The Development of a Logistics Module in the Norwegian and Swedish National Freight Model Systems

Deliverable 4: Final Progress Report on Model Development

Report for the Samgods group and the Working group for transport analysis in the Norwegian national transport plan

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Preface

In a project for the Work Group for transport analysis in the Norwegian national transport plan and the Samgods group in Sweden, RAND Europe, together with SITMA from Norway, has carried out further work on the development of a logistics module as part of the Norwegian and Swedish national freight model systems. The national model systems for freight transport in both countries are lacking logistic elements (such as the use of distribution centres). A report on the logistics model specification was written in 2004. The current report includes the following:

- The data requirements for developing and applying the logistics module and specification of new surveys on missing data (this is a revision/update of material that was presented in D1a of April 2005);
- A number of specification issues have been worked out further and some other specification issues have been revisited (this is a revision/update of material that was presented in D1b of June 2005).
- A description of the work carried out to develop a preliminary version of the logistics module that uses only existing data, and of its key outcomes.

This report was made for freight transport modellers with an interest in including logistics into (national) freight transport planning models, in particular the Norwegian and Swedish national model systems for freight transport. It should be read in combination with the 2004 report on model specification.

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CHAPTER 1 Introduction

1.1 Background

Developments in logistics (e.g. outsourcing, smaller inventories, use of distribution centres) have been spreading very fast in recent decades and have influenced transport flows significantly. Furthermore, optimisation and analysis tools in the sphere of logistic operations are regularly used within the private sector, especially within larger firms. Nevertheless, the Swedish national freight model system (Samgods model) and its Norwegian counterpart NEMO are almost completely based on other concepts and considerations (an exception is the definition of commodity groups in terms of common handling characteristics for multi-modal assignment). Both countries wish to include logistics in a more direct and explicit way.

Indeed, one of the most important shortcomings of practically all current public sector ('planning') models for freight transport is the treatment of logistics. Often, logistic decision-making is completely ignored, and in many other cases it is included in a very approximate and indirect manner.

In 2001, a process to renew the Swedish national freight transport model system Samgods was started. Strengthening the link with logistic decision-making was identified as one of the key areas for improvement. This was confirmed by each of the four ideas studies on a new model system for goods transport that were commissioned by the Samgods group. All four idea-studies discussed this issue in more or less detail and put forward recommendations for developing additional logistic modules (e.g. choice of distribution centre, vehicle type choice), either as extensions of the mode/route choice model, or in a separate model phase.

Subsequently, three pre-studies were carried out, including one on a logistics module for Samgods (TFK et al., 2002) and another one on spatial computable general equilibrium models for goods flows (WSP et al., 2002).

In Norway a process to update and improve the existing national freight model system NEMO has started as well.

In 2004, RAND Europe, together with Solving and Mike Florian of Inro-Canada, carried out a study to specify a logistics model and how this could be implemented in NEMO and Samgods, jointly for The Work Group for transport analysis in the Norwegian national transport plan and the Samgods group in Sweden. At the same time, another consortium, headed by Inregia, worked on the specification of new base matrices for Samgods. In the report 'The specification of logistics in the Norwegian and Swedish national freight model systems' (RAND Europe et al., 2004), the structure of a new logistics model was laid out: an 'aggregate-disaggregate-aggregate' model system. The flows between production zones and consumption zones (PWC or P/C flows) are determined in an aggregate fashion, the logistics decisions are treated in disaggregate models, and the assignment of OD flows to routes (network model) is at the aggregate level again. 'Disaggregate' means that the unit of observation in the models is that of the decision-maker (the firm). The two aggregate models are for flows between zones, not distinguishing between firms.

Figure 1 is a schematic representation of the envisaged structure for the national model systems (the boxes indicate model components).

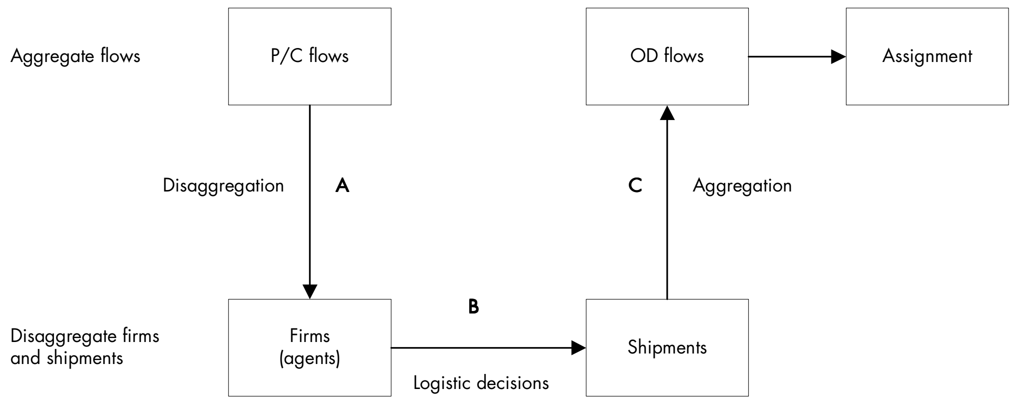

Figure 1 - Envisaged structure of the national model systems

The logistics model then consists of three steps:

A. Disaggregation to allocate the flows to individual firms at the P and C end;

B. Models for the logistics decisions by the firms; and

C. Aggregation of the information per shipment to OD flows for assignment.

In RAND Europe et al. (2004), several options for the logistics model (steps A, B and C) were distinguished (see Table 1). We recommended option IB, and the client groups accepted this recommendation. Another feature of this option is the cutting of the logistics choices in two parts (shipment size choice and transport chain and mode choice), which will make the model more tractable and easier to develop and apply.

The Swedish Samgods group and the Working group for transport analysis in the Norwegian national transport plan have commissioned RAND Europe to further design, estimate and implement the proposed model.

1.2 Scope and Objectives

The objectives of the project are to provide:

1. The further design;
2. The estimation; and
3. The implementation of a logistics model for the Norwegian and Swedish national freight model systems.

The logistics model reads in base matrices[1] that give flows in tonnes from production zones to consumption zones and delivers OD (origin-destination) matrices to be assigned in the network models. In addition, the logistics module project, together with the network models, provides matrices to the base matrix projects on the generalised logistic costs between zones and (generalised) paths.

The zones are municipalities in Sweden and Norway, and a number of international zones. Choices covered in the logistics module concern the use of consolidation and distribution centres, shipment size, mode choice, vehicle size and loading unit. Inclusion of these logistics choices should lead to a better representation of transport and logistic chains (e.g. goods which go to a consolidation centre first, are transported on the main haul to a distribution centre and are distributed from there). This would also lead to a better use of the information from wholesale and retail trade statistics in the national planning models for freight transport.

In parallel with this project on the logistics module for Norway and Sweden have run two projects on developing new base matrices, one for Norway and one for Sweden.

The variant of the new logistics module that will be developed is Option1B (see RAND Europe et al., 2004). This will be carried out largely in 2006, and the new data will be collected in 2005 and in the first half of 2006. In the second half of 2005, an initial version of the logistics module was developed on the basis of existing data. Parts of this initial module can be used in later phases as well; other parts will be replaced by components using the new data from 2006 onwards. The 2006 logistics model will contain random utility discrete choice models for the logistic choices, estimated on data for individual shipments in/to/from Sweden and Norway. The 2005 logistics model includes a disaggregation of the PWC zone-to-zone flows to firm-to-firm flows, but the logistic choices are based on deterministic optimisation, with only a calibration at the aggregate level.

This report D4 includes:

- The data requirements for developing and applying the logistics module and specification of new surveys on missing data (this is a revision/update of material that was presented in D1a);
- A number of specification issues have been worked out further and some other specification issues have been revisited (this is a revision/update of material that was presented in D1b);
- A description of the work carried out to develop a preliminary version of the logistics module that uses only existing data, and of its key outcomes.

1.3 Overview of the report

This report was written by RAND Europe together with Stein Erik Grønland of SITMA.

[1] These base matrices are PWC (production-wholesale-consumption) matrices in which flows from production to wholesale and flows from wholesale to consumption are included as well as the flows from production to consumption.

Chapters 2 and 3 (which together make up Part A) deal with the logistics model (that will have disaggregate choice models for logistics decisions) to be developed in 2006. Some features of the envisaged 2006 logistics model have already been developed/used in the 2005 model (e.g. the commodity classification in 32/34 groups, the characterisation of the type of decision-making on transport and inventories for each of those groups, the vehicle/vessel type classification, the disaggregation to firm-to-firm flows). The way these aspects were worked out in practice will be described in Part B. However, in 2006, it will be investigated whether these components are still valid and what needs to be revised, especially in the light of additional data collected.

The data collection specification is discussed in Chapter 2 and includes a summary of D1a of April 2005 and an overview of progress since then. In Chapter 3, the model specification is worked out further, refining and extending RAND Europe et al. (2004). This chapter provides a revision and update of D1b, which was submitted in June 2005, to lay down the progress made since June 2005.

Part B consists of Chapters 4-7 and concerns the 2005 logistics model, which is a preliminary model (without estimation on disaggregate data) that uses existing data. Chapter 4 reports the work on the disaggregation from zone-to-zone flows to firm-to-firm flows. The treatment of the logistics choices (shipment size and choice of logistic/transport chain) is described in Chapter 5. The results of this preliminary 2005 logistics model on generalised costs matrices are given in Chapter 6 and those on OD matrices in Chapter 7.

Finally Chapter 8 contains a summary and conclusions on both Parts A and B, and highlights the decisions that have been taken in this project.

Part A. Preparing for the 2006 logistics model

CHAPTER 2 Summary of the data collection specification

2.1 Comparison between required data and available data in Norway

In Table 1 we compare the data that are required for step A (the disaggregation from zone-to-zone flows to firm-to-firm flows, see previous chapter) of the logistics module with the available data for Norway.

Table 1 - Required versus available data for step A in Norway

Data item required	Available source/missing
Number of firms involved in production	Production statistics (Statistics Norway). Does not include wholesalers and retailers (should come from register data); data for oil industry and agriculture can be added
Relevant size measure for the production of these firms (preferably turnover, otherwise number of employees)	Production statistics (Statistics Norway); turnover data at municipality level has to be approximated through employment
Number of firms involved in consumption	Consumption statistics (Statistics Norway). Does not include wholesalers and retailers (should come from register data);
Relevant size measure for the consumption of these firms (preferably turnover, otherwise number of employees)	Consumption statistics (Statistics Norway); turnover and employment data at municipality level has to be taken from the production statistics

For Norway, most of the information that is required for the disaggregation to the firm level (step A) seems to be available both for the P and the C end (according to Statistics Norway). The production and consumption statistics have the proper level of commodity and spatial detail. What is missing in the production and consumption statistics (e.g. production and consumption by wholesale firm) can probably be added (in an approximate way) from other statistics.

The same analysis for step B for Norway can be found in Table 2. The issue of which data should be in the same file, is discussed later (section 2.9). The endogenous variables are the shipment frequency f_{kmn} (or shipment size q_{kmn}) and the transport chain $l_{kmn} = \{ (h_{1kmn} , t_{1kmn}), \ldots, (h_{ikmn} , t_{ikmn}), \ldots, (h_{Il_{kmn}} , t_{Il_{kmn}})\}$

Where:

k=commodity type

Table 2 - Required versus available data for step B in Norway

Data item required	Available data/missing
Endogenous variables (for estimation):	
Location of sender of individual shipment	Lorry surveys (but different definition of shipment). Missing for other modes
Location of receiver of individual shipment	Lorry surveys (but different definition of shipment). Missing for other modes
Location of all ports, airports and railway terminals used for individual shipment	Maritime surveys, air surveys
Location of all consolidation centres used for individual shipment	Missing
Location of all distribution centres used for individual shipment[2]	Missing
Modes used for each leg of the individual shipment	Only some choice-based information from lorry surveys (but different definition of shipment), maritime surveys and air surveys. Rail: only aggregate information. Chain information is missing
Loading units for each leg of the individual shipment	Missing
Shipment size (or frequency) for the individual shipment	Lorry and maritime surveys (but different definition of shipment). Missing for other modes
Annual frequency	Missing
Number of stops in collection and distribution tours	Missing
Type of vehicle/vessel used for each leg of the individual shipment	Some information in lorry, maritime and air surveys (but different definition of shipment). Missing for rail. Chain information is missing
Explanatory variables at the shipment level (for estimation and application)	
Commodity type for the individual shipment	Lorry and maritime surveys (but different definition of shipment), at NSTR 2 or 3 (adequate level) Missing for other modes (rail: only aggregate information)
Value and value density of the individual shipment	Missing
Whether the individual shipment is contracted out or not; flexibility/capacity of the transport supplier	Missing (but it is known that most transports in Norway are contracted out)
Variables at the sender or receiver level costs (for estimation and application):	
Sector and size of sender of individual shipment	Missing
Sectorand size of receiver of individual shipment	Missing
Size of inventories kept and average lead times	Missing
Explanatory variables on logistics costs (for estimation and application):	
Data on transport costs, transport time and transport time reliability per vehicle/vessel between OD pairs	Network model data bank, cost models
Locations of consolidation and distribution centres, ports, airports and railway terminals	Register data, terminal survey, Norwegian Petroleum Institute. Missing: non-liquid bulk terminals
Indication of infrastructure capacity	Missing
Cost/price of handling (including transhipment) and	Terminal survey: road, sea, general cargo. Missing

[2] All (intermodal) freight terminals and marshalling yards should be included in the consolidation centres and distribution centres, together with the ports and airports.

storage at ports, airports and railway terminals	for rail and other cargo terminals, cost models
Cost/price of consolidation and distribution centres (including transfers between modes /vehicles, loading, unloading and storage)	Terminal survey: road, sea, general cargo. Missing for rail and other cargo terminals, cost models
Storage cost for inventories (at P, W or C)	Cost models

m=sender firm (with a specific location zone)

n=receiver firm (with a specific location zone)

l: transport chain

i: leg within a transport chain, 1=1, …, I_l

h: mode, vehicle/vessel type.cargo unit

t: transhipment location.

There is no commodity flow survey in Norway that could be used in the estimation of a model for the logistics choices (step B). There is some information on individual shipments in the lorry surveys and the maritime surveys, and maybe also for rail and air transport. A problem with using these data for the logistics module is that they generally define a shipment as the load of a vehicle at some point in time, whereas we would like to allow for various shipments in one vehicle/vessel (consolidation). All this information could be combined to form a sample of shipments for various modes. Of course this would be a selective sample, since it would be based on the mode actually used (endogenously stratified sample), but such information can successfully be used in estimation. The main problem is that this dataset would not include information on the use of consolidation and distribution centres. It can only be used to estimate a model for mode and port choice.

For Norway, the data situation on the explanatory variables is as follows: available are transport costs, new but incomplete cost of distribution centres, transport time, delays and the value of the goods (data on the last variable are available through the PWC matrices). Data for aggregate calibration/validation (transport statistics) are available.

2.2 Comparison between required data and available data in Sweden

In Table 3 we compare the data that are required for step A of the logistics module with the available data for Sweden.

Table 3 - Required versus available data for step A in Sweden

Data item required	Available source/missing
Number of firms involved in production	Register data (CFAR, Statistics Sweden) and production statistics.
Relevant size measure for the production of these firms (preferably turnover, otherwise number of employees)	Register data and production statistics (Statistics Sweden); turnover data at municipality level has to be approximated through employment
Number of firms involved in consumption	Combination of trade statistics, transport statistics and make/use tables (or input-output tables)
Relevant size measure for the consumption of these firms (preferably turnover, otherwise number of employees)	Turnover and employment data at municipality level can be taken from the Register data

The information that is required for step A (the disaggregation to the firm level) at the P end is available for Sweden, but would require a combination of register data and production statistics. For the C end in Sweden, the required information is not readily available. A combination of several data sources (trade statistics, transport statistics and make/use tables) could provide approximations, but the CFS 2004/2005 would probably be able to give much better information, since the receiving sector will be included for the outgoing domestic and international flows, not just for the incoming international flows as in the CFS 2001. The CFS can also provide some information on the number of interactions (by commodity group) between producers and consumers: how many suppliers does a firm consuming some commodity have, and how many clients (other producers, wholesalers, retailers) does a producer of some commodity have? This information can be used in the development of the step A procedures.

The same analysis for step B for Sweden can be found in Table 4.

Table 4 - Required versus available data for step B in Sweden

Data item required	Available data/missing
Endogenous variables (for estimation):	
Location of sender of individual shipment	CFS 2001, CFS 2004/2005, transport statistics
Location of receiver of individual shipment	CFS 2001, CFS 2004/2005, transport statistics
Location of all ports, airports and railway terminals used for individual shipment	Some information in CFS 2001 and CFS 2004/2005 (international shipments), transport statistics
Location of all consolidation centres used for individual shipment	Chain information is missing
Location of all distribution centres used for individual shipment[3]	Chain information is missing
Modes used for the individual shipment	CFS 2001, CFS 2004/2005: mode chains (but some errors in responses); some choice-based information from transport statistics.
Loading units for the individual shipment	CFS 2001, CFS 2004/2005
Shipment size (or frequency) for the individual shipment	In CFS 2001 and 2004/2005 only some indirect information on frequency. Some shipment size information in transport statistics.
Annual frequency	In CFS 2001 and 2004/2005 only some indirect information on frequency
Number of stops in collection and distribution tours	Missing
Type of vehicle/vessel used	Some information in transport statistics. Chain information is missing
Explanatory variables at the shipment level (for estimation and application)	
Commodity type for the individual shipment	CFS 2001 and CFS 2004/2005; Also in transport statistics; generally at adequate level of detail
Value and value density of the individual shipment	CFS 2001, CFS 2004/2005
Whether the individual shipment is contracted out or not; flexibility/capacity of transprt supplier	Missing
Variables at the sender or receiver level costs (for estimation and application):	
Sector of sender of individual shipment	CFS 2001, 2004/2005
Sector of receiver of individual shipment	Missing in CFS 2001; will be included in CFS 2004/2005 (but wholesale and retail are one category)
Size of inventories kept and average lead times	Missing
Explanatory variables on logistics costs (for estimation and application):	
Locations of consolidation and distribution centres, ports, airports and railway terminals	Register data, limited information in terminal surveys
Data on transport costs, transport time and transport time reliability per vehicle/vessel between OD pairs	Network model data bank, cost models
Indication of infrastructure capacity	Approximations from network model possible
Cost/price of handling (including transhipment) and storage at ports, airports and railway terminals	Limited information in terminal surveys, cost models

[3] All (intermodal) freight terminals and marshalling yards should be included in the consolidation centres and distribution centres, together with the ports and airports.

Data item required	Available data/missing
Cost/price of consolidation and distribution centres (including transfers between modes /vehicles), loading, unloading and storage)	Limited information in terminal surveys (might have to model public terminal costs and apply this model to private terminals as well), cost models
Storage cost for inventories (at P, W or C)	Cost models

The transport statistics in Sweden suffer from the same problem as their Norwegian counterparts: the focus is on the load of the vehicle/vessel, not on the shipments that make up the load.

For the estimation of a model for logistics decisions, data are needed that give the sender, receiver, commodity, shipment size and use of ports, airports, consolidation and distribution centres for individual shipments. The CFS 2001 provides information on a large number of individual shipments and as such is a unique dataset in Europe. However its main file (outgoing flows) only includes information on sender, commodity and mode, and on use of ports and airports for international shipments (or at least the border crossing point). Information on the receiver (except location), the shipment size (or frequency) and the use of consolidation and distribution centres is missing.

The fact that the frequency of the shipments by commodity type is not provided in the CFS files makes it hard to use the CFS as a basis for the estimation of the trade-off between inventories and transport (the determination of the economic order quantity). There might be some indirect information on shipment frequency in the CFS: the local units were asked to give data on some fraction of their shipments (all commodities together). Also, there is an expansion to total tonnes in Sweden. SIKA has asked Statistics Sweden to provide these data.

Because of the absence of data on the receiver (e.g. the sector) and on the use of consolidation and distribution centres, the CFS 2001 can only be used to estimate models explaining mode choice and use of port and airport (and even this with some reservations, also see Andersson, 2004). The lorry surveys and other transport statistics might be used to enrich the CFS information, because these surveys also contain information on individual shipments, including by definition the mode used. This would make the estimation database partly an endogenously stratified sample. However, transport statistics only contain limited information on shipments and no information on individual shipments that are transported in the same vehicle/vessel.

It might be possible to infer from the CFS 2001 whether transhipment locations were used (and to a limited degree also how many and of which type) from the sequence of modes used (but only changes of mode, not of vehicle size within a mode). The CFS 2004/2005 will constitute a step forward, because it will also give the sector of the receiver (but with wholesale and retail in one category). It will not provide information about consolidation and distribution either: we will not know what logistic facilities have been used in practice for the CFS shipments. We must conclude that for a key component of the logistics model (use of consolidation and distribution centres) there is no appropriate dataset that can be used in model estimation.

The available data on the explanatory variables in Sweden are limited to:

- Transport costs;

- Some scattered information on cost of distribution centres;
- Transport time, and delays;
- The value of the goods (is available through the base matrix project and also directly in the CFS and in the foreign trade statistics, and is required at the level of the value-to-weight transformations used in that project).

Data for aggregate calibration/validation (transport statistics) are available.

2.3 Conclusions on missing data

For step A, it seems possible to move ahead with the current data (though the data situation could be improved, e.g. on consumption by production firms in Sweden). The crucial data deficiencies occur for step B.

For Norway, the current data on individual shipments (lorry surveys and other transport statistics) are of limited use for estimating logistics choices. The following variables are missing at the shipment level (needed for all parts –legs- of the chain):

- The use of consolidation and distribution centres;
- The contracting out;
- The transport mode;
- The vehicle type;
- The loading unit;
- The shipment size.

Also unknown are:

- A characterisation of collection and distribution tours (e.g. by number of stops);
- The sector of the sender and receiver;
- The value and value density of the individual shipments;
- Information on inventories (size, policies, storage costs) and on customer requirements (such as lead time);
- Cost of non-general-cargo terminals and rail terminals.

The most important missing data for Sweden are:

- Data on the use of consolidation and distribution centres for individual shipments (whether such centres are used, and if so where and at what costs, which vehicle types are used for the different legs);
- Data on inventory logistics (inventory size, policies, storage costs) and customer requirements (including lead times);

- Information at the shipment level about contracting out, delivery frequency and collection and distribution tours.

2.4 Specification of variables to be collected: Norway

Most of the missing information for Norway for step B can be provided by the transport companies. NTP has discussed the delivery of data on individual shipments with some of the largest logistic service providers (LSPs) operating in Norway and it seems likely that several firms will supply shipment data for Norway (at least the biggest one, Schenker/Linjegods will). Furthermore, NTP is involved in a process with TakeCargo (www.takecargo.no) to obtain electronic shipment data at the commodity level (for several sectors. All of this will probably yield extremely valuable information for the logistics module, most of all because it will provide transport and logistics chain information and data on the use of consolidation and distribution centres. If possible we would like to be involved in the specification of the data that will be provided through this new effort.

The biggest logistic service provider in Norway (Schenker/Linjegods) alone has 5.5 million consignments per year. NTP discussed provision of data on individual shipments by this company. At this company, the following information can be supplied:

For every individual shipment:

- Starting point of the shipment: sender or terminal if delivered by the customer (postal code);
- End point of the shipment: receiver or terminal if picked up by the receiver (postal code);
- Information on the sector of the sender: 29 sectors, which need to be mapped to the NEMO-32 clasification
- Volume (for 80% of the shipments) and weight (all shipments);
- Specific needs (hazardous goods, thermo, refrigerated, volume goods, return of packaging, etc.)
- Customer number, so that all shipments for a given customer (sender) can be summed to get the number of receivers for companies that hire Linjegods for all their transports.

For every leg of the shipment:

- Starting point of the shipment: terminal name if terminal;
- End point of the shipment: terminal name if terminal;
- Mode (lorry, lorry with trailer, semi-trailer, train)
- Time when the actual leg of the transport starts
- Time when the actual leg ends
- Time in terminal (based on the difference between the end time of one leg and the start time of the next)

- Handled in terminal or not.

This company does not use the commodity group classification used by the national model for goods transport (NEMO), but classifies the transported goods in the following commodity groups:

- Dangerous goods;
- Warm goods;
- Cooled commodities;
- Frozen commodities;
- Other.

This segmentation above is more one in terms of loading units/handling types than commodity groups. Furthermore, the sector of the sender can be used to get a better picture of the commodty type, but the sector code may not be very reliable (is under investigation by Linjegods), and the conversion to NEMO 32 is not straightforward.

A weakness of the Linjegods dataset is that sea transport is not included (Tollpost Globe and Norcargo do use vessels). Also the sector of the receiver is missing.

The different big transport organisations handle the following commodity groups (using the old NEMO 13 classification[4]):

Tollpost Globe	4, 6
NorCargo	1-4, 6
Posten	6
DHL	6
Schenker/Linjegods	1-4, 6

So these companies cover all types of goods, except vehicles/machines (5) and bulk goods. These are transported by other firms (own account transport or other transport companies that are more involved in direct transports).

The larger transport companies mentioned cover a substantial part of the market for goods transport. In addition, "industry transport' (transport on own account) also constitutes a (possibly small) share of transport. For these transports the choice of transport mode takes place in closed system and the transport might go to/from closed ports and terminals. It will be necessary to survey these types of transport as well. Besides this, we need to get an impression of transports by small transport companies. Small transport companies can have a large local market.

[4] 1=Food commodities; 2=Fish (fresh); 3=Fish (other types); 4=Thermo commodities; 5=Vehicles/machines; 6=General cargo; 7=Timber and wood products; 8=Minerals and stone products; 9=Chemical products; 10=Metals and ore; 11=Liquid bulk; 12=Oil and gas; 13=Air freight.

In the present circumstances, the companies will not provide transport cost data. The transport authorities could well direct a specific inquiry in a letter that describe what type of cost data the transport authorities would like and for which purpose it will be used (to get the average cost level for transport with different transport modes and for different commodity groups). Costs and time use at the terminal for consignments can be made accessible to us for the model development work.

We hope that the shipment database from the logistics service providers will not only provide the transport modes (in the NEMO classification: road, rail, sea, ferry and air), but also be able to provide information on vehicle type and loading unit.

Nevertheless, it is not expected that this database from the private sector will be enough to fill all the data gaps. Information on the final leg of the transport and logistic chain (occasionally also on the first leg) will be missing for a number of transports, when these are managed by receivers (e.g. retailers). The transporters might also not be able to supply all required attributes of the goods themselves (e.g. value) and of the receiver, when their client is the sender. Generally speaking, this database contains a large amount of information on individual shipments, but is relatively poor on data about the sending and receiving firms. For estimating the step B models, this information is required in an integrated file (meaning that for each shipment, we also need the sender/receiver information). The preferred approach would be to contact and interview senders, receivers and transporters on the same shipment (as is done to some degree in the new French Shippers Survey). The transporters might be able to give contact information on the companies at both ends. Finally, it is doubtful whether information about the transport cost and the cost of using consolidation and distribution centres can be supplied by shipment by the transport companies. On the other hand, they might be prepared to supply information in a more aggregate way (e.g. by commodity type) and/or for some years ago. Alternatively, information on costs and rates could be obtained from public terminals.

Taking into account the database that will be provided by the big private logistic service providers (LSPs) in Norway, the following data, that are required for the estimation of the logistics model (steps B), are still missing:

1. Shipments of vehicles/machines and bulk commodities;
2. Shipments carried out by shippers with own account transport and by small and medium-size haulage companies;
3. It is not clear whether the data on transport, handling and storage costs from the big private LSPs will be sufficient (in combination with data from the network model database and the terminal survey);
4. It is not clear whether the information from the big private LSPs on modes, vehicle types and loading units will be sufficient;
5. Value of the goods, customer requirements (e.g. lead time, delivery frequency);
6. Sometimes information on the first or last leg (e.g. when a retailer carries out the transport from the distribution centre to the supermarket) of the transport chain is missing.

The items 1 and 2 are about missing shipments. Additional data collection on shipments, especially on the commodity classes not yet covered is needed. This will almost by definition also provide information on shipments carried out by shippers and smaller carriers.

The items 3-6 are about real and potential missing data problems: information on the relevant shipments will become available, but for these shipments the information is incomplete. The ideal solution then would be to search for the missing items from a sample of these shipments, to extend the existing shipment database. This would require further assistance of the big LSPs in Norway. They would have to supply additional information on their shipments and also give contact details for the sender and/or receiver. Subsequently, the sender and/or receiver should be asked to provide another part of the missing data items. Whether this would all be feasible is questionable. The second-best option would then be to collect information on another set of shipments. This might work best by starting at the senders and receivers, asking for a number of data items and for the contact details of the carriers, who would then be surveyed on the same shipments.

2.5 Specification of variables to be collected: Sweden

A survey is planned to take place in Sweden for the Samgods group and the transport industry to complement the Swedish Commodity Flow survey (CFS)

The following variables might be included (in the first phase):

- Commodity group;
- Weight and volume of the consignment;
- Sending/receiving zone;
- Sending/receiving sector;
- Modes in the transport chain;
- Size of the modes;
- Loading units in the transport chain;
- Terminal handling.

The resulting data could be used to enrich the shipment data from the CFS in Sweden. As the Norwegian database from the big LSPs, there will be a large amount of shipment information, but rather limited information on the senders and receivers (which for estimation of the logistic choice models are needed in an integrated file). This new data collection tohether with the Swedish Transport Industry (Sveriges Transportindustriförbund STIF) has however been postponed until after the summer of 2006 and can therefore not be used in the estimation of the 2006 model.

Even if we would have this new dataset on shipments from the transport companies, the following data items, that are required for the development of the logistics module, would still be missing in Sweden:

1. Information on the cost/price of using consolidation and distribution centres and storage costs;
2. Information on the customer requirements (such as lead times, inventory policy, frequency);
3. Sometimes information on the first or last leg (e.g. when the retailer carries out the transport from the distribution centre to his supermarket) of the transport chain is missing.

Ideally item 1 should be asked in the same questionnaire as used to interview the transport companies on their shipments. These companies have the required knowledge, while the shippers often will not know this. For the items 2 and 3 the preferred option would be to contact senders and/or receivers for the shipments in the database from the transport industry or re-contact sending/receiving firms that responded to the CFS. If these first-best solutions would be infeasible, an additional (third, after CFS and the transporters database) might have to be collected, focussing on the above items. This could be implemented by starting at the senders and receivers, asking for a number of data items and for the contact details of the carriers, who would then be surveyed on the same shipments (especially on costs).

2.6 Suggestions for survey methodology and sample size

To estimate models with different coefficients for 30-35 commodity groups[5], the data requirements should be formulated not so much in terms of the total number of observations but on the minimum number of observations per commodity group. A random sample of shipments that would be of the appropriate size in terms of the total number of observations would contain insufficient numbers of observations for shipments of good categories that occur less frequently. Therefore, what we need for estimation data is a stratified (random) sample: targets need to be defined for the minimum number of observations in each commodity group. The selective nature of the data can be handled in the estimation of discrete choice models. In application of course we need to expand the data for each category using its population share, to predict the flows in goods transport.

For the estimation of relatively complex (many choice alternatives, many explanatory variables) discrete choice models at least 200 observations (in this case shipments) are needed for each goods category. This would imply that we need a dataset (in each of the two countries) of at least 6,000-7,000 shipments (with the required balanced composition). But for some of the goods categories, singular flows and simple transport chains will dominate (especially for some bulk commodities) and these can be singled out or treated on the basis of fewer observations. We would like to have these shipments from as many different companies as possible (say up to ten shipments per local unit).

Below, we investigate whether the required minimum (more is better) numbers of 200 shipments per goods category can be obtained from existing data and planned data collection.

[5] The idea is not to have 30-35 different models for 30-35 segments in the end, but to test for equality of at least some of the model coefficients for 30-35 different commodity groups in total.

For a substantial part of the above shipments, the Swedish CFS, the Swedish transport industry database and the Norwegian private sector shipment database can provide (most of the) required data items. The Swedish CFS lacks data on the use of consolidation and distribution centres, but does contain most of the information on direct flows from producers to consumers (and wholesalers). This can largely be compensated by the data collected together with the transport industry. If some additional questions can be asked in the transport industry survey, and if senders and receivers can be approached to fill some gaps, no additional surveys in Sweden would be necessary, and the estimation database can be a combination of the CFS and the new transporters data (provided the number of shipments and distribution over goods classes are sufficient to satisfy the above requirements). Otherwise, a third shipment database might be needed (which would seem highly inefficient) in Sweden. Yet another possibility is simultaneous estimation of the logistics module on the data for Norway and Sweden (see Section 2.9).

The Norwegian private sector shipment data does include information on consolidation and distribution centres, but does not include all goods categories and lacks some information at the sender and receiver end. Therefore, additional data collection on shipments of vehicles/machines and bulk goods is recommended (with at least 200 shipments per detailed commodity category). Furthermore, we recommend to add missing data items (especially on the sender/receiver) to the shipments in the database from the big LSPs or to collect this kind of data together with shipment attributes in a new survey.

For reasons of efficiency the new surveys (the big-LSP database for Norway, and especially the database that will be compiled together with the transport industry in Sweden) should:

- First provide the material to characterise different commodity groups in terms of shares of direct and indirect transports (following up on the interviews that Solving Bohlin and Strömberg carried out in the 2004 project);
- Then focus on shipments of commodities that use consolidation and distribution centres, and ask details fore these.

For the first objective, interviews with industry experts would probably work just as well. An efficient way of reaching the second objective would be to do intercept surveys at consolidation and distribution centres: to get observations on the use of those centres, shipments are effectively selected that use them. Preferably this could be done on the basis of lists of shipments supplied by a sample of consolidation and distribution centres (from the terminal operators). Alternatively, one could try to obtain permission to distribute questionnaires to the drivers of trucks and operating crew of ships and trains at the terminal (partly to be filled in by themselves, partly by the logistic managers) or intercept transports on roads close to specific consolidation and distribution centres.

The data from these surveys are vital for the estimation of the logistics. New stated preference (SP) information from shippers and carriers, e.g. with experiments on mode choice, whether or not to use a distribution centre, and on the trade-off between transport and keeping inventories, could also be very useful in Norway and Sweden for model estimation, especially because in SP surveys it is possible to avoid strong correlation between explanatory variables.

2.7 Progress since April 2005

2.7.1 Updated overview of data requirements

Table 5 below includes an overview of the data items that are needed for model estimation of the choices in step B. The table also lists the required level of detail for each variable (e.g. at the shipment level, at the commodity group level).

Table 5 - Required detail and level per data item

Data item required	Contents/detail	Required level
A. Choice set data (endogenous variables):		
1. Shipment size	Discrete size classes	Individual shipment
2. Annual frequency		Individual shipment
3. Location of sender	Municipality in Sweden/Norway, transport zones abroad	Individual shipment
4. Location of receiver	Municipality in Sweden/Norway, transport zones abroad	Individual shipment
5. Location of all ports, airports and rail terminals actually used for the shipment	Municipality in Sweden/Norway, transport zones abroad	Individual shipment
6. Location of all consolidation centres actually used for the shipment	Municipality in Sweden/Norway, transport zones abroad	Individual shipment
7. Location of all distribution centres actually used for the shipment[6]	Municipality in Sweden/Norway, transport zones abroad	Individual shipment
8. Modes actually used for the shipment	For every leg (OD pair) of the transport chain: road, rail, water and air transport	Individual shipment
9. Loading units actually used for the shipment	For every leg (OD pair) of the transport chain	Individual shipment
10. Type of vehicle/vessel actually used for the shipment	For every leg (OD pair) of the transport chain: several types per mode (including size of vehicle/vessel)	Individual shipment
11. Number of stops actually used in collection and distribution tours		Individual shipment (or by commodity type)
B. Explanatory variables (for segmentation) on the shipment		
1. Commodity type	Consistent with the 32/34 commodity groups used	Individual shipment
2. Whether the shipment is contracted out or not; flexibility/capacity of the transport supplier	For every leg (OD pair) of the transport chain	Individual shipment
3. Value and value density	For every leg (OD pair) of the transport chain	Individual shipment
C. Explanatory variables (for segmentation) on the receiver:		
1. Sector of receiver of the shipment	Detailed sector classification, including industry codes, wholesaler and retailer	Receiver
2. Size of inventories kept, average lead times, variation in lead times		Commodity type
3. Size of receiver	Turnover or employment categories	Receiver
D. Explanatory variables (for segmentation) on the sender:		
1. Sector of sender of the shipment	Detailed sector classification, including industry codes, wholesaler and retailer	Sender
2. Size of sender	Turnover or employment categories	Sender

[6] All (intermodal) freight terminals and marshalling yards should be included in the consolidation centres, distribution centres, ports and airports.

Data item required	Contents/detail	Required level
E. Explanatory variables on logistic cost items (including network variables):		
1. Locations of consolidation and distribution centres, rail terminals, ports and airports	Municipality in Sweden/Norway, transport zones abroad	Zones
2. Data on transport costs, transport time and transport time reliability	Preferably as separate items; this also for fuel, vehicle and staff-related costs, including access/egress to the networks	By mode, vehicle/vessel type, cargo unit, commodity type and OD pair
3. Indication of infrastructure capacity	By mode and OD pair	By mode and OD pair
4. Cost of handling (including transhipment) and storage at ports, airports and rail terminals	Unit costs (per tonne); also: public versus private	By mode (or combination of modes in and out) and commodity group
5. Cost of consolidation and distribution centres (including transfers between modes /vehicles, loading, unloading and storage)	Unit costs; also: public versus 'closed' terminals	By mode (or combination of modes in and out) and commodity group
6. Storage cost for inventories (at P, W or C)	Unit costs	By commodity type

2.8 Cost data required from Norway and Sweden

These cost elements from the Table 5 above (under E) are worked out below.

Ad 1. Location

For every zone we need to know how many (including 'none)' facilities there are for:

- Road-water and water-road transfers (ports);
- Rail-water and water-rail transfers (ports);
- Road-air and air-road transfers (airports);
- Rail-air and air-rail transfers (airports);
- Road-rail and rail-road transfers (railway terminals for combined transport);
- Water-water transfers (feeder lines for big vessels)
- Consolidation centres for road;
- Distribution centres for road;
- Consolidation/distribution and transfers within rail (marshalling yards)

Some facilities could be combinations of the above. We also need to know for which commodity classes these facilities are available and whether they are 'open' (public) or 'closed' (private; only available to a specific shipper).

For zones without one of these facilities, we need to know which other zones are eligible for access to/egress from rail, water or air transport.

Ad 2. Data on transport cost, time and transport time reliability.

It has been decided not to use transport time reliability. Since the logistics model will include mode choice, we need the transport cost and time separately for every available mode (including all road, rail, water and air transport). We need transport cost and time:

- By commodity;
- By cargo type;
- By mode;
- For each OD combination (zone pairs), with a specific code for the mode (e.g. missing value =99999) if a mode is unavailable for this OD.

We are thus not looking for the cost and time of the optimal mode or chain of modes between the OD (it is the logistics model that should determine what is optimal here), but for unimodal OD costs and time. Preferably we would like to get this information in the form of one file with all link costs and one file with all transfer costs (see below under ad 4. for the latter).

