 10% higher than in the reference case.

4. Apply the distribution module again with the specific set of logsums for the policy case and read the number of tkm from the output files of the distribution module.

In the table below are the tkm elasticites that we calculated in this way from BASGOED.

Table 8: Own time and cost elasticities of the total (all modes) number of tkm (distribution-effect).

	NSTR0	NSTR1	NSTR2	NSTR3	NSTR4	NSTR5	NSTR6	NSTR7	NSTR8	NSTR9
	agri	food	mining	oil	ores	metal	constr.	fertiliser	chemic.	misc.
road time	-0.0011	-0.0051	0.0000	-0.0025	0.0000	-0.0009	-0.0269	-0.0272	-0.0050	-0.0006
road cost	-0.0021	-0.0084	0.0000	0.0008	0.0021	-0.0015	-0.0472	-0.0332	-0.0098	-0.0011
rail time	-0.0002	0.0001	-0.0004	0.0000	-0.0021	-0.0001	-0.0071	-0.0212	-0.0007	-0.0001
rail cost	-0.0009	0.0039	-0.0010	-0.0143	-0.0043	-0.0001	-0.0518	-0.1239	-0.0047	0.0004
IWW[1] time	0.0005	-0.0035	-0.0021	-0.0152	-0.0064	-0.0007	-0.0201	-0.0332	-0.0028	-0.0005
IWW cost	0.0005	-0.0022	-0.0017	-0.0421	-0.0043	-0.0001	-0.0027	0.0000	0.0001	-0.0001

1. IWW=Inland waterways transport

The table shows that the effect of time and cost changes in the BASGOED distribution module are all quite small. This can be explained by the fact that the distribution model only determines the cell values for OD relations. The row and column totals of the OD matrix are given by the Economy module. The Economy Module of BASGOED (which was adopted from SMILE+) itself is not influenced by time and cost of the modes, as used in the modal split module. Through scenario inputs it can include a trend towards more (or less) globalisation of production, but this is not made dependent on changes in the unit transport cost. If transport would become more expensive, then for instance a region along the coast of The Netherlands (the West) will shift some of its consumption from suppliers in the East of the country to suppliers in more nearby regions. But with given row and column totals, the East of the country will not reduce its production, or the West its consumption. So the shift is only possible if at the same time the East will supply more to regions in its proximity.

For international relations, the property of fixed row and column totals is even more restrictive. It means that the total import from a foreign zone to the Netherlands (in a commodity group) is given, as is the total export from the Netherlands to a foreign zone. Only the distribution of the import and export over the zones in the Netherlands is then allowed to change. This happens because the model only includes relations in, to and from The Netherlands, not for instance the relation between Germany and Italy. BASGOED is not a global or European transport model.

Some studies say that the effects of transport cost on production and consumption per region are substantial (Significance and CE Delft, 2010), but others have found small effects for this (e.g. see TML, 2008). Further research on this issue is clearly needed. From the simulations with BASGOED we cannot reach conclusions on the full effects on the production and consumption structure, because only pure distribution effects (matching of producing and consuming zone, given total production and consumption of some good in each zone) are included in the model.

We can only say that we found the latter effects to be small and that that seems a plausible outcome.

Table 8 also contains some positive values for the own elasticities. Technically this can happen because the distribution module is not a strict choice model (which will be well-behaved; the modal split model is a choice model), but employs different methods, including a Furness procedure. But given that the distribution elasticities are in all cases very small, whereas the modal split effects have the right sign and are not very small (also see section 8.2), the combined effect of the modal split and distribution elasticities will have the right sign for each mode.

8.2 Modal split elasticities

The modal split elasticities from BASGOED will be compared with road and rail cost elasticities from two recent studies that reviewed available empirical evidence on the price sensitivity of freight transport. The relevant key outcomes from these reviews are reported in Table 9. For the impacts of changes in the costs of inland waterway transport and for transport time elasticities, no recent overview studies were available, and we had to revert to the somewhat older EXPEDITE project.