If a mode (e.g. train) is not available for a certain OD combination (e.g. because there is no rail access location in the origin zone), then the cell for this mode and this OD pair will have the missing value (say 99999). We do need to know for every zone without rail, air or water access, in which zones there would be eligible options for access to rail, air and water transport (see ad 1). Truck access and egress to intermodal rail terminals, ports and airports will also be handled in the logistics module. The network model should provide optimal unimodal routes. A route can consist of several links, but these should all refer to the same mode.

The above definition of mode should also include vehicle/vessel type and size. The logistics model would need as inputs transport cost and time by mode (including vehicle/vessel type and size), by commodity type and by cargo type (e.g. containers). We understand that certainly for the inputs to the 2005 model, the network models cannot provide this level of detail. Cost models/standard calculation rules however can give transport costs and other costs items for a detailed vehicle/vessel and cargo type classification. For the 2005 logistics model, it would be sufficient to get the time and costs by OD and commodity type for all the modes and commodities that are in the network model at the moment, and let the cost models take care of the further differentiation to cover the range of modes (including vehicle/vessel type and sizes) and cargo units used in the model. In this case we need as inputs to the cost models OD matrices of the unimodal distances and times, as well as the fixed costs per shipment (e.g. loading, unloading, overheads) for each of the current modes and commodity classes from the network models.

We need cost per vehicle or vessel, not per tonne. For the 2005 model, the costs models will give the costs for a vehicle of a certain size (based on OD distance, time and fixed costs). We also need to know other costs items (pilot and fairway dues for ships, infrastructure fees) at the OD and mode/commodity level.

For the 2006 logistics model, the network model preferably should give costs per vehicle. Also in the 2006 logistics model there will be scope for amended cost models, to provide costs inputs for the large number of vehicle/vessel types that are distinguished.

Ad 3. Infrastructure capacity

Physical constraints (e.g. bridges that do not allow large vehicles) that are already in the networks will automatically be taken into account when determining the optimal unimodal routes. Reactions to congestion (flows exceeding capacity) cannot be incorporated in a formal way (feedbacks, iterative demand-supply model) in the 2005 preliminary model. Even for the full model this will be very difficult to realise. However, average costs and times (taking likely congestion into account) can be used in the 2005 logistics model and later models.

Ad 4. Handling/transhipment and storage costs

The above concerned link cost (for one or more links for the same mode between an origin and a destination). Link costs and transfer costs can be delivered separately. For transfers between modes we need the transfer costs for each combination of incoming mode and outgoing mode and commodity type. Transfer costs can also differ between different cargo units (e.g. container handling, stuffing and stripping). Therefore the transfer costs (maybe not from the network models, but after applying the cost models to the network mode inputs) should also be by cargo unit.

We also need to know an estimate of the time that a shipment will be at the CC, DC, port, airport or rail terminal. This is needed to calculate the storage costs, but also to calculate the total transport time of the chain from door to door. This is required by mode in, mode out and commodity class. Storage costs can be per tonne per day and per commodity class (not location or mode specific). But storage also implies unloading and loading and these costs have to be mode and commodity class specific. So for the transfer costs we need:

- Handling/transhipment costs for direct transfers from one mode to the other, such as cross-docking or loading a container from a ship to a truck (including changes of vehicle size, e.g. transfers from a large to a small road vehicle);
- Time at the transhipment point, either for the direct transhipment, or for unloading and unloading;
- Storage costs;
- Storage time at the terminal facility;
- Loading/unloading costs for situations where the goods are not directly transferred from one mode to the other, but stored for a shorter or longer time.

Ad 5. Cost of consolidation and distribution centres (including transfers between modes /vehicles, loading, unloading and storage)

These need to be delivered in the same way as described under 4, distinguishing between transfer costs, time, storage costs and loading/unloading costs.

Ad 6. Storage costs.

Same treatment as for storage costs under Ad 4.

2.9 Which data items are needed from a single file?/possibilities for approximation

It would be ideal to for each of the countries have all Table 5 data in one file with shipments as the file records. However, we acknowledge that this will not be feasible. The data for E can come from network models, augmented with cost models/standard calculation rules to give additional detail (for the observed choices, costs can be compared against the synthetic costs, as a validation exercise). For the later phases of the logistics module project, it is recommended that the network model cost routines are revised to produce costs per commodity group per vehicle instead of per tonne, for several vehicle types and cargo units, but probably some use of cost calculation rules will be necessary to get all the required detail in. These items from E (logistic cost items) will not be by shipment, but more aggregated (see third column). For estimation, these data are inserted in the shipment database, based on the origin, destination, mode, vehicle/vessel type, cargo unit, commodity type (possibly also size of the firms involved), that are in the shipment database. For shipments that are the same on these attributes, these costs will be the same. Effectively, instruments for the costs of various alternative chains are calculated based on existing shipment attributes. This approach could be used for other variables that are missing at the shipment level. C2 (size of inventories, average lead times, variation in lead times) could come from external sources (expert judgement) and be inserted in the shipment database on the basis of the commodity type of the shipments. C3 (value and value density) and D2 (size of sender) could come from register data on firms, provided the firms could be identified in the shipments database. B2 (contracting out, flexibility) might be left out, in the absence of data on this, since it is probably not of great importance.

More difficult will be to get the required data on the choices made. For a shipment we need to know the following choice information:

- Origin r (at P or W level);
- Destination s (W or C);
- Commodity type k;
- (Sector and size of sender (sender=m));
- Sector and size of receiver (receiver=n);
- Chain used (modes, vehicles/vessels, cargo units, ports, airports, rail terminals, consolidation and distribution centres, collection/distribution stops) hz;
- Shipment size q^{rskn} (this is specific for a zone pair rs, a commodity type k and receiver n);
- Total annual flow (demand) Q^{rskn} from zone r to zone s for commodity type k and receiver n, or frequency Q^{rskn}/ q^{rskn}.

2.9.1 **Options for model estimation**

Estimation of the chain type model

This is the model for the choice of mode/route from P (W) to C (W), including choice of mode, vehicle type, cargo unit and all transhipment and storage points on the way.

Available data

Origin, destination, commodity type and sector of sender are in the CFS 2001 and the CFS 2004/2005 will also contain sector of the receiver. The size of the sender can be appended, based on the firm identifier (if allowed) and register data. The receiving firms get no identifier in the CFS and can therefore not be used to append size of the receiving firm. For estimation of the step B model, we might have to insert the firms based on simulation in step A (but this is itself dependent on the size of the firms). The mode chain data is in the CFS (and some information on ports/airport locations used), cargo units are also known (limited detail), but vehicle/vessel types, railway terminals and consolidation and distribution centres used are not. The Schenker/Linjegods (LG) data will have origin, destination and commodity type, but with aggregate/incomplete commodity types. Information about senders and receivers will largely be absent[7], there will be information on modes (but no information on vehicle/vessel types and cargo units) and use of ports, airports, rail terminals, distribution and consolidation centres. The LG data will not cover all commodity types (weak on vehicles, machines, bulk goods). Sweden might get similar data from the transport industry (but this has been postponed, and will not be available for estimation in 2006).

With regards to the chain type choice hz, Sweden has data (CFS) that can be used to estimate a mode chain choice (with as alternatives several combinations of modes between r and s), with a relatively fine segmentation by commodity type and some segmentation by sender and receiver (possibly a mode chain – shipment size model). Norway has data to estimate a chain type model with more alternatives (e.g. with consolidation centres and distribution centres at specific locations), but with less segmentation by commodity group and no segmentation by sender/receiver (possibly a chain type – shipment size model). These models can be estimated using existing discrete choice software (e.g. Alogit), but we would like to develop a chain type choice model for Sweden with more than just mode choice, as well as for Norway. This is worked out below.

Joint estimation

The specification of the full chain type choice model could be worked out for Sweden too, but for estimation, the unobservables have to be integrated out. We can regard the chain type model as nested logit model with mode chain choice at the top level and the choice which locations are used for the transhipments between the modes at the lower level. For every mode chain alternative we sum over various feasible transhipment location alternatives. The likelihood function used in the estimation on the Swedish data will then contain aggregations over transhipment location alternatives (in the form of logsums). This

[7] If Schenker/LG would provide the addresses of the sender and receiver, it might be possible to append information on those firms using information from registers of firms.

model could be estimated (but not with existing software, one would have to program one's own likelihood function, e.g. in GAUSS). It is not unlikely to run into identification problems for this model. However, the danger of identification problems can greatly be reduced by estimating both models (Norway and Sweden) simultaneously on both datasets together with a number of common cost and time coefficients (other coefficients can be different between both countries)[8]. Both models will have the same basic specification, but will work in estimation with different aggregations of choices and commodity types. Again this requires programming the likelihood functions oneself (might be feasible in phase 2, needs further investigation).

Hierarchical estimation

A less efficient way of estimating the chain type model for Norway and Sweden would be sequential estimation. This means estimation on the Norwegian data first. Then one could apply the estimates for Norway in Sweden, using the Swedish flows and network data, to get logsum values for the transhipment alternatives. These are then used in the estimation of the Swedish mode chain model. The advantage of this approach is that it can be done with existing discrete choice software. The disadvantage is that it is statistically less efficient than full information maximum likelihood (FIML: joint estimation as described above). Also the hierarchical model is less flexible in terms of equating/not-equating coefficients (or ratios of coefficients, see footnote 4) in Norway and Sweden. In hierarchical estimation one can scale the logsum variable as a whole, but there is not the possibility to differentially scale coefficients from the transhipment location model (that is incorporated in the logsum). In FIML this can be done.

Estimation combined with deterministic optimisation

Another possibility would be to impose (from an optimisation, normative) the consolidation and distribution centres (maybe also vehicle types) on the CFS data, for each available mode chain. This would require that for each shipment in the CFS, the available mode chains are enumerated and that for each of those the optimal consolidation and distribution centres (and maybe also vehicle sizes) are determined. For the estimation of the mode chain model, these optimal routes would then be used. As chosen alternative we would use the chosen mode chain, with the corresponding optimal route. An advantage of this procedure is that for the calculation of the full logistic costs of each mode chain alternative, identification of the feasible locations for consolidation and distribution and calculation of their costs is required anyway. So the consolidation and distribution centres would then follow from optimisation and the modes used would be studied in a discrete choice model to be estimated. A serious disadvantage of this approach is that deterministic optimisation is not an appropriate method when there is a lot of unexplained variation in the model, which will be the case here, with large commodity groups and sometimes large

[8] The combination of data from Norway and Sweden in FIML estimation is like the joint model estimation on revealed and preference data. Instead of assuming a number of common coefficients across the multiple datasets (equality of coefficients) one can also use the weaker assumption of common ratios of coefficients (e.g. values of time) in Norway and Sweden.

geographic zones. We therefore prefer the estimation of the stochastic model described above (FIML or hierarchical).

New data

New data that would have all the choice attributes would be very valuable, even if these data would come from a small sample of just a few commodity types. The full chain type choice model on this data could be estimated simultaneously with the above choice models on the CFS and the LG data, with some common coefficients. For Sweden there is also be the option to estimate on the CFS plus a much smaller but more complete (especially use of consolidation and distribution centres) shipment database. The latter database could focus on commodity types that do not often use direct transports. For Norway, a small additional database is most needed for commodities not yet covered (vehicles, machines, bulk goods), as is information on the frequency of shipments for all commodity types. The latter might come from expert judgement. We would prefer to estimate the model on all four datasets together.

Estimation of the model for choice of shipments size or annual frequency of shipments

Available data

Annual flow (or annual frequency) for the receiving firm, A2 in Table 5, is missing in Norway and will also not be included in the data from Schenker/Linjegods (LG). For Sweden, the CFS could give an approximation for the annual frequency of a certain shipment from the sender. The CFS includes information on the total number of shipments in the reporting period. The reporting period was one-three weeks (this length is registered too). Please note that these data have been requested as additional data items from the CFS from Statistics Sweden by SIKA, and have been received by RAND Europe. However, we need the frequency seen from the receiving end. We might assume that these frequencies are the same (but this requires that the shipments are defined in the CFS as the collection of units of a product that are delivered together (at the same time) at the receiver, not batches or parts of this that could result from consolidation and distribution). Statistics Sweden will also analyse whether it is possible to derive the structure of shipments sent between companies (number, size and weight of the shipments; number, size and sector of receiving companies) by matching CFS data (full datasets) and CFAR information.

Shipment size is in the CFS and will be in the LG data. In D1 (RAND Europe et al., 2004) we envisaged a sort of nested logit model of shipment size (or annual frequency) and chain type. In the EOQ model, the shipment size depends on annual demand at the receiving firm. On this we have no survey information in Norway (except some information for sending firms that exclusively rely on Linjegods for their transports) and only approximations from the CFS sampling procedure in Sweden. If we would explain frequency, we would have a similar data problem, but on the endogenous variable. So it does not really matter much whether we explain shipment size or frequency, in both cases we run into the problem of lack of observations on annual demand.

Joint estimation

In step A we calculate the total demand per firm from the total flow to the zone (by commodity group). This procedure will be subject to an error margin, that we might be able to quantify (through repeated simulation). The resulting distribution can be used for Norway, and then be integrated out, just as we suggested for other missing data problems above. It is possible to estimate simultaneously a model of shipment size and chain type for Sweden on the CFS (integrating over transhipment location alternatives) and shipment size (integrating over the demand volume categories) and chain type in Norway on the LG data.

Alternatively the joint model could have frequency instead of shipment size. Also new, smaller, but more complete, datasets could be added.

Hierarchical estimation

If we would estimate in a hierarchical fashion, the chain type model would be estimated first, and the logsum from it would be used in the subsequent estimation of the shipment size (or frequency) model. This is what we proposed in option IB of Deliverable 1. FIML estimation of the shipment size and chain type model was seen as unduly complicated. We still think that this was a right choice. Whether within the chain type model two steps are needed or not was discussed above. In this respect we prefer FIML estimation for the chain type choice model, but have to check whether the programming of the estimation procedure will be feasible, within the time and budget constraints of the coming phases. Three-step sequential estimation (transhipment locations for Norway, then mode chains for Norway and Sweden with transhipment location logsums, then shipment size or frequency for Sweden with mode chain logsums) is the alternative: less efficient but easier to carry out the estimation (existing software).

Instrumental variables estimation

Instead of using integration, annual demand per firm might be estimated from attributes of the firm and shipment (instrumental variables), and the error term of these regressions (estimated on Swedish data) entered in the shipment size choice model. Whether this would be possible depends on which variables would be available to explain total demand (probably not many), and the quality of these regressions.

Estimation plus deterministic optimisation

Furthermore, there is the possibility not to estimate shipment size or frequency, but to let the annual frequency follow from optimisation (normative again) using EOQ equations, including time and cost that is (approximately) consistent with the chain type choice. This optimal shipment size would then be used in the conditional chain type choice model estimation. The drawback is that this is good for the logistics planning of a firm, with all the firm-specific data available, but not very appropriate for a national transport planning with aggregates of modes and locations. For such higher levels of abstraction, a probabilistic approach is needed.

2.10 Application

For application, we need less variables than for estimation, since in application the models will produce synthetic versions of the endogenous (choice) variables, in the form of choice probabilities, which can be used to assign discrete choice alternatives to shipments (micro-simulation). On the other hand, the application needs to provide a picture of the freight flows for all commodity types and zones. In estimation, one can sometimes use samples of shipments. For some models, such as multinomial logit, standard estimation on a selective choice-based sample (e.g. overrepresentation of road observations) is appropriate even without expansion, provided that the alternative-specific constants are corrected afterwards on population statistics. In application we need to use the population of the shipments or develop a procedure to properly expand the samples used. The data required for this consist of the PWC matrices, which are allocated to firms in step A. Both the PWC matrices and the data on the location and size of firms need to be complete (no missing commodities or sectors). This implies that we have to find ways to include wholesale and retail firms, the oil industry and agriculture, which in Norway are in different datasets. For the application of the models it is also required that the explanatory variables are available at the shipment level for all commodity groups. This makes it even more difficult to use B2 (contracting out, flexibility), which probably needs to be discarded. The variables in E (logistic cost items) as they were used in estimation, can be used in application as well. The other variables in B, C and D (explanatory variables) need to become available for all shipments that are generated in the application of the logistics module. Step A will produce the sector and size (number of employees) of the relevant firms. B3 (value and value density) can be supplied by the base matrices (will be in tonnes and value). C2 (size of inventories, lead times) probably needs to be based on expert judgement and can be handled as a commodity-type specific item.

CHAPTER 3 Further specification of key logistic aspects

3.1 Commodity groups, decisions and logistic behaviour

Two important aspects may have an influence on the optimisation of logistical flows. One is the decision-making level within a supply chain, which will have the decision-making power in terms of inventory optimisation: Producers, Wholesalers, and Retailers. This is in terms of "common language" differentiation. In the model, the PWC roles will vary between the categories above. The second aspect is the "logistical logic" applied in the supply chain, as:

- Delivery and production to order (I);
    - JIT deliveries (Ia);
    - Postponement, cost minimisation of deliveries (Ib);
- Production to inventory, deliveries from inventory (II);
- Production driven, but with direct deliveries to market (III).

In categories I and III there will typically be "zero inventories" (or close to zero), which is obviously not the case in category II.

One should also take into account that for a given supply chain, the logic may differ on various steps. *As an example,* a supply chain may have JIT production with deliveries to inventory-holding wholesalers, which again delivers order-based to non-stockholding retailers or consumers. There are large variations in behaviour and logic between categories and within subcategories of these. In this respect, only individual company data would cover all possibilities, although this would not be a feasible approach. To make the model operational, we may however try to stereotype typical behavioural logics within the main categories.

Colour code:	Meaning:
	Quite often part of supply chain within category
	Occasionally part of supply chain within category
	Rarely part of supply chain, can be omitted in model

Table 6 - Norwegian Nemo 32 stereotypes on logistic decision-making

Category	Producers P	Whole-salers W	Retailers/ consumers as customers R/C	Customer who are next tier producer C(P)	Key decision level(s)
1. Bulk food	II	II	II	II	W, C(P)
2. Consumption food	II	II	II	II	W, R/C
3. Beverages	II	II	II	II	W, R/C
4. Fresh fish	III	Ia	Ia	Ia	P, R/C
5. Frozen fish	III	II	II	II	W
6. Other fish	III	II	II	II	W
7. Thermo input	III	II	II	II	W, C(P)
8. Thermo consumption	III	II	Ia	II	W
9. Machinery and equipment	Ia	II	II	Ia	R/C, C(P)
10. Vehicles	Ia	Ia	Ia	Ia	R/C
11. General cargo – high value goods	Ia	II	II	Ia	W, R/C, C(P)
12. General cargo – live animals	III	II	Ia	Ia	W, C(P)
13. General cargo – building materials	II	II	II	II	W, C(P)
14. General cargo – other inputs	II	II	II	II	C(P)
15. General cargo – consumption goods	II	II	II	II	W
16. Timber – pulpwood	II	II	II	II	C(P)
17. Timber – saw-logs	II	II	II	II	C(P)
18. Pulp	Ia	Ia	Ia	Ia	C(P)
19. Paper intermediates	Ia	Ia	Ia	Ia	C(P)
20. Wood products	II	II	II	II	W, R/C
21. Paper products	II	II	II	II	W, R/C
22. Mass commodities	II	II	II	Ib	C(P)
23. Coal, ore and metal waste	II	II	II	Ib	C(P)
24. Cement, plaster and cretaceous	II	II	II	Ib	C(P), W
25. Non-traded goods	III	Ib	Ib	Ib	P
26. Chemical products	Ib	Ib	II	II	P, C(P)
27. Fertilizers	III	II	II	II	W
28. Metal and metal goods	Ia	Ia	Ia	II	P, C(P)
29. Aluminium	Ia	Ia	Ia	Ia	C(P)
30. Crude petroleum	III	II	II	II	C(P), P
31. Petroleum gas	III	II	II	II	C(P), P
32. Refined petroleum products	III	II	II	II	W, R/C

The categories shown in Table 6 follow the Norwegian Nemo 32 classification. For the new Swedish grouping, (34 commodity groups), we can in the same way generate the assumptions for the main logistical behaviour (see Table 7). We intend to use these classifications, as well as those in the Table 7-10, in building the 2006 logistics model (but also already used these in the 2005 model, see in Part B).

Table 7 - Swedish 34 stereotypes on logistic decision-making

Category	Producers P	Whole-salers W	Retailers/ consumers as customers R/C	Customer who are next tier producer C(P)	Key decision level(s)
1. Cereals	II	II	II	II	W, C(P)
2. Potatoes, other vegetables fresh or frozen	II	II	II	II	W, R/C
3. Live animals	III	II	Ia	Ia	W, C(P)
4. Sugar beet	III	II	Ia	Ia	P, C(P)
5. Timber for paper industry (pulpwood)	II	II	II	II	C(P)
6. Wood roughly squared or sawn lengthwise, sliced or peeled	II	II	II	II	C(P)
7. Wood chips or wood waste	II	II	II	II	C(P)
8. Other wood or cork	II	II	II	II	C(P)
9. Textiles, textile articles and manmade fibres, other raw and animal and vegetable materials	II	II	II	II	C(P)
10. Foodstuff and animal fodder	II	II	II	II	W, C(P)
11. Oil seeds and oleaginous fruits and fats	III	II	II	Ia	C(P)
12. Solid mineral fuels (coal etc)	II	II	II	Ib	C(P)
13. Crude petroleum	III	II	II	II	C(P), P
14. Petroleum products	III	II	II	II	W, R/C
15. Iron ore, iron and steel waste and blast-furnace dust	II	II	II	Ib	C(P)
16. Non-ferrous ores and waste	II	II	II	Ib	C(P)
17. Metal products	Ia	Ia	Ia	II	P, C(P)
18. Cement, lime, manufactured building materials	II	II	II	Ib	C(P), W
19. Earth, sand and gravel	II	II	II	Ib	C(P)
20. Other crude and manufactured minerals	II	II	II	Ib	C(P)
21. Natural and chemical fertilizers	III	II	II	II	C(P)
22. Coal chemicals	Ib	Ib	II	II	P, C(P)
23. Chemicals other than coal chemicals and tar	Ib	Ib	II	II	P, C(P)
24. Paper pulp and waste paper	Ia	Ia	Ia	Ia	C(P)
25. Transport equipment, whether or not assembled, and parts thereof	Ia	Ia	Ia	Ia	P, C(P)
26. Manufactures of metal	Ia	Ia	Ia	II	P, C(P)
27. Glass, glassware, ceramic products	II	II	II	II	W
28. Paper, paperboards; not manufactured	Ia	Ia	Ia	Ia	C(P)
29. Leather textile, clothing, other manufactured articles than 28	II	II	II	II	W
30. General cargo	II	II	II	II	C(P)
31. Timber for sawmill	II	II	II	II	C(P)
32. Machinery, equipment, engines	Ia	II	II	Ia	R/C, C(P)
33. Paper, paperboard and manufactures thereof	II	II	II	II	W, R/C
34. Packaging materials, used	III	Ib	Ib	Ib	P

The possible impact for the optimisation logic is given in Table 9 and Table 10. To highlight common patterns, the following colour code is used:

Table 8 - Colour coding for optimisation logic

(green)	Inventory optimisation by W – (optimisation of total cost inventory W and transportation P-W)
(light blue)	Inventory optimisation by C - (optimisation of total cost inventory C and transportation W-C, or P-C directly)
(orange)	Transportation cost minimisation (only – disregard inventory effects)
(pink)	Cost minimising for transport only, given time constraints (time restrictions given for transit time P-W, W-C or P-C)
(yellow)	Cost minimisation of transport given shipment size constraints (shipment size restrictions given for transfer batches)
(red)	Not applicable (no flows on this relationship for given cargo category)

Also combinations which only are a subset (minor, but still significant) of the flows for the category ("yellow situations in Table 6 and Table 7) may be included with a certain fraction and are therefore also shown in the table.

Table 9 - Consequences for logistical modelling (Norwegian categories)

Category	Logistical implications (model) – P-W relationships	Logistical implications W-C relationships	Logistical implications P-C relationships
1. Bulk food	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
2. Consumption food	Inventory optimisation by W	Inventory optimisation by C	Not applicable
3. Beverages	Inventory optimisation by W	Inventory optimisation by C	Not applicable
4. Fresh fish	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints
5. Frozen fish	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Inventory optimisation by C
6. Other fish	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Inventory optimisation by C
7. Thermo input	Cost minimisation for transport only, given time constraints	Not applicable	Inventory optimisation by C
8. Thermo consumption	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Not applicable
9. Machinery and equipment	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Cost minimisation for transport only, given time constraints
10. Vehicles	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Not applicable
11. General cargo – high value goods	Inventory optimisation by W	Inventory optimisation by C	Cost minimisation for transport only, given time constraints
12. General cargo – live animals	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints
13. General cargo – building materials	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
14. General cargo – other inputs	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
15. General cargo – consumption goods	Inventory optimisation by W	Inventory optimisation by C	Not applicable
16. Timber – pulpwood	Not applicable	Not applicable	Inventory optimisation by C
17. Timber – saw-logs	Not applicable	Not applicable	Inventory optimisation by C
18. Pulp	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints
19. Paper intermediates	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints

Category	Logistical implications (model) – P-W relationships	Logistical implications W-C relationships	Logistical implications P-C relationships
20. Wood products	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
21. Paper products	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
22. Mass commodities	Not applicable	Not applicable	Transportation cost minimisation
23. Coal, ore and metal waste	Not applicable	Not applicable	Transportation cost minimisation
24. Cement, plaster and cretaceous	Inventory optimisation by W	Inventory optimisation by C	Transportation cost minimisation
25. Non-traded goods	Transportation cost minimisation	Not applicable	Transportation cost minimisation
26. Chemical products	Transportation cost minimisation	Inventory optimisation by C	Inventory optimisation by C
27. Fertilizers	Transportation cost minimisation	Inventory optimisation by C	Not applicable
28. Metal and metal goods	Transportation cost minimisation	Not applicable	Inventory optimisation by C
29. Aluminium	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints
30. Crude petroleum	Cost minimisation for transport only, given time constraints	Not applicable	Inventory optimisation by C
31. Petroleum gas	Cost minimisation for transport only, given time constraints	Not applicable	Inventory optimisation by C
32. Refined petroleum products	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Inventory optimisation by C

For the aggregated Swedish groups, the recommendation is as shown in Table 10.

Table 10 - Consequences for logistical modelling (Swedish categories)

Category	Logistical implications (model) – P-W relationships	Logistical implications W-C relationships	Logistical implications P-C relationships
1. Cereals	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
2. Potatoes, other vegetables fresh or frozen	Inventory optimisation by W	Inventory optimisation by C	Not applicable
3. Live animals	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints
4. Sugar beet	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Cost minimisation for transport only, given time constraints
5. Timber for paper industry (pulpwood)	Not applicable	Not applicable	Inventory optimisation by C
6. Wood roughly squared or sawn lengthwise, sliced or peeled	Not applicable	Not applicable	Inventory optimisation by C
7. Wood chips or wood waste	Not applicable	Not applicable	Inventory optimisation by C
8. Other wood or cork	Not applicable	Not applicable	Inventory optimisation by C
9. Textiles, textile articles and manmade fibres, other raw and animal and vegetable materials	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
10. Foodstuff and animal fodder	Inventory optimisation by W	Inventory optimisation by C	Not applicable
11. Oil seeds and oleaginous fruits and fats	Inventory optimisation by W	Not applicable	Cost minimisation for transport only, given time constraints
12. Solid mineral fuels (coal etc)	Not applicable	Not applicable	Transportation cost minimisation
13. Crude petroleum	Cost minimisation for transport only, given time constraints	Not applicable	Inventory optimisation by C
14. Petroleum products	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Inventory optimisation by C
15. Iron ore, iron and steel waste and blast-furnace dust	Not applicable	Not applicable	Transportation cost minimisation
16. Non-ferrous ores and waste	Not applicable	Not applicable	Transportation cost minimisation
17. Metal products	Transportation cost minimisation	Not applicable	Inventory optimisation by C
18. Cement, lime, manufactured building materials	Inventory optimisation by W	Inventory optimisation by C	Transportation cost minimisation
19. Earth, sand and gravel	Not applicable	Not applicable	Transportation cost minimisation
20. Other crude and manufactured minerals	Not applicable	Not applicable	Transportation cost minimisation
21. Natural and chemical fertilizers	Transportation cost minimisation	Inventory optimisation by C	Not applicable

Category	Logistical implications (model) – P-W relationships	Logistical implications W-C relationships	Logistical implications P-C relationships
22. Coal chemicals	Transportation cost minimisation	Inventory optimisation by C	Inventory optimisation by C
23. Chemicals other than coal chemicals and tar	Transportation cost minimisation	Inventory optimisation by C	Inventory optimisation by C
24. Paper pulp and waste paper	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints
25. Transport equipment, whether or not assembled, and parts thereof	Cost minimisation for transport only, given time constraints	Cost minimisation for transport only, given time constraints	Not applicable
26. Manufactures of metal	Inventory optimisation by W	Inventory optimisation by C	Not applicable
27. Glass, glassware, ceramic products	Inventory optimisation by W	Inventory optimisation by C	Not applicable
28. Paper, paperboards; not manufactured	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints
29. Leather textile, clothing, other manufactured articles than 28	Inventory optimisation by W	Inventory optimisation by C	Not applicable
30. General cargo	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
31. Timber for sawmill	Not applicable	Not applicable	Inventory optimisation by C
32. Machinery, equipment, engines	Cost minimisation for transport only, given time constraints	Inventory optimisation by C	Cost minimisation for transport only, given time constraints
33. Paper, paperboard and manufactures thereof	Inventory optimisation by W	Inventory optimisation by C	Inventory optimisation by C
34. Packaging materials, used	Transportation cost minimisation	Not applicable	Transportation cost minimisation

3.2 Singular flows

Singular flows are in this context flows between (a few) origins and destinations that are significant in terms of volumes. These are normally linked to important industrial activities. A further question concerns the stability of the flow that for instance could be due to fixed infrastructure investments both on the sender and receiver side. In terms of stability, the iron ore mine in Kiruna can not be moved, and there is virtually no competition involved related to the terminal facilities in Narvik, so the flow between Kiruna and Narvik will within a fairly long time horizon be regarded as singular. However, if we expand the time horizon long enough, the mine may run out of ore. As another example, the Aluminium smelters along the Norwegian west coast represent major investments, and will not be moved in the short/medium term. Basic transport routes for serving international customers through ports in the Netherlands also remains fairly stable. Of course, in the longer run, the last assumption may change, due to changes in the European transport infrastructure and customer locations. The smelters themselves will not be moved, but may in the long run in principle be shut down due to the competition from other technologies and producers. When identifying “singular flows” it is therefore also of some importance to set the time horizon for when the flows should be regarded stable. By identifying and isolating these flows, we may be able to simplify the residual transport flows.

To get some more information on these issues, SITMA has contacted 15-20 companies in total in Sweden and Norway, selected from the largest industrial companies. The first point of contact has been with the head of logistics or the transport manager, followed by an e-mail with questions and background information on our request. Some companies have returned the e-mail with a description of the major transport flows, while others have referred to their websites or presented the information by phone. The overall impression is that the companies are willing to share the information around their transport flows, but the feedback process often takes time. There is also a tendency that the volume estimates may be slightly rounded from some of the companies, while others give them with a large degree of accuracy.

The statistics below were gathered partly to test the notion of getting better models by removing singular flows before model estimation, and partly to test how difficult it is to get the necessary information. Most of the information obtained from the firms was given in the form of **origin-destination flows** (e.g. from producer to port) and not as PWC flows. As a result, they cannot directly be compared to PWC statistics (in Part B and Annex 5 of this report we shall compare singular flows to total flows -from the PWC matrices- from a producing zone or to a consuming zone). Some data may obviously be missing, as for example the iron ore flows from Kiruna to Luleå. This is a flow around 5 million tonnes per year, but due to time restrictions we did not get accurate figures before the deadline (may be updated later on). On the other hand, we also received information about several flows for example within the fishery industries that are too small (and unstable) to qualify as singular flows. The present report is therefore more an example of what should be completed for the 2006 model than a full list, but should be sufficient for test purposes.

We have received the transport flows from several of the companies at a fairly detailed level. The presentation is limited to singular flows with more than 100.000 tonnes per year. All figures are converted to tonnes from the companies themselves, based upon actual 2004 volume or 2005 forecast.

3.2.1 **Metal industry**

Table 11 - Singular flows in the metal industry

Company	Loading	Unloading	Product	Tonnes year	Mode	Average load
LKAB	Kiruna	Narvik	Iron ore products	15.5 million	Train	4.000 tonnes. 12 trains daily.
LKAB	Narvik	Kiruna	Various	400.000	Train	Various
Elkem	Leirpollen, Tana	Grundartanga, Island	Silica	165.000	Ship	6.000 tonnes
Elkem	Leirpollen, Tana	Svelgen (Bremanger)	Silica	143.000	Ship	6.000 tonnes
Elkem	North Spain	Thamshavn, Orkdal	Silica	100.000	Ship	3.500 tonnes
Elkem	Surinam, S-America	Farsund	Alumina	174.000	Ship	10.000 tonnes
Elkem	Surinam, S-America	Mosjøen	Alumina	365.000	Ship	20.000 tonnes
Elkem	Mosjøen	Rotterdam	Aluminium	210.000	Ship	4.000 tonnes
Hydro (outbound summary)	Karmøy	Rotterdam	Sheet ingot	317.220	Ship	20-100 tonnes Further distr. from Holland
"	Sunndal	Rotterdam	Sheet ingot	348.760	Ship	"
"	Årdal	Rotterdam	Sheet ingot	187.070	Ship	"
Hydro	Brasil	Karmøy	Alumina	199.800	Ship	
Hydro	Brasil	Sunndal	Alumina	259.000	Ship	
Hydro	Brasil	Årdal	Alumina	162.800	Ship	
Hydro	Jamaica	Karmøy	Alumina	110.700	Ship	
Hydro	Jamaica	Sunndal	Alumina	143.500	Ship	
Hydro	Surinam	Karmøy	Alumina	118.800	Ship	
Hydro	Surinam	Sunndal	Alumina	154.000	Ship	
Hydro	New Orleans	Årdal	Pet coke	107.000	Ship	
SSAB	Luleå	Borlänge	Steel sheets	2.1 million	Train	
SSAB	Borlänge	Luleå	Scrap for reuse	200.000	Train	
SSAB	Oxelösund	Borlänge	Steel rolls, plates	700.000	Train	
SSAB	Borlänge	Oxelösund	Raw material	700.000	Train	
SSAB	Borlänge	Malmö	Steel products	600.000	Train	Train centr. EU
SSAB	Borlänge	Gothenburg	Steel products	200.000	Train	Overseas
Outo-kumpu Stainless	Avesta	Sheffield (UK)	Slabs, coils, tubes	700.000	Train/ Ship	Via Gothenburg
Outo-kumpu Stainless	Torneå (Finland)	Avesta	Steel plates	200.000	Train	

The iron ore products from LKAB are sold to steel mills all over the world. Approximately 90 % of the iron production distributed from Kiruna to Narvik is stored at the warehouse in Narvik before it is shipped to customers. Several projects have been launched to utilise the return capacity, but without success so far.

The raw material flow to Elkem's four Ferro-silica plants amount to 1.03 million tonnes per year. The major flows are listed above. One might also expect the outputs flows from Elkem to be among the singular flows. However, these flows of silicon and micro silica are shipped (in 20 feet containers by ship) from each of the plants to ports all over the world. None of these flows represent more than 20.000 tonnes per year. Therefore, these output flows have not been included in the list of singular flows presented above.

The largest transport flows of alumina to the smelters and of aluminium from the smelters to the central point of distribution are indicated above (Elkem).

From Hydro Aluminium we have received a spreadsheet with 170 transport flows where six Norwegian plants are involved, with a total of 4.17 million tonnes in 2005. Most of the flows are below 100.000 tonnes per year. Sea transportation is widely used, except for transportation of finished goods in Norway and Sweden. Much of the flows are concentrated on Rotterdam as an entry point to Europe, and then distributed in smaller flows from there.

SSAB transported 5.5 million tonnes of steel products in Sweden in 2004, 90% whereof were transported by train. Sandvik Materials Technology had a total production of 150.000 tonnes during 2004. None of the flows exceeded 100.000 tonnes per year.

3.2.2 **Process industry**

Table 12 - Singular flows in the process industry

Company	Loading	Unloading	Product	Tonnes year	Mode	Average load
SCA	Piteå	Umeå	Paper	800.000	Train	
StoraEnso	Borlänge	Gothenburg	Sawn wood products	600.000	Train	
StoraEnso	Karlstad	Gothenburg	Paper/ board	400.000	Train	
StoraEnso	Halmstad	Gothenburg	Paper/ Sawn wood	400.000	Train	Factory located 50 km north of Halmstad
Norske Skog, Skogn	Skogn	Tilbury, UK	Paper	150.000	Side port vessel	
Norske Skog, Follum	Hønefoss	Halden	Paper	250.000	Train	This flow will expand during 2006
Yara	Grenland	Overseas	Fertilizers	1.18 million	Ship	
Yara	Grenland	Great Britain	"	249.000	Ship	
Yara	Grenland	France/Spain	"	212.000	Ship	
Yara	Murmans k Russia	Grenland	Phosphate	500.000	Ship	
Yara	Klaipede, Lithuania	Grenland	Calcium Chloride	135.000	Ship	
Yara	Kårstø	Grenland	Etan	137.000	Ship	
Yara	Sture, Bergen	Grenland	LPG	344.000	Ship	

Stora Enso has a world wide production capacity of 16.4 million tonnes of paper and board, and 7,7 million cubic metres of sawn wood products.

From SCA Transforest we have received very detailed information about their flows. However, no flows are above 100.000 tonnes.

From Norske Skog, Skogn we have received a detailed specification of all flows, both into the factory and of finished goods to customers. In order to produce 530.000 tonnes of paper this year, 1.2 million tonnes of timber and other types of products are required. However, there is only one singular flow above 100.000 tonnes per year.

From Yara Porsgrunn there is no further specification of harbours for loading/unloading.

Borealis has a total production of 350.000 tonnes per year. None of the singular flows exceeds 100.000 tonnes per year.

3.2.3 Oil production

The oil company with the leading responsibility for oil field is listed as "company." According to information from Hydro Oil & Gas there is a conversion factor of 49,8 between barrels per day and tonnes per year.

Table 13 - Singular flows in the oil production

Company	Loading	Unloading	Product	Tonnes year	Mode	Average load
Statoil	Troll	Mongstad	Crude oil	19.92 million	Pipeline	16-20 inch lines
Statoil	Heidrun	Mongstad	Crude oil	11.95 million	Ship	N/A
Hydro	Oseberg	Sture (at Bergen)	Crude oil	38.10 million	Pipeline	28-inch line
TotalFin Elf	Frøya/ Frigg	Oseberg	Crude oil	4.98 million	Pipeline	16-inch line
Philips	Ekofisk	Teeside, UK	Crude oil	38.84 million	Pipeline	34-inch line
Statoil	Ula/Gyda	Ekofisk	Crude oil	12.46 million	Pipeline	20-inches lines
Statoil	Sleipner	Kårstø	Condensate	9.96 million	Pipeline	20-inch line

The Sture facility handles approximately 200 tankers every year for further oil distribution.

We have not added information about the gas production with a complex system of pipeline transportation. The Norwegian gas exports to continental Europe and UK will be approx. 80-90 million cubic meters during 2005.

3.2.4 Food and finished goods

Information was gathered from several companies within the fish industry as Lerøy and Pan Fish, but none of these companies had singular flows of over 100.000 tonnes. In fact the largest companies hardly had total volumes exceeding that level.

3.2.5 Summary on singular flows

We can sum up preliminary singular flows as shown in Table 14 and Table 15 below. One should however appreciate that these flows are preliminary, and should be adjusted, updated and completed for the 2006 model. By identifying and isolating these flows, we may be able to make the residual transport flows more homogeneous, and thus increase the quality of the estimated models.

Table 14 - Summary of singular flows from Norway (preliminary 2005)

From	To	Transport mode	Tonnes per year	Nemo category	Est. avg. shipments	Comment
Kiruna (Sw)	Narvik	Train	15,500,000	72	4000	Slightly rounded number - may be adjusted
Narvik	Kiruna (Sw)	Train	400,000	54	-	Miscelanous. May be distributed across several Nemo catagories
Narvik	Overseas	Ship	15,500,000	72	Large	Large bulk shipments - Slightly rounded number - may be adjusted
Tana	Iceland	Ship	165,000	72	6000	Silica
Tana	Bremanger	Ship	143,000	72	6000	Silica
Spain	Orkdal	Ship	100,000	72	3500	Silica
Surinam (overseas - South-America)	Farsund	Ship	174,000	71	10000	Alumina
Surinam (overseas - South-America)	Mosjøen	Ship	365,000	71	20000	Alumina
Mosjøen	Rotterdam	Ship	210,000	92	20-100 (4000)	
Karmøy	Rotterdam	Ship	317,220	92	20-100 (4000)	
Sunndal	Rotterdam	Ship	348,761	92	20-100 (4000)	
Årdal	Rotterdam	Ship	187,073	92	20-100 (4000)	
Brasil	Karmøy	Ship	199,800	71	Large	Alumina
Brasil	Sunndal	Ship	259,000	71	Large	Alumina
Brasil	Årdal	Ship	162,800	71	Large	Alumina
Jamaica	Karmøy	Ship	110,700	71	Large	Alumina
Jamaica	Sunndal	Ship	143,500	71	Large	Alumina
Surinam (overseas - South-America)	Karmøy	Ship	118,800	71	Large	Alumina
Surinam (overseas - South-America)	Sunndal	Ship	154,000	71	Large	Alumina
New Orleans (USA)	Årdal	Ship	107,000	72	10-20000	Petcoke
Skogn	Tilbury (UK)	Ship	150,000	64	3-10000	
Hønefoss	Halden	Train	250,000	64	500-1000	
Halden	Europe	Ship	250,000	64	3-10000	This is Follums part of the cargo. It is consolidated with Cargo from Norske Skog Halden and (partly still Union)
Troll	Mongstad	Pipeline	19,920,000	101	Continuous	
Heidrunn	Mongstad	Pipeline	11,950,000	101	Continuous	

Oseberg	Sture (at Bergen)	Pipeline	38,100,000	101	Continuous	
Ekofisk	Teeside (UK)	Pipeline	38,840,000	101	Continuous	
Frøya/Frigg	Oseberg	Pipeline	4,980,000	101	Continuous	
Herøya (Porsgrunn)	Overseas (outside Europe)	Ship	1,180,000	82	10-40000	Outside Europe
Herøya (Porsgrunn)	UK	Ship	249,000	82	2-10000	
Herøya (Porsgrunn)	France/Spain	Ship	212,000	82	2-10000	
Murmansk	Herøya (Porsgrunn)	Ship	500,000	73	5-20000	Phosfate
Klaipede (Litauania)	Herøya (Porsgrunn)	Ship	135,000	82	5-20000	Calsium Chloride
Kårstø	Herøya (Porsgrunn)	Ship	137,000	102		Etan
Bergen	Herøya (Porsgrunn)	Ship	344,000	102		LPG

Table 15 - Summary of singular flows from Sweden (preliminary 2005)

From	To	Transport mode	Tonnes per year	SAMGODS category	Est. avg. shipments	Comment
Kiruna	Narvik	Train	15,500,000	15	4000	Slightly rounded number - may be adjusted
Luleå	Borlänge	Train	2,100,000	17		Steel sheets
Borlänge	Luleå	Train	200,000	15		Steel scrap
Oxelösund	Borlänge	Train	700,000	17		Steel rolled products
Borlänge	Oxelösund	Train	700,000	15		
Borlänge	Malmö	Train	600,000	17		
Borlänge	Gothenburg	Train	200,000	17		
Gothenburg	Overseas	Ship	200,000	17		Destination not defined
Avesta	Gothenburg	Train	700,000	17		Final destination Sheffield
Gothenburg	Sheffield (UK)	Ship	700,000	17		
Torneå (Finland)	Avesta	Train	200,000	17		
Piteå	Umeå	Train	800,000	28		
Borlänge	Gothenburg	Train	600,000	6		
Karlstad	Gothenburg	Train	400,000	28		
Halmstad	Gothenburg	Train	400,000	28		

3.3 Step A: allocation to firms

In this section, the following issues will be discussed:

1. Which method should be used in step A to disaggregate the PWC zone-to-zone flows to the level of firm to firm?

2. What are the implications for the modelling of shipment size in step B of the heterogeneity of commodity types within the commodity classes used for the PWC flows?
3. How to achieve consistency in total flows between steps A and C? What are the implications of this consistency requirement for the modelling of shipment size in step B?
4. Should the application of the models in step B and the aggregation in step C be performed using (sample) enumeration and adding up of predicted probabilities or using micro-simulation of realisations drawn from predicted probabilities?

Discussion of issue 1:

Step A is not a choice model, but rather a prerequisite to get down to the level of the decision-making unit, so that the nature of the industry can be captured at the actor level. Instead of trade between zones we shall get trade between firms. These firms are manufacturers, wholesalers or retailers. Carriers come into the picture in step B.

Consider the following three general approaches to generate a disaggregate population or sample of firm-to-firm flows:

1. Re-weighting: use an existing sample or population and re-weight using marginal distributions (i.e. the row and column totals);
2. Synthetic: draw from a sequence of conditional distributions;
3. Hybrid: begin with re-weighting and enrich the set of characteristics using synthetic draws.

The re-weighting approach is the simplest, but the available data are not sufficient to enable this approach. In Sweden the Commodity Flow Survey (CFS) sample could be the starting point. The problem is that it is a sample of suppliers (or rather of their shipments), whereas our focus is on the behaviour of the receivers. This problem is solved by considering the CFS as a sample of supplier/receiver pairs. The fact that the CFS only has one-three weeks data on an observed supplier/receiver pair poses an additional problem. Due to this limitation, re-weighting this sample may not be a viable option. Finally, there is no such CFS in Norway. This all led us to the conclusion that we have to develop a synthetic or a hybrid approach for step A.

This approach could consist of the following steps (all within step A of the logistics module):

1. Use information on the existing distributions of producing and consuming firms (the latter including retail) by commodity type/sector and zone, and on their size distribution. Carry out proportional allocation by size of establishment to assign total supply and demand.
2. Assign suppliers to each receiver. This is the difficult step because the information is unavailable. We need a distribution of the number of suppliers per receiver and a model for the choice of supplier by the receiver. The way around this problem is to go backwards. Derive from the CFS the distributions of the number of receivers per supplier and a model for the choice of receiver by the supplier. A supplier can

have more than one receiver. Therefore, receiver choice cannot be treated as selecting one receiver from a set of mutually exclusive receiver alternatives. Instead, develop a binary choice model: will a firm be receiving goods in this category from this supplier? Note that this model should depend on the establishment size. By applying this model we can generate a population of supplier/receiver pairs.

3. Assign annual tonnage to each supplier-receiver pair. In step 1 above we assign to each firm by proportional allocation of total supply and demand for the commodity. To obtain starting values use a gravity model (i.e. the product of total supply and demand and an exponential of minus a coefficient inversely related to average shipment length multiplied by a generalized cost estimate). Collect all the supplier-receiver pairs that belong to an OD pair from the PWC matrices and scale the starting values to match the total flow in the corresponding matrix.
4. After the scaling in step 3 the allocation of total P's and C's will be distorted. To amend this, add an iterative step 4 to balance total P's and C's by business establishment. This is done as in a doubly constrained gravity model where the starting values are calculated using modified P's and C's. After step 3 we will be consistent with the PWC matrices. Step 4 will allow us to also be consistent with the proportional allocations of step 1 but these should not be hard constraints because it is based on an assumption.

In terms of data availability the missing piece is the number of receivers (on an annual basis) that we need for step 2 in this process. In a one-three week CFS this can only partially and very approximately be observed and we recommend a special survey for this (but maybe industry experts would be sufficient). This does not have to be a large survey. The number of questions can be very limited (focusing on the number of receivers and the number of suppliers for firms in production, wholesale and retail) and the sample size could be brought down to a few hundred observations.

For Norway, there will be data on the amount of tonnes delivered to specific receiving firms by municipality and commodity class (it is not clear whether this would also include deliveries to wholesale and retail). This means that for Norway, step 1 can be done on the basis of observed quantities delivered, not on the basis of assumptions on proportionality with the number of employees. In the absence of a CFS for Norway, step 2 and 3 either have to be done on Swedish data only (and the supplier choice model transferred to Norway) or additional data (or industry expert advice) would have to be collected in Norway about the supplier-receiver relations (especially on the number of receivers per supplier per commodity group). Step 4 would be used as a hard constraint, since the totals per receiving firm from step 1 would be coming from observed data.

If a commodity class were perfectly homogenous then there would not be any benefit from an allocation of these flows also among firms at the origin. However, the commodity classes are heterogeneous and therefore it is likely that the goods received at the destination may have separate inventories and shipments of the different commodities included in a class. Thus, for a given flow by commodity class, the number of shipments from an origin zone to a business establishment at the destination depends on the degree of heterogeneity. To capture this effect it is therefore advisable to also disaggregate the flows at the origin. Of course there can be consolidation of shipments (consolidation of the same good from different suppliers in the same zone as well as of different goods within the same commodity class from the same zone). We prefer to model this as part of the chain type choice in step B of the logistics module, instead of assuming perfect consolidation in step A.

Discussion of issue 2:

The above mentioned heterogeneity has direct implications for the modelling of the optimisation of inventory and logistics costs since inventories are maintained at the level of the detailed commodities that make up a class. Thus, the modelling of shipment size in step B should be done by supplier rather than by commodity class.

Discussion of issue 3:

Modelling discrete categories of shipment size may lead to inconsistencies in total flows between steps A and C. Therefore, it would be preferable to model the number of shipments. For a given flow from a supplier to a receiver, the model in step B will first predict the chain type (conditional on the number of shipments) and then the number of shipments. In the discussion on inventory logistics in Section 3.4, the focus is on determining the optimal shipment size. However, optimising of shipment sizes (lot sizes) is of course equivalent to optimising the frequency (for a given annual demand) and thereby the number of shipments.

Discussion of issue 4:

The prediction of shipments by chain type with an integrated logistics model would be too complex without a micro-simulation approach. When one would use enumeration of probabilities for all 'number of shipments/chain type' alternatives over the individual shipments, the accounting framework would become much more complicated than if one would assign (Monte Carlo simulation on the basis of the choice probability space) a single alternative to each shipment.

3.4 Inventory logistics

3.4.1 Safety stocks

The calculations of safety stocks can in terms of modelling be divided into a couple of alternatives: medium to high frequency products with replenishment, low frequency products with replenishment and "one-time" (seasonal) products.

Medium-high frequency products

In D1 (RAND Europe et al. ,2004) we only presented an equation for the safety stock that used the Poisson distribution. This refers to products that are ordered infrequently. However, low-frequency products are the exception, whereas medium to high frequency products are the rule. Therefore we shall now focus on medium-high frequency products, where the safety stock equation uses the Normal distribution (but for products with low frequencies we shall also come back to the Poisson distribution). The boundary between medium and low frequency is somewhat arbitrary (and should in theory be tested regarding the properties of the statistical distribution for the demand – however this is not practical in our case.) It is suggested that this model is used as the default situation.

The formula for the safety stock is as follows:

$$\text{(I) } b = a * \sqrt{((LT*\sigma_d^2) + (d^{2}*\sigma_{LT}^2))}$$

Where:

b	– safety stock
a	– a constant to set the safety stock in such a way that there is some fixed probability of not running out of stock. For medium/high frequency products, a common assumption is that the demand (and lead-times) follows a Normal distribution. a will then be:
a	= $F^{-1}(CSL)$, where F^{-1} is the inverse Standard Normal Distribution and CSL is the cycle service level, that is service level (the size of the inventory) at the end of the a replenishment cycle. By assuming a positive CSL we assume a positive probability that the stock will not be empty during a replenishment cycle.
LT	- expected lead-time for a replenishment (time between placing the order and replenishment)
σ_{LT}	– standard deviation for the lead-time
d	– expected demand
σ_d	– standard deviation for the demand

The expression under the squareroot is the variance in the inventory level, at the end of a replenishment cycle. The first contribution is the variance caased by demand fluctuations and it is the sum of variances for so many time periods as the LT times consist of. So in principle, LT is a "counting variable" counting the number of periods. The second contribution is due to the variance in the lead-time, but to make this a variance in inventory level, the standard deviation is multiplied with the expected demand, and making it a variance, it is squared (covariances between lead time and demand is normally disregarded).

More information can be found in textbooks on operations research and/or logistics such as Chopra and Meindl (2004), Stock and Lambert (2001) and Grønland (2002).

If Q_k is the yearly demand, and σ_{Q_k} is the standard deviation for the yearly demand, the formula for the one-product case becomes:

$$\text{(II)} \qquad b = a * ((LT*\sigma_{Q_k}^2)+(Q_k^{2}*\sigma_{LT}^2))^{1/2}$$

For a given product and a given demand within a company, the safety stock calculated according to (I) will give an expected end-of-cycle service level as stated. For a given product, the company would have a reorder point:

$$\delta = Q_k*LT + b$$

Taking the formula (5) in the report on specification of the model (RAND Europe et al., 2004), this will be changed to:

$$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 + (w_k + (i*v_k))*(q_k/2) + a * ((LT*\sigma_{Q_k}^2)+(Q_k^{2}*\sigma_{LT}^2))^{1/2}$$

(5 – revised)

Optimal order size will be the same (EOQ) regardless of whether safety stock is included or not:

$$q^* = ((2*o_k*Q_k)/(w_k + (i*v_k)))^{1/2} \qquad (6a, 6b)$$

In the basic situation (now based on the Normal and not on the Poisson distribution for the safety stock) there is no mathematical connection between q and safety stock, as long as the safety stock is based on CSL. For other assumptions (not used in our framework, see the note below, which is included as a reference for potential future use).

Note on optimisation of service levels

The recommended use of a shipment size independent safety stock is based on the assumption that the companies in their optimisation tend to look at the CSL when setting the appropriate service level. This will in many cases be a good approximation to actual behaviour, and therefore be well suited for the purpose of the model.

However, if the company instead were trying to optimise their service level defined as their fill rate, we would have to modify the calculations (Chopra, Meindl, 2004):

Case 1: Demand during stock-out is backlogged: $CSL^* = 1 - ((i+v_k)*q_k)/(Q_k*C_u)$, where C_u is equal to the cost of under-stocking with one unit, normally calculated as expected contribution (price - cost) for one unit for the supplier. We would have to substitute with this expression in the calculation of service level as follows: $a = F^{-1}(CSL)$, and the previous expression 5 would change to:

$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 + (w_k+(i*v_k))*(q_k/2) + F^{-1}(1 - ((i+v_k)*q_k)/(Q_k*C_u))* ((LT*\sigma_{Qk}^2)+(Q_k^{2}*\sigma_{LT}^2))^{1/2}$ (5 – revised - b)

Optimal shipment sizes would follow from:

$-(o_k*Q_k)/q_k^2 + (w_k + i*v_k)/2 + \partial T_{rskq}/\partial q_k + \partial F^{-1}(1 - ((i+v_k)*q_k)/(Q_k*C_u))/ \partial q_k *(((LT*\sigma_d^2)+(d^2*\sigma_{LT}^2)))^{1/2} = 0$

This would have to be solved numerically for obvious reasons.

Case 2: Demand during stock-out is lost: $CSL^* = 1 - ((i+v_k)*q_k)/(((i+v_k)*q_k) + Q_k*C_u)$, where C_u is equal to the cost of understocking with one unit, normally calculated as expected contribution (price - cost) for one unit for the supplier. We would have to substitute with this expression in the calculation of service level as follows: $a = F^{-1}(CSL)$, and the previous expression 5 would change to:

$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 + (w_k+(i*v_k))*(q_k/2) + F^{-1}(1 - ((i+v_k)*q_k)/(((i+v_k)*q_k) + Q_k*C_u)))*(((LT*\sigma_d^2)+(d^{2}*\sigma_{LT}^2)))^{1/2}$ (5 – revised -c)

Optimal shipment sizes would follow from:

$-(o_k*Q_k)/q_k^2 + (w_k + i*v_k)/2 + \partial T_{rskq}/\partial q_k + \partial F^{-1}(1- ((i+v_k)*q_k)/(((i+v_k)*q_k) + Q_k*C_u)) / \partial q_k *(((LT*\sigma_d^2)+(d^{2}*\sigma_{LT}^2)))^{1/2} = 0$

This would have to be solved numerically for obvious reasons.

The recommendation for the model is not to do explicit optimisation of service levels as outlined here. There are two reasons for this. The first is that it will be difficult at this stage to distinguish between companies where demand during stock-out is delivered later, lost or where other mechanisms are used. The other is that few companies actually optimise their service levels in practice, and therefore the actual behaviour will generally be less optimal than the models would have predicted.

With economy of scale in transport, the adjusted formula for optimal shipments would be:

$$-(o_k{*}Q_k)/q_k^2 + (w_k + i{*}v_k)/2 + \partial T_{rskq}/\partial q_k = 0 \text{ (6c revised)}$$

The relationship 6c may be of some importance related to sea transportation, while the standard EOQ may be a good approximation in most other cases. The optimal shipments sizes will in the standard cases not be influenced by the safety stock, or vice versa. However, different transport alternatives with different transit times will also have an impact on the safety stock through the lead-time (and possibly through the standard deviation for the lead-time), and thereby also on the inventory cost (and the total cost). This may be the case for alternative modes. In principle, lead-time should then be a function of the mode (h): LT = LT(h).

Low frequency items

As mentioned above, most commodities can be regarded as medium to high freqeuncy products, but some are low frequency. For the sake of completeness we now also include the equations for low frequency items. For future logistics models (after 2006) it needs to be investigated whether the Normal case is sufficient across the board or whether we also need the Poisson case for some special flows or product groups.

For low frequency items, a better approximation to the demand distribution than the Normal distribution will in many cases be the Poisson distribution. This leads to formulas closer to the one used in the original specification:

> $b_{rsk} = a_k{*}(LT{*}Q_k)^{1/2}$ (substituting the original u_k+t_{rs} which only looked at the transport time including the frequency effect, by the total lead-time.)

In this case, $(LT{*}Q_k)^{1/2}$ would be the standard deviation of demand during the lead-time, and the a_k would be the inverse value of the Poisson distribution, giving the proper percentage-point. The formula disregards the effect of uncertainty in the lead-time, and considers this effect on the total uncertainty in inventory level as negligible. Since Q_k should not be considered a function of q_k,, it can be considered independent of the optimisation of shipment sizes and the EOQ would still be the optimal solution, or with economy of scale in transportation, the revised (6c) would still apply. Since low frequency flows is a more special case than medium/high frequency cases, it is recommended that the latter will be used in the model for determining inventory levels, taking into account that there may be exceptions on the detailed level where low-frequency situations will occur. However, this should eventually only be considered on a very detailed product group categorisation level. For the optimisation of shipment sizes and thereby shipments, the calculations are neutral to the safety stock assumptions. There is a minor exception from this, and that is the (real) low-frequency items where the shipment sizes are down to a very few units, in particular one. The shipment sizes will then not be a function of EOQ optimisation, but rather be determined by the accepted risk level for the company and by how often the minimum inventory level (order point) is reached at the company. Again, those special cases should probably only be considered at a very detailed cargo group level, and should be disregarded in the first versions of the model.

"One-time" (seasonal) products

These are products where all the demand for a season is delivered in one shipment prior to a season, with limited possibilities for replenishment. There is then an optimisation of shipment size based on a risk assessment of expected effects of under-stocking versus expected effects of overstocking and (subjective) assessments of the probability distribution for the demand is used in determining the shipment size. (A simple version of this problem is called the Newspaper boy problem). These special cases should only be considered at a very detailed cargo group level, and should be disregarded in the first versions of the model.

3.4.2 **Differentiated service levels**

The service level is an important factor for setting the proper level for the safety stock, and thereby for the inventory and reorder point. In practice, service levels may be one of the competitive factors for a company. As a result, the service levels may vary considerably between companies within the same industry, or between suppliers / customers within the same product groups (differentiated service levels). Due to the sharp increase in inventories with increasing service levels, there may be large variations in inventory management practices and inventory levels even within similar industries. However, to enable the inventory cost calculations in the model, standard values for service levels, which are close to "standard service practice" within an industry, may be used. Although there are no surveys made of such standard values, case observations may give some indications regarding the proper levels to choose. In the long run, service standards should be surveyed and more properly be set for the various detailed cargo groups. In the short run, and with the lacking relationship between safety stocks and shipment sizes, standardised values should be appropriate for the sake of cost calculations.

3.4.3 **Aggregation and disaggregation effects**

Aggregation of shipments

The optimisation of shipment sizes/shipment sizes and inventories as outlined in Section 6.1, is made under the following assumptions:

- Each product is optimised independently;
- Each company is optimised independently;

Let us assume that one company have τ products within the same cargo category, delivered from the same supplier. Let us further assume that the products are all homogeneous in terms of value. Let us use the following symbols:

Q_r – annual demand, product r;

τ – total number of products ordered within the same category and from the same firm;

q_r – shipment size (shipment size) for product r;

o – unit cost per order;

f – order frequency (annually);

h_r – inventory holding cost per unit and time unit ($h_r = w_r + i^*v_r$);

h – joint inventory holding cost with homogenous products with same value, h $= h_r$ for all r.

Let us further assume as an approximation that all products from the same supplier are bought with a common frequency. Then the ordering and inventory holding cost will be:

$$f^*o + \Sigma((Q_r^*h)/(2^*f))$$

The '2' in the denominator results from the fact that holding cost is based on average inventories q/2.

With the summation symbol is meant the sum from r=1 till r=τ.

The first-order condition from the above equation is:

$$[\ o - 1/2f^2.\Sigma\ = 0$$

Minimum cost will therefore be :

$$\text{(III)} \qquad f^{opt} = ((\Sigma(Q_r^*h))/(2o))^{1/2} = ((h^*\Sigma(Q_r))/(2o))^{1/2}$$

Now let y_r be the portion of the total demand in the category for product r: $y_r = Q_r/\Sigma Q_r$. Optimal shipment sizes for the product r will then be (disregarding scale of economy for transportation):

$$\text{(IV)} \qquad q_r = Q_r/f = ((2^*o^*Q_r^*y_r)/(h))^{1/2}$$

(IV) comes from substituting III for f into the expression Q_r/f, and from substituting $\sum Q_r$ with Q_r/y_r.

For the cargo flow between a supplier and a receiver, with the number of products within the same category being m, the annual number of shipments will be :

$$\text{(V)} \qquad ((h^*\ \Sigma(Q_r))/(2o))^{1/2}$$

Note that this is identical to III.

Total shipment each time will consist of:

$$\text{(VI)} \qquad \Sigma((2^*o^*Q_r^*y_r)/(h))^{1/2} \text{ number of units}$$

with a value equal to the unit value for each item multiplied with the total number of units. The difference from the standard EOQ formula is that the optimal shipment size is reduced with a factor that is the square root of one divided by the portion of the demand for the product of the total demand to the supplier. If the τ products have a fairly similar demand, we could approximate formulas (VI) to:

(VIb) $\Sigma((2^*o^*Q_r)/(\tau^*h))^{1/2}$ number of units ($y_r = 1/\tau$)

This is a better approximation than taking the EOQ without adjusting for multiple products, and it is recommended that (VI) or as a simplification (VIb) is used in the calculations. However, this is not the absolute minimum that would be achieved by allowing for any number of combinations between ordering frequencies for the various products, but can serve as a practical approximation. If we also take into account economy of scale within transportation, the optimal frequencies should be found from:

$$o - (1/f^2)^*(h\Sigma Q_r/2) + \partial T_{rskq}/\partial z^*(-\Sigma Q_r/f^2) = 0 \text{ ; where } z = \Sigma q_r = \Sigma(Q_r/f)$$

This problem must be solved numerically. The safety stock for each product will not be influenced as long as the various products are not substitutes.

Impact on inventory calculations of disaggregated cargo flows.

The data for a given cargo category will be aggregated data between zones. This means that if within a cargo group there are Ψ companies in zone r sending to Ω companies in zone s, the total flow and inventory calculations need to be disaggregated. For the inventory, the company's average demand would be:

$$Q_k = (\Sigma Q_{krs}/\Psi^*\Omega)$$

What the equation says is that the average in a given flow is the total divided by the number of senders multiplied with the number of receivers (the total number of relations and flows).

If we define the share of the total demand for company i in zone r as γ_i, (γ_i = (demand company i)/(Q_k); the demand for company i can be written as:

$$Q_{ki} = (\Sigma Q_{krs}/\Psi^*\Omega)^*\gamma_i$$

If a different number of customers is served by the various companies within zone r, we can differentiate the parameter Ω to be dependent on the company: Ω_i. With no economy of scale in transport, optimal shipments for company i will then according to EOQ be:

$$\text{(VII)} \qquad q_{ki} = ((2^*o^*\gamma_i^*\Sigma Q_{krs})/(h^*\Psi^*\Omega_i))^{1/2}$$

Adjusted for the average number of products sent out per company:

$$\text{(VIII)} \qquad q_k = ((2^*o^*\gamma_i^*\Sigma Q_{krs})/(h^*\Psi^*\Omega_i^*y_{ki}))^{1/2}$$

where also the number of products may be differentiated between companies as y_{ki}. With economy of scale in transportation, the optimal shipment sizes would be found by solving:

(IX) $o - (1/f^2)*((h* \gamma_i*\Sigma Q_{krs})/(2*\Psi*\Omega_i*y_{ki})) + \partial T_{rskq}/\partial z*(-\Sigma(\gamma_i*Q_r)/(f^2*\Psi*\Omega_i*y_{ki})) = 0$;

where $z = \Sigma q_r = \Sigma(Q_{krs}/f*\Psi*\Omega_i*y_{ki})$

For the disaggregated safety stocks, we will make the following modifications:

(X) $a * ((LT*\sigma_{Qki}^2)+(Q_{ki}^{2}*\sigma_{LTi}^2))^{1/2} = a*((LT_i*\sigma_{Qkrsi}^2/ (\gamma_i*\Psi*\Omega_i)) + (Q_{ki}^{2}*\sigma_{LTi}^2))^{1/2}$

Here we have: $Q_{ki} = \gamma_i*\Sigma Q_{krs} / (\Psi*\Omega)$

The total number of shipments would then be the sum across the number of shipments from the various companies. As a first approximation, it may be possible to calculate averages based on fairly equal distributions of number of companies, products and customers within each zone. As the EOQ formula is fairly robust, this may be feasible if the size distribution within a zone is not too large. With increased detailed in the goods categories, this may tend to be easier.

3.4.4 Relationship between shipment sizes and safety stock

This section is meant to summarise the argument regarding the relationship between safety stock and shipment sizes (based on the formulas in previous sections).

As previously stated in this chapter, the relationship between safety stocks and shipment sizes will heavily depend on which assumptions are used for service levels. We may distinguish between:

1) The company optimises its inventory and transportation cost towards a given goal for the end of cycle service level. In this case there is no relationship between shipment sizes (and frequencies) on the one hand and safety stock levels on the other. The dimensioning of safety stock and optimisation of shipment sizes are done independently. Although this practice is less than optimal compared with a practice based on optimal fill-rates, in terms of behaviour in practice this policy is the most common. Typically the market leaders within commercial ERP (Enterprise Resource Planning) systems tend to use this logic for their logistical optimisation. Deviations in this (towards more advanced modelling as in point 2) would tend to be done by some of the more advanced companies within the retailing industries.

2) The company optimises its service level defined as fill-rate as a part of a cost-minimisation exercise for inventory and transportation cost. In this case, there will be relationships between safety stock and shipment sizes, as they are part of a joint optimisation. This is not a clear-cut relationship which can be shown in a simple formula, but qualitatively the relationship would tend to be such that larger safety stocks goes along with lower shipment sizes (and higher frequencies) and vice versa. The relationship would however be indirect as the shipment sizes are

determined as a part of the cost minimisation. The corresponding level for the cycle service level and thereby the safety stock would then be calculated as a consequence of the optimal shipment sizes.

3) A special case is the situation where the established total lead-times are so short that a company doesn't need to hold safety stocks any more. One way of establishing "virtual" short lead-times is with more or less continuous (very high-frequency) deliveries.

The conclusion for the logistical model is that no relationship between safety stocks and shipment sizes should be established when using the same transportation mode. There might be an exception for very advanced industries if the more detailed cargo groups will allow for this. Another exception could in principle be in the modal choice, when different transport modes have different transit times, and thereby the lead-times and safety stock would in fact be influenced. In this case, the modal choice should be integrated with safety stock calculations, and jointly optimised. It is not suggested to actually do these calculations in the first versions of the model.

3.4.5 **The alternatives for optimisation of transport and inventories**

We now move on to the decision-making on both transport and inventories and distinguish three basic situations. The idea is to distinguish between the situations with joint inventory and transportation cost minimisation and the situations where we only try to minimise transport cost. These distinctions are in practice quite important because they lead to principally different outcomes.

Joint optimisation of inventories and transport

The first, and most general situation is optimisation of both inventory and transport cost based on a common cost function:

$$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 + (w_k+ (i*v_k))*(q_k/2) + a * ((LT* \sigma_{Q_k}{}^2)+(Q_k{}^{2}* \sigma_{LT}{}^2))^{1/2} \text{ (I)}$$

$$\rightarrow$$

$$-(o_k*Q_k)/q_k{}^2 + (w_k + i*v_k)/2 + \partial T_{rskq}/\partial q_k = 0 \text{ (II)}$$

(I) is equation (5-revised), that is eq (5) from D1, after the revision in this report; (II) is (6c revised).

Minimisation of transport cost only ("zero inventories")

In this situation, the inventory holding cost would be virtually equal to zero, and the cost function would be:

$$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 \text{ (III)}$$

$$\rightarrow$$

$$-(o_k*Q_k)/q_k{}^2 + \partial T_{rskq}/\partial q_k = 0 \text{ (IV)}$$

With no economy of scale in transportation (decreasing annual transport costs with increasing shipment size for each of the shipments in a year), the last part of expression would be 0, and one should try to send as large shipments as possible (but constrained by the size of Q). With economy of scale, we would have: $\partial T_{rskq}/\partial q_k < 0$, which would not give a feasible solution, implying again that the conclusions with as large as possible shipment sizes would hold. Only if there was diseconomy of scale would we find a proper optimal shipment size. This is hardly the case in transportation, until we reach capacity restrictions that would lead to high shadow prices for the transportation capacity, thereby introducing diseconomies of scale. We would then have to consider the situation where zero-inventory situations would occur:

a) A situation where the zero-inventory is a result of a high frequency delivery system ("JIT");

b) A situation where zero-inventory occur due to postponement behaviour based on pure cost minimisation.

In situation a), the behaviour would be to send the shipment sizes ordered, and use the most cost effective transport route to handle the delivery, that is keep the shipment size and use cheapest transport method within quality requirements. In Chapter 2, this situation was described as "Transport cost minimisation with shipment size constraints."

In situation b), the behaviour would be to wait until largest feasible transport unit available between sender and receiver can be fully utilised. In practice, this would be within certain constraints. Whatever comes first, full transport unit or time limit for (oldest) order, will determine the actual aggregated shipment size. The individual shipments will be according to order, but the aggregate size of the total transport between origin and destination will be as described. In Chapter 2 on decisions and logistical behaviour, this situation was described as "Transport cost minimisation".

Optimisation within lead time constraints

A common situation would be when a decision has to be made about choice of transport, but where there will be constraints as to what is regarded as feasible delivery times. The decision problem would then, for a given shipment size, be to first disregard all transportation alternatives where the total lead-time would exceed the constraint. Between the remaining alternatives, the one chosen would be the one with the lowest cost.

3.5 Transport logistics

3.5.1 Empty vehicles

Currently (at least in Samgods) the total tonne-km are divided by the total vehicle-km by commodity: empty transports are included in the load factors. This will produce the proper total number of vehicles, but the direction of the empty vehicles will not be right, unless the load factor would be the same in both directions. It would be better to assign all product OD flows (from zone r to zone s) to vehicles first and then define another product: 'empties'. The flows for these vehicles (similarly for vessels, aircraft) are the mirror image of the loaded OD flows: they go from s to r.

The assumption suggested originally in the specification in November 2004 was to try to use the Noortman and van Es equation. Here the number of empty flows between zones r and s is a function of the commodity flow in the opposing direction, from s to r, multiplied by a constant p that is determined empirically. If one also assumes that the average payload from r to s is equal to that from s to r, the Noortman and van Es equation for empty trips becomes:

$$z_{rs} = \frac{m_{rs}}{\alpha_{rs}} + P(E)\frac{m_{sr}}{\alpha_{sr}} = \frac{m_{rs}}{\alpha_{rs}} + P(E)x_{sr}$$

Where:

z_{rs}	- loaded plus empty trips from r to s in vehicle units;
m_{rs}	- flows in tonnes from r to s;
P(E)	- the probability of returning empty;
x_{sr}	- the loaded trips from s to r in vehicle units;
α_{rs} and α_{rs}	- parameters to be estimated.

In this formulation, the probability that some of the potential empty capacity will also be used for taking part of the goods transported the opposite direction is taken into account. A more simplified notion is outlined below, which may be more effective than the original suggestion. Our practical recommendations for the 2005 logistics model, which may also be used for the 2006 model (but need to be revisited) are in section 5.5.

We might assume that the empties are only half of these rs flows, and the rest is already taken into account in the loaded OD flows. Then if we denote the number of loaded vehicle flows of mode/vehicle type h and commodity type k from zone r to zone s by V_{hkrs}, the number of empty vehicle flows with the same mode and vehicle type in the reverse direction will be:

$$V_{h,k=empty,sr} = 0.5 \,.\, \sum_{k=1,32} V_{hkrs}$$

Where the summation takes place over all 32 (or 34) commodity-types except the empties. This OD matrix in terms of vehicle flows can be generated after all loaded OD matrices (in vehicles for particular commodities to be transported) have been produced. The percentage (50 is this example) could vary with the number of transport flows leaving a particular destination:

$$V_{h,k=empty,sr} = \sum_{k=1,32} \alpha_s(\sum_{hr} V_{hksr}) \,.\, V_{hkrs}$$

Where α is a parameter that is a function of the number of loaded flows leaving s (for al commodity types k and all modes/vehicle types h; alternatively we could not sum over commodity types and/or modes/vehicles types here and require that these should match). It will be hard to get data on observed α's, the percentage of empty returns. The transport statistics, such as the lorry surveys and OD surveys, often include empty as a category and should be useful here, but if the transport is an empty return trip, there is no information in the survey on the outward trip. We may have to try out different assumptions here.

In the choices to be made by shippers, the transport cost of empty flows will be taken as zero: the costs of these flows need to be captured (on average) in the loaded flows, for which a price can be charged (by the carriers). But for the route choice of the empty vehicle flows within assignment we can use minimisation of generalised transport costs. A good way to follow this further would be to try to test it on empirical data.

We may have to distinguish between different situations. The assumption that there is a 50% utilisation on traffic going both ways may be more representative for typical distribution traffic in local areas. On longer distances there may be significant differences in traffic to and from the various areas, and on longer hauls there may also be a larger tendency towards using the available capacity to a larger extent, trying to go as close to full capacity as possible on the directions with positive load balance. On the direction with over-capacity, there may be a larger tendency to compete for loads based on low prices. Whether this leads to a more even spread of loads on the returning vehicles, or a tendency to full loads on some vehicles and then return the rest empty is a little bit hard to establish without going into specific empirical studies. It may however have some impact on the prices and cost in the "empty" direction, although the impact on total traffic may be less.

As an alternative assumption, we may outline the following. Take as defined in the paper the total number of loaded vehicles arriving in zone s for a given mode/vehicle type h to be:

$$V^{a}_{hs} = \Sigma_r(\Sigma_{k=1,32(34)} V_{hkrs})$$

The corresponding need for loaded vehicles leaving zone s for the same mode/vehicle type would be:

$$V^{L}_{hs} = \Sigma_r(\Sigma_{k=1,32(34)} V_{hksr})$$

Overcapacity in terms of more available vehicles than needed would be:

$$\theta_{hs} = V^{a}_{hs} - V^{L}_{hs} \text{ (If } V^{a}_{hs} - V^{L}_{hs} > 0 \text{)}$$

$$= 0 \text{ (otherwise)}$$

If we assume that the main tendency is to utilise available capacity first, we may set up the following:

$$\text{If } \theta_{hs} > 0,\ V_{s,\,k=empty} = \theta_{hs} + P(E)\Sigma_r x_{sr} = \theta_{hs} + (\Sigma_{k=1,32(34)}(\Sigma_{hr} V_{hksr})) \text{ (I)}$$

$$\text{If } \theta_{hs} = 0,\ V_{s,\,k=empty} = (0 +)\ P(E)\Sigma_r x_{sr} = (\Sigma_{k=1,32(34)}(\Sigma_{hr} V_{hksr})) \text{ (II)}$$

(II) can be taken as a special case of (I) with $\theta_{hs} = 0$.

As an approximation, the empties on each leg may be calculated as:

$$V_{h,k=empty,sr} = [(\Sigma_{k=1,32(34)} V_{h,k,rs})/(\Sigma_r(\Sigma_{k=1,32(34)} V_{hksr}))]^{*}\ V_{s,\,k=empty} \text{ (III)}$$

If the unbalances are small, it may be that the constraint in (II) may be a little relaxed,

e.g. if (θ_{hs}/ V^{L}_{hs} < "defined threshold value", use formulation (II))

Another assumption which may be considered is a further aggregation of areas (sum over a defined set of "s") before calculation of unbalances as the effect of those may be clearer on an aggregated set of geographical relations than on a local (municipal) level. The same kind of considerations may also be taken when modelling potential effects of unbalances for prices/cost for transport (discounts on legs with a large proportion of empties etc.).