Table 9: Transport cost and time elasticities of freight transport from the literature

Significance and CE Delft (2010):	
Road tkm price elasticity on tkm by road transport:	
All effects	-1.0
Modal split effect only	-0.4
Significance and VTI (2010):	
Rail tkm price elasticity on tkm by rail transport:(modal split effect only)	
Broad margin:	-0.5 to -3.9
Likely margin:	-0.8 to -1.6
EXPEDITE consortium (2002); De Jong (2003:)	
IWW tkm price elasticity on tkm by IWW transport: (modal split effect only)	
Belgium	-0.76
SCENES European model	-0.34
Road time elasticity on tkm by road transport: (modal split effect only)	
Belgium	-0.73
Norway	-0.09
Sweden	-0.63
Rail time elasticity on tkm by rail transport: (modal split effect only)	
Belgium	-0.77 - -1.26
Norway	-0.69
Sweden	-2.15
IWW time elasticity on tkm by IWW transport: (modal split effect only)	
Belgium	-0.58

For BASGOED, we calculated own price and cross elasticities using the implemented modal split module. These elasticities are not quite the same as those that we also estimated on the estimation files, which were based on OD relations where there was a modal choice (meaning: at least two available modes). The elasticities from the implemented module, as reported in this paper, refer to all OD relations.

The road cost elasticity of road transport is around -0.3, which is close to the value of -0.4 (see Table 9), that was found in the literature for the modal split elasticity of a road cost change (on the BASGOED estimation data this was -0.5). Because of the large market share of road transport, the cross elasticities for the effects on rail and inland waterways are substantial.

Table 10: Own time- and cost elasticities (in bold) and cross elasticities of the implemented modal split module of BASGOED (in terms of tkm)

	cost elasticities			time elasticities		
stimulus:	road	rail	IWW	road	rail	IWW
response:						
road	**-0.274**	0.009	0.084	**-0.099**	0.002	0.086
rail	0.434	**-0.882**	0.409	0.223	**-0.211**	0.600
IWW	0.657	0.070	**-0.258**	0.231	0.016	**-0.284**

The rail cost elasticity of rail transport that we find in BASGOED is about -0.9. which is well within the likely margin from the literature. The impact of this on road transport however remains very limited The direct elasticity for a change in inland waterway cost is similar to that for road cost. In BASGOED, just like in the available literature, rail transport is considerably more elastic to price changes than road transport. The BASGOED inland waterways cost elasticity of inland waterways transport is just below that from runs with the SCENES model within EXPEDITE, but clearly below the elasticity for Belgium from the NODUS model for the Walloon region (also see Beuthe et al., 2001).

In BASGOED, the sensitivity of the modal split to time changes is usually smaller than to changes in transport costs. In EXPEDITE, the time elasticities were of similar magnitude as the cost elasticities. But given that not all transport costs are time dependent (e.g. fuel costs are more distance dependent) and that the importance of capital costs on the goods in transit and inventory considerations is limited for most goods, it seems plausible that time elasticities are smaller than cost elasticities in freight transport modal choice.

9. SUMMARY AND CONCLUSIONS

In The Netherlands, freight transport modelling went ''back to basics''. The new national freight transport model BASGOED does not try to include inventories and multi-modal transport chains, so that the model would be easier to build, understand and maintain. This is the first step in an effort to deliver the products that the transport policy decision-makers need, in a modular, transparent and flexible way. However, the road map for future model development includes representing logistics and other choices (e.g. vehicles types, ports).

The production and attraction per zone in BASGOED comes from the existing SMILE+ Economy module. The distribution and the modal split models are new ad

were estimated on the national Dutch freight transport database of 2004 ("Basisbestand Goederenvervoer"). Furthermore, transport distances and transport times from existing uni-modal road, rail and inland waterway transport network models were used as input (also taking account of road access to and egress from train stations and inland ports). The commodity classification used is NSTR1 (10 commodity groups) and the zoning system distinguishes 40 zones in The Netherlands and 29 zones abroad.

These models are aggregate models (e.g. the modal split model is an aggregate logit model). A recent revealed preference data base at the disaggregate level, such as a shippers survey or a commodity flow survey, is not available in The Netherlands.

Various functional forms have been tested for the model specification in both models. This included the specification of transport cost and transport time, but also the influence of border resistance, zone-internal transport, containerisation and the residual influences of specific origin and destination zones or origin-destination combinations.

The link between the distribution model and the modal split model is a logsum variable that is calculated over the modes in the modal split model using the coefficients estimated for this model, and then converted to the transport resistance variable in the distribution model.

The estimated models were implemented in a computer code in a scientific programming language. Elasticities for changes in time and cost by mode have been calculated using this implemented model (that also includes transport flows for which only one mode is available). The time and cost elasticities from the new modal split model are comparable to the existing literature. In BASGOED, changes in transport time and cost will not only affect the mode shares, but also the distribution, through the logsum variable. However, with production and consumption per zone given, the time and cost induced changes in the distribution pattern are quite small.

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