3.5.2 **Categorisation of cargo units (in the model)**

The number of alternative cargo units should be large enough to reflect variations in practice and also to reflect various cost structures, at the same time be small enough to be workable within the framework of a model. This means that only variations in cargo units that may have a significant impact on the cost structure should be considered. In Table 16 below, typical cargo units used within the various categories are shown (Norwegian categories). Since the cargo categories are rather aggregated, there are larger variations in the actual usage of cargo units, than what the table shows. Further, there will be larger variations in shares covered by "typical" and "minor" units between different categories.

The term container also covers a combination of other cargo units with the container, for example pallets and boxes in containers. In addition, the term container covers various standards of containers, such as 20 feet ISO (and other ISO containers as 40 feet etc.) and CEN containers. For the purpose of the model, basically containers should be treated as one group, including combination of containers with other smaller units applied inside.

Table 16 - Typical cargo units per commodity type, Norway

Category	Description	Typical cargo unit	Minor units
11	Bulk food	Direct in transport unit	Containers, swap-bodies
12	Consumptions food	Pallets and boxes in transport unit	Containers
13	Beverages	Pallets and boxes in transport unit	Containers
21	Fresh fish	Temperature controlled (refrigerated) transport unit	Temperature controlled (refrigerated) container
22/23	Other fish	Temperature controlled (refrigerated) transport unit	Temperature controlled (refrigerated) container
31	Thermo input	Temperature controlled (refrigerated) transport unit	Temperature controlled (refrigerated) container
32	Thermo consumption	Temperature controlled (refrigerated) transport unit	Temperature controlled (refrigerated) container
41	Machinery and equipment	Pallets and boxes in transport unit	Containers
42	Vehicles	Direct in transport units	-
51	General cargo - high value goods	Pallets and boxes in transport unit	Containers
52	General cargo - live animals	Direct in special transport units	-
53	General cargo - building materials	Pallets and boxes in transport unit	Containers
54	General cargo - other inputs	Pallets and boxes in transport unit	Containers
55	General cargo - consumptions goods	Pallets and boxes in transport unit	Containers
61	Timber - "Saw logs"	Direct on transport units	-
62	Timber - "Round logs"	Direct on transport units	-
63	Pulp	Direct in transport units	Containers
64	Paper intermediates	Direct in transport units	Containers
65	Wood products	Pallets and boxes in units	Containers
66	Paper products	Direct in transport units	Containers
71	Mass commodities	Direct in bulk units	Bulk containers
72	Coal, ore and metal waste	Direct in bulk units	Bulk containers
73	Cement, plaster and cretaceous	Direct in bulk units	Bulk containers
74	Non-traded goods	Direct in bulk units	Bulk containers
81	Chemical products	Direct in bulk units	Bulk containers
82	Fertilizers	Pallets in transport units (bagged products)	Direct in bulk units
91	Metal and metal goods	Direct in transport units	Containers
92	Aluminium	Direct in transport units	Containers
101	Crude petroleum	Direct in (liquid) bulk units	Bulk containers
102	Petroleum gas	Direct in gas units	-
103	Refined petroleum products	Direct in (liquid) bulk units	Bulk containers

We can show a similar table for the Swedish categories (see Table 17; not based on the CFS). The comments regarding further variations in units are the same as for the table of Norwegian categories.

Table 17 - Typical cargo units per commodity type, Sweden

Good	Description	Most common cargo unit	Other cargo units used
1	Cereals	Direct in transport unit	Containers, swap-bodies
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	Pallets and boxes in transport unit	Container
3	Live animals	Direct in transport unit	-
4	Sugar beet	Direct in transport unit	Pallets and boxes in transport unit
5	Timber for paper industry (pulpwood)	Direct in transport unit	-
6	Wood roughly squared or sawn lengthwise, sliced or peeled	Direct in transport unit	-
7	Wood chips and wood waste	Direct in special units	Bulk containers
8	Other wood or cork	Direct on transport units	Pallets and boxes in transport unit
9	Textiles, textile articles and manmade fibres, other raw animal and vegetable materials	Pallets and boxes in transport unit	Containers
10	Foodstuff and animal fodder	Pallets and boxes in transport unit	Container
11	Oil seeds and oleaginous fruits and fats	Pallets and boxes in transport unit	Container
12	Solid mineral fuels	Direct on bulk units	Bulk containers
13	Crude petroleum	Direct on (liquid) bulk units	-
14	Petroleum products	Direct on (liquid) bulk units	(Liquid) bulk containers
15	Iron ore, iron and steel waste and blast-furnace dust	Direct on bulk units	Bulk containers
16	Non-ferrous ores and waste	Direct on bulk units	Bulk containers
17	Metal products	Pallets and boxes in transport unit	Container
18	Cement, lime, manufactured building materials	Direct on bulk units	Bulk containers
19	Earth, sand and gravel	Direct on bulk units	Bulk containers
20	Other crude and manufactured minerals	Direct on bulk units	Bulk containers
21	Natural and chemical fertilizers	Direct in bulk units	Pallets in transport units (bagged)
22	Coal chemicals, tar	Direct on bulk units	Bulk containers
23	Chemicals other than coal chemicals and tar	Direct on bulk units	Bulk containers
24	Paper pulp and waste paper	Pallets and boxes in transport unit	Container
25	Transport equipment, whether or not assembled, and parts thereof	Pallets and boxes in transport unit	Container
26	Manufactures of metal	Pallets and boxes in transport unit	Container
27	Glass, glassware, ceramic products	Pallets and boxes in transport unit	Container
28	Paper, paperboard; not manufactures	Pallets and boxes in transport unit	Container
29	Leather textile, clothing, other manufactured articles than paper, paperboard and manufactures thereof	Pallets and boxes in transport unit	Container

Good	Description	Most common cargo unit	Other cargo units used
30	General cargo	Pallets and boxes in transport unit	Container
31	Timber for sawmill	Direct on transport unit	-
32	Machinery, equipment, engines	Pallets and boxes in transport unit	Container
33	Paper, paperboard and manufactures thereof	Pallets and boxes in transport unit	Container
34	Used packaging materials	Direct on transport unit	-

We can summarise the recommended choices of cargo units in the model as shown in the Table 18 and Table 19 below.

Table 18 - Summary of recommended cargo units, Norway

Cargo unit:	Transport mode:	Norwegian Nemo category:
Pallets	Truck, rail, lo/lo and sideport vessel	12,13,41,51,53,54,55,65,82
Containers	Truck, rail, lo/lo vessel, ro/ro vessels	11,12,13,41,51,53,54,55,63 ,64,65,66,91,92
Swap-bodies	Truck, rail, ro/ro vessels	11,12,13,41,51,53,54,55,63 ,64,65,66,91,92
Pallets, boxes	Refrigerated trucks, vessels with refrigeration	21,22/23,31,32
No unit	Refrigerated trucks, reefer vessels	21,22/23,31,32
Refrigerated containers	Trucks, rail, lo/lo vessels, ro/ro vessels	21,22/23,31,32
No unit	Trucks, rail, side-port vessel, lo/lo vessels, ro/ro vessels	41,52,61,62,63,64,66,91,92
No unit	Special dry bulk transport units: Trucks, vessels, rail	71,72,73,74,81,82
Dry-bulk containers	Trucks, rail, lo/lo vessels, ro/ro vessels	71,72,73,74,81,82
No unit	Special liquid bulk transport units: Trucks, vessels, rail	81,101,102,103
Liquid bulk containers	Trucks, rail, lo/lo vessels, ro/ro vessels	81, 102,103
Airfreight containers, airfreight pallets	Trucks, airplanes	51

Table 19 - Summary of recommended cargo units, Sweden

Cargo unit:	Transport mode:	Swedish cargo category:
Pallets	Truck, rail, lo/lo and sideport vessel	2,4,8,9,10,11,17,21,24,25,26,27,28,29,30,32,33
Containers	Truck, rail, lo/lo vessel, ro/ro vessels	1,2,9,10,11,17,24,25,26,27,28,29,30,32,33
Swap-bodies	Truck, rail, ro/ro vessels	1,2,9,10,11,17,24,25,26,27,28,29,30,32,33
Pallets, boxes	Refrigerated trucks, vessels with refrigeration	2,10
No unit	Refrigerated trucks, costal vessels with refrigeration	2,10
Refrigerated containers	Trucks, rail, lo/lo vessels, ro/ro vessels	2,10
No unit	Trucks, rail, side-port vessel, lo/lo vessels, ro/ro vessels	3,4,5,6,7,8,31,34
No unit	Special dry bulk transport units: Trucks, vessels, rail	1,12,15,16,17,18,19,20,21,22,23
Dry-bulk containers	Trucks, rail, lo/lo vessels, ro/ro vessels	1,12,15,16,17,18,19,20,21,22,23
No unit	Special liquid bulk transport units: Trucks, vessels, rail	13,14,23
Liquid bulk containers	Trucks, rail, lo/lo vessels, ro/ro vessels	14,23
Airfreight containers, airfreight pallets	Trucks, airplanes	30

Taking away the reference to the various cargo groups, we get the following choice of units.

Table 20 - Transport mode by cargo unit

Cargo unit: → Transport unit:	Pallets and boxes	Con-tainer	Swap-bodies	None (cargo direct in transport unit)	Refrigerated Container	Dry-bulk con-tainer	Liquid bulk con-tainer.	Comments
Truck, trailer, semi-trailer (several sizes and categories)	x	x	x	x	x	x	x	Units loaded directly; need covered units, container units need to be adapted to container transport, e.g. power supply for refrigeration
Rail (rail-wagon) (several sizes/ categories)	x	x	x	x	x	x	x	Same remarks as above for truck
Side-port vessel (several sizes)	x			x				
Lo/lo vessel (several sizes/ categories)	x	x		x	x	x	x	
Ro/ro vessel (several sizes)		x	x	x	x	x	x	
Refrigerated vessel (several sizes)	x							
Refrigerated trucks (several sizes)	x							
Refrigerated rail (several sizes) (rail wagon)	x							
Special truck for dry bulk (several sizes)				x				
Special rail (rail-wagon) for dry bulk (several sizes)				x				
Dry-bulk vessel (several sizes)				x				
Special truck for liquid bulk (several sizes)				x				
Special rail (rail-wagon) for liquid bulk (several sizes)				x				
Liquid bulk vessel (several sizes)				x				

This gives seven alternative cargo units, including "none" (cargo direct on transport unit). There are fourteen alternative transport "modes" (including some quite aggregated groupings), and 38 potential combinations of cargo and transport units. Some of the combinations are small variations of another combination, in particular the special container types (refrigerated and bulk) will not have any significant impact on transport cost compared with standard containers, if the effect of special requirements to transport unit is allocated to transport unit cost. The total number of alternative vehicles and their detailed availability for the different cargo types for the 2005 model are described in more detail in Chapter 5.

3.5.3 The allocation of flows in tonnes to vehicles

The logistics module will use PWC flows in tonnes as inputs, but will provide outputs in terms of vehicle flows between OD pairs. Within the logistics module, a transformation from tonnes to vehicle will take place, as well as the choice of transport mode and vehicle type within each mode. To do this, the transport costs that it takes from the network models need to be per vehicle. That means different costs for different vehicle sizes (embodying some 'economies of scale' in transport[9]). Preferably we would also use different costs for different loading units or cargo units (see Section 3.5.2). However, the transport costs from the network model databases in Norway and Sweden are per tonne per mode (and also per commodity type). It has been suggested to multiply these costs per tonne by the average weight per vehicle (which can differ by commodity type). This would however imply that within a commodity type and mode, the transport costs per tonne are the same over the whole range of tonnes that can be transported with that mode of transport. In reality, the transport costs per tonne of an articulated truck are lower than those of a solo truck, which in turn are lower than those of a van[10]. In order to be able to include vehicle type choice in the logistics model, a way of transforming the cost per tonne data by mode and commodity type to costs for a number of different vehicle types is required. Plausible assumptions on this could be made and existing cost models could be applied, but preferably, the reduction in transport costs per tonne for an articulated truck and the increase in the transport cost per tonne for a van, both relative to a solo truck should be based on Norwegian and Swedish data (e.g. price lists with offered truck rates). The network model database apparently assumes that freight rates are listed in terms of prices per tonne (fully variable), and also that the prices per tonne are constant. In practice, freight rates may be given not only as fully variable, but also as a fixed amount per shipment plus a rate per km or hour (within a certain shipment size range) or tonne-km.

The cost functions should also take account of the fact that transport costs per vehicle are very similar for a range of tonnages up to the capacity of the vehicle: twelve tonnes in a twelve tonne-vehicle is about as costly as two tonnes in the same vehicle (note that the rates charged may increase with tonnage to be transported). The cost function for road transport of some commodity could look like Figure 2 below.

The first slope (seen from the origin) is for freight transport by car. Then there comes a (commodity-specific) threshold, the shipment becomes too heavy or too big for the capacity of a car and the costs jump to a higher level, that is for using a van. After the van comes the solo truck and after this comes the articulated truck. The transport costs per tonne shipped for a full articulated truck are considerably lower than for a full van. This

[9] Such economies of scale in transport exist not only between modes (e.g. ships having lower transport cost per tonne-km than trucks), but also within modes.

[10] In the present Samgods model, there is an allocation of road freight flows to solo trucks and articulated trucks (truck with trailer) that is not based on costs data, but simply takes a fixed percentage (from the transport statistics) for solo trucks for distances below 100 km and used articulated vehicles for the remainder (Vierth, 2005).

cost function, being shaped as described above, provides an incentive to transport big shipments (or combine shipments with other shipments in the same vehicle), which needs to be compared to the forces that stimulate small shipments (e.g. from inventory-minimisation). Especially shipment sizes that are just above one of the thresholds (e.g. the one from solo to articulated truck) need to be avoided from a transport costs perspective, either by in the choice of shipment size itself, or –given the shipment size- by consolidation with other shipments.

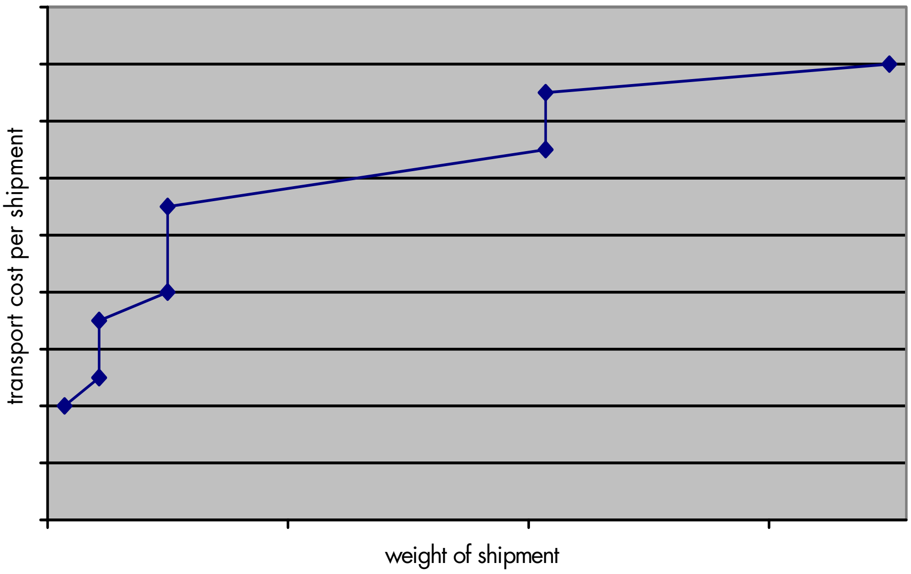

Figure 2 - Transport cost function for different vehicle types within road transport

From the network model databases, we also do not get transport costs for different loading units (containers, swap bodies, pallets, boxes, cooled/refrigerated, solid bulk, liquid bulk; see Section 3.5.2). But to model the choice of loading unit, we need to know about costs differences of loading units, which can then be combined with other attribute differences (e.g. probability of damage, handling time and costs, security). Again, plausible assumptions could be made for these differences (by commodity type) and costs models/standard calculation rules with such distinctions might be available, but real world data on the average costs for various available loading units would be highly preferable.

The network model transport costs also do not distinguish between contracting out and own account transport by the shippers. Small shippers (with little scope for reaching high load factors and economies of scale in transport) will usually contract out; for larger shippers, own account transport might be an attractive option (if they can optimise transport as well as a carrier), because it saves them the profit margin of the carrier. A logistics model in which this choice would be endogenous, would at least require separate cost functions for the relevant modes (and extra terms for loss of control and such could be added). In the absence of a distinction between transport fares for shippers that contract out and transport costs for shippers with own account transport, this choice cannot be modelled. It needs to be treated as exogenous (e.g. per commodity type), which is consistent with what we proposed in option 1B. But even if this distinction is taken to be given exogenously, in the absence of costs differences, the question whether a shipper contracts out or organises his own transport will not lead to consequences for the transport costs.

We recommend that the data for the transport costs for the initial (2005) logistics module will come from the existing network models, augmented with cost models/standard calculation rules to give additional detail. For the later phases of the logistics module project, it is recommended that the network model cost routines are revised to produce costs per commodity group per vehicle instead of per tonne, for several vehicle types and cargo units, but probably some use of cost calculation rules will still be necessary to get all the required detail in.

Some of the alternative routes between the supplier (producer or wholesaler) and the receiver (producer, wholesaler or retailer) will include consolidation and/or distribution centres ('multi-purpose terminals'). A part of the physical terminals can serve both for consolidation and distribution. Therefore, to each given physical facility and location, its function should be allocated: which purposes does the terminal serve?

Another issue is how to handle intra-zonal flows. From the base matrices, we shall get the PWC flows that stay within the zones and we shall assume that these are all handled by road transport, unless specific information on the use of other modes is available (e.g. within the Kiruna zone there is a large amount of iron-ore transport by rail; this could be handled as a singular intra-zonal flow). The selection of vehicle type would require transport costs for different road vehicle types, which cannot be supplied by the network model database, not only because the network model does not include costs for different road vehicle types, but also because the network model data are only for movements from a zone to another zone. Probably it will be necessary to use vehicle type fractions for short-distance freight flows from the statistics (this may not be easy, because vans are not included in the lorry statistics: only vehicles with capacity of 3.5 tonnes and more).

The above refers to intra-zonal PWC flows, which will also lead to intra-zonal OD flows. But there will be many more intra-zonal OD flows: when the P (W) location and the consolidation centre (CC) are in the same zone or when the distribution centre and the (W) C location are in the same zone. A practical problem for the modelling of these intra-zonal first and last legs (intra-zonal OD flows) of transport chains is that the network model database cannot give transport costs for these flows. Again we shall have to assume that these intra-zonal OD movements take place by road transport and that the vehicle types are determined on the basis of fixed fractions derived for short distance freight from the statistics.

3.5.4 **International flows**

Transport flows related to import and export will in principle be treated the same way as domestic transport. This means that access to ports and airports abroad and egress from foreign ports and airports will be included in the modelling (choice of mode, choice of port and airport), and handled in the same costs minimisation framework (though possibly in different minimisation stages). The choice of distribution centres and consolidation centres (except ports and airports) abroad and the collection and distribution tour formation abroad will not be modelled explicitly: the model will not give the use of specific foreign distribution centres and consolidation centre for land-based transport, but provisions for the cost of consolidation and distribution (differentiated by commodity type) will be made. Data on the location of CCs and DCs abroad is not available for Sweden and Norway. The mode and port choice model for the non-domestic parts will necessarily be rather crude, because the foreign zones are quite large and the network in these areas is not fine. For instance the current NEMO has two zones in Finland, one zone in Denmark, three zones on Germany, two zones in France, one in Ireland, one in Holland, two in Belgium, three in Great Britain, two in Russia and not more than one per country in all other countries. Other continents are included as a single zone for each continent. Only a limited number of ports have been included in these zones. Samgods has 173 zones outside Sweden, including eighteen in Norway, nineteen in Finland, sixteen in Germany, fifteen in Denmark, six in France, two in The Netherlands and 25 outside Europe.

In RAND Europe et al. (2004) the word 'overseas' was meant to indicate flows to and from the Scandinavian peninsula, not necessarily intercontinental flows.

The choice of ports, airports and modes for *transit flows* (both origin r and destination s are outside the country studied, either Norway or Sweden, but domestic ports, airports and/or roads/rail are used) will be included in the logistics module. An example of a transit flow is when the wholesaler is located in Sweden/Norway, but the producer and consumer are not. In this case, in the logistics module the PW and WC flows will be treated as import/export flows, in order to be consistent with the PWC concept. The other transit flows to be considered (on a PWC basis) will be taken from the base matrices, and allocated to:

- Modes, foreign and domestic ports (including ferries and the Öresund fixed link) and airports (all of this in the logistics module); and
- Domestic roads and railway lines (in the network model, for domestic OD combinations that are assigned to road or rail transport in the logistics module, within the transit chains).

Which flows will be included as transit flows (flows that would use domestic infrastructure) needs to be determined in the base matrix project? For this, existing trade, port, road, rail, ferry and airport statistics can be used. It seems logical to restrict the search for eligible transit flows at one end of the flow to countries that are direct neighbours of Norway/Sweden or at least the direct neighbours of the direct neighbours. At the other end of the flow, this might be over-restrictive. For Norway, flows from Sweden and Finland to the rest of the world can be included and flows vice versa. For Sweden, flows from Norway, Finland, Denmark and Russia to and from the rest of the word could be included. For the eligible flows (that might use domestic infrastructure), a selection of flows that will (probably) use the domestic infrastructure needs to be made. Preferably this should be done on the basis of observed transit flows, but if the data for the base matrix team do not allow this, a simple network model could be used.

3.6 Progress since June 2005: choice formulation for the logistics model

In the sections above we already used the new commodity classification and the categorisation in cargo units that was agreed upon in the summer of 2005. This section contains a description of further progress on the specification of the 2006 logistics model.

Below the choice formulation for the logistics model is worked out, focussing on the transport logistics part of the model (the choices of mode, vehicle/vessel type and size, cargo unit and use of consolidation and distribution centres, ports, airports and intermodal rail terminals). These are all the choices in step B of the logistics model, except the inventory logistics choice on shipment size or shipment frequency. We call this set of choices: logistic chain choice.

3.6.1 Logistic chain choice (all choices except frequency)

First we introduce some notation. This is not fully consistent with the notation of the 2004 report, because full consistency with that notation would make the present choice formulation less concise and less coherent.

Table 21 - Symbols used for logistic chains

Sender	m
Receiver	n
Logistic chain	l
Commodity type (omitted)	k
Value	v
Mode/vehicle type/cargo unit	h
Transhipment location	t
Leg	i
Number of legs	I_l

In the following we omit the subscript for commodity type. Commodity types are independent: all equations are simply repeated over all commodity types. We are also not using the zone subscripts r and s, because the locations of sender and receiver are implied in m and n.

The logistic chain *l* (l of Leonard) consists of a chain of modes and transhipment locations:

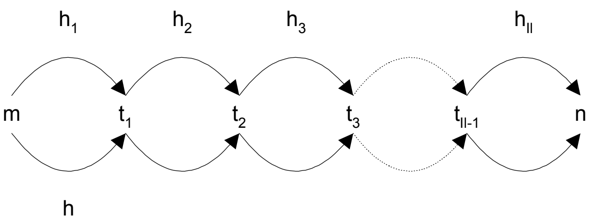

Figure 3 - Logistic chain

From sender m (producer P or wholesaler W) this is a transport of one or more (OD) legs to receiver n (C or W). We denote a leg of logistics chain *l* by i, and the number of legs of logistic chain *l* is I_l (I of Isaac, sub *l* of Leonard). The mode on the first leg is denoted h_1, the mode on the second leg h_2, etc., but there could be several modal alternatives at each leg (as an example we depicted two mode options per leg in Figure 3 above). The mode alternatives do not just introduce the distinction between road, rail, waterborne transport and air transport, but also between different types and sizes of vehicles and vessels and also different cargo units (e.g. pallets, containers). Between the OD legs there are transshipment locations, which can be consolidation/distribution centres, ports, airports or intermodal rail terminals. At these locations (denoted t_1 till t_{Il-1}), goods change modes, but there can be temporary storage as well.

The logistic chain can now be written as a series of mode-transshipment location points, one for each leg of the chain, with the last being a mode-receiver location pair (equivalently we could have started with the sender and the first mode):

$$l = \{(h_1, t_1), (h_2, t_2), \ldots, (h_{Il}, n)\} \quad (1)$$

Each pair indicates a leg i , i =1,..., I_l

We can regard this as three sub choices within *l*:

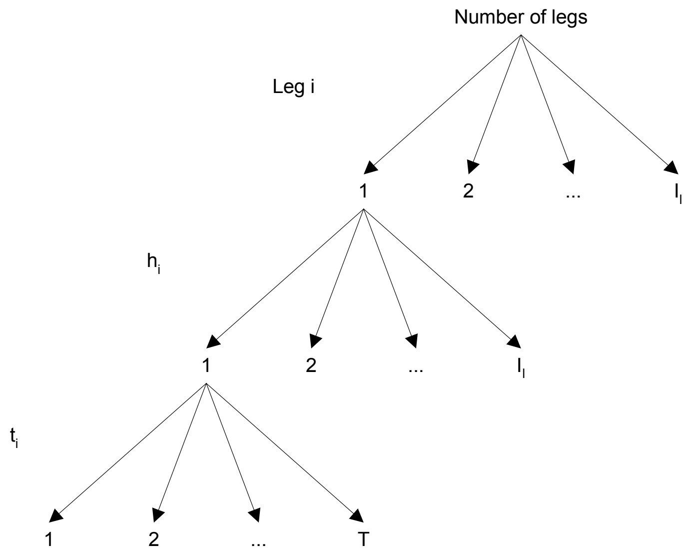

Figure 4 – Choices within logistic chain

The explanatory factors are included in the logistic costs function G_{mnl}

$$G_{mnl} = \sum_{i=1}^{I_l} \textit{specific to leg } i + \textit{specific to the chain } l$$

$$P(l|\{i,\ldots,L_{mn}\}) = P(l|L_{mn}) = P[G_{mnl} + \varepsilon_{mnl}] = \min_{l \in L_{mn}}[G_{mnl} + \varepsilon_{mnl}] \quad (2)$$

L_{mn} = choice set of logistic chains per mn

The full logistics model (step B) is obtained by adding shipment size choice or shipment frequency choice to *l*.

Where:

Q_{mn}	- Annual flow
q_{mn}	- Average shipment size
$f_{mn} = Q_{mn}/q_{mn}$	- Frequency

3.6.2 Cost specification

The logistics costs have been worked out previously. The basis components are given below:

$$G_{mnql} = O_q + T_{mnql} + D + Y_{mnl} + I_q + K_q + Z_{mnq} \quad (3)$$

Where:

G - total annual logistics costs

O - order costs

T - transport, consolidation and distribution costs

D - cost of deterioration and damage during transit

Y - capital costs of goods during transit

I - inventory costs (storage costs)

K - capital costs of inventory

Z - stockout costs

This has previously been worked out in more detail:

$$G_{mnql} = o.(Q/q) + X_{mnql} + J_{mnql} + r.j.g.v_k.Q_k + (r.t_{mnl}.v.Q)/365 +$$
$$(w + (r.v)).(q/2) + a \;.\; ((LT.\sigma_Q^2)+(Q^2.\sigma_{LT}^2))^{1/2} \qquad (4)$$

Where:

O - the constant unit cost per order

Q - the annual demand (tonnes per year)

X_{mnql} - the link costs of all OD legs from m to n

J_{mnql} - the transhipment and storage costs at all consolidation/distributions centres, ports, airports and intermodal rail terminals between m and n

q - the average shipment size.

r - the discount rate (per year)

j - the fraction of the shipment that is lost or damaged (might vary between modes)

g - the average period to collect a claim (in years)

v - the value of the goods that are transported (per tonne).

t - the average transport time (in days).

w - the storage costs per unit per year.

a - a constant to set the safety stock in such a way that there is some fixed probability of not running out of stock. For medium/high frequency products, a common assumption is that the demand (and lead-times) follows a Normal distribution. a will then be: $a = F^{-1}(CSL)$, where F^{-1} is the inverse Standard Normal Distribution and CSL is the cycle service level, that is the probability that the stock will not be empty during a replenishment cycle.

LT - expected lead-time for replenishment (time between placing the order and replenishment)

σ_{LT} - standard deviation for the lead-time

σ_{Q} - the standard deviation for the yearly demand,

This function can be parameterised as:

$$U_{mnql} = \beta_{0ql} + \beta_1.(Q/q) + X_{mnql} + J_{mnql} + \beta_2.j.v.Q + \beta_3.(t_{mnl}.v.Q)/365 + (\beta_4 + \beta_5.v).(q/2) + a.((LT.\sigma_Q^2)+(Q^2.\sigma_{LT}^2))^{1/2} + \varepsilon_{mnql} \quad (5)$$

Where:

β_{0ql} - alternative-specific constant

β_1 = o

β_2 = r.g

β_3 = r (in transit)

β_4 = w

β_5 = r (warehousing).

What we have done in eq (5) is to include a number of items, such as order costs, storage costs and capital carrying costs, in the coefficients to be estimated. The reason for this is that data on these items will be very difficult to obtain. As a result, the coefficients have specific logistical interpretations. We could distinguish between the implied discount rate (r) of the inventory in transit (β_3) and of the inventory in the warehouse (β_5), because these need not be the same. Cost minimisation thus becomes equivalent to utility maximisation. Including revenues for the shippers and doing profit maximisation instead of cost minimisation is not required here, since the PWC flows (and therefore the sales) are already given.

In the minimisation, we assume that firm size does not matter. This assumption may be relaxed to accommodate economies of scale in warehousing, ordering and transport. Also, variation of the discount rate for the inventory capital costs and of other preferences between firms could be included.

3.6.3 **Observational issues**

Sweden

In the CFS, transhipment locations are unobserved. For road we also don't know I_l (number of legs), since we do not have information on the use of consolidation and distribution centres. Because we have data on the sequence of modes uses, we know how many transhipment locations have been used (with some observation error), in terms of changes between the nine modes distinguished in the CFS, but we do not know in which zones the transhipments took place.

$$\tilde{G}_{mnl} = Min_{I_l, t_i, i=1,\ldots,I_l} \quad (6)$$

Given $\lfloor h_1, h_2, \ldots, h_{I_l} \rfloor$ Find the corresponding t_i's

For Sweden we shall use the full model specification (as above), but we note that the transhipment locations t_i are not observed. In the loglikelihood, we use the expectation of the outcome of the transhipment choice, which in the logit formulation will be the logsum (e.g. for the first leg):

$$\ln \sum_{t_1|h_1} \exp(-G_{mnl}) \tag{7}$$

By estimating the Swedish logistic chain choice model together with the Norwegian one (and if posible use new datasets in this at the same time), the parameters of all choices can be identified (also see Section 2.9).

Norway

In the LG data (Schenker/Linjegods) we will have information on the modes h and transhipment locations used t. But information on the sender and receiver (except their location) will be limited if not absent, and most importantly, we won't know commodity type k (only some information on the way of handling: e.g. refrigerated)

So, what we observe is a sum over commodity types. We may be able to link a commodity type (but not using a detailed classification) to information in the dataset, e.g. on the value (and/or weight) of the shipment:

$$P(l|\theta) = \sum_k P(l|\theta, k) \cdot P(k|value, \ldots) \tag{8}$$

Also, we can try to identify parameters by commodity type by combining the data with the data from Sweden and performing simultaneous estimation.

The 2005 and 2006 models

This concludes the specification of the 2006 logistics model, which will be estimated on disaggregate data in 2006. In 2005 we developed a preliminary logistics model on existing data, which already uses micro-simulation, but has a weak empirical foundation since it is not based on disaggregate estimation. In part B of this report, the 2005 logistics model is described

Part B. The 2005 logistics model

CHAPTER 4 Activities carried out for the disaggregation step

The 2005 model is a normative cost minimisation model. Normative means here that the coefficients for the different items in the logistics cost function to be minimised are determined in advance (not estimated on data). The model yields shipment size and transport chain choice (modes used, vehicle/vessel types, cargo units, location of consolidation centres, distribution centres, intermodal rail terminals, ports and airports used). It contains:

- A disaggregation step (step A) from zone-to-zone flows to firm-to-firm flows (which will be the starting point for the development of the step A procedure in 2006, when step A will be revisited for the full logistics model).
- A deterministic optimisation model for determining shipment size and transport chain (step B). In 2006 we plan to estimate a set of discrete choice models for these choices on disaggregate data.
- Aggregation: the outcomes of the 2005 logistics model have been aggregated to the zone-to-zone level (step C) and the model has been calibrated on aggregate mode shares data.

This chapter describes the activities carried out for step A. Chapter 5 deals with step B of the 2005 model. Results from the calibrated model are described in Chapters 6 and 7.

4.1 Preliminaries

4.1.1 PWC matrices

The starting point are the PWC matrices giving commodity flows from zones of production (P) to zones of consumption (C: intermediate consumption or retail) or to zones of wholesale (W), as well as flows from W to C. We received different matrices for Norway and Sweden. There will also be two logistics models, but with a similar (or the same) structure in both countries. The flows in the PWC matrices are in tonnes per year, by commodity type (distinguishing 32 commodity groups in Norway and 34 in Sweden). We also received value-to-weight ratio (value density) information by commodity type. These have been used to estimate the total logistics costs in Chapter 7.

4.1.2 Take out singular flows

Large flows to/from a number of large firms, that are likely to remain stable (in terms of modes, vehicle types, etc) in the next years should be removed from the PWC matrices.

For these flows we have company-specific information on the shipment size and transport chain used. Information on the size of the singular flows and their shipments size and transport chain was obtained from SITMA (see Section 3.2).

However, when comparing the singular flow volumes in tonnes (as obtained from the companies involved) with the PWC matrices for Norway and Sweden for the same commodity types, we found serious inconsistencies. Almost all singular flows from Section 3.2 (using the origin and destination zones as stated in Table 15 and Table 16) are much bigger that the PWC flows between these zones for the corresponding commodity types (see Annex 5). For some part this is simply due to the fact that the locations for loading ('from') and unloading ('to') in Table 15 and Table 16 are not always the proper P, W and C locations. Often these locations are ports that do not produce or consume a large amount of the goods that are transhipped there: many flows in Table 15 and 16 are OD flows. But if we sum all the PWC flows that depart from the production zones of singular flows, in many cases we still get a total PWC flow (of all senders) that is only a small fraction of the flow from the single large sender. Conversely, if we sum all the PWC flows to a particular zone that has a large consuming firm, we also get (for the relevant commodity group) volumes that are several times smaller than received by the single large firm (also see Annex 5). This makes it impossible to subtract the singular flows from the PWC matrices (that would result in some very small and some highly negative goods flows). In addition, we expect that the information on the singular flows obtained from the individual firms will be more reliable than the PWC matrices. The impression we got from this comparison is that the PWC matrices in both Norway and Sweden are spatially more balanced than the actual goods flows, which, at least for some very bulky products, are heavily concentrated on certain production and consumption zones. We decided not to subtract the singular flows from the PWC flows for the 2005 model, but may consider the possibility to add the singular flows after the PWC flows have been allocated to transport chains.

4.2 Step A: from zone-to-zone flows to firm-to-firm flows

4.2.1 Assign to sending firms

In this step we assign P and W flows (by commodity type k) leaving zone r to the local units (firms and parts of firms) established in zone r. These will be the sending firms m. The allocation is done proportionally to the share in the production (approximated by the size of the firm in terms of the number of employees) of each firm located in zone r of products that belong to commodity type k. Several conversions between classifications systems for goods and sectors proved necessary. For exports (in the PWC matrices the production zone is domestic, but the consumption zone is abroad), we only assign the sending end to sending firms, while the receiving end remains an aggregate over firms.

Sweden

Starting point for the disaggregation are the PWC matrices and the CFAR data from the Statistics Sweden (SCB).

Table 22 - 34 Commodity groups in Sweden

Commodity	Product category NSTR	Description
1	10	Cereals
2	20	Potatoes, other vegetables fresh or frozen
3	31	Live animals
4	32	Sugar beet
5	41	Timber for paper industry (pulpwood)
6	42	Wood roughly squared or sawn lengthwise, sliced or peeled
7	43	Wood chips or wood waste
8	44	Other wood or cork
9	50	Textiles, textile articles and manmade fibres, other raw and animal and vegetable materials
10	60	Foodstuff and animal fodder
11	70	Oil seeds and oleaginous fruits and fats
12	80	Solid mineral fuels (coal etc)
13	90	Crude petroleum
14	100	Petroleum products
15	110	Iron ore, iron and steel waste and blast-furnace dust
16	120	Non-ferrous ores and waste
17	130	Metal products
18	140	Cement, lime, manufactured building materials
19	151	Earth, sand and gravel
20	152	Other crude and manufactured minerals
21	160	Natural and chemical fertilizers
22	170	Coal chemicals
23	180	Chemicals other than coal chemicals and tar
24	190	Paper pulp and waste paper
25	200	Transport equipment, whether or not assembled, and parts thereof
26	210	Manufactures of metal
27	220	Glass, glassware, ceramic products
28	231	Paper, paperboards; not manufactured
29	232	Leather textile, clothing, other manufactured articles than 28
30	240	General cargo
31	45	Timber for sawmill
32	201	Machinery, equipment, engines
33	233	Paper, paperboard and manufactures thereof
34	250	Packaging materials, used

The PWC matrices contain commodity flows in tonnes per year from zones of production (P) to zones of consumption (C) or to wholesale (W), as well as flows from W to C. Table 22 gives an overview of the 34 commodities that are distinguished, including the corresponding NSTR categories. Data for both domestic and import/export flows were provided by SIKA. The CFAR data contains information about individual Swedish firms. The variables that are used for this analysis are the unique combination of organisation number and work place ID (=the local unit), information about the zone in which the firm is located, the Swedish Standard Industrial Classification (SNI) and the average[11] number of employees. In this step the two data sources mentioned above (PWC and CFAR) are combined to assign, by commodity, the P and W flows leaving each zone to individual sending firms. Preferably this would have been done proportionally to the share in the production (in money units) of each firm producing commodity k and located in zone r. However, as this data is not available, the average number of employees has been used as a proxy[12].

In order to combine the two data sources, a conversion from the SNI industrial classification to the commodity classification in NSTR has been used. This conversion table has been provided by SIKA (it is also used in the development of the base martrices) and contains for each SNI category a probability that this SNI belongs to one of the NSTR commodity categories. Evenly (uniformly) distributed random numbers between 0 and 1 are used to assign a firm to a NSTR commodity, using this conversion table with accumulated probabilities for each SNI, summing up to 1 for each NSTR commodity category[13].

Once firms are assigned to a commodity category, the flows of each commodity k from each production zone r can be assigned to the individual firms. To calculate the share an individual firm will get of the total flow (per zone r and commodity k), the number of employees of each firm divided by the total number of employees for firms producing commodity k in zone r has been used.

However, before being able to assign those commodity-flows to individual firms, some intermediate steps needed to be taken. Analysing the data showed that for some combinations of production zone and commodity in the PWC matrix, the CFAR database did not contain firms and vice versa. Also, because the CFAR database only contains information about Swedish firms, import flows could not be assigned because the production zone is located outside Sweden. To solve these problems, virtual companies are assigned to each missing production zone and commodity combination. Those virtual companies are given a unique, easy to recognise company ID[14], so those non-existing, virtual companies can be identified in further analyses. Firms that are part of the CFAR

[11] The original data contained information about employees in employee classes and also a distinction between firms with single and multiple locations; for each firm at a unique location (in other words: for each local unit) the average value of each class has been taken for further analyses.

[12] For Sweden, data about the turnover of each firm could have been used as a proxy, but for Norway this data was not available and for consistency it has been decided to use the same proxy variable for both countries. In this way, it was not necessary to use a different approach for both countries.

[13] Only SNI classifications 1-36 are taken into account as classifications above 36 are not considered to be companies/organisation producing/handling goods that needs transport, at least SIKA does not have any reliable data on that from the foreign trade statistics from which it derived the conversion data.

[14] Organisation ID, organisation number and workplace ID all start with a 7. The number of employees per firm and per commodity/zone combination, and the calculated percentage have been set to 100 and 1 (=100%) respectively.

database and for which no flows can be assigned because the PWC matrix does not contain this combination of zone and commodity are excluded from the analyses.

Result of this step is a table containing individual firms, located in production zone r and producing a certain volume (tonnes per year) of commodity k. The production zone can be outside Sweden, in which case a virtual firm has been created.

Figure 5 shows the flow diagram of the steps that has been taken.

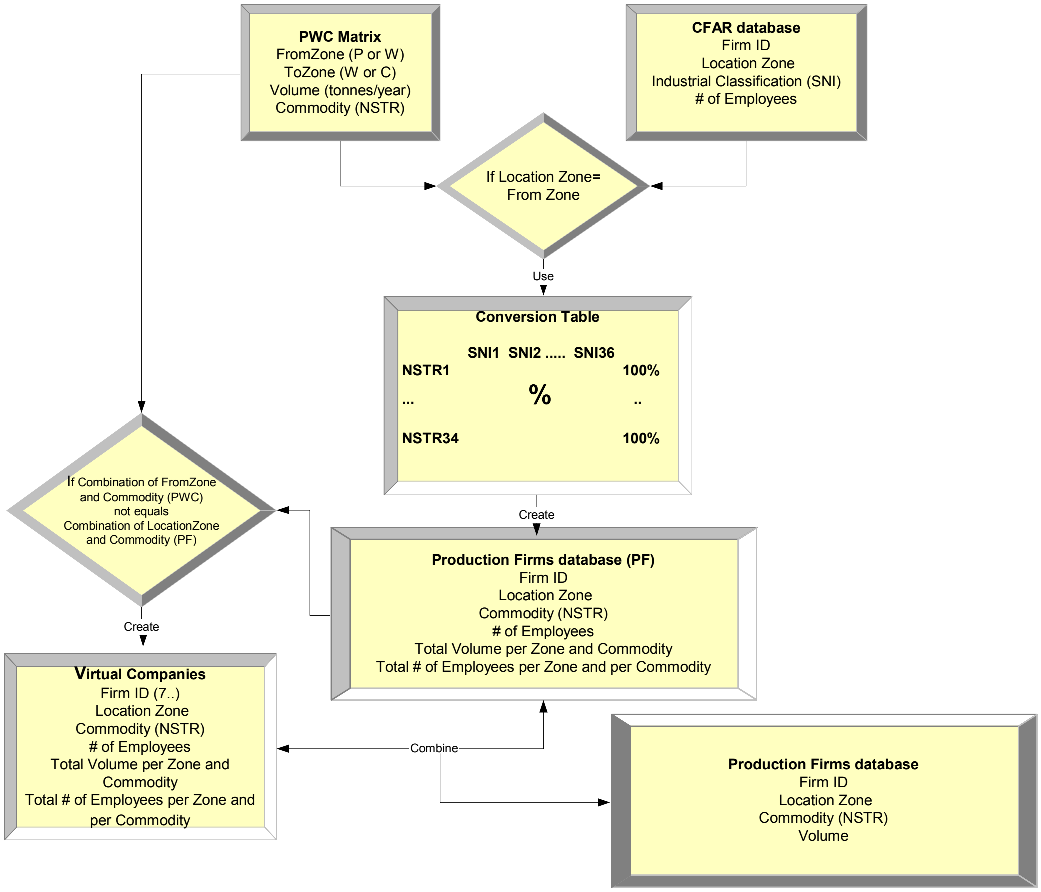

Figure 5 - Assign to sending firms - Sweden

Norway

For Norway a different company classification, from the business register, applies which is used, together with the Norwegian PWC matrix, as starting point for disaggregating zone-to-zone flows into flows per individual sender.

Table 23 gives an overview of the 32 commodities that can be distinguished (also including the corresponding NEMO-32 numbers).

Table 23 - 32 Commodity groups in Norway

Commodity	NEMO number	Description
1	11	Bulk food
2	12	Consumption food
3	13	Beverages
4	21	Fresh fish
5	22	Frozen fish
6	23	Other fish (conserved)
7	31	Thermo input
8	32	Thermo consumption
9	41	Machinery and equipments
10	42	Vehicles
11	51	Gen cargo, high value
12	52	Gen cargo, living animals
13	53	Gen cargo, building materials
14	54	Gen cargo, inputs
15	55	Gen cargo, consumption
16	61	Sawlogs
17	62	Pulpwood
18	63	Pulp and chips
19	64	Paper intermediates
20	65	Wood products
21	66	Paper products and printed matters
22	71	Mass commodity
23	72	Coal, ore and metal waste
24	73	Cement, plaster and cretaceous
25	74	Non-traded goods
26	81	Chemical products
27	82	Fertilizers
28	91	Metal and metal goods
29	92	Aluminium
30	101	Crude petroleum
31	102	Petroleum gas
32	103	Refined products

The company classification table provides information about individual Norwegian firms. The company file comprises of records on individual companies containing location (zone), size category (in number of employees[15]) and the commodity produced according

[15] The original data contained information about employees in employee classes and also a distinction between firms with single and multiple locations; for each firm at a unique location (in other words: for each local unit) the average value of each class has been taken for further analyses.

to the SITC classification (consequently we do not need a conversion from sector to commodity, as we use for Sweden). In addition, each company is assigned a unique identifier to allow tracing through the model later on.

The SITC commodity groups can be linked to the NEMO classification in 32 commodity groups, but not one a one-to-one basis. The share of NEMO commodity k of the total commodities in a SITC group is used to assign companies that produce commodity k. This share is used as the probability that a company produces commodity k, which is implemented by taking random draws.

Since there is no data available on the volumes per commodity sent by each individual company, each company is assigned a share from the total volume of commodity k in zone r. The average number of employees is used as a proxy for the company's size to determine the share of production of each firm producing commodity k and located in zone r. This share is derived proportionally to the ratio of number of employees of the firm and total employees within zone r producing commodity k.

From comparing the PWC matrix and the companies file it appears that these data sources do not contain exactly the same set of commodity-zone combinations. For cases in which commodity k is produced in zone r (according to the PWC matrix), but no company in this zone produces commodity k, a new company is generated. Since the company file only comprises of Norwegian companies while the PWC matrix includes flows with foreign origins and destinations, for these flows virtual companies need to be generated as senders. These virtual companies are assigned an ID that allows identification in the model later on. Firms that are part of the company file and for which no flows can be assigned from the PWC matrix are assigned a production of 0. These companies might only consume goods (such as service sector companies), for which reason they should be kept on board for the next phase (assigning consumption).

The final table generated in this step contains individual firms, located in production zone r and producing a certain volume (tonnes per year) of commodity k. The production zone can be outside Norway, in which case a virtual firm has been created.

Figure 6 shows the flow diagram of the steps that has been taken.

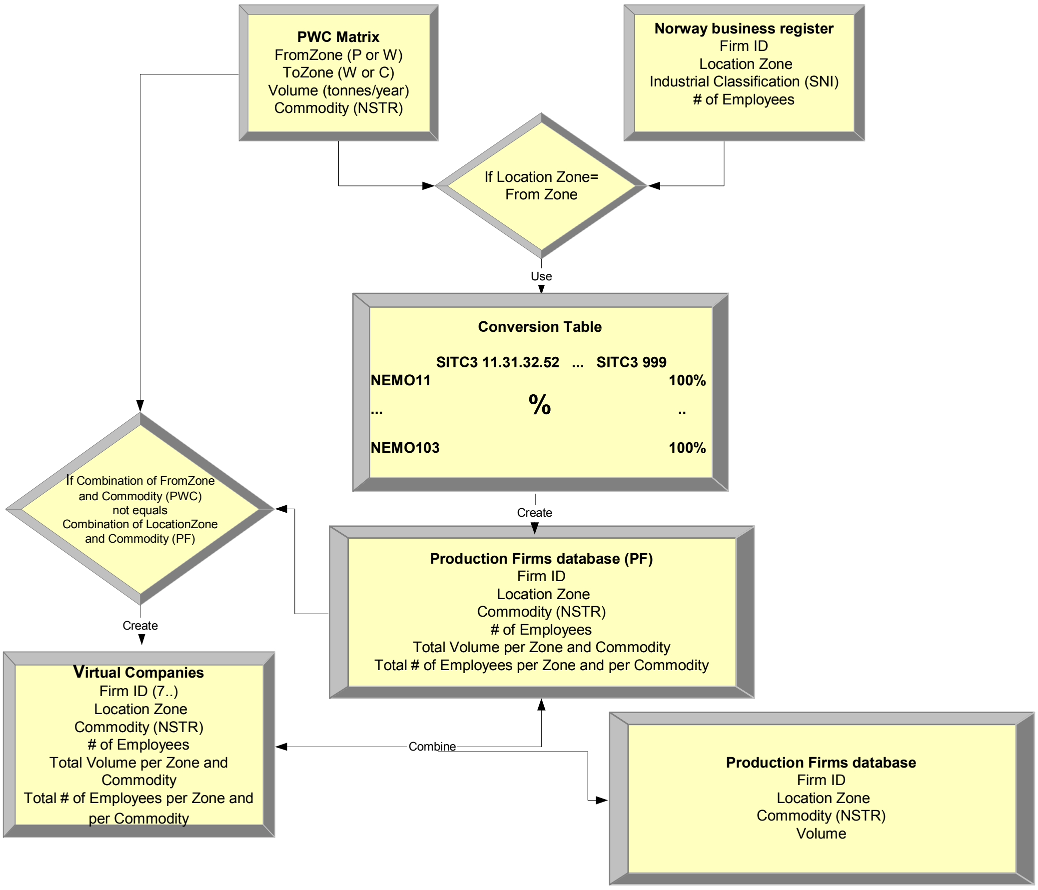

Figure 6 - Assign to sending firms - Norway

4.2.2 Assign to receiving firms

In this step we assign W and C flows (by commodity type k) entering zone s to the local units (firms and parts of firms) established in zone s: the receiving firms n. Assignment is done proportionally to the share in consumption of each firm located in zone s of products that belong to commodity type k. For this we use the number of employees of each firm n in zone s in each sector, in combination with national Use tables. These tables give the consumption of each sector by commodity type (a sector can consume goods from several commodity classes). Again several conversions were necessary between classifications systems for goods and sectors. For imports (in the PWC matrices the production zone is abroad, but the consumption zone is domestic), we only assign the receiving end to receiving firms, while the sending end remains an aggregate over firms.

Sweden

The next step in development of the logistic model is to assign, for each of the 34 commodities, the W and C flows entering a zone to the local firms established in those zones. These will be the receiving or consuming firms. Starting point for this assignment are again the PWC and CFAR databases. Preferably, the assignment would have been done proportionally to the share in the consumption (in money units) of each firm, by zone and by commodity. As in the assignment to sending firms, the average number of employees per zone and per commodity is used as a proxy for determining those volume shares.

The CFAR database contains information about the SNI industrial classification of the individual firms. Although in reality firms can consume more than one commodity, in this step each firm will be assigned to consume one specific commodity. The national Swedish Use table of 2001 that has been produced as an integral part of the National Accounts has been used to assign a consumption commodity to each firm. This Use table contains for each of the SNI industrial sectors (types of firm) an overview of the volumes of each type of product (again in SNI classification) that those sectors consume. Calculating the shares per commodity for each of the sectors give us a probability that this sector consumes one of the SNI 'commodity types'[16]. Use of evenly distributed random numbers between 0 and 1 are used to assign an individual firm (belonging to a certain sector) to a SNI 'commodity', using the accumulated probabilities for each possible SNI, summing up to 1 for each sector[17].

The next step in the assignment is the conversion from SNI 'commodity' to NSTR commodity. The same conversion table and method as described above for the senders has been used to assign an NSTR commodity to each consuming firm. As in the assignment to sending firms, combining the flows of the PWC matrix with the company table (CFAR database) results in some commodity and zone combinations for which no firms can be found in the CFAR database. One virtual firm is added for each of these 'missing' commodity-zone combinations. Those virtual firms are also given unique, easy to recognize company ID's[18]. Firms that are part of the CFAR database and for which no flows can be assigned because the W to C part of the PWC matrix does not contain this combination of zone and commodity are excluded from the analyses.

Once firms are assigned to a commodity category, the flows of each commodity k to each consumption zone c can be assigned to the individual firms. To calculate the share an individual firm will get of the total flow (per zone s and commodity k), the number of employees of each firm divided by the total number of employees for firms consuming commodity k in zone s has been used.

Result of this step is a table containing individual firms, located in zone s and consuming a certain volume (tonnes per year) of commodity k. The consumption zone can be outside Sweden, in which case a virtual firm has been created.

Figure 7 shows the flow diagram of the steps that has been taken.

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[16] This are not real commodity types but products that are part of the SNI industrial classification

[17] Please note that, in most cases, the production commodity and consumption commodity of a firm will not be the same.

[18] Organisation ID, organisation number and workplace ID all start with an 8. The number of employees per firm and per commodity/zone combination, and the calculated percentage have been set to 100 and 1 (=100%) respectively.

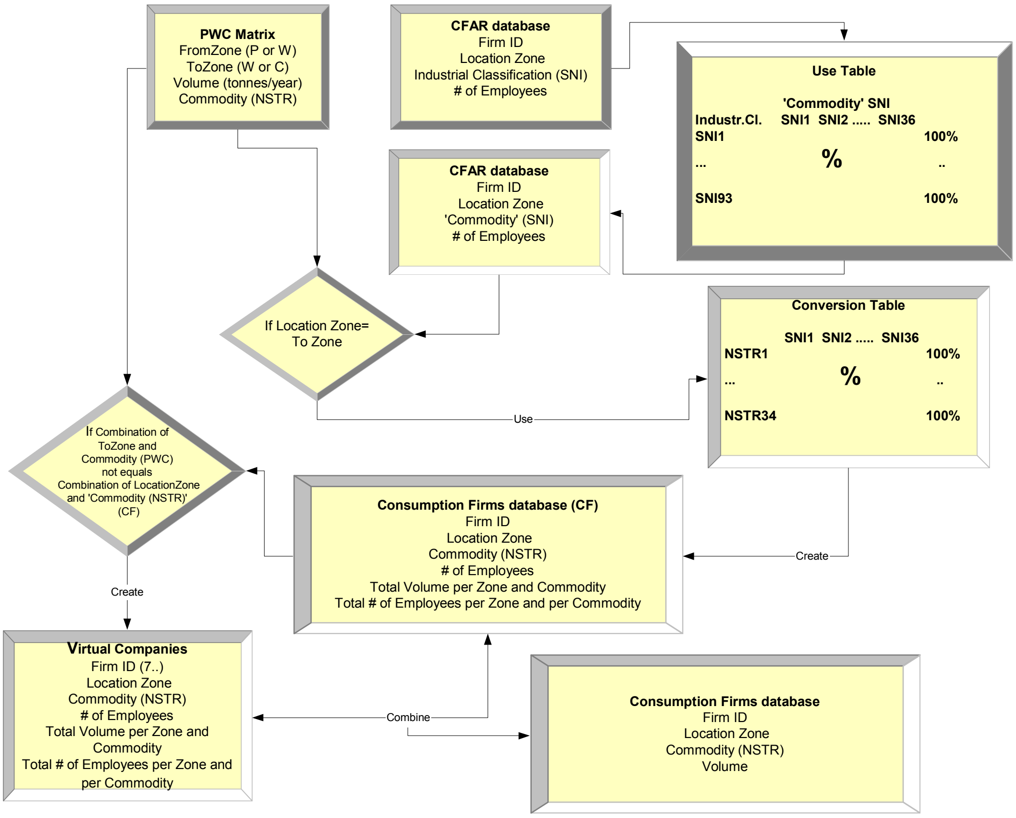

Figure 7 - Assign to receiving firms – Sweden

Norway

Again the PWC and company file (business register) databases form the starting point for this assignment. As for to the division of production over the companies within a company class zone combination, from the PWC matrix a volume can be derived per commodity that is consumed within each zone. For the consumption assignment phase the output table from the production assignment can be used.

The link between commodities and companies is different for consumption than for production. Companies producing one type of good often consume another type of good. The Use table converts type of goods produced to type of goods consumed (both following the SITC classification).

Through the Use table the volume per commodity type consumed by each company sector per zone can be derived. From the companies provided through the production output table an overview of the number of companies and their employees active per SITC category per zone is available. Similar to what we found in assigning production, also in assigning consumption it happens that commodity – zone combinations that exist within the PWC for incoming flows and the companies located in these zones according to the production output table (which is derived from the companies file and contains all companies included in this file) are not the same. For incoming flows for which no company with the respective commodity is present in that zone, a new company is generated. If no flows to a zone in which companies with the respective commodity are located exist, no consumption is assigned to these companies.

After adding these companies, the incoming flows from the PWC matrix can be distributed over the companies for each production commodity – zone combination. For each combination, consumption is assigned on the basis of the number of employees of an individual firm compared to the total number of employees within that commodity group and zone. The total volume for each commodity-zone combination is divided over the firms proportionally.

From this the total volume of consumption of companies per commodity - zone combination is determined. However, since a company may consume more than one commodity type, the Use-table is applied to determine the commodities consumed by each company. Now, for assigning the volume of a specific commodity to firms, consumption of a single commodity within a group is taken as a percentage of total consumption of that group. This percentage is multiplied with total consumption of an individual company composing consumption volumes per commodity.

The final result of this step is a table containing individual firms, located in zone s and consuming a certain volume (tonnes per year) of commodity k. The consumption zone can be outside Norway, in which case a virtual firm has been created.

Figure 8 shows the flow diagram of the steps that has been taken.

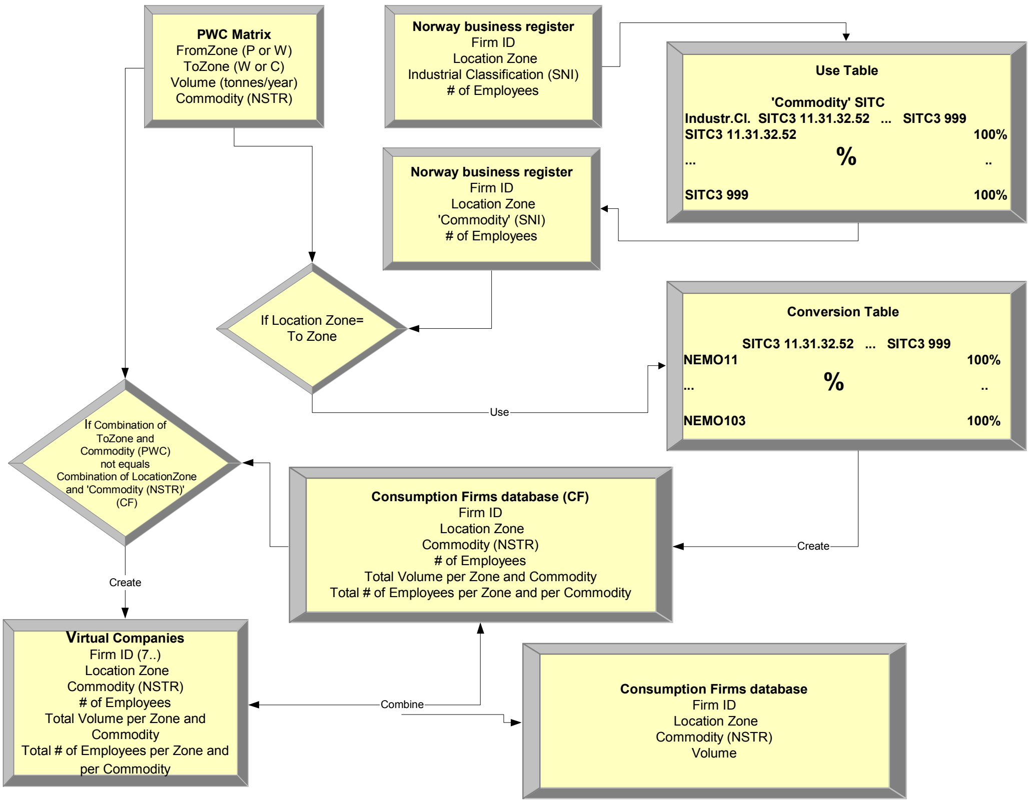

Figure 8 - Assign to receiving firms - Norway

4.2.3 Assign sending firms to each receiving firm and derive flows

We first select a sender m for a commodity class k and then aggregate over all zones s to which this firm is sending k and enumerate all the potential receiving firms n for commodity k in all the zones s (from Section 4.2.2 above). This depends on the sectors that are consuming k according to the Use tables. Some sectors consume a zero or small amount of good k and its firms will not be included as candidate receivers for sender m of commodity k. The number of candidate firms will therefore be considerably lower than the total number of firms in Sweden or Norway.

to: from:	…	s 1 2 . n . N_s		…	total
.					
1 2 . r m . M_r					$F_{m.}$
			F_{rs}		$\sum_m F_{m.}$ $= F_{r.}$
.					
Total		$F_{.n}$	$\sum_n F_{n.} = F_{.s}$		F

Figure 9 - PWC matrix at zone-to-zone (r to s) and firm–to-firm (m to n) level for commodity k

Figure 9 summarises the information that is available from the PWC matrices and the assignment steps to firms at the production and consumption end (Sections 4.2.1. and 4.2.2). From the PWC files we know the total flow of commodity type k from zone r to zone s (the sum of the heavily shaded area, also represented by F_{rs}). From the allocation to production firms we know $F_{m.}$, the flow with firm m (located in zone r) as sender. This flow can go to all zones, not only to zone s. The total flow of good k from all senders in r is also known from the PWC matrices: $F_{r.}$. Conversely we know the flow to firm n (in zone s) and the flow to all receivers in zone s: $F_{.n}$ and $F_{.s}$. Finally we have from expert knowledge an estimate of the number of receivers R_m for a sending firm (by commodity type, but we drop that subscript here for convenience[19]).

We now calculate:

$$F^1_{ms} = F_m * (F_{rs}/F_{r.})$$

This gives a prior estimate (that's why we have given it the superscript 1) of the flow from firm m to zone s. It says that each firm in zone r will have the same spatial pattern of

[19] If a commodity is produced both for domestic consumption and for export we use the total number of domestic and foreign receivers (sum of the first two columns in Annex 2). Otherwise we use only the number of domestic receivers (first column) or only the number of foreign receivers (second column), depending on the PWC flows. We use a single receiving firm for each foreign zone that receives exports from Sweden/Norway. For imports we select a number of sending zones (third column in Annex 2) for the flow to the receiver, and allocate the flow that goes to this receiver to the selected sending zones (also one sending firm per zone).

receivers. It cannot be used as a final estimate, because then firm m would be delivering to all zones that receive deliveries for this good from zone r. It is quite likely that there will be more receiving zones from the sending zone as a whole than from a single sender in this zone.

Therefore, we also use the estimate of the number of receivers per sender R_m. First we draw R_m receiving zones for a sender m on the basis of proportionality with F^1_{ms}. So a higher value for F^1_{ms} for a zone gives a higher probability that this zone will be included as a receiving zone for m. For different sending firms, draws with different seeds are used to get variation. The zones are drawn with replacement, so that the same zone can be selected a a receiving zone more than one (especially if there are many receivers per sender for some commodity type).

After this, we draw a receiving firm n within each selected zone. For zones that have been selected more than once we draw as many fims as there are replications for this zone. The drawing of receiving firms within a zone is done on the basis of proportionality with $F_{.n}/F_{.s}$, (the share of firm n located in zone s in all receivers in zone s) this time without replacement.

After having selected the receiver zones and receiving firms for sender m, the actual volume of F^2_{ms} (a better, sort of a posteriori estimate) is determined by distributing $F_{m.}$ over the selected zones proportional to $F_{rs}/F_{r.}$. After this, within each selected receiving zone s, the flows F^2_{ms} are distributed over the selected firms, proportional to $F_{.n}/F_{.s}$, to get F_{mn}.

4.2.4 **Results from step A**

Norway

We assigned the P(W) side in Norway to 108,000 firms (senders) and the C(W) side to 391,000 firms (receivers). There are more receivers than senders because senders can only be firms producing goods or wholesalers whereas receivers include firms in all sectors (e.g. also including services). The number of firm-to-firm flows generated for Norway is 24 mln. This number refers to annual flows (business relationships), each of which can consist of several shipments. The program that was written by RAND Europe for the 2005 logistics model thus creates a file with 24 mln records. For each of those records we now have a sending firm (m) in some zone (r), a receiving firm (n) in some zone (s), a commodity type k and an annual total flow Q. The shipment size and frequency for this flow will be determined in step B (see next Chapter), as will be the transport chain choice. These results are in first instance generated for each firm-to-firm flow (so we get a transport chain for every record) and added to the 24 mln firm-to-firm records. The 2005 model therefore already is a micro-simulation model. From this large micro-level file, several more aggregate files can be derived.

Sweden

For Sweden we assigned we assigned the P(W) side to 183,000 sending firms and the C(W) side to 463,000 receiving firms (receivers). The number of firm-to-firm flows generated for Sweden is 98 mln. This number is considerably higher than for Norway, not only because we have more senders and receivers in Sweden, but also because the average number of senders per receiver in Sweden is larger (see Annex 2). As a result, computer run times for the Swedish model will be considerably longer.

CHAPTER 5 Activities carried out on the logistic choices step

5.1 Determine the optimal shipment size

From Chapter 4 we now have annual flows from firm m (in zone r) to firm n (in zone s), by commodity type. We have got this for all flows in/to/from/through Sweden or Norway respectively that were in the PWC matrices. This is therefore not a sample to be expanded, but the population of commodity flows. In Chapter 3, different types of inventory behaviour have been discussed. For each commodity class this has provided the dominant type of behaviour. This determines the formula to be used for optimal shipment size. We use a priori fixed parameters here. The outcome will be an average optimal shipment size q for every kmn flow. This splits the annual total into a number (the average optimal frequency) of shipments. We could represent this at the shipment level, by making each shipment an observation (with the same shipment size for each kmn combination), but it is more efficient to add this shipment size q as an attribute to the kmn flows. In other words: to have one shipment observation for each kmn combination, but with a certain weight (its annual frequency to give the total annual kmn flow). Initially (in the 2005 model) we shall work with the situation that all flows in a year for commodity k from m to n are of the same size. Later, in the 2006 model, we shall investigate whether it is possible to specify a shipment size distribution for the kmn flow and draw shipments of various sizes (each representing some share of the annual flow).

For exports we only have kms flows (firm m to foreign zone s) and for imports only krn flows (foreign zone r to firm n). From expert knowledge we add the number of firms abroad that are involved as receivers or senders in these flows. Assuming an equal distribution of these flows to the firms abroad, we get the volume of the annual firm-to-firm flow that can be used as the starting point for the determination of the optimal shipment size. For the exports, we have to do the optimisation from the perspective of the sender (in Sweden or Norway) since we will have no information on the receiving firm abroad.

In Section 3.1 on decisions and logistical behaviour, some basic stereotypes for decision-making in the supply chains are described. Table 24 and Table 25 below link these stereotypes to the equations used in the 2005 logistics model for optimising the different

Table 24 - Equations and procedures used for determining shipment size, Norway

Category	Logistic implications (model) – P-W relationships	Logistic implications W-C relationships	Logistic implications P-C relationships
1. Bulk food	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
2. Consumption food	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
3. Beverages	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
4. Fresh fish	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A
5. Frozen fish	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
6. Other fish	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
7. Thermo input	Cost minimisation for transport only, given time constraints Procedure A	Not applicable	Inventory optimisation by C Eq.: I-II
8. Thermo consumption	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Not applicable
9. Machinery and equipment	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Cost minimisation for transport only, given time constraints Procedure A
10. Vehicles	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Not applicable
11. General cargo – high value goods	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Cost minimisation for transport only, given time constraints Procedure A
12. General cargo – live animals	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A
13. General cargo – building materials	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
14. General cargo – other inputs	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
15. General cargo – consumption goods	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
16. Timber – pulpwood	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
17. Timber – saw-logs	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
18. Pulp	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints Procedure B
19. Paper intermediates	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints Procedure B

Category	Logistic implications (model) – P-W relationships	Logistic implications W-C relationships	Logistic implications P-C relationships
20. Wood products	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
21. Paper products	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
22. Mass commodities	Not applicable	Not applicable	Transportation cost minimisation Procedure C
23. Coal, ore and metal waste	Not applicable	Not applicable	Transportation cost minimisation Procedure C
24. Cement, plaster and cretaceous	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Transportation cost minimisation Procedure C
25. Non-traded goods	Transportation cost minimisation Procedure C	Not applicable	Transportation cost minimisation Procedure C
26. Chemical products	Transportation cost minimisation Procedure C	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
27. Fertilizers	Transportation cost minimisation Procedure C	Inventory optimisation by C Eq.: I-II	Not applicable
28. Metal and metal goods	Transportation cost minimisation Procedure C	Not applicable	Inventory optimisation by C Eq.: I-II
29. Aluminium	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints Procedure B
30. Crude petroleum	Cost minimisation for transport only, given time constraints Procedure A	Not applicable	Inventory optimisation by C Eq.: I-II
31 Petroleum gas	Cost minimisation for transport only, given time Procedure A constraints	Not applicable	Inventory optimisation by C Eq.: I-II
32. Refined petroleum products	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II

Table 25 - Equations and procedures used for determining shipment size, Sweden

Category	Logistic implications (model) – P-W relationships	Logistic implications W-C relationships	Logistic implications P-C relationships
1. Cereals	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
2. Potatoes, other vegetables fresh or frozen	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
3. Live animals	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A
4. Sugar beet	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Cost minimisation for transport only, given time constraints Procedure A
5. Timber for paper industry (pulpwood)	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
6. Wood roughly squared or sawn lengthwise, sliced or peeled	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
7. Wood chips or wood waste	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
8. Other wood or cork	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
9. Textiles, textile articles and manmade fibres, other raw and animal and vegetable materials	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
10. Foodstuff and animal fodder	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
11. Oil seeds and oleaginous fruits and fats	Inventory optimisation by W Eq.: I-II	Not applicable	Cost minimisation for transport only, given time constraints Procedure A
12. Solid mineral fuels (coal etc)	Not applicable	Not applicable	Transportation cost minimisation Procedure C
13. Crude petroleum	Cost minimisation for transport only, given time constraints Procedure A	Not applicable	Inventory optimisation by C Eq.: I-II
14. Petroleum products	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
15. Iron ore, iron and steel waste and blast-furnace dust	Not applicable	Not applicable	Transportation cost minimisation Procedure C
16. Non-ferrous ores and waste	Not applicable	Not applicable	Transportation cost minimisation Procedure C
17. Metal products	Transportation cost minimisation Procedure C	Not applicable	Inventory optimisation by C Eq.: I-II

Category	Logistic implications (model) – P-W relationships	Logistic implications W-C relationships	Logistic implications P-C relationships
18. Cement, lime, manufactured building materials	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Transportation cost minimisation Procedure C
19. Earth, sand and gravel	Not applicable	Not applicable	Transportation cost minimisation Procedure C
20. Other crude and manufactured minerals	Not applicable	Not applicable	Transportation cost minimisation Procedure C
21. Natural and chemical fertilizers	Transportation cost minimisation Procedure C	Inventory optimisation by C Eq.: I-II	Not applicable
22. Coal chemicals	Transportation cost minimisation Procedure C	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
23. Chemicals other than coal chemicals and tar	Transportation cost minimisation Procedure C	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
24. Paper pulp and waste paper	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints Procedure B
25. Transport equipment, whether or not assembled, and parts thereof	Cost minimisation for transport only, given time constraints Procedure A	Cost minimisation for transport only, given time constraints Procedure A	Not applicable
26. Manufactures of metal	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
27. Glass, glassware, ceramic products	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
28. Paper, paperboards; not manufactured	Not applicable	Not applicable	Cost minimisation of transport given shipment size constraints Procedure B
29. Leather textile, clothing, other manufactured articles than 28	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Not applicable
30. General cargo	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
31. Timber for sawmill	Not applicable	Not applicable	Inventory optimisation by C Eq.: I-II
32. Machinery, equipment, engines	Cost minimisation for transport only, given time constraints Procedure A	Inventory optimisation by C Eq.: I-II	Cost minimisation for transport only, given time constraints Procedure A
33. Paper, paperboard and manufactures thereof	Inventory optimisation by W Eq.: I-II	Inventory optimisation by C Eq.: I-II	Inventory optimisation by C Eq.: I-II
34. Packaging materials, used	Transportation cost minimisation Procedure C	Not applicable	Transportation cost minimisation Procedure C

relationships (P-W, W-C, P-C)[20], as in Tables 6 and 7. What has been added are references to specific equations and procedures for determining shipment size. The numbers used for reference to the equations are the ones used in the Section 3.4 (but also repeated below). This holds for the 'reference' situation where there is a joint optimisation of transport and inventory cost.

Here we repeat eq. I and II for the most general situation: optimisation of both inventory and transport cost based on a common cost function:

$G_{rskmnqh} = o_k*(Q_k/q_k) + T_{rskqh} + i*j*g*v_k*Q_k + (i*t_{rs}*v_k*Q_k)/365 + (w_k + (i*v_k))*(q_k/2) + a * ((LT* \sigma_{Qk}^2)+(Q_k^{2}* \sigma_{LT}^2))^{1/2}$ (I)

$\rightarrow$

$-(o_k*Q_k)/q_k^2 + (w_k + i*v_k)/2 + \partial T_{rskq}/\partial q_k = 0$ (II)

As a simplifying assuption for the 2005 model, we disregards economies of scale in transport in the determination of optimal shipment size[21]. The last term on the left-hand side drops out, and the optimal shipment size becomes:

$$q_k = \sqrt{\frac{(o_k * Q_k * 2)}{(w_k + i * v_k)}}$$

where o represents order costs per order, Q the annual firm-to-firm flow in tonnes, w the storage costs per tonne per year, i the annual interest rate and v the commodity value per tonne. For different commodities we have different values for these variables (Q from Chapter 4 and the others from the costs models, see Annex 3). Using these we calculate the optimal shipment size for all commodities where equations I and II apply (see Table 22 and Table 23).

Then we have three other situations, where the link between inventories and transport is weaker, and where the requirements are basically for transport cost minimisation within certain given constraints:

- Cost minimisation for transport only, given time constraints: This is basically for consumer goods or other high frequency goods with very limited time in inventories (direct deliveries). The optimisation would be one of transport cost minimisation, but within strong requirements for frequency. We applied procedure A below for this optimisation (see below).
- Cost minimisation of transport given shipment size constraints: This is for more transport cost sensitive goods (inventory cost is fairly small compared with

[20] In the 2005 model, we used the procedure in the P-C column for each commodity type (except when it says that P-C is not applicable, then we used the P-W column), because we could not distinguish P-W, W-C and P-C flows in the base matrices. If in the 2006 model the base matrices can be split among those three categories, we shall use different procedures for each of these.

[21] In the 2006 logistics module, economies of scale need to be taken into account, either by estimating an overall costs function that envelopes the costs functions of all the modes, or by using a logsum-type variable from the transport chain choice.

transport cost). At the same time, there will be limitations to the shipment sizes due to space and capital restrictions for the receiver. We applied procedure B below for this optimisation (see below).

- Transportation cost minimisation: This is a situation where the transport cost is even more dominant than inventory cost for the receiver, than in the previous case. The basic limitations to shipment sizes would here mainly be storage capacity, and of course to avoid the risk of the inventories becoming obsolete. We applied procedure C below for this optimisation (see below).

A: Cost minimisation for transport only, given time constraints: As a first approximation, we based the optimisation on high frequency deliveries. We applied the following procedure:

- Use as a constraint (upper-bound) for the delivery shipment size in a P-W, W-C or P-W relation a maximum shipment size of 2 weeks demand. (Thereby transforming a time constraint to a shipment size constraint).
- With this constraint, find the transport alternative with the lowest cost (eq. III and IV)

B: Cost minimisation for transport, given shipment size constraints: As a first approximation, we based the shipment size constraints on fairly low-frequency deliveries. We applied the following procedure:

- Use as a constraint (upper-bound) for the delivery shipment size in a P-W, W-C or P-W relation a maximum shipment size of 13 weeks demand.
- Within this shipment constraint, find the transport alternative with the lowest cost (eq. III and IV)

C: Cost minimisation for transport (only): This should in principle lead to economies of scale in transportation only, using the largest vehicle available. However, to make this situation realistic, one should not use larger deliveries than a maximum period of say one year's demand. The procedure we applied is:

- Use as a constraint (upper-bound) for the delivery shipment size in a P-W, W-C or P-W relation a maximum shipment size of 52 weeks demand.
- Within this shipment constraint, find the transport alternative with the lowest cost (eq. III and IV)

To find more appropriate shipment sizes for situations A-C, one should in the 2006 model calibrate on empirical data for each of the categories and commodity groups distinguished (if possible), instead of using assumptions on a fixed average shipment size and frequency per category.

5.2 Determine the available transport chain alternatives.

The transport chain consists of:

- Choice of the number of legs between m and n (e.g. direct transport is 1 leg; every change of mode h gives a new leg), the leg index is *l*.
- Choice of mode in a broad sense: modes in strict sense (Norway: road, sea, rail, ferry, air transport; Sweden: road, sea, rail, combi; will be extended in 2006), vehicle/vessel types and cargo units (e.g. containerised) used between m and n: this is called 'mode' choice in this report, with h as the mode index (in a broad sense).
- Choice of location t for each change of mode h.

The availability of the mode in the strict sense of the word 'mode' (e.g. road, rail, sea, air) differs between zone pairs and depends on the inputs from the networks (e.g. no sea route between two inland zones). This is taken into account in the 2005 logistics model through the distance and time inputs that are taken from the network models of Norway and Sweden. If a mode is available, several vehicle/vessel types (that are part of the mode definition in the broader sense) can be available. The availability of vehicle types varies between commodities, and is defined in Annex 3 on the cost models.

The number of legs can be 1, 2, 3 or 4. In practice there are a few transports with more than four legs, but according to the CFS these form a very small share[22]. In fact transports with three legs occur rather infrequently (see Annex 1).

There are two types of transfer location in the 2005 model:

- Transfer locations within the road transport system, for changes of road vehicle type within a transport chain (e.g. from LGV to HGV): consolidation centres (CC) and distribution centres (DC);
- Transfer locations for changes from one mode (in the strict sense, e.g. road to rail, sea to road): intermodal train terminals, ports and airports.

The optimal CC and DC locations (that is within road transport) are determined within the logistics model program, using the files on the locations of road terminals in Norway and Sweden, and their availability by commodity type. This is done by enumerating all available location alternatives for a transfer (from the terminal files we received from SIKA and TØI; we selected the road terminals) within a certain road chain, given the locations of sender and receiver, and choosing the one with the lowest transport costs (including transfer costs)[23].

The road chains included here are:

- Road chain with two legs (with one CC or DC)

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[22] As George Orwell wrote in Animal Farm (1945): 'Four legs good, two legs better'.

[23] Another method would be to use a limited search area (e.g. a slice from a circle) for CCs and defining it for instance on the basis of geographical or network distances seems a good idea. But this means that this has to be done in a network program or another program that contains topography (or that these provide inputs on availability of alternative CCs). At present we use all CCs (for some commodity) in the program as alternatives. For most commodities there are not many alternatives (the terminal files are small) at the moment.

- Road chain with three legs (from sender to CC first, then to DC, then to receiver).

Because the types of road vehicles used are still unknown at this stage, we had to choose particular vehicle types to perform the cost minimisation for the optimal CC and DC locations. We use light distribution vehicles (capacity of 8.4 tonnes) for all legs connected to the sender and the receiver, and articulated semi with container (capacity of 42 tonnes) for the legs between road terminals. Please note that these vehicle types are only used for determining the optimal road transfer locations. In subsequent steps of the 2005 logistics model, other vehicle types can be chosen, but for road chains with two or three legs we keep using the transfer locations determined in this initial optimisation step.

In the note on a common understanding, Bates/Swahn/Grönland (2005) remarked that the choice of transfer location for transfers between modes would probably best be made in the multimodal network assignment program. We considered the various options (especially doing a full enumeration of all possible intermodal transfer locations within the logistics model versus intermodal transfer location choice within the network model) and concluded that, certainly for the 2005 model, the selection of the optimal intermodal transfer locations can indeed best be done in the network model. One of the reasons for this is that ports and airports are not necessarily located near to the zone centroids and the easiest way to account for this is to use the network assignment. In the logistics model itself we can only work with zones and their centroids; in the network model we have an explicit geographical respresentation, where each zone can contain several network nodes that can function as locations for the intermodal transfers.

The network models deliver for the optimal route, by commodity type, the zones where the intermodal transfers take place (for each of the mode chains specified in advance, for a specification see below). This might depend on commodity type, e.g. if some port is not available for some commodity or has lower cost for some commodity due to specialisation). The optimal intermodal transfer locations are stored in a file for use later in the determination of the optimal transport chain.

For Sweden, the available mode chains are listed in Table 26 and those for Norway in Table 27.

Table 26 - Available mode chains and transfer locations in Sweden

Mode chain	Transhipment location chain alternatives (CC=consolidation centre, DC=distribution centre, number indicates leg in chain)
Road	Direct
Road->road	CC1, DC1
Road->road->road	CC1+DC2
Sea	Direct
Rail	Direct
Combi (rail)	Direct
Road->sea	Port1
Sea->road	Port2
Road->sea->road	Port1+Port2
Road->rail	Rail terminal1
Rail->road	Rail terminal2
Road->rail->road	Rail terminal1+rail terminal2
Road->combi	Rail terminal1
Combi->road	Rail terminal2
Road->combi->road	Rail terminal1+rail terminal2

Table 27 - Available mode chains and transfer locations in Norway

Mode chain	Transhipment location chain alternatives (CC=consolidation centre, DC=distribution centre, number indicates leg in chain)
Road	Direct
Road->road	CC1, DC1
Road->road->road	CC1+DC2
Road->sea->road	Port1+Port2
Road->rail->road	Rail terminal1+rail terminal2
Road->ferry->road	Port1+Port2
Road->air->road	Airport1+airport2
Road->sea->rail->road	Port1+port2+rail terminal3
Road->rail->sea->road	Rail terminal1+port2+port3

The available modes are not the same in both countries, which is mainly caused by the fact that the current network models in Norway and Sweden use different modes. In Norway we use only transport chains that use road transport at the first and last leg.[24] The idea is that other transports (e.g. from or to firms with their own railway sidings or quays) will mostly be included in the singular flows (see Section 3.2). However, this is only a prelimary solution agreed with the clients and TØI, to get the 2005 model running. It also led to zone pairs for which no transport chain is available (especially for overseas import

[24] The decision to use only chains that use road transport at the first and last leg for Norway was taken for reasons of convenience in the delivery of data for the network models that supply transport distances and times to the logistics module. It is overrestrictive and leads to a number of zone pairs not being connected by any transport chain (especially zones overseas). The restriction will not be used in the 2006 model.

and export, where the foreign road access/egress to the ports is not coded). In the 2006 model, chains starting or ending with other modes than road transport will be added for Norway, as will be chains with sea to sea transfers (e.g. feeder ships).

For Sweden, the list of chains also is provisional. In the 2006 model air transport, sea to sea transfers, road and rail ferries will be added. In order to get chains with international road ferries already in the 2005 model, we approximated the costs for such chains by taking the sea transport time and distance, combined with the ferry costs for Sweden from Annex 3.

The locations of the optimal consolidation centres and distribution centres (and their availability for specific firms and commodities) are stored in separate files.

To summarise: an initial optimisation gives the optimal locations t. After that, we calculate the total logistic costs for all available hl alternatives, given the optimal t, and determine the optimal transport chain.

5.3 Read in/calculate the logistics costs for each available transport chain alternative

For each transport chain alternative hlt that is available for each observation kmn (with shipment size q), we calculate the total logistics cost, using the total generalised cost function from D1b (with a priori fixed coefficients) as the starting point. The input for this comes from the network outputs that we received from SIKA and TØI, in combination with the cost functions.

The network models produce the following inputs for the costs models:

- The distance for each mode (per leg);
- The time for each mode (per leg);
- The other (not time-dependent or distance-dependent) costs for each mode (per leg, e.g. pilot dues in sea transport); and
- The transfer time and cost.

The cost models are described in Annex 3.

The network output gives unimodal distance and time for every zone-to-zone combination (by commodity class k, for each mode). We build up the logistics costs from m to n as the costs of all the legs for each alternative transport chain. The transport cost of each leg are calculated separately, using its distance and time. The cost of loading/unloading/transfers and storage are calculated based on the cost and time outputs that are in the transfer files from the network models and the transfer costs functions (also in Annex 3). These are added for every transfer in the chain to the link-based cost for each leg in the chain.

The cost function that we use in the determination of the optimal transport chain includes:

- Distance-dependent transport costs by vehicle/vessel type on each leg of the transport chain;
- Time-dependent transport costs by vehicle/vessel type on each leg of the transport chain;

- Cost for initial loading at the sender and final unloading at the receiver by vehicle/vessel type;
- Other, non-time-dependent and non-distance-dependent transport costs on each leg of the transport chain by mode (in the strict sense);
- Transfer costs between each of the legs (including cost of stuffing and stripping containers) by vehicle/vessel type pair.

Order costs and inventory holding costs have been used for the determination of shipment size (for some commodity groups). But once the shipment size and frequency have been determined, these costs no longer play a role in finding the optimal transport chain. Cost of damage and loss during the transport, capital costs on the inventory in transit and costs of the safety stock have not been used in the determination of the optimal transport chain in the 2005 model. Empirical data on these items are largely missing and in most situations it can safely be assumed that these costs items are of no or limited relevance for the determination of the optimal transport chain.

The cost functions (see Annex 3) include the time and distance-based transport costs in terms of the cost between a pair of zones for an entire vehicle. For larger vehicles, these costs are generally higher than for smaller vehicles (though the gradient is not very steep, e.g. because of the labour costs). So for a given shipment size of, say, eight tonnes, there is a tendency to choose the vehicle type that is just big enough to carry the eight tonnes[25]. We are assuming that for legs directly from a sending firm, there are no possibilities for consolidating this flow with other goods[26]. However, if a consolidation centre is used, the load of eight tonnes may, from there on, be loaded onto a larger vehicle, and the transport costs can be shared with those for the shipper of these other goods. For legs departing from a road terminal we are assuming that all vehicles that are available for a certain commodity type would be 90% loaded (in 2006 this provisional assumption needs to be verified or replaced by empirical data on the load factor for flows leaving road terminals). So using consolidation centres can help to reduce the time and distance-dependent transport costs for shipments that are smaller than the capacity of a full truck. Whether this will be optimal depends on the trade off between the transport costs of the legs and the transfer costs between the legs.

In initial runs with the program for Norway we found out that it generated a large amount of road-road chains (usullay a small vehicle first and a large one after that), but hardly any road-road-road (small-large-small) chains. If consolidation is attractive, then (in the initial program) it makes no sense to transfer back to smallere vehicles. This is usually not correct however, because in most cases the different consolidated shipments in the larger vehicle

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[25] In the 2005 logistics module we do not make use of restrictions on the volume of the goods that can be carried in a vehicle or vessel and the volume-to-weight ratios of the commodities. This would not only require average volume-weight factors by commodity type, but also a characterisation of all vehicle and vessel types in terms of their capacity in volume (m^3) terms.

[26] A possible extension would be to allow for consolidation of flows from a sender if we would have shipments from a single sender going to several receivers in the same zone (or groups of nearby zones). Another extension would be to allow for bigger but less frequent shipments (than determined for the flow to the receiver) from the sender to a distribution centre: to have different cycles within a logistic chain from P (W) to C (W).

need to be delivered at different locations, which needs to be taken into account. Either the large vehicle needs to deliver at multiple receivers or a second transfer is necessary. As a temporary measure (for the 2005 model only) we therefore changed the program to rule out road-road chains unless the shipment is going to a very large receiver (in which case it can be assumed that all the consolidated flows in the vehicle are for the same receiver). The revised program produces considerably more road-road-road chains than road-road chains, which is more in line with reality. This was implemented for both Norway and Sweden.

If a shipment size exceeds the capacity of some vehicle/vessel type, we calculate the costs for this vehicle/vessel type on the basis of multiple vehicles/vessels of this type (the lowest number that provides the required capacity): a convoy. But in most cases using one larger vehicle/vessel will have lower costs, and the transport chain optimisation takes this into account.

A consolidated flow will in most cases consist of goods for multiple receiving firms. This means that the vehicle transporting the consolidated flows has to visit several destinations (in a multi-drop distribution tour), or that the consolidated goods have to be split up and loaded onto several (smaller) vehicles at a DC. If all of the consolidated flow would go to the same receiver s, then road-CC-road would always be preferred to road-CC-road-DC-road (why 'deconsolidate'?). But to go to different receivers with a large truck might be disadvantageous. DC are often used to re-group the shipments: from CC to DC we have a truck with potatoes only (from several producers), but from the DC to the supermarket goes a truck (not necessarily smaller) with some potatoes, some cabbages, some peas, etc. For the 2005 model we have assumed that the latter option (leading to road-road-raod chains) will prevail unless the receiving firm is a very large receiver of goods (which makes multiple shipments to the same receiver more likely). This needs to be revisited for the 2006 logistics model.

The nineteen different road vehicle types used in the 2005 logistics model are (also taking into account different cargo types):

- LGV;
- Light distribution vehicle;
- Heavy distribution vehicle, closed unit;
- Heavy distribution vehicle for containers;
- Articulated semi-trailer, closed vehicle;
- Articulated semi-trailer, with container;
- Heavy combination (Sweden only);
- Heavy combination with container (Sweden only);
- Tank truck with hanger;
- Semi-trailer, tanker oil products;
- Tank truck with hanger (chemicals);
- Semi-trailer, tanker liquid bulk;
- Tank dry bulk truck with hanger;

- Semi-trailer, dry-bulk products;
- Timber truck with hanger (4 axles);
- 'Flis' truck with hanger (4 axles);
- Semi-trailer ('Flis');
- Thermo-truck with hanger;
- Semi-trailer, thermo.

For sea transport, 37 vessel types are included in the model:

- Load one-load off (lo/lo) general cargo, subdivided in eight vessel sizes;
- Dry bulk, subdivided in eight vessel sizes;
- Side-port vessel;
- Container vessel lo/lo, subdivided in five vessel sizes;
- Roll on-roll off (ro/ro), cargo, subdivided in three vessel sizes;
- Reefer, subdivided in three vessel sizes;
- Product tanker, subdivided in two vessel sizes;
- Crude oil tanker, subdivided in three vessel sizes;
- Liquid bulk tanker, subdivided in two vessel sizes;
- LNG, subdivided in two vessel sizes.

The train types uses differ somewhat between Norway and Sweden:

- Norway (only):
    - Electrical, container;
    - Electrical, timber;
    - Diesel, container;
    - Diesel, timber.
- Sweden:
    - Electrical, wagonload;
    - Electrical, combi;
    - Electrical, system;
    - Diesel, wagonload;
    - Diesel, combi;
    - Diesel, system.

Air transport (currently only for Norway, the intention is to use the same airplane types for Sweden in the future):

- Airbus A300B4-200F
- Boeing 747-400F.

Cargo units (see Tables 18 and 19) were not distinguished separately in the 2005 model, but are implicit in the vehicle/vessel types listed above. If one looks at Tables 16 and 17 (from which Tables 18 and 19 are aggregated), one can see that the transport units used in the 2005 model correspond fairly well with the cargo units recommended for 2006. Bulk containers were not implemented in the 2005 model as a means of bulk transport, but if needed, costs functions could be developed for this and this cargo unit could be included in 2006 if desired.

5.4 Allocate to transport chains

The 2005 model is a normative cost minimisation model, with a priori fixed parameters in the costs function. In 2005 there will be no disaggregate model estimation. We could have developed and applied this 2005 model to produce OD matrices without doing any calibration by ourselves, just leaving the comparison with observed OD data to the validation team. However, we prefer to include alternative-specific constants in the 2005 model and calibrate values for these on observed data on mode shares for aggregate commodity classes.

In the 2005 model, intrazonal PWC flows were excluded. Most of these flows will be handled by road transport (but there are also substantial intrazonal rail flows in the Kiruna zone). We recommend to include these in the 2006 model, determine their shipment size and use a single-leg road transport chain (except for some singular flows). The vehicle type will then be determined through costs minimisation, and will depend heavily on shipment size. Transit flows (from foreign country to foreign country, through Norway or Sweden) were not included in the 2005 model either. These were excluded from the Norwegian PWC files. In the Swedish PWC files we received were no transit flows.

After having determined the generalised costs for each transport chain, we perform an all-or-nothing assignment: each firm-to-firm flow (taking into account its commodity type and shipment size, and the locations of the sender and receiver) is allocated to a single transport chain, characterised by a number of legs and the vehicle/vessel types used on each leg[27]. The optimal transfer locations have been determined in an earlier optimisation step (see 5.2). This is only an initial outcome, which serves to start the calibration. At this stage, the singular flows could be inserted (please note that in the 2005 model these were not subtracted from the PWC flows, see Section 4.1.2).

The loaded vehicle flows can be taken directly from the transport chain optimisation outcomes: for every mn relation (and all its shipments) the type of vehicle and vessel for

[27] Initially in the 2005 model we use the optimal chain for each kmn flow with shipment size q. Later on we might sample from a probability distribution of transport chains and have several hlt alternatives used for the same kmn flow (with one or more shipment sizes q) in a year.

every leg of the transport chain is generated. This can be aggregated over firms and chains (e.g. the same type of vehicle can be used several times in one chain) by zone to give loaded zone-to-zone flows by vehicle and vessel type and by commodity type.

We calibrated to data on the mode shares by commodity type in domestic goods transport, import and export, using the generalised cost function described above, but with alternative-specific constants for modes h. The calibration data are described in Annex 4.

5.5 Add empty flows

The above gives vehicle flows for loaded trips. But for assignment we also need the empty vehicles. These are calculated using the information on the loaded vehicle flows (as return flows, some of which will be empty), as derived above, and the equations for empty vehicle flows as described in Section 3.5.1. Below the equations for road are worked out in more detail, with coefficients fixed a priori. For the moment in the 2005 logistics model we have only calculated the empty vehicle flows for road transport, but similar equations have been worked out for sea vessels, trains and airplanes as well.

According to the Swedish road statistics, 24-25% of all domestic vehicle kilometres of lorries registered in Sweden is driven empty (SIKA and SCB, 2005). We assume that this percentage will be higher for trips zones that are close to each other and will decline (but not become zero) if distance increases. We distinguish between:

- Zones with an OD distance of less than 50 km.
- Zones that are more than 50 km apart.

For vehicles travelling between zones in the first category, we initially assume that empties are half of the full flows. We use this relationship, as a first approximation, for both countries, but only for nearby zones. Transport to nearby zones concerns to a large extent distribution transport, and is based on a fairly low utilisation. For zones with an OD distance of less than 50 km, the number of empties for each vehicle category is calculated as:

$$V_{h,k=empty,sr} = 0{,}5 * \Sigma_{k=1,32(34)} V_{hkrs}$$

For non-neighbouring zones and OD-combinations with a longer distance than 50 km, the calculations are based on a vehicle balance approach:

Take the total number of arriving and loaded vehicles for a given mode/vehicle type h to be:

$$V^{a}_{hs} = \Sigma_r(\Sigma_{k=1,32(34)} V_{hkrs})$$

The corresponding need for loaded vehicles leaving (for the same mode) is:

$$V^{L}_{hs} = \Sigma_r(\Sigma_{k=1,32(34)} V_{hksr})$$

Overcapacity in terms of more vehicles available than needed is:

$\theta_{hs} = V^a_{hs} - V^L_{hs}$ (If $V^a_{hs} - V^L_{hs} > 0$)

= 0 (otherwise)

The idea here is that overcapacity always has to return empty to the starting point. The main tendency is to utilise available capacity first. For the other vehicles it is a question of matching the flows in and out, which we assume will be done more efficiently for longer distances.

If $\theta_{hs} > 0$, $V_{s,\,k=empty} = \theta_{hs} + P(E)\Sigma_r x_{sr} = \theta_{hs} + (\Sigma_{k=1,32(34)}\ \alpha_s\ (\Sigma_{hr} V_{hksr}))$

If $\theta_{hs} = 0$, $T_{s,\,k=empty} = (0 +)\ P(E)\Sigma_r x_{sr} = (\Sigma_{k=1,32(34)}\ \alpha_s\ (\Sigma_{hr} V_{hksr}))$

Although we do not have empirical studies of this, it is reasonable to believe that the $_s$ values would be falling with increasing distances. As a preliminary approximation (before acquiring empirical data), we use the following values:

α_{sr} = 0,58 - (0,0016*distance(r,s)), if distance(r,s) ≤ 300 km

= 0,1 if distance(r,s) > 300 km

This gives:

If $\theta_{hs} > 0$, $V_{s,\,k=empty} = \theta_{hs} + P(E)\Sigma_r x_{sr} = \theta_{hs} + (\Sigma_{k=1,32(34)}\ \alpha_{sr}\ (\Sigma_{hr} V_{hksr}))$

If $\theta_{hs} = 0$, $V_{s,\,k=empty} = (0 +)\ P(E)\Sigma_r x_{sr} = (\Sigma_{k=1,32(34)}\ \alpha_{sr}\ (\Sigma_{hr} V_{hksr}))$

$V_{h,k=empty,sr} = [(\Sigma_{k=1,32(34)} V_{h,k,rs}) / (\Sigma_r(\Sigma_{k=1,32(34)} V_{hksr}))]^*\ V_{s,\,k=empty}$

CHAPTER 6 Interim results on OD matrices (step C: aggregation to zone-to-zone flows)

6.1 Inputs and outputs of the program

For the 2005 logistics module, a computer program has been developed that is operated by means of a control file. There are different programs for Norway and Sweden, with different control files, but the structure is the same.

The control file lists the input files for the program and specifies the output files. It also contains switches to change parameters in he logistics costs function (such as trucking rates, unit inventory costs, transfer costs, values of time).

The input files are:

- The PWC flows, domestic as well as export and import, giving the commodity flows in tonnes per year by production (wholesale) and consumption (wholesale) zone by commodity type (32 or 34). It will be possible for the user of the program to insert a different PWC matrix (the average value of the goods per tonne by commodity group is only used in the calculation of some of the costs items – cost of loss and damage, capital costs).
- A file with the singular flows that need to be subtracted from the PWC flows before further processing (and will be inserted again before the aggregation to OD flows). This file was not used in the 2005 model runs.
- A file with the shares per commodity and zone in the commodity flows of the different firms at the production side (including export). This file was made in MS-Access.
- A file with the shares per commodity and zone in the commodity flows of the different firms at the consumption side (including import). This file was made in MS-Access.
- A file with the locations of the terminals (at least containing the road terminals: consolidation and distribution centres). These are used in the program to determine the optimal locations to use in the road-based transport chain alternatives. The user can insert a different file than the default one.

- A file with the distances, times and "other" costs at the OD-leg level. These will be combined with costs functions in the program. The control file will allow the user to change parameters of the cost functions.
- A file with the cost and time inputs for modal transfers and storage. These will be combined with the transfer and storage cost functions in the program. The control file will allow the user to change parameters of the cost functions.
- A file with the optimal locations for intermodal transfers (ports, airports, intermodal rail terminals), from the network program. The program compares the various transport chain alternatives (defined in terms of number of legs, modes/vehicles/cargo type used) and chooses the optimal one.
- A file with calibration data (modal shares, major aggregate origin and destination volumes) for the base-year.

The program then builds a firm-to-firm database of annual commodity flows (24 mln for Norway, 98 mln for Sweden), determines the shipment size and annual shipment frequency, determines the transport chains (legs, modes/vehicles/cargo type), and empty flows. Furthermore it can aggregate to OD flows and produce logistics costs at the PWC level, taking into account the OD (chain) pattern. The outputs therefore are:

- Firm2firm.out: the file with the shipment size and transport chain information at the disaggregate firm-to-firm level. This contains: Origin-Zone, Origin-Firm, Destination-Zone, Destination-Firm, Commodity, Flow, Shipment Size, Chain-Type, Vehicle-Types for each leg, Chain-Node-Numbers, Shipment cost, Total cost per Year.
- Totaltonnes.dat. This file contains three tables corresponding to Import, Export and Domestic transport. Each table contains the total transport volume per commodity and chain type (aggregated over all firms and zones). Using this table, an Excel file Totaltonnes.xls is produced that contains the annual tonnes for each chain type by commodity type, both at the PWC level (one chain per shipment) and the OD level (possibly multiple legs per shipment, so road-road-road counts as three OD relations). This file can be used to inspect the shares of the transpport chains and of the transport modes and to compare these against the calibration data (it is also used to calculate the calibration factors). Furthermore It can be used to compare the total tonnes (at the PWC level) to the tonnes in the PWC matrices by commodity group to see whether tonnes are missing.
- Trips.dat: a file of OD flows in vehicle units by commodity type , including empty trips (labelled commodity=0). At the moment, the origins and destinations can be zones as well as transfer nodes. However, conversion files are available to convert transfer nodes into the corresponding zones and derive an OD matrix with zones only.
- Cost.dat: a generalised logistics costs matrix at the PWC level, taking into account all components of the logistic costs function, and adding over all legs of the transport

chains selected in the deterministic optimisation.[28] The total costs given here can be divided by the tonnes from the other output matrices to give costs per tonne.

By collecting all the OD legs from the transport chains determined above (including the empty vehicle flows) for all PWC flows at the zonal level (adding over firms and transfer locations that are in the same zone), we get OD flows. These can be expressed in tonnes and in vehicles. For assignment we prefer to have vehicle flows. These will be delivered to the clients, so that in the network model new optimal unimodal OD routes can be selected (given that only the rail assignment includes capacity effects, the route selection for the other modes will be equivalent to the routes used as inputs to the logistics module).

The run time for the Norwegian model was 3-7 hours (depending on the computer), but the Swedish model needed 2 days to run.

6.2 Results for the 2005 model

Norway

In total we have in the firm-to-firm file for Norway:

- 257 mln tonnes of domestic PWC flows
- 174 mln tonnes of import PWC flows
- 135 mln tonnes of export PWC flows.

The program allocated 131 mln tonnes of these to intrazonal flows (this is an overestimation of the real intrazonal flows, probably due to the matching of senders and receivers, which includes a selection of receiving zones for each sender; this needs to be checked for the 2006 model). These intrazonal PWC flows are not allocated a transport chain in the 2005 model.

For 1.4% of the domestic flows we could not determine a transport chain (this is caused by a change of zone number for one of the zones, resulting in a mismatch between zone numbers in the network inputs and in the PWC files).

70% of the export flows and 89% of the import flows did not get a transport chain because there were no available chain alternatives (this is due to the fact that we agreed with TØI and the clients that for Norway only chains that start/end with road transport would be taken into account, and for many international flows the road link abroad has not been coded). This will be remedied in the 2006 model.

The remaining PWC flows have been allocated to transport chains. One has to keep in mind that this is done purely on the basis of cost optimisation; for each shipment, the lowest cost chain (according to the network information combined with the cost models) is chosen. One should not expect the outcomes of this (uncalibrated) to produce a good match with observed market shares, since many other factors may play a role in the selection of transport chains than can be incorporated in our rather aggregate logistic cost

[28] In the 2006 model we also plan to use a unique tansport chain for each firm-to-firm relation or shipment, but simulated from a probabilistic model.

functions. In the 2006 model, disaggregate random utility models will be estimated on observede data. The alternative-specific contants and disturbance terms of these models can capture such other factors.

The most important transport chains turn out to be:

- Domestic:
    - direct road transport
    - road-road-road
    - road-sea-road
- Import/export:
    - Road-sea-road.

When we collect the tonnes by mode per leg (e.g. each tonne in road-sea-road contributes to sea transport once and to road transport twice), we obtain the following mode split (for domestic transport in Norway, at the OD level), before calibration:

- Lorry: model: 191 mln tonnes (77%), observed: 240 mln tonnes (91%)
- Sea: model: 52 mln tonnes (21%), observed: 19 mln tonnes (7%)
- Rail: model: 4 mln tonnes (2%), observed: 4 mln tonnes (2%).

The uncalibrated model therefore gives the correct amount of rail tonnes, is relatively close for road transport (too low) and produces too much sea transport. When we consider that most of the intrazonal flows (now without a transport chain) are by road, the lack of predicted tonnes by lorry will disappear. For sea transport we conclude that either the cost models depict sea transport as too cheap in Norway or that other factors than costs (e.g. reliability, flexibility) also play a role in mode choice.

In the calibration for domestic transport we calculated multiplicative factors by mode and aggregated (ten groups) commodity type and applied these to the uncalibrated model outcomes to reproduce the observed OD tonnes by mode. We did not use the calibration data for import and export because in the model too many international shipments did not get a transport chain.

For the import and export that did have at least one chain available, road-sea-road is highly dominant. Ferry transport did not get any tonnes (the same applies for domestic transport). In a costs minimisation procedure with many alternatives it can easily happen that some alternative will not be the lowest cost alternative for the whole range of choice situations evaluated (there always is at least one alternative that is cheaper). Testing by TØI revealed that the absence of ferry choices is indeed caused by the costs of ferry transport in the cost models. When these were lowered, ferry did get a non-zero share. Air transport was not selected either; this is probably too expensive in a pure costs minimisation as well. Air transport is chosen in practice not because of its costs advantages, but because of its speed, for specific time-sensitive goods. To model this properly we need specific commodity segments with high values of time. The program generated very few road-only chains for import and export, underestimating road transport flows crossing the Norwegian-Swedish border.

The first commodity (NEMO code 11, bulk food) has been analysed in more detail:

- The PWC base matrices have 4,430,000 tonnes for domestic (of which 855,000 intrazonal), the model gives 4,459,000 tonnes for domestic (of which 1,393,000 intrazonal).
- The PWC base matrices have 786,000 tonnes for import, the model gives 787,000 (of which 243,000 does not get a transport chain).
- The PWC base matrices have 196,000 tonnes for import, the model gives 92,000 (of which 41,000 does not get a transport chain).
- There is no transit for this commodity type in the PWC files or the model.

With respect to other commodities, the model does not include a large part of the flows for petroleum and gas, because flows to/from the continental shelf were excluded.

In the trips.dat file (OD matrix) we have 37 mln loaded road transport vehicles and 22 mln empty road vehicle trips, giving a share of empty trips in total trips of 37%. For consolidated legs within transport chains (e.g. road-road-road or road-sea-road), a shipment of say 2 tonnes only contributes to one-ninth of a vehicle that has a capacity of 20 tonnes (using 90% of the capacity for consolidated flows).

Sweden

For Sweden, the firm-to-firm file from the program contains:

- 161 mln tonnes of domestic PWC flows
- 38 mln tonnes of import PWC flows
- 44 mln tonnes of export PWC flows.

This is very close to the tonnes in the base matrix that we received from SIKA:

- Domestic: 160 mln tonnes
- Import: 47 mln tonnes
- Export: 46 mln tonnes.

The program allocated 37 mln tonnes of these to intrazonal flows, which is close to what is in the PWC base matrices for intrazonal flows (35 mln tonnes) In the 2005 model, these intrazonal PWC flows are not allocated a transport chain. Unlike for Norway, practically all other shipments could be assigned to a transport chain (in Sweden the restriction to use only chains starting/ending with road transport was not used).

The most important transport chains turn out to be:

- Domestic:
    - direct road transport
    - road-sea-road
    - road-rail
    - direct rail
    - rail-road
- Import/export:
    - Road-sea-road
    - Road-sea-rail-road
    - Road-rail-sea-road
    - Sea-road
    - Direct rail
    - Rail-road.

After collecting the tonnes by mode per leg, we obtain the following mode split for domestic transport within Sweden, at the OD level, before calibration:

- Lorry: model: 81 mln tonnes (48%), observed: 304 mln tonnes (82%)
- Sea: model: 16 mln tonnes (10%), observed: 12 mln tonnes (3%)
- Rail: model: 71 mln tonnes (42%), observed: 54 mln tonnes (15%).

The model for Sweden correctly predicts that Sweden has a considerably higher market share for rail than Norway. Even if most of the intrazonal flows would be road transports, the predicted number of tonnes transported by road would still be quite a lot smaller than the observed tonnes by road. In trying to explain this difference, one has to keep in mind that the model reproduces the tonnes from the base matrices at the PWC level quite well. The difference for road transport at the OD level then must be due to an underprediction of road-road and road-road-road flows (which count two/three times in terms of OD tonnes) and an underprediction of transports that use road transport as access and egress to road and rail transport[29]. A possible explanation for the underprediction of road-road and road-road-road chains is the low number of available road terminals in the Swedish terminal file. Only 51 of the zones in Sweden have a road terminal for one or more commodity types (by commodity type, there are even considerably fewer road terminals), according to this input file. For Norway, 287 zones have a road terminal for one or more commodity types. The predictions of the tonnes for sea transport and rail transport are much closer to the observed data, but there is an overprediction of direct rail (presumably because it is too cheap in the cost models).

[29] Unless the base matrices are missing tonnes that would have been allocated to road transport.

In the calibration for domestic transport we calculated multiplicative factors by mode and aggregated (ten groups) commodity type and applied these to the uncalibrated model outcomes to reproduce the observed OD tonnes by mode. As for Norway, we did not use the calibration data for import and export, for Sweden because we only have calibration data for sea transport. The predicted number of OD tonnes for import is 72 mln, whereas the statistics for sea, lorry on ship and train on ship have 71 mln tonnes in total. For export we predict 97 mln OD tonnes. The statistics for sea, lorry on ship and train on ship add up to 58 mln tonnes (but from the singular flows we would have to add at least 15 mln tonnes for direct rail from Kiruna). Both for import and export the model predicts about 20 mln tonnes for direct rail transport (distributed over several commodities, not concentrated on iron ore)

Ferry transport, which was added in the runs for Sweden in a very artificial way did only get a few hundred tonnes. We expect that –as for Norway- this is caused by too high costs of ferry transport in the cost models.

In the trips.dat file (OD matrix) we have 56 mln loaded road vehicles and 39 mln empty road vehicle trips. The share of empty trips therefore is 41%, which is rather high. The assumption used for nearby zones (50%) probably was too pessimistic (or the gradient at which this percentage declines with distance should have been steeper).

CHAPTER 7 Interim results on generalised costs matrices

By using the logistic cost function generalised logistic costs matrices can be calculated at the PWC zone-to-zone level. This can be done with new inputs from the network model (after assignment of the logistic model's OD flows), but if the network model outputs do not change in reaction to different OD flows (no supply-demand equilibration), then the initial network outputs with the cost functions can be used here. The demand flows calculated give the modes and number of legs (but now at the PWC level by adding over all legs of the kmn flow) and therefore will influence (in a sort of weighting procedure) the total logistics costs over all modes.

$$G_{mnql} = o.(Q/q) + X_{mnql} + J_{mnql} + r.j.g.v_k.Q_k + (r.t_{mnl}.v.Q)/365 +$$

$$(w + (r.v)).(q/2) + a \;.\; ((LT.\sigma_Q^2) + (Q^2.\sigma_{LT}^2))^{1/2}$$

Where:

o : the constant unit cost per order

Q: the annual demand (tonnes per year)

X_{mnql}: the link costs of all OD legs from m to n

J_{mnql}: the transhipment at all consolidation/distributions centres, ports, airports and intermodal rail terminals between m and n

q : the average shipment size.

r: the discount rate (per year)

j: the fraction of the shipment that is lost or damaged (might vary between modes)

g: the average period to collect a claim (in years)

v: the value of the goods that are transported (per tonne).

t: the average transport time (in days).

w: the storage costs per unit per year.

a: a constant to set the safety stock in such a way that there is some fixed probability of not running out of stock. For medium/high frequency products, a common assumption is that the demand (and lead-times) follows a Normal distribution.

a will then be: $a = F^{-1}(CSL)$, where F^{-1} is the inverse Standard Normal Distribution and CSL is the cycle service level, that is the probability that the stock will not be empty during a replenishment cycle.

LT: expected lead-time for a replenishment (time between placing the order and replenishment)
σ_{LT}: standard deviation for the lead-time

σ_Q : the standard deviation for the yearly demand,

The terms on the right-hand side stand for (respectively):

1. Order costs
2. Link-based transport costs
3. Transfer, consolidation/distribution centre costs
4. Costs of loss and damage
5. Capital costs during transport
6. Inventory and capital costs (at receiver)
7. Stockout cost (through costs of safetey stock).

The items 1 and 6 can be taken from the cost models (see Annex 3), in combination with the annual (firm-to-firm) demand Q and shipment size q calculated in the program. Items 2 and 3 can be calculated by combining the cost models with the network model output (e.g. distances, transport times, optimal intermodal transfer locations) and using the optimal transport chains selected by the program.

The cost of loss and damage of the goods is given by:

$$r.j.g.v_k.Q_k$$

The firm-to-firm flows Q come from the program, and for the value v of the goods per tonne we have received information for both Norway and Sweden per commodity class. For the other components r, j and g we have to make assumptions.[30]

In The Netherlands the average probability of deterioration or damage during transport from a not-fully-representative sample of firms is about 1 per 1,000 (RAND Europe, SEO and Veldkamp/NIPO, 2004). Vieira (1992) found in the US (by estimating on a sample of individual shippers) that in cost terms the product r.j was 1.74 per day, or 0.005 per year,

[30] In many ways this is only an approximation of the cost of loss and damage. In reality the damage often exceeds the amount that can be claimed and compensated. Also the goods damaged could constitute some remaining value.

which is equivalent to a 5% interest per year and 0.1 years to collect the claim. So for the cost of loss and damage we get:

$$0.000005.v_k.Q_k$$

The capital cost during transport can be calculated from:

$$(r.t_{mnl}.v.Q)/365$$

With Q and v from the sources described above, transport time t from the networks and an interest rate r of 5% (0.05 in the equation), this can be calculated.

For calculating the stockout cost we are lacking information on too many variables (lead time, standard deviation of lead time, standard deviation of demand, cycle-service level for 32/34 commodity groups). Therefore, in the 2005 logistics model, we have to leave this component out, and to use six of the above seven cost components. Maybe it will be possible to get emprical information or expert advice on this for the 2006 model.

To calculate transport cost per P(W)-C(W) pair, we add all transport costs for all OD-legs and transfers that are part of the selected optimal route for each firm-to-firm flow (with a specific shipment size). We aggregate these costs over all shipments and firms and obtain the total logistics costs between a production (wholesale) zone and a consumption (wholesale) zone, as well as the average on a per tonne basis (average costs per shipment would also be possible). If desired we can also provide these costs separately for each of the six costs items used.

CHAPTER 8 Summary and conclusions for Parts A and B

8.1 Further model specification and data requirements for the 2006 model (Part A)

In RAND Europe et al. (2004), the new logistics model, that will become part of the Norwegian and Swedish national freight model systems, was specified. The envisaged new logistics component will contain disaggregate choice models for a number of logistic decisions (including shipment size, mode choice and the use of consolidation and distribution centres). It will read in commodity flows for the base-year (around 2001) from production and wholesale to consumption and wholesale (PWC matrices) and provide inputs for network assignment and logistics costs for the production of new PWC matrices. The data requirements of this model were specified in this deliverable 4, extending an earlier deliverable (D1a). This also included a comparison with available data and specification of missing variables and of surveys to collect missing variables. New data will be collected between now and the summer of 2006. After this, the specified model will be estimated for Norway and Sweden, probably simultaneously to benefit from differences in the data availability situation in both countries.

A number of specification issues needed to be worked out further and some other specification issues had to be revisited. Both of this has been done in deliverable 1b, which can be regarded as an Addendum to the 2004 specification report. In D1b, we did not cover the entire model specification, but focussed on the aspects that needed extra detail or a different formulation. In the current D4, we provided a summary and extension/update of D1b.

The logistics module will work with 32 (Norway) and 34 (Sweden) commodity classes, although not all data sources and model system components (e.g. the network models of the Norwegian and Swedish model systems) currently can provide information at this level. In model estimation, we intend to use the classifications at different levels to search for similarities and differences in behavioural coefficients. We plan to use different structures for joint inventory and transport optimisation, and for transport optimisation (with and without constraints). Within each of these structures, different commodity groups (and countries) can have (but not necessarily will have; this is an empirical question) different coefficient values.

Different types of optimisation behaviour (joint optimisation on inventories and transport costs, transport cost minimisation only and transport cost minimisation with time constraints) have been distinguished. Also, stereotypes on this and on the key decision-maker in the supply chain from producer (P) to consumer (C, can be retail), producer to wholesaler (W) and from wholesaler to consumer have been identified for each of the Swedish and Norwegian commodity classifications. For most commodity types in Sweden and Norway, in P-W flows the key decisions (mostly inventory and transport, sometimes only transport) are made by the W side, and in P-C and W-C flows the key decisions are made by the C side.

Singular flows are large commodity flows that will remain stable (e.g. in terms of modes and ports used) at least in the short to medium run. Such flows will be subtracted from the PWC flows first (and then treated as fixed), before the modelling. A number of such flows have been identified, characterised and quantified in Norway and Sweden.

In the allocation of zone-to-zone flows to firms (step A) we need to identify the receiver, because this is the key logistic decision-maker for most supply chains. However, we also need to determine the sender for each flow, since inventory optimisation will take place per supplier, not for all (heterogeneous) goods within a commodity class together. A procedure was developed for the allocation to firms.

The equations for the safety stock for medium-high frequency products have been presented, as well as the consequences this has on logistic optimisation. It is proposed to use this formulation instead of the one for low frequency items (as was also used in RAND Europe et al., 2004), maybe with some exceptions for low frequency items and seasonal products in later stages. Also, the optimal shipment size equations have been given, taking account of the fact that receivers get different products from different suppliers.

Seven different cargo units (e.g. containers, pallets and boxes) have been distinguished, as well as fourteen to sixteen different mode and vehicle/vessel type combinations. We recommend to use these categories for the logistics module to be developed in 2006/2007 (and already used these as much as the current data allowed for the 20005 initial logistics module).

The logistics module (both 2005 and 2006/2007 versions) will produce flows in terms of numbers of vehicles and vessels and will use as inputs (amongst other inputs) transport costs per vehicle. The current network model routines in Norway and Sweden produce costs by mode and commodity group (twelve or thirteen classes) per tonne. To get transport costs per vehicle/vessel type these need to be multiplied by the average vehicle/vessel load per commodity type. This procedure does not take account of the fact that the costs per tonne decrease as one moves from smaller to larger vehicles or vessels. Also it does not give different costs for different cargo units. For the 2005 version we therefore combined the network model outputs with outcomes from costs models/standard calculation rules to get the required differentiation. For the later version of the logistics module, we recommend that the network routines be revised to produce transport costs per vehicle, with a differentiation between vehicle/vessel type and cargo unit, but there will remain to be scope for cost models/standard calculation rules to derive inputs for the many vehicle/vessel types and cargo units distinguished.

The port and airport access and egress abroad will be handled the same way as domestic transport, although the foreign zones sometimes are very large (especially for the

Norwegian model) and the networks abroad less detailed. International transit flows that the base matrix teams will produce will be allocated to international and domestic infrastructure. The empty vehicle flows will not be based on the loaded flows in the same direction, but on the reverse flows of the different commodity classes. This goes for both the initial and full version of the logistics module.

8.2 The 2005 logistics model (Part B)

An initial version of the logistics module (the 2005 model) was developed using available data. The new distinction in 32/34 commodity types is already used in this model, as are detailed classifications by vehicle/vessel type for road, sea, rail and air transport (also encompassing distinctions by cargo unit).

When comparing the singular flow volumes in tonnes, obtained from the large manufacturing companies, with the PWC matrices for Norway and Sweden for the same commodity types, we found serious inconsistencies. Often the companies provided information on flows between their plant and a port; these are not proper PWC flows, but OD flows. However, if we sum all the PWC flows that depart from the production zones of singular flows, in many cases we get a total PWC flow (of all senders) that is only a small fraction of the flow from the single large sender. Conversely, if we sum all the PWC flows to a particular zone that has a large consuming firm, we also get (for the relevant commodity group) volumes that are several times smaller than received by the single large firm. This makes it impossible to subtract the singular flows from the PWC matrices (that would result in some very small and some highly negative goods flows). We decided not to subtract the singular flows from the PWC flows for the 2005 model. Also we recommend that the base matrix teams in Norway and Sweden compare their data to the singular flow volumes from the interviews with large manufacturers.

The 2005 model already contains a disaggregation of the zone-to-zone flows of the PWC matrices to firm-to-firm flows (step A of the logistics module). This disaggregation will be used as the starting point in the development of the full 2006 logistics model: in 2006, the current disaggregation procedure will be scrutinised and where possible, assumptions and shortcuts will be replaced by empirical evidence. Particularly, this concerns the number of receiving firms per sender (and number of senders per receiver).

For the 2005 model, we assigned the P(W) side in Norway to 108,000 firms (senders) and the C(W) side to 391,000 firms (receivers). After that, we generated 24 mln firm-to-firm flows for Norway is 24 mln. This number refers to annual flows (business relationships), each of which can consist of several shipments. In the program these are 24 mln records. For Sweden we assigned we assigned the P(W) side to 183,000 sending firms and the C(W) side to 463,000 receiving firms. The number of firm-to-firm flows generated for Sweden is 98 mln.

In the 2005 model, the logistics choices (step B) were handled through normative cost minimisation (importing coefficient values instead of model estimation). The 2005 logistics model simulates all annual firm-to-flows in/to/from a country and allocates these to shipments of a certain size, and to transport chains. For the determination of shipment size, simplifying assumptions were used as well in 2005 (especially on a fixed shipment size for several commodity types, independence from transport costs and uniform shipment size per firm-to-firm flow). These issues will be revisited in the 2006 model and based on empirical data as much as possible.

The transport chains are characterised by:

- The number of legs (one to four) from sender to receiver;
- The mode in a broad sense for each leg: modes in strict sense (Norway: road, sea, rail, ferry, air transport; Sweden: road, sea, rail, combi; will be extended in 2006), vehicle/vessel types and cargo units (e.g. containerised);
- The locations for changing modes (ports, airports, railway terminals) and for changes within road transport (consolidation and distribution centres).

For the 2005 model, the intermodal transfer locations were provided by the network models. The optimal locations for transfers within the road system were determined in an initial optimisation step within the logistics model. The number of legs and the mode, vehicle/vessel type and cargo type were allocated in a subsequent step, by deterministic cost minimisation.

The 2005 model first provides a file with the shipment size and transport chain information at the disaggregate firm-to-firm level. The predicted OD flows were calibrated to aggregate mode share data by commodity type. After aggregation the model provides:

- A file with three tables corresponding to Import, Export and Domestic transport. Each table contains the total transport volume per commodity and chain type (aggregated over all firms and zones).
- A file of OD flows in vehicle units by commodity type, including empty trips.
- A generalised logistics costs matrix at the PWC level, taking into account all components of the logistic costs function, and adding over all legs of the transport chains selected in the deterministic optimisation.

For Norway, the model produces a fairly good allocation to transport chains with the largest shares for direct road transport (domestic), road-road-road chains (domestic) and road-sea-road chains (domestic and international). Sea transport (non-ferry) is overpredicted and ferry transport and air transport get a zero market share. We expect that with estimation of random utility models on disaggregate data and differentiation in coefficients (e.g. on the importance of time components) by commodity this can be improved. Also sensitivity checks with the model for Norway that TØI carried out (changing road transport costs, transfer costs) produce reasonable results.

The model for Norway does not generates transport chains for many flows that are in the PWC matrices. The main reasons for this are the following:

- Intrazonal and transit flows were not included in the 2005 model (but will be in 2006)
- For many international flows we did not have network input because we had to restrict ourselves to transport chains with road transport for the first/last leg (this can easily be solved for the 2006 model).
- Flows to/from the continental shelf were not included.

For Sweden the only major difference between the PWC base matrices and the PWC flows from the model are that the latter excludes intrazonal transport.

The most important transport chains in Sweden are according to the model: direct road (domestic), road-sea-road (domestic sand international) and chains with rail transport (domestic and international). The model thus predicts a higher market share for rail in Sweden than for Norway, which is in line with the actual market shares. The model underpredicts the amount of road vehicle trips, possibly because it does not produce sufficient chains with more than one road transport leg. Transfers within the road system are not very attractive in the Swedish model because only a limited number of road terminals has been coded. We recommend to collect and include more information on road terminals in Sweden. As for Norway, ferry and air transport receive a zero market share.

The full model will be developed and validated in 2006 and 2007. Here, the coefficient values will be the results of estimating the discrete choice models on disaggregate data. In application the logistics model already is a micro-simulation model, simulating all the firm-to-firm commodity flows in a country, and so will the final model.

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Annex 1: logistics chain alternatives in the CFS

In the logistic model specification, mode h indictes not just road/rail/water/air, but also vehicle/vessel type and size and cargo type. But if we aggregate to modes in the strict sense:

1 - road;

2 - rail;

3 - water; and

4 - air,

we then can specify the transshipment location alternatives as depicted in Table 28.

Table 28 - Mode chains and transshipments

Mode chain	Transshipment location chain alternatives (CC=consolidation centre, DC=distribution centre, RT=intermodal rail terminal number indicates leg in chain)
1	Direct, CC1, DC1, CC1+DC2
2	Direct
3	Direct
4	Direct
12	RT1
21	RT1
121	RT1+RT2
13	Port1
31	Port2
131	Port1+Port2
14	Airport1
41	Airport1
141	Airport+Airport2

The choice from available alternatives for a CC is determined by the minimum transport costs from the P (W) location (possibly with some random error). Similarly the DC is chosen on the basis of the minimum transport costs to the C (W) location. This choice could be different for different commodity types and different cargo units (if the data would allow this). The same method applies to ports, airports and intermodal rail terminals: they are chosen on the basis of transport costs minimisation at either the sender or receiver end.

From an initial analysis of the Swedish CFS 2001, we find that most shipments use only one (of the nine available modes in CFS) mode (especially road transport). Some use two or three modes. There are no sequences of four or more aggregate modes that have more than 1,000 observations in the CFS (of more than 900,000 shipments in total), even when we combine the modes in Sweden and those abroad. So, it is possible to simplify the logistics chain choice model considerably and still represent almost all shipments by setting the maximum number of modes in a logistic chain at three and the maximum number of transhipment locations a two. When further aggregated from the nine CFS modes to the four modes (road, rail, water, air), we obtain the mode chains as in the Table 28 above. So this table includes all the important mode chain alternatives in the CFS.

There can also be chains at the more detailed mode level that are not apparent when using the aggregates road, rail, water and air. An example is a chain: sender-small truck-consolidation centre-large truck-distribution centre-small truck-receiver (see the first row of the table).

Chains with more than three legs (e.g. road-rail-sea-road) could be included in the logistics module (the model specification allows for this); the issue is whether the data (especially the CFS) will be able to support this.

Annex 2. Number of receivers per sender

The actual number of receivers per sender is hard to estimate, due to lack of proper statistics covering this issue. Also from the point of making expert judgements based on experience, there are several issues that make this complicated to estimate:

- Large variations, depending on cargo category (and industry). For example, for companies delivering raw materials, there would tend to be rather few receivers, while companies supplying ordinary consumption materials like for example office supplies would tend to have a fairly large number of receivers
- The number tends to increase as we move downstream in the supply chains. There would typically be more receivers from a company on the W-level, than on the P-level, and the closer the production gets to the consumer level, the more receivers would we have
- Size of the company obviously will have an impact – the larger a company is within its industry, the more customers and thereby receivers would there be a tendency to have; as well as a large company would tend to have more suppliers than a small one (within the same industry).
- Pareto ("80/20") effects; there would normally tend to be a rather biased distribution of receivers with a small part taking a major part of the delivered volume, while a large number of receivers only take smaller volumes

General estimates must therefore be treated as indications only, with large variations between companies.

The indications of numbers below should be taken as subjective estimates, and with all the reservations made above. To the extent the numbers are used, they should only be taken as reflecting estimates of the number of magnitude for "average" companies, and special adjustments should be made for the very large and very small companies within a group. Further, the deliveries might be considered distributed according to a statistical distribution reflecting the bias in delivery shipments between various customers. For the 2006 model, it might be worthwhile to gather some data from samples within each category to get more firm estimates for the number of customers, also as a function of company size.

Table 29 - Number of firm-to-firm relations

		Receivers per sender - domestic	Receivers per sender - export	Senders per receiver - imports
11	Bulk food	50	30	50
12	Consumptions food	500	100	50
13	Beverages	1000	200	10
21	Fresh fish	150	30	10
22	Frozen fish	150	30	10
23	Other fish	100	20	5
31	Thermo input	30	30	30
32	Thermo consumption	150	20	20
41	Machinery and equipment	100	50	50
42	Vehicles	30	30	20
51	General cargo - high value goods	1000	200	200
52	General cargo - live animals	15	10	10
53	General cargo - building materials	500	50	100
54	General cargo - other inputs	500	50	100
55	General cargo - consumptions goods	2000	50	100
61	Timber - "Saw logs"	15	10	10
62	Timber - "Round logs"	15	10	10
63	Pulp	5	15	10
64	Paper intermediates	10	30	20
65	Wood products	300	100	20

66	Paper products	50	25	20
71	Mass commoditites	10	20	10
72	Coal, ore and scrap	10	20	10
73	Cement, plaster and cretaceous	200	20	50
74	Non-traded goods	10	0	10
81	Chemical products	40	100	400
82	Fertilizers	20	100	10
91	Metals and metal goods	300	100	40
92	Aluminium	10	250	5
101	Raw oil	0	5	2
102	Petroleum gas	0	5	2
103	Refined petroleum products	2000	100	50

Rough expert judgement estimate – Norwegian conditions

		Receivers per sender - domestic	Receivers per sender - export	Senders per receiver - imports
1	Cereals	70	42	70
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	700	140	70
3	Live animals	21	14	14
4	Sugar beet	150	30	10
5	Timber for paper industry (pulpwood)	15	10	
6	Wood roughly squared or sawn lengthwise, sliced or peeled	420	140	28
7	Wood chips and wood waste	100	10	2
8	Other wood or cork	100	10	2
9	Textiles, textile articles and manmade fibres, other raw animal and vegetable materials	700	18	35
10	Foodstuff and animal fodder	70	42	70
11	Oil seeds and oleaginous fruits and fats	70	42	70
12	Solid mineral fuels	1000	20	10
13	Crude petroleum	0	5	2
14	Petroleum products	2800	140	70
15	Iron ore, iron and steel waste and blast-furnace dust	100	50	15
16	Non-ferrous ores and waste	100	50	15
17	Metal products	420	140	56
18	Cement, lime, manufactured building materials	280	28	70
19	Earth, sand and gravel	100	5	10
20	Other crude and manufactured minerals	14	28	14

21	Natural and chemical fertilizers	28	140	14
22	Coal chemicals, tar	14	28	14
23	Chemicals other than coal chemicals and tar	56	140	560
24	Paper pulp and waste paper	7	21	14
25	Transport equipment, whether or not assembled, and parts thereof	42	42	28
26	Manufactures of metal	420	140	56
27	Glass, glassware, ceramic products	2800	70	140
28	Paper, paperboard; not manufactures	70	35	28
29	Leather textile, clothing, other manufactured articles than paper, paperboard and manufactures thereof	2800	70	140
30	Mixed and part loads, miscellaneous articles etc	700	70	140
31	Timber for sawmill	21	14	14
32	Machinery, apparatus, engines, whether or not assembled, and parts thereof	140	70	70
33	Paper, paperboard and manufactures thereof	70	35	28
34	Used packaging materials	14	0	14

Rough expert judgement estimate – Swedish conditions

Annex 3. The cost models

Introduction

Cost functions covered

This Annex describes cost models for transportation units, generally termed "vehicles". They are established for use in the the logistics model in Norway and Sweden.

The cost models are preliminary, and there may be further adjustments. However, the cost models could be (and have been) applied as a first version for vehicle costing in the prototype for the logistics model.

The objective of the annex is to provide cost parameters and cost functions that could be used in the logistics model for:

- Costing of vehicles (regardless of cargo) per km and per hour;
- Costing of loading, unloading and transfer of goods in terms of cost per ton;
- Establishing feasibility as to which vehicles can be used for which cargo;
- Preliminary costing of inventory holding (per cargo group) and average ordering cost.

The cost functions should enable for realistic vehicle choices in the logistics model. However, it is obviously beyond the scope of this annex to cover all possibilities for vehicle choices that exist in reality.

The objective for the cost models is to enable more differentiation between transport modes, units and cargo, than what is feasible within the network models. The basis for transport cost is vehicles as basic units. The models themselves are contained in a set of separate documents in a spreadsheet format (Excel). One set is for Norwegian conditions, and one set is for Swedish conditions.

The following cost elements are included:

1) Cost for modes, vehicle types, cargo units (containerised or not)
2) Cost calculation models for terminals: loading, unloading and transfer
3) Inventory holding cost and ordering cost related to generation of new shipments

The cost models are in principle as outlined in Figure 10 below. The structure of the cost models is outlined below. In this figure, the red line depicts the suggested interface between the cost models and the logistics model. The cost functions will be time and distances based and will give the specific vehicle cost for a each OD pair. The cost function incorporates three functions as can be seen below:

> Cost vehicle = f_1(distance) + f_2(time) + f_3(additional fixed cost for a given OD (tolls, pilot charges, etc.)).

This projects delivers the two first components: f_1(distance) + f_2(time). The third component results directly from the network models.

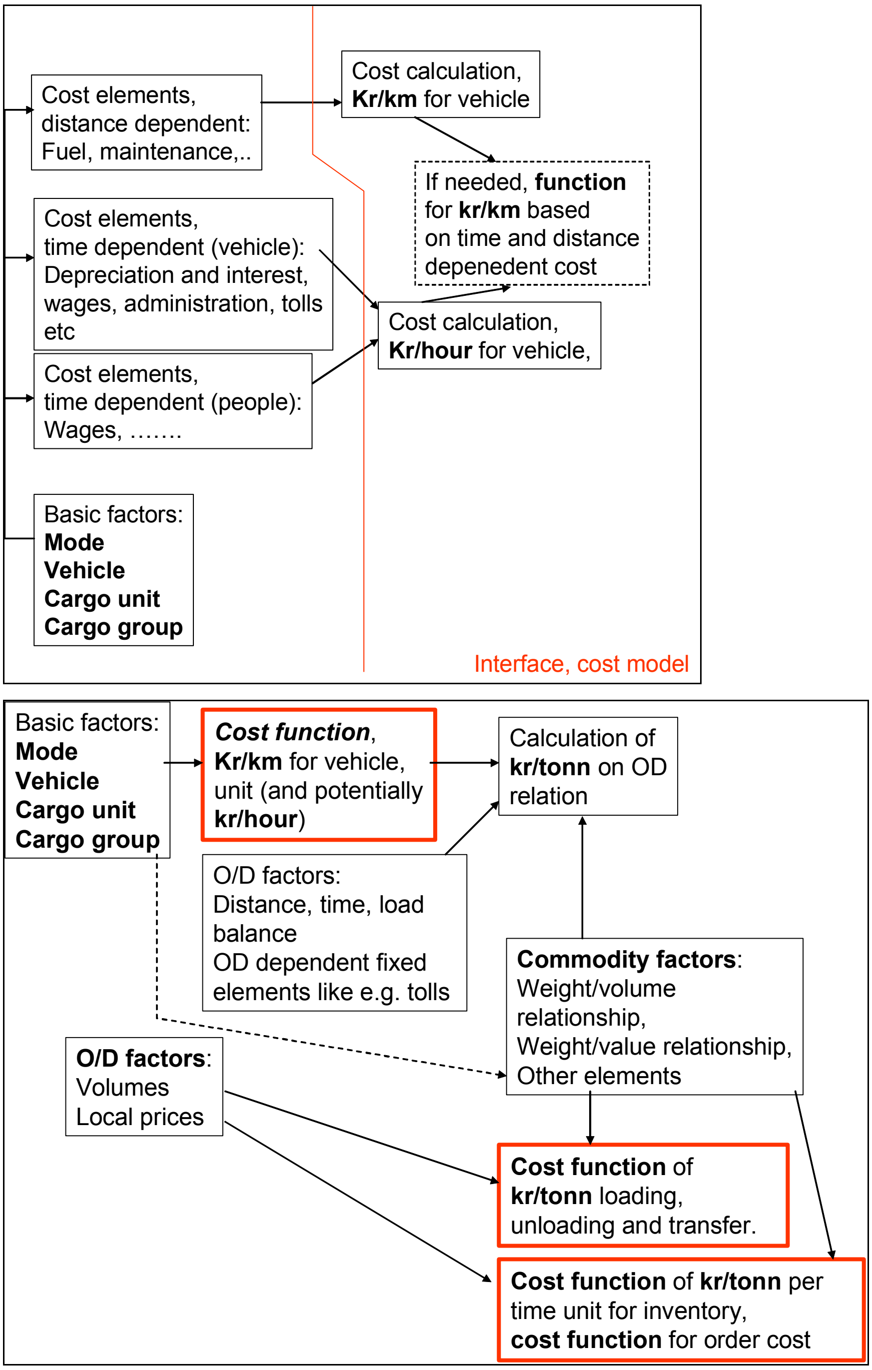

Figure 10 – Interface between cost functions for logistics model, and other cost parameters

The logistics model is depicted on the right side of the red line in the upper part of Figure 10. The cost functions to be used are presented in the red borded squares in the lower part of the figure.

Distance travelled influences the cost mostly through its effect on utilisation of the vehicle. A cost element that decreases with increasing distance are the terminal cost per km. In absolute terms however, these cost remain the same as total terminal cost are distance independent. In the study, the non-distance dependent cost, such as terminal cost, will be treated separately and are not included in the equations for the distance dependent part. Time dependent cost, such as vehicle and driver cost related to terminals, will be included in this time dependent part. (Alternatively these costs could be allocated to the trip thereby generating degressive unit cost per km.)

There are in general difficulties in allocating costs to distance and time, given their correlation. Another issue is also the allocation of fixed cost, and to what extent the fixed costs really enter into optimisation decisions. However for the practical use in the logistics model, the methods used in this annex should give a feasible allocation of the various cost elements.

Advantages of scale of larger vehicles/vessels are imbedded in the cost functions. Of course advantage of scale of using larger transport units can only be reaped when sufficiently utilising capacity.

A general problem in determining representative cost for use in the model is that in real life several of the components will actually fluctuate quite strongly over time due to the market situation. Although this is particularly true for the time charter (TC) rates in the shipping markets, it also holds for the other components due to the competitive marketplace for transport operators. In designing the cost models, these variations have been smoothened by using long-term averages for TC-rates and by using representative vehicles as a basis for the calculations. However, in practice forwarders' prices will deviate from our calculations.

Other factors that can influence cost are fluctuations in currencies and fuel prices. The calculation uses current values, which are global parameters in the models and can easily be adjusted.

The cost tables in this annex present costs in Swedish Kroner (SEK) for Sweden and in Norwegian Kroner (NOK) for Norway unless stated otherwise. When reffering to weight in tons, we refer to metric tons.

Detailed spreadsheet documentation

More detailed documentation and calculations are provided in two sets of (excel) spreadsheet files; one set per country[31]. Since not all spreadsheet cells contain references to other cells, some cells will require uypdating in order to update the calculations. The naming of the sheets is intended to simplify determining which cells need updating and which information can be found on which sheet. The following spreadsheets are available:

[31] Since these spreadsheets contain crossreferences, they should be kept together for future use.

Table 30 - Overview of associated spreadsheets

Files Norway	Files Sweden	Contents
Basic parameters NO	Basic parameters – SE	Contains the basic parameters for the calculations as wages, currency levels, fuel prices in international markets etc. These are the parameters that should be updated from time to time. The linked spreadsheets will then be automatically updated.
Air-freight cost – NO	Airfreight cost – SE	Calculation of air vehicle cost
Cost models – road – no	Cost models – road – SE new STAN – rev290905	Calculation of cost models for road vehicles
Cost models – sea - NO	Cost models – sea - SE	Cost calculations for the various sea vessels ("sea vehicles")
Cost models – ferries – NO	Cost models – ferries – Sweden	Cost calculations for ferries
inventory cost – no	inventory cost – se –rev STAN – rev 28102005	Inventory cost (order cost and holding cost) calculations
rail cost no	rail cost SE	Cost calculations rail
terminal cost - no	terminal cost – SE	Cost calculation loading and unloading cost for different modes and vehicles
transfer cost – no	transfer cost – SE	Cost calculations of transfer cost between various vehicles within the same mode, and across modes
havnekostnader – avgifter – no – kladd	havnekostnader – avgifter – kladd	Background material for calculation of terminal costs, not to be used directly, but must be kept because they contain linked information
Summary spreadsheet – Norway – 28102005-b	Summary cost Sweden – rev STAN – rev 28102005	Summary spreadsheets for all cost calculations except transfer costs
Summary transfer cost – no	Summary transfer cost – SE	Summary spreadsheets for transfer costs

The spreadsheet files listed above are not referred to in detail in the annex, although the tables shown in the annex are extracted and copied from them. Generally cost parameters are listed in the spreadsheet files "basic parameters" (NO and SE).

Some costs have been assumed based on market assumptions, such as the TIC-markets for ships. This implies that there may be a need to update data elements additional to those listed in the basic parameters. The update can then be done directly in the respective sheets related to the mode/vehicles.

The spreadsheet documentation of the model will be revised in 2005, bringing it to a more user friendly format for further calculations:

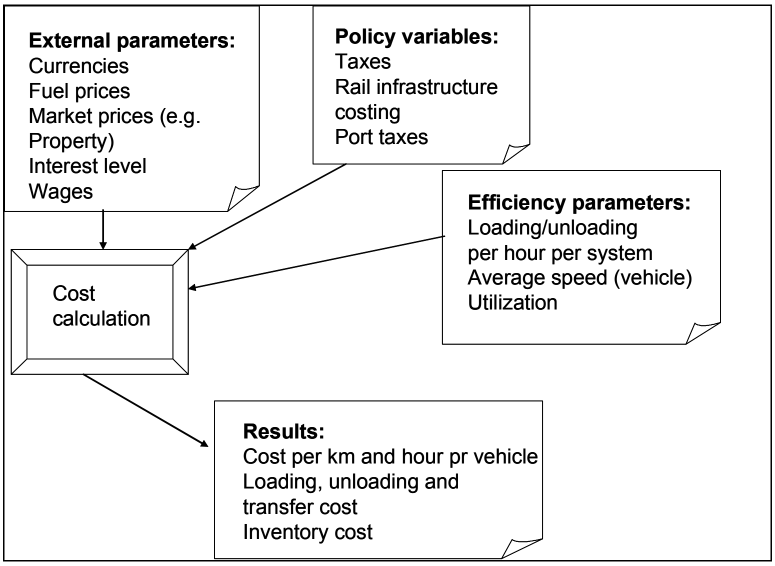

Figure 11 - Overview of future structure for spreadsheets.

Acknowledgements

The cost models incorporate data from several sources. In addition to aggregate data from case studies in Norway and Sweden, the following sources have also provided data:

- Fearnleys (freight rate statistics);
- Platous (freight rate statistics);
- SIKA (previous calculations of freight cost models);
- TØI (previous calculations of freight cost models);
- LO (Swedish transport employee wages);
- SSB (Norwegian transport employee wages);
- Leaseplan (cost data for trucks);
- Car manufacturers/importers (provision of data for special trucks, particularly by MAN);
- Foss, Virum - Transportlogistikk (data related to efficiency of loading/unloading operations and technical data on transport means);
- Wergeland, Wijnholst - Shipping (data on ships);
- Wilson, Seatrans, Lyseline, and DFDS Tor;
- Jernbaneverket and CargoNet;
- Swedish and Norwegian ports (port cost and dues);
- Norsk Petroleumsinstitutt (data on loading and unloading capacities).

Trucks

Feasibility of vehicles

Cost models have been developed for the following set of trucks:

Vehicle type
LGV
Light distribution
Heavy distribution closed unit
Heavy distribution for containers, spec. Cont
Articulated semi - total - closed
Articulated semi - with container
Heavy combination
Heavy combination with container
Tank truck with hanger
Semitrailer, tanker oil products
Tank truck with hanger (chemicals)
Semitrailer, tanker liquid bulk
Tank dry bulk truck with hanger
Semitrailer, dry bulk products
Timber truck with hanger (4 axles)
"Flis" truck with hanger (4 axles)
Semitrailer, "Flis"
Thermo Truck with hanger
Semi, thermo

The category 'Heavy combination' is only included for Sweden, as this is not a relevant size for Norway. For Norway, the relationship between the Nemo 32 categories and the feasibility of the various categories is given in Table 32. Table 31 lists the Nemo 32 categories.

Table 31 – NEMO categories

New Nemo category	Description	New Nemo category	Description	New Nemo category	Description
11	Bulk food	52	General cargo - live animals	72	Coal, ore and scrap
12	Consumptions food	53	General cargo - building materials	73	Cement, plaster and cretaceous
13	Beverages	54	General cargo - other inputs	74	Non-traded goods
21	Fresh fish	55	General cargo - consumptions goods	81	Chemical products
22	Frozen fish	61	Timber - "Saw logs"	82	Fertilizers
23	Other fish	62	Timber - "Round logs"	91	Metals and metal goods
31	Thermo input	63	Pulp	92	Aluminium
32	Thermo consumption	64	Paper intermediates	101	Raw oil
41	Machinery and equipment	65	Wood products	102	Petroleum gas
42	Vehicles	66	Paper products	103	Refined petroleum products
51	General cargo - high value goods	71	Mass commoditites		

Table 32 - Feasibility – road vehicles Norway

Vehicle type	New Nemo category																															
	11	12	13	21	22	23	31	32	41	42	51	52	53	54	55	61	62	63	64	65	66	71	72	73	74	81	82	91	92	101	102	103
LGV	na	ok	ok	na	na	na	na	na	ok	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Light distribution	na	ok	ok	na	na	na	na	na	ok	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Heavy distribution closed unit	na	ok	ok	na	na	na	na	na	ok	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Heavy distribution for containers, spec. cont	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Articulated semi - total - closed	na	ok	ok	na	na	na	na	na	ok	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Articulated semi - with container	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Tank truck with hanger	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok
Semitrailer, tanker oil products	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok
Tank truck with hanger (chemicals)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	na	na	na	na	na
Semitrailer, tanker liquid bulk	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	na	na	na	na	na
Tank dry bulk truck with hanger	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	ok	ok	na	ok	na	na	na	na	na
Semitrailer, dry bulk products	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	ok	ok	na	ok	na	na	na	na	na
Timber truck with hanger (4 axles)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
"Flis" truck with hanger (4 axles)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	ok	na	na	na	na	na	na	na	na	na	na
Semitrailer, "Flis"	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	ok	na	na	na	na	na	na	na	na	na	na
Thermo Truck with hanger	na	na	na	ok	ok	ok	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Semi, thermo	na	na	na	ok	ok	ok	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Similarly, for the new Swedish STAN 34, the feasibility is as presented in Table 33, with the list of STAN codes given in Table 34.

Table 33 - Feasibility – road vehicles Sweden

Vehicle type	New Stan category																																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
LGV	na	ok	na	ok	na	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Light distribution	na	ok	ok	ok	na	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Heavy distribution closed unit	na	ok	ok	ok	na	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Heavy distribution for containers, spec. cont	ok	ok	na	ok	na	na	na	ok	ok	ok	ok	ok	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Articulated semi - total - closed	na	ok	ok	ok	na	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Articulated semi - with container	ok	ok	na	ok	na	na	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Heavy combination	na	ok	ok	ok	na	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	na	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Heavy combination with container	ok	ok	na	ok	na	na	ok	ok	ok	ok	ok	ok	na	na	ok	ok	ok	ok	na	ok	ok	na	na	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok
Tank truck with hanger	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Semitrailer, tanker oil products	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Tank truck with hanger (chemicals)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	na	na	na	na	na	na	na	na	na	na
Semitrailer, tanker liquid bulk	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	na	na	na	na	na	na	na	na	na	na
Tank dry bulk truck with hanger	ok	na	na	na	na	na	na	na	na	na	na	ok	na	na	ok	ok	na	ok	ok	ok	ok	ok	na	na	na	na	na	na	na	na	na	na	na	ok
Semitrailer, dry bulk products	ok	na	na	na	na	na	na	na	na	na	na	ok	na	na	ok	ok	na	ok	ok	ok	ok	ok	na	na	na	na	na	na	na	na	na	na	na	ok
Timber truck with hanger (4 axles)	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	na	na	na
"Flis" truck with hanger (4 axles)	na	na	na	na	na	na	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Semitrailer, "Flis"	na	na	na	na	na	na	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Thermo Truck with hanger	na	ok	na	ok	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Semi, thermo	na	ok	na	ok	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 34 – STAN categories

STAN category	Description	STAN category	Description
1	Cereals	18	Cement, lime, manufactured building materials
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	19	Earth, sand and gravel
3	Live animals	20	Other crude and manufactured minerals
4	Sugar beet	21	Natural and chemical fertilizers
5	Timber for paper industry (pulpwood)	22	Coal chemicals, tar
6	Wood roughly squared or sawn lengthwise, sliced or peeled	23	Chemicals other than coal chemicals and tar
7	Wood chips and wood waste	24	Paper pulp and waste paper
8	Other wood or cork	25	Transport equipment, whether or not assembled, and parts thereof
9	Textiles, textile articles and manmade fibres, other raw animal and vegetable materials	26	Manufactures of metal
10	Foodstuff and animal fodder	27	Glass, glassware, ceramic products
11	Oil seeds and oleaginous fruits and fats	28	Paper, paperboard; not manufactures
12	Solid mineral fuels	29	Leather textile, clothing, other manufactured articles than paper, paperboard and manufactures thereof
13	Crude petroleum	30	Mixed and part loads, miscellaneous articles etc
14	Petroleum products	31	Timber for sawmill
15	Iron ore, iron and steel waste and blast-furnace dust	32	Machinery, apparatus, engines, whether or not assembled, and parts thereof
16	Non-ferrous ores and waste	33	Paper, paperboard and manufactures thereof
17	Metal products	34	Used packaging materials

Cost models

The cost models for Norway and Sweden are based on respectively 17 and 19 different truck types in terms of size and configuration. To determine the depreciation periods, expected re-sale/scrappage values and market data were used. Maintenance cost were estimated and used for the various truck types based on several alternative km/cost relationships. As an example, the calculation for one of the truck types (Norway and Sweden) is shown below. For the complete calculations for Norwegian and Swedish cost, we refer to the separate spreadsheet calculations for each truck category.

Summarising, we have the following cost models per vehicle for road:

Table 35 - Cost models, road Norway

Vehicle type	Capacity	Cost per km, ex. VAT, incl. profit	
		Distance dependent	*Time dependent*
LGV	Max = 2	1.68	383.66
Light distribution	Max = 8,4	3.92	385.94
Heavy distribution closed unit	Max = 15,6	5.03	372.91
Heavy distribution for containers, spec. Cont	Max = 15,6	4.91	405.47
Articulated semi - total - closed	Av = 30, max = 42	6.11	413.30
Articulated semi - with container	Av = 30, max = 42	6.11	433.13
Tank truck with hanger	Max = 39,8	5.68	532.87
Semitrailer, tanker oil products	Max = 35,2	5.91	466.71
Tank truck with hanger (chemicals)	Max = 51,6	5.68	532.87
Semitrailer, tanker liquid bulk	Max = 45,6	5.91	466.71
Tank dry bulk truck with hanger	Max = 47,3	5.75	513.57
Semitrailer, dry bulk products	Max = 41,8	5.98	454.41
Timber truck with hanger (4 axles)	Max = 32	5.73	463.39
"Flis" truck with hanger (4 axles)	Max = 29,5	5.75	496.59
Semitrailer, "Flis"	Max = 31,5	5.98	449.15
Thermo Truck with hanger	Max = 30	5.64	485.31
Semi, thermo	Max = 32	5.98	456.17

Table 36 - Cost models, road Sweden

Vehicle type	Capacity	Cost per km, ex. VAT, incl. profit		Cost per km, incl. VAT, ex. profit	
		Distance dependent	*Time dependent*	*Distance dependent*	*Time dependent*
LGV	Max = 2	2.06	321.26	2.46	382.45
Light distribution	Max = 8,4	4.92	323.14	5.86	384.69
Heavy distribution closed unit	Max = 15,6	6.31	306.76	7.52	365.19
Heavy distribution for containers, spec. cont	Max = 15,6	6.18	345.15	7.36	410.90
Articulated semi - total - closed	Av = 30, max = 42	7.62	355.43	9.07	423.13
Articulated semi - with container	Av = 30, max = 42	7.62	379.14	9.07	451.36
Tank truck with hanger	Max = 39,8	7.10	481.30	8.45	572.98
Semitrailer, tanker oil products	Max = 35,2	7.28	408.07	8.67	485.80
Tank truck with hanger (chemicals)	Max = 51,6	7.10	481.30	8.45	572.98
Semitrailer, tanker liquid bulk	Max = 45,6	7.39	408.07	8.79	485.80
Tank dry bulk truck with hanger	Max = 47,3	7.18	460.09	8.54	547.72
Semitrailer, dry bulk products	Max = 41,8	7.36	394.56	8.76	469.71
Timber truck with hanger (4 axles)	Max = 32	7.15	404.94	8.51	482.07
"Flis" truck with hanger (4 axles)	Max = 29,5	7.18	441.42	8.54	525.50
Semitrailer, "Flis"	Max = 31,5	7.47	388.77	8.89	462.82
Thermo Truck with hanger	Max = 30	7.05	428.71	8.39	510.36
Semi, thermo	Max = 32	7.47	396.49	8.89	472.01
Heavy combination	50	7.98	463.82	9.49	552.16
Heavy combination with container	50	7.98	469.43	9.49	558.85

For vehicles with containers, the container costs are included in the vehicle cost/hour. The costs are based on average fuel consumption and will be elaborated upon further in the development of the models to easier differentiate between loaded and empty vehicles.

For loading and unloading of trucks the cost models are based on a combination of case materials and data on efficiency and cost of various loading/unloading equipment and methods.

The "adjusted cost" in kr/ton is a sum:

Direct cost loading + (hour/ton loaded)*(time cost for vehicle per hour)

Table 37 includes the profit element for the forwarders on top of their costs.

Table 37 - Loading or unloading cost road vehicles – Norway

	Incl. profit and ex. VAT			
	Cost per ton	Cost per hour, transport means	Adjusted cost per ton	Hour/ton
LGV	232	365	424	0.52
Light distribution	194	386	349	0.40
Heavy distribution	171	355	286	0.33
Heavy distribution - container	9	386	12	0.01
Heavy distribution - special container	9	387	12	0.01
Articulated semi trailer	171	394	299	0.33
Articulated semi trailer – container	9	413	12	0.01
Articulated semi trailer - spec. Container	9	389	12	0.01
Heavy combination (Sweden)	na	na	na	na
Heavy combination (Sweden)	na	na	na	na
Tank truck oil products, with hanger	4	507	9	0.01
Semitrailer oil products	4	444	9	0.01
Tank truck liquid chemicals, with hanger	4	507	9	0.01
Semitrailer liquid chemicals	4	444	9	0.01
Truck, dry bulk with hanger	6	489	14	0.02
Semitrailer dry bulk	6	433	13	0.02
Timber truck for with 4 axle hanger	12	441	28	0.04
"Flis" Truck, with hanger	6	473	14	0.02
Semitrailer - "Flis"	6	434	13	0.02
Thermo, hanger	134	462	230	0.21
Thermo, semi	85	434	138	0.12

Table 38 - Loading or unloading cost road vehicles – Sweden

	Incl. profit and ex. VAT			
	Cost per ton	Cost per hour, transport means	Adjusted cost per ton	Hour/ton
LGV	187	306	347	0.52
Light distribution	157	323	287	0.40
Heavy distribution	139	292	234	0.33
Heavy distribution - container	8	329	10	0.01
Heavy distribution - special container	8	330	10	0.01
Articulated semi trailer	139	339	249	0.33
Articulated semi trailer - container	8	361	11	0.01
Articulated semi trailer - spec. Container	8	333	11	0.01
Heavy combination (Sweden)	139	442	283	0.33
Heavy combination (Sweden)	8	447	11	0.01
Tank truck oil products, with hanger	3	458	8	0.01
Semitrailer oil products	3	388.64	7	0.01
Tank truck liquid chemicals, with hanger	3	458.38	8	0.01
Semitrailer liquid chemicals	3	388.64	7	0.01
Truck, dry bulk with hanger	5	438.18	12	0.02
Semitrailer dry bulk	5	375.77	11	0.02
Timber truck for with 4 axle hanger	9	385.65	23	0.04
"Flis" Truck, with hanger	5	420.40	12	0.02
Semitrailer - "Flis"	5	377.61	11	0.02
Thermo, hanger	111	408	195	0.21
Thermo, semi	70	378	117	0.12

Costs for loading and unloading containers do not include costs for stuffing (loading a container) and stripping (unloading a container). The costs of loading are defined to be incurred the moment a container is used for a given set of shipments. If somewhere in the transport chain goods are repacked from a conventional to a container unit, stuffing cost will be incurred. In the cost functions stuffing cost are only incurred as an additional loading cost for stuffing break-bulk cargo ("stykkgods") into a container. Stripping costs are incurred when finishing the last leg of a container transport, either by delivery to a final receiver or by transferring from a container to a conventional transport vehicle along the transport chain.

The cost of stuffing and/or stripping is not assigned for all loading or unloading operations of a containerised transport chain, but should be added to the cost the first time the container is loaded and the last time it is unloaded. For transfers between containerised and traditional break-bulk cargo, stuffing and stripping is incorporated in the transfer cost (see section on transfer cost).

For stuffing or stripping an additional cost of 145 NOK/tons and 119 SEK/tons are added for loading/unloading respectively in Norway and Sweden.

Examples of cost curves

Figure 12 illustrates economies of scale. Although this is merely an illustration of the effects, it is based on the cost models calculated above. The curve in the figure relates to conventional break-bulk cargo.

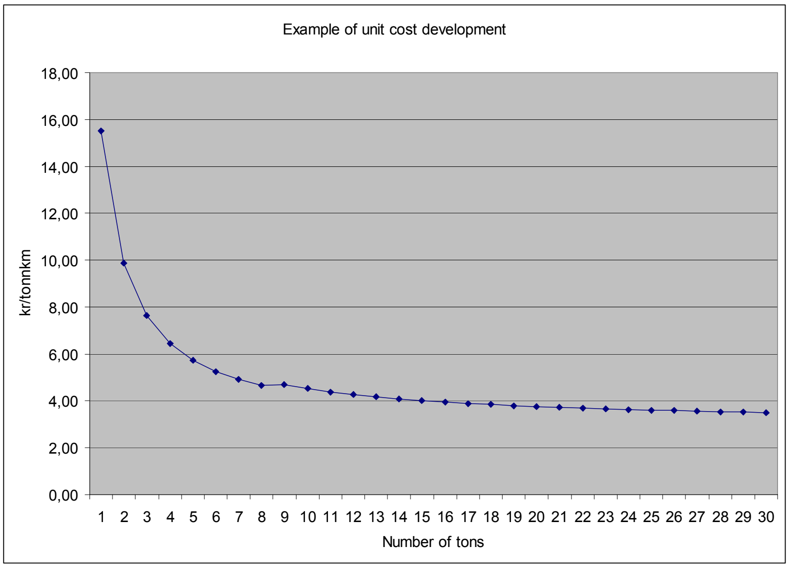

Figure 12 - Example of unit cost (cost per tonkm) development with shipment size, using most optimal vehicle

Sensitivity road cost

Based on a request from the Commissioners, we have looked at the sensitivity of the cost per km related to the occupancy of the vehicles. The cost figures calculated are average cost based on a large number of vehicles and their use, which is a mix of full, partly full and empty trips.

The difference in utilisation mostly impacts energy consumption. Based on an average rolling resistance of 130 N/ton and an average road inclination of 4% we can calculate the variations in cost per km (distance dependent cost) as shown in the tables below. We assume an average utilisation rate of 50%. Variations from 50% to full or empty vehicle are based on: the above relationships for rolling resistance and inclinations, its effect in terms of changed effects (kw or hp), and a consumption rate of 0,187 l/(hp*hr).

Table 39 - Effect of cost per km of occupancy (empty, average and max. tonnage) – Norway

	Cost differences per km compared with average			Deviations in %	
	100% full vehicle (based on tonnage)	Empty vehicle	Average cost per km	100% full vehicle (based on tonnage)	Empty vehicle
LGV	0,019	0,019	1,68	1,1%	-1,1%
Light distribution	0,078	0,078	3,92	2,0%	-2,0%
Heavy distribution closet unit	0,116	0,116	5,03	2,3%	-2,3%
Heavy distribution - for containers, spec Cont	0,097	0,097	4,91	2,0%	-2,0%
Articulated semi – total closed	0,261	0,261	6,11	4,3%	-4,3%
Articulated semi – with container	0,261	0,261	6,11	4,3%	-4,3%
Tank truck with hanger	0,247	0,247	5,68	4,3%	-4,3%
Semitrailer tanker oil products	0,218	0,218	5,91	3,7%	-3,7%
Tank truck with hanger (chemicals)	0,320	0,320	5,68	5,6%	-5,6%
Semitrailer tanker liquid bulk	0,283	0,283	5,91	4,8%	-4,8%
Tnak dry bulk truck with hanger	0,294	0,294	5,75	5,1%	-5,1%
Semitrailer dry bulk products	0,259	0,259	5,98	4,3%	-4,3%
Timber truck with hanger (4 axles)	0,199	0,199	5,73	3,5%	-3,5%
"Flis" Truck with hanger (4 axles)	0,183	0,183	5,75	3,2%	-3,2%
Semitrailer - "Flis"	0,196	0,196	5,98	3,3%	-3,3%
Thermo truck with hanger	0,186	0,186	5,64	3,3%	-3,3%
Semi, thermo	0,199	0,199	5,98	3,3%	-3,3%

Table 40 - Effect of cost per km of occupancy (empty, average and max. tonnage) – Sweden

	Cost differences per km compared with average			Deviations in %	
	100% full vehicle (based on tonnage)	Empty vehicle	Average cost per km	100% full vehicle (based on tonnage)	Empty vehicle
LGV	0,024	0,024	2,06	1,2%	-1,2%
Light distribution	0,101	0,101	4,92	2,0%	-2,0%
Heavy distribution closet unit	0,150	0,150	6,31	2,4%	-2,4%
Heavy distribution - for containers, spec Cont	0,125	0,125	6,18	2,0%	-2,0%
Articulated semi –total- closed	0,336	0,336	7,62	4,4%	-4,4%
Articulated semi – with container	0,336	0,336	7.62	4,4%	-4,4%
Tank truck with hanger	0,318	0,318	7,10	4,5%	-4,5%
Semitrailer tanker oil products	0,281	0,281	7,28	3,9%	-3,9%
Tank truck with hanger (chemicals)	0,412	0,412	7,10	5,8%	-5,8%
Semitrailer tanker liquid bulk	0,364	0,364	7,39	4,9%	-4,9%
Tnak dry bulk truck with hanger	0,378	0,378	7,18	5,3%	-5,3%
Semitrailer dry bulk products	0,334	0,344	7,36	4,5%	-4,5%
Timber truck with hanger (4 axles)	0,256	0,256	7,15	3,6%	-3,6%
"Flis" Truck with hanger (4 axles)	0,236	0,236	7,18	3,3%	-3,3%
Semitrailer - "Flis"	0,252	0,252	7,47	3,4%	-3,4%
Thermo truck with hanger	0,240	0,240	7,05	3,4%	-3,4%
Semi, thermo	0,256	0,256	7,47	3,4%	-3,4%
Heavy combination	0,399	0,399	7,98	5,0%	-5,0%
Heavy combination with container	0,399	0,399	7,98	5,0%	-5,0%

Sea

Cost models

The structure of the cost function for vessels are is similar to the ones for road in that it is divided into a time dependent element (the time-charter rate (TC)) and a distance dependent element.

The time cost (TC) for commonly used vessels, such as “box vessels” for lo/lo and bulk carriers, are derived from historical data for various sizes of vessels adjusted to the present level based on statistical indexes for TC-development in Scandinavian waters. A good description for the TC-rate as a function of size (NOK) was found to be:

$$y = x^*e^{(5,59864-0,4308^*\ln(x))} \cong 270,06 * x^{0.5692}$$

Here x is the size of the vessel measured in dead-weight-tonnage (DWT) and y the TC per hour in NOK. This was used for the estimation of TC-cost per hour.

For the distance related costs, relationships between engine power, DWT and speed were used. A good approximation was found by the following relationship:

$$z = (0{,}15*x*e^{(3{,}5867-0{,}4422*\ln(x))})/(1{,}852*v) \cong 2{,}925 * x^{0{,}5578} / v$$

Where z is the cost per km, x as previously the size in DWT and v the speed in knots. This equation is not universal, but only holds within limited variations in speed and size. All cost elements are in US $ and, as there is a common market for these vessels between Sweden and Norway, the cost in SEK is found through currency conversions.

Similarly, cost functions are found for the other vessel types. The difference in approach is that since fewer vessels sizes are used for the other types, no functional relationships are used for the TC. Instead this is based on direct market data. For a more detailed explanation, we refer to the appendix in excel-format.

If we sum up the cost functions for the various vessel types (“vehicles”), we get the following results:

Table 41 – Vessel cost (cost per vehicle) for various categories, Norway

Ship category	Vessel size	Cost per hour		Cost per km	
	(in DWT)	Ex VAT	Incl. VAT	Ex VAT	Incl. VAT
Lo/lo, general cargo	500	387	483	12	15
Lo/lo, general cargo	1250	651	814	19	23
Lo/lo, general cargo	2000	851	1064	24	30
Lo/lo, general cargo	3600	1189	1487	29	37
Lo/lo, general cargo	6350	1643	2053	40	50
Lo/lo, general cargo	10000	2127	2659	48	61
Lo/lo, general cargo	14500	2628	3285	60	75
Lo/lo, general cargo	20000	3156	3945	71	89
Dry bulk	500	387	483	12	15
Dry bulk	1250	651	814	19	23
Dry bulk	2000	851	1064	24	30
Dry bulk	3600	1189	1487	29	37
Dry bulk	6350	1643	2053	40	50
Dry bulk	10000	2127	2659	48	61
Dry bulk	14500	2628	3285	60	75
Dry bulk	20000	3156	3945	71	89
Sideport vessel	5000	1434	1792	44	55
Container vessel lo/lo	5300	1724	2154	45	57
Container vessel lo/lo	16000	2507	3133	78	97
Container vessel lo/lo	27200	3813	4767	104	130
Container vessel lo/lo	48000	5893	7367	124	155
Container vessel lo/lo	64000	7627	9533	146	182
Ro/ro (cargo)	3648	4534	5667	98	123
Ro/ro (cargo)	5000	5102	6377	154	192
Ro/ro (cargo)	6336	6328	7910	177	221
Reefer	2500	2977	3721	30	37
Reefer	5000	5954	7443	38	47
Reefer	10000	11909	14886	52	65
Product tanker	6416	1716	2145	36	45
Product tanker	40000	4862	6078	105	131
Crude oil tanker	100000	6978	8722	175	219
Crude oil tanker	150000	9316	11644	220	275
Crude oil tanker	300000	14631	18289	323	404
Liquid bulk - Chemicals	9500	48978	61222	36	45
Liquid bulk - Chemicals	17000	87644	109556	73	91
LNG	28870	6178	7722	100	125
LNG	48817	7274	9093	143	179

Table 42 – Vessel cost (cost per vehicle) for various categories, Sweden

Ship category	Vessel size	Cost per hour		Cost per km	
	(in DWT)	Ex VAT	Incl. VAT	Ex VAT	Incl. VAT
Lo/lo, general cargo	500	459	574	14	18
Lo/lo, general cargo	1250	774	967	22	28
Lo/lo, general cargo	2000	1011	1264	29	36
Lo/lo, general cargo	3600	1413	1766	35	43
Lo/lo, general cargo	6350	1951	2439	48	60
Lo/lo, general cargo	10000	2527	3158	58	72
Lo/lo, general cargo	14500	3122	3902	71	89
Lo/lo, general cargo	20000	3749	4686	85	106
Dry bulk	500	459	574	14	18
Dry bulk	1250	774	967	22	28
Dry bulk	2000	1011	1264	29	36
Dry bulk	3600	1413	1766	35	43
Dry bulk	6350	1951	2439	48	60
Dry bulk	10000	2527	3158	58	72
Dry bulk	14500	3122	3902	71	89
Dry bulk	20000	3749	4686	85	106
Sideport vessel	5000	1703	2129	52	65
Container vessel lo/lo	5300	2637	3297	54	67
Container vessel lo/lo	16000	4761	5951	92	115
Container vessel lo/lo	27200	7561	9451	124	155
Container vessel lo/lo	48000	12349	15437	147	184
Container vessel lo/lo	64000	16191	20239	173	216
Ro/ro (cargo)	3648	5366	6707	117	146
Ro/ro (cargo)	5000	6033	7541	183	228
Ro/ro (cargo)	6336	7482	9353	210	263
Reefer	2500	4586	5733	35	44
Reefer	5000	9172	11465	45	56
Reefer	10000	18344	22930	61	77
Product tanker	6416	2038	2547	43	54
Product tanker	40000	5775	7219	125	156
Crude oil tanker	100000	8288	10360	208	260
Crude oil tanker	150000	11065	13831	261	326
Crude oil tanker	300000	17379	21723	384	480
Liquid bulk - Chemicals	9500	58175	72719	43	54
Liquid bulk - Chemicals	17000	104103	130129	86	108
LNG	28870	6178	7722	119	149
LNG	48817	7274	9093	170	213

For both countries, the tables so far do not include ferries (road and rail). They are included in a later chapter.

The loading and unloading cost depend on cargo category (break-bulk, containers, liquid bulk, dry bulk etc.), on the methods applied, and to a certain degree on size. For this part of the calculation we have used case data and some general efficiency and investment data related to the methods.

We checked these data against published prices from several ports. In addition, data on port dues, which is typically based on BT, related to arrival and occupancy of berths is available. With BT, we mean “Bruttotonnasje” (Gross tonnage), defined as:

$BT = (0,2 + 0,02*\log10V)*V$,

Where V is the volume of the ship’s closed compartments in m^3

Since the calculation of BT is based on several dimensions, DTW cannot be calculated into BT. There are heuristical relationships based on averages between DTW and BT which give a good fit:

$DWT = BT / a$

Where a = 1,5 for DWT≤ 20000, 2 for BT ≥ 100000; and with intermediate values in between. DWT is the ship’s total carriage capacity of cargo, bunker, fresh water, stores and crew, defined normally for loading to summer freeboard.

In addition, also cargo dues affect the cost of shipping. As these dues vary among ports, we used data from different ports (Norwegian for Norway and Swedish for Sweden) to estimate representative cost figures. The cargo dues as well as the methodological aspects lead to cargo dependent loading or unloading cost. This is shown in the tables below. These tables also contain information about the feasibility of alternative vessel types for alternative cargo. In this context “na” means “not applicable”.

Table 43 – Loading/unloading cost – Norway

Ship category/ Vessel type / TEUs	Vessel size	Port charge (anløpsavgift +kaiavgift)	Loading capacity per hour	Cost per hour	Port cost per ton loading	TC/hour vessel + cont	Adjusted cost per ton		Loading or unloading cost per ton ex VAT per goods category																															
									11	12	13	21	22	23	31	32	41	42	51	52	53	54	55	61	62	63	64	65	66	71	72	73	74	81	82	91	92	101	102	103
							Ex VAT	Inc VAT	*7.9*	*11.0*	*12.5*	*11.6*	*11.8*	*11.8*	*11.6*	*11.6*	*11.9*	*49.1*	*12.3*	*11.7*	*11.9*	*11.5*	*12.3*	*8.1*	*8.1*	*8.3*	*9.1*	*10.6*	*10.1*	*6.4*	*7.6*	*5.7*	*4.8*	*9.2*	*8.5*	*8.9*	*11.9*	*8.3*	*8.3*	*7.5*
Lo/lo, general cargo (cargo)	500	1.45	42	909	23.10	387	32.3	40.4	40.2	na	na	na	44.1	44.1	na	na	44.2	na	44.6	na	44.2	43.8	44.6	40.4	40.4	40.6	41.4	42.9	42.4	na	na	38.0	37.1	na	40.8	41.2	44.2	na	na	na
	1250	1.38	56	909	17.62	651	29.3	36.6	37.2	na	na	na	41.0	41.0	na	na	41.2	na	41.5	na	41.2	40.8	41.5	37.3	37.3	37.5	38.3	39.8	39.4	na	na	34.9	34.1	na	37.8	38.1	41.2	na	na	na
	2000	1.19	70	909	14.18	851	26.3	32.9	34.3	na	na	na	38.1	38.1	na	na	38.2	na	38.6	na	38.2	37.8	38.6	34.4	34.4	34.6	35.4	36.9	36.5	na	na	32.0	31.1	na	34.9	35.2	38.2	na	na	na
	3600	1.11	100	1,24	13.55	1189	25.5	31.8	33.4	na	na	na	37.2	37.2	na	na	37.4	na	37.7	na	37.4	37.0	37.7	33.5	33.5	33.7	34.5	36.0	35.6	na	na	na	30.2	na	na	34.3	37.4	na	na	na
	6350	1.01	200	2,48	13.45	1643	21.7	27.1	29.6	na	na	na	33.4	33.4	na	na	33.6	na	33.9	na	33.6	33.6	33.9	29.7	29.7	29.9	30.7	32.2	31.8	na	na	na	26.5	na	na	30.6	33.6	na	na	na
	10000	0.97	280	1,81	7.46	2127	15.1	18.8	23.0	na	na	na	26.8	26.8	na	na	27.0	na	27.3	na	27.0	26.6	27.3	23.1	23.1	23.3	24.1	25.6	25.2	na	na	na	19.9	na	na	24.0	27.0	na	na	na
	14500	0.92	400	2,48	7.14	2628	13.7	17.1	21.6	na	na	na	25.5	25.5	na	na	25.6	na	26.0	na	25.6	25.2	26.0	21.8	21.8	22.0	22.8	24.3	23.9	na	na	na	18.5	na	na	22.6	25.6	na	na	na
	20000	0.92	800	4,97	7.14	3156	11.1	13.9	19.0	na	na	na	22.8	22.8	na	na	23.0	na	23.4	na	23.0	22.6	23.4	19.2	19.2	19.4	20.2	21.6	21.2	na	na	na	15.9	na	na	20.0	23.0	na	na	na
Sideport vessel	5000	1.06	300	125	41.67	1434	46.5	58.1	na	57.4	58.9	na	na	na	na	na	na	na	na	na	58.4	58.0	58.7	54.5	54.5	54.7	55.5	57.0	56.6	na	na	na	na	na	na	na	58.4	na	na	na
Container vessel lo/lo 331	5300	1.07	125	111	9.95	1744	23.9	na	34.9	36.4	na	35.7	35.7	na	na	35.8	na	36.2	na	35.8	35.4	36.2	na	na	32.2	33.0	34.5	34.1	na	na	na	na	na	na	na	na	na	na	na	
1000	16000	0.92	200	111	6.47	2570	19.3	na	30.3	31.8	na	31.1	31.1	na	na	31.2	na	31.6	na	31.2	30.8	31.6	na	na	27.6	28.4	29.9	29.5	na	na	na	na	na	na	na	na	na	na	na	
1700	27200	0.92	400	222	6.47	3920	16.3	na	27.2	28.7	na	28.1	28.0	na	na	28.2	na	28.5	na	28.2	27.8	28.5	na	na	24.6	25.3	26.8	26.4	na	na	na	na	na	na	na	na	na	na	na	
3000	48000	1.10	600	333	6.65	6082	16.8	na	27.7	29.3	na	28.5	28.5	na	na	28.7	na	29.1	na	28.7	28.3	29.1	na	na	25.1	25.9	27.3	26.9	na	na	na	na	na	na	na	na	na	na	na	
4000	64000	1.10	800	444	6.65	13668	23.7	na	34.7	36.2	na	35.5	35.5	na	na	35.6	na	36.0	na	35.6	35.2	36.0	na	na	32.0	32.8	34.3	33.9	na	na	na	na	na	na	na	na	na	na	na	
Ro/ro (cargo) 228	3648	1.11	960	144	16.17	4534	20.9	na	31.9	33.4	32.5	32.7	32.7	32.5	32.5	32.8	70.0	33.2	na	32.8	32.4	33.2	na	na	29.2	30.0	31.5	31.0	na	na	na	na	na	na	29.8	32.8	na	na	na	
313	5000	1.06	960	144	16.12	5102	21.4	na	32.4	33.9	33.0	33.2	33.9	33.0	33.0	33.3	70.6	33.7	na	33.3	32.9	33.7	na	na	29.7	30.5	32.0	31.6	na	na	na	na	na	na	30.3	33.3	na	na	na	
396	6336	1.01	960	144	16.07	6328	22.7	na	33.6	35.1	34.2	34.4	34.4	34.2	34.2	34.6	71.8	34.9	na	34.6	34.2	34.9	na	na	30.9	31.7	33.2	32.8	na	na	na	na	na	na	31.6	34.6	na	na	na	
Reefer	2500	1.14	70	909	14.13	2977	56.7	70.8	na	na	na	68.2	68.4	68.4	68.2	68.2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	5000	1.06	200	248	13.50	5954	43.3	54.1	na	na	na	54.8	55.0	55.0	54.8	54.8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	10000	0.97	400	248	7.19	11909	37.0	46.2	na	na	na	48.5	48.7	48.7	48.5	48.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Product tanker	6416	1.01	321	605	2.89	1716	8.2	10.3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	15.7
	40000	1.08	2000	605	1.38	4862	3.8	4.8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	11.3
Crude oil tanker	100000	1.10	5000	908	1.28	6978	2.7	3.3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	11.0	na	na
	150000	1.10	7500	908	1.22	9316	2.5	3.1	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	10.8	na	na
	300000	1.10	15000	908	1.16	14631	2.1	2.7	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	10.4	na	na
Chemicals	9500	0.97	475	908	2.88	48978	106.0	132.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	115.2	na	na	na	na	na	na
	17000	0.92	850	908	1.99	87644	105.1	131.4	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	114.3	na	na	na	na	na	na
Dry bulk	500	1.45	200	636	4.63	387	6.6	8.2	14.5	na	na	na	na	na	na	na	na	na	na	na	na	18.1	na	na	na	na	na	na	na	12.9	14.1	12.2	11.4	15.8	15.1	na	na	na	na	na
	1250	1.38	300	114	5.20	651	7.4	9.2	15.3	na	na	na	na	na	na	na	na	na	na	na	na	18.9	na	na	na	na	na	na	na	13.7	14.9	13.0	12.2	16.6	15.9	na	na	na	na	na
	2000	1.19	500	114	3.48	851	5.2	6.5	13.1	na	na	na	na	na	na	na	na	na	na	na	na	16.7	na	na	na	na	na	na	na	11.6	12.8	10.8	10.0	14.4	13.7	na	na	na	na	na
	3600	1.11	750	114	2.64	1189	4.2	5.3	12.2	na	na	na	na	na	na	na	na	na	na	na	na	15.7	na	na	na	na	na	na	na	10.6	11.8	9.9	9.0	13.4	12.8	na	na	na	na	na
	6350	1.01	1000	127	2.28	1643	3.9	4.9	11.9	na	na	na	na	na	na	na	na	na	na	na	na	15.4	na	na	na	na	na	na	na	10.3	11.5	9.6	8.7	13.1	12.4	na	na	na	na	na
	10000	0.97	1250	145	2.13	2127	3.8	4.8	11.8	na	na	na	na	na	na	na	na	na	na	na	na	15.3	na	na	na	na	na	na	na	10.2	11.4	9.5	8.6	13.0	12.4	na	na	na	na	na
	14500	0.92	1500	157	1.97	2628	3.7	4.7	11.7	na	na	na	na	na	na	na	na	na	na	na	na	15.2	na	na	na	na	na	na	na	10.1	11.3	9.4	8.5	12.9	12.2	na	na	na	na	na
	20000	0.92	2000	157	1.70	3156	3.3	4.1	11.2	na	na	na	na	na	na	na	na	na	na	na	na	14.8	na	na	na	na	na	na	na	9.7	10.8	8.9	8.1	12.5	11.8	na	na	na	na	na
LNG	28870	0.92	2887	121	1.34	6178	3.5	4.4	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	11.8	na
	48817	1.10	4882	121	1.34	7274	2.8	3.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	11.1	na

Table 42 – Loading/unloading cost – Sweden

Ship category/ Vessel type / TEUs	Vessel size	Port charge (anløpsavgift +kaiavgift)	Loading capacity per hour	Cost per hour	Port cost per ton loading	TC/hour vessel + cont	Adjusted cost per ton Ex VAT	Adjusted cost per ton Inc VAT	Loading or unloading cost per ton ex VAT per goods category 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
									10.0	*11.0*	*27.3*	*23.1*	*9.4*	*9.4*	*6.8*	*7.6*	*27.3*	*21.6*	*21.6*	*13.7*	*14.6*	*19.9*	*16.7*	*16.8*	*27.3*	*7.7*	*11.2*	*16.4*	*16.0*	*13.4*	*23.4*	*10.0*	*27.3*	*27.3*	*27.3*	*10.6*	*27.3*	*27.3*	*7.6*	*27.3*	*10.6*	*9.1*
Lo/lo, general cargo (cargo)	500	1.72	42	1080	27.4	459	38.4	48.0	na	49.3	na	61.4	47.8	47.8	45.2	45.9	65.6	60.0	60.0	na	na	na	na	na	65.6	46.1	na	54.7	54.3	na	na	48.3	65.6	65.6	65.6	48.9	65.6	65.6	45.9	65.6	48.9	47.5
	1250	1.64	56	1080	20.9	774	34.7	43.4	na	45.7	na	57.8	44.1	44.1	41.6	42.3	62.0	56.3	56.3	na	na	na	na	na	62.0	42.4	na	51.1	50.7	na	na	44.7	62.0	62.0	62.0	45.3	62.0	62.0	42.3	62.0	45.3	43.8
	2000	1.42	70	1080	16.8	1011	31.3	39.1	na	42.2	na	54.3	40.7	40.7	38.1	38.8	58.5	52.9	52.9	na	na	na	na	na	58.5	39.0	na	47.6	47.3	na	na	41.3	58.5	58.5	58.5	41.9	58.5	58.5	38.8	58.5	41.9	40.4
	3600	1.32	100	1478	16.1	1413	30.2	37.8	na	41.2	na	53.3	39.6	39.6	37.1	37.8	57.5	51.8	51.8	na	na	na	na	na	57.5	na	na	46.6	na	na	na	40.2	57.5	57.5	57.5	40.8	57.5	57.5	37.8	57.5	40.8	39.3
	6350	1.19	200	2955	16.0	1951	25.7	32.2	na	36.7	na	48.8	35.1	35.1	32.6	33.3	53.0	47.3	47.3	na	na	na	na	na	53.0	na	na	42.1	na	na	na	35.7	53.0	53.0	53.0	36.3	53.0	53.0	33.3	53.0	36.3	34.8
	10000	1.15	280	2160	8.9	2527	17.9	22.4	na	28.8	na	40.9	27.3	27.3	24.7	25.4	45.1	39.5	39.5	na	na	na	na	na	45.1	na	na	34.2	na	na	na	27.9	45.1	45.1	45.1	28.5	45.1	45.1	25.4	45.1	28.5	27.0
	14500	1.09	400	2955	8.5	3122	16.3	20.4	na	27.2	na	39.3	25.7	25.7	23.1	23.8	43.5	37.9	37.9	na	na	na	na	na	43.5	na	na	32.6	na	na	na	26.3	43.5	43.5	43.5	26.9	43.5	43.5	23.8	43.5	26.9	25.4
	20000	1.09	800	5910	8.5	3749	13.2	16.5	na	24.1	na	36.2	22.6	22.6	20.0	20.7	40.4	34.7	34.7	na	na	na	na	na	40.4	na	na	29.5	na	na	na	23.1	40.4	40.4	40.4	23.7	40.4	40.4	20.7	40.4	23.7	22.2
Sideport vessel	5000	1.26	300	14847	49.5	1703	55.2	69.0	na	66.1	na	78.2	na	na	na	62.7	82.4	76.8	76.8	na	na	na	na	na	82.4	na	na	na	71.1	na	na	65.1	na	na	na	65.7	82.4	82.4	na	na	65.7	na
Container vessel lo/lo 331	5300	1.27	125	1318	11.8	2638	32.9	41.1	na	43.9	na	56.0	na	na	na	na	60.2	54.5	54.5	na	na	na	na	na	60.2	na	na	na	48.9	na	na	42.9	60.2	60.2	60.2	43.5	60.2	60.2	na	60.2	43.5	na
1000	16000	1.09	200	1318	7.7	4761	31.5	39.4	na	42.4	na	54.5	na	na	na	na	58.7	53.1	53.1	na	na	na	na	na	58.7	na	na	na	47.5	na	na	41.5	58.7	58.7	58.7	42.1	58.7	58.7	na	58.7	42.1	na
1700	27200	1.09	400	2637	7.7	7561	26.6	33.2	na	37.5	na	49.6	na	na	na	na	53.8	48.2	48.2	na	na	na	na	na	53.8	na	na	na	42.6	na	na	36.6	53.8	53.8	53.8	37.2	53.8	53.8	na	53.8	37.2	na
3000	48000	1.30	600	3955	7.9	12349	28.5	35.6	na	39.4	na	51.5	na	na	na	na	55.7	50.1	50.1	na	na	na	na	na	55.7	na	na	na	44.4	na	na	38.4	55.7	55.7	55.7	39.0	55.7	55.7	na	55.7	39.0	na
4000	64000	1.30	800	5274	7.9	16191	28.1	35.2	na	39.1	na	51.2	na	na	na	na	55.4	49.7	49.7	na	na	na	na	na	55.4	na	na	na	44.1	na	na	38.1	55.4	55.4	55.4	38.7	55.4	55.4	na	55.4	38.7	na
Ro/ro (cargo) 228	3648	1.32	960	14457	16.4	4340	20.9	26.1	na	31.9	na	44.0	na	na	na	28.5	48.2	42.5	42.5	na	na	na	na	na	48.2	na	na	na	36.9	na	na	30.9	48.2	48.2	48.2	31.5	48.2	48.2	na	48.2	31.5	na
313	5000	1.26	960	14457	16.3	4625	21.1	26.4	na	32.1	na	44.2	na	na	na	28.7	48.4	42.7	42.7	na	na	na	na	na	48.4	na	na	na	37.1	na	na	31.1	48.4	48.4	48.4	31.7	48.4	48.4	na	48.4	31.7	na
396	6336	1.19	960	14457	16.3	5701	22.2	27.7	na	33.1	na	45.2	na	na	na	29.7	49.4	43.8	43.8	na	na	na	na	na	49.4	na	na	na	38.2	na	na	32.2	49.4	49.4	49.4	32.8	49.4	49.4	na	49.4	32.8	na
Reefer	2500	1.36	70	1080	16.8	4586	82.3	102.9	na	93.2	na	na	na	na	na	na	na	103.9	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	5000	1.26	200	2955	16.0	9172	61.9	77.4	na	72.8	na	na	na	na	na	na	na	83.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	10000	1.15	400	2955	8.5	18344	54.4	68.0	na	65.3	na	na	na	na	na	na	na	76.0	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Product tanker	6416	1.19	321	472	2.7	2038	9.0	11.3	na	na	na	na	na	na	na	na	na	na	na	na	na	28.9	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	40000	1.28	2000	472	1.5	5775	4.4	5.5	na	na	na	na	na	na	na	na	na	na	na	na	na	24.3	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Crude oil tanker	100000	1.30	5000	708	1.4	8288	3.1	3.9	na	na	na	na	na	na	na	na	na	na	na	na	17.7	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	150000	1.30	7500	708	1.4	11065	2.9	3.6	na	na	na	na	na	na	na	na	na	na	na	na	17.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	300000	1.30	15000	708	1.3	17379	2.5	3.1	na	na	na	na	na	na	na	na	na	na	na	na	17.2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chemicals	9500	1.15	475	708	2.6	58175	125.1	156.4	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	138.5	148.5	na	na	na	na	na	na	na	na	na	na	na
	17000	1.09	850	708	1.9	104103	124.4	155.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	137.8	147.8	na	na	na	na	na	na	na	na	na	na	na
Dry bulk	500	1.72	200	755	5.5	459	7.8	9.7	17.8	na	na	na	na	na	na	na	na	na	na	na	na	na	24.5	24.6	na	15.5	18.9	na	23.8	21.2	na	na	na	na	na	na	na	na	na	na	na	16.9
	1250	1.64	300	1360	6.2	774	8.8	10.9	18.7	na	na	na	na	na	na	na	na	na	na	na	na	na	25.5	25.5	na	16.4	19.9	na	24.7	22.2	na	na	na	na	na	na	na	na	na	na	na	17.8
	2000	1.42	500	1360	4.1	1011	6.2	7.7	16.1	na	na	na	na	na	na	na	na	na	na	na	na	na	22.9	22.9	na	13.8	17.3	na	22.1	19.6	na	na	na	na	na	na	na	na	na	na	na	15.2
	3600	1.32	750	1360	3.1	1413	5.0	6.3	15.0	na	na	na	na	na	na	na	na	na	na	na	na	na	21.8	21.8	na	12.7	16.2	na	21.0	18.4	na	na	na	na	na	na	na	na	na	na	na	14.1
	6350	1.19	1000	1511	2.7	1951	4.7	5.8	14.6	na	na	na	na	na	na	na	na	na	na	na	na	na	21.4	21.4	na	12.3	15.8	na	20.6	18.1	na	na	na	na	na	na	na	na	na	na	na	13.7
	10000	1.15	1250	1722	2.5	2527	4.5	5.7	14.5	na	na	na	na	na	na	na	na	na	na	na	na	na	21.3	21.3	na	12.2	15.7	na	20.5	17.9	na	na	na	na	na	na	na	na	na	na	na	13.6
	14500	1.09	1500	1865	2.3	3122	4.4	5.5	14.4	na	na	na	na	na	na	na	na	na	na	na	na	na	21.1	21.2	na	12.1	15.6	na	20.4	17.8	na	na	na	na	na	na	na	na	na	na	na	13.5
	20000	1.09	2000	1865	2.0	3749	3.9	4.9	13.9	na	na	na	na	na	na	na	na	na	na	na	na	na	20.6	20.7	na	11.6	15.0	na	19.9	17.3	na	na	na	na	na	na	na	na	na	na	na	13.0
LNG	28870	1.10	2887	943	1.4	7338	4.0	5.0	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	48817	1.30	4882	943	1.5	8640	3.3	4.1	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Costs for loading and unloading of containers do not include cost for stuffing and stripping. For stuffing or stripping of containers in the port, an additional cost of 145 NOK/tons should be added in the Norwegian loading/unloading cost, and an additional cost of 119 SEK/tons for the Swedish loading/unloading cost.

Examples of cost curves

One might within a mode, as sea, visualise economy of scale by some cost curves, based on the more detailed break-down above. This is merely for illustration of the effects, but based on the cost models calculated above. The example is based on traditional lo/lo vessels.

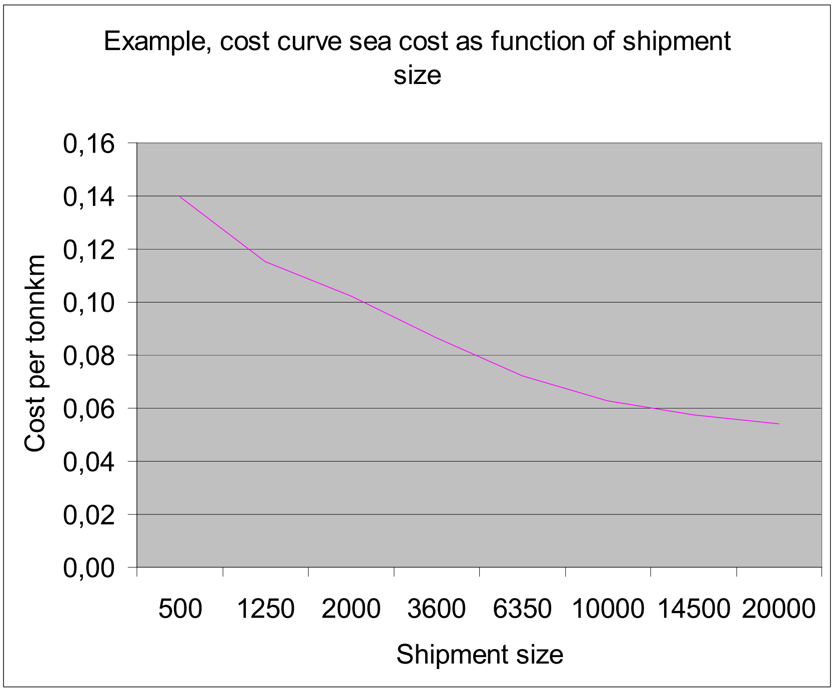

Figure 13 - Example of unit cost (cost per tonnkm) development with shipment size, using most optimal vehicle

Rail

The available data for rail transport are less rich than for the other transport modes. Therefore the cost calculations for rail may be less detailed. Still we consider these costs to reflect the correct level compared to other vehicles and modes, justifying their use in the model.

For Norwegian rail, we have based calculations on data received from Jernbaneverket and Cargonet. The data covers two types of wagons: container wagons and timber wagons. Calculations are based on full wagonloads for containers and timber for either electrical or diesel traction. These calculations are to be enhanced at a later stage, to enable further differentiation. The loading/unloading cost is calculated accordingly.

Table 44 - Cost for vehicle '(complete trains)' – Norway

Train type	Hour/ton	Kr/hour		Kr/km		Loading or unloading, kr/ton adjusted	
		Ex VAT	Incl. VAT	Ex VAT	Incl. VAT	Ex VAT	Incl. VAT
Electrical, container	0.004	5609	7011	31.47	39.34	35.33	44.16
Electrical, timber	0.017	3780	4725	63.51	79.39	237.61	297.01
Diesel, container	0.004	5374	6717	52.28	65.35	34.42	43.02
Diesel, timber	0.017	3545	4431	84.33	105.41	233.69	292.11

The feasibility for these alternatives is as follows:

Table 45 - Feasibility, train options Norway

	11	12	13	21	22	23	31	32	41	42	51	52	53	54	55	61	62	63	64	65	66	71	72	73	74	81	82	91	92	101	102	103
Container train	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	na	ok	ok	ok	na	na	ok	ok	ok	ok	na	na	na	na	na	ok	ok	ok	na	na	na
Timber train	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	ok	ok	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

For Sweden, the costs are recalculated based on previous calculations by Banverket and published by SIKA. There are some differences in the allocation between cost based on hours and cost based on kms compared to the other calculations, but that will not interfere with calculating the total OD-cost. For Sweden the calculations cover three types of trains (vehicles): wagonload trains, system trains, and "combi" trains. Each train type can have electrical or diesel traction. As for the other vehicles with "combi" or container trains the cost of containers is included in the cost/hour for the vehicle. Terminal (loading / unloading) cost is calculated according to principles similar to for Norway.

The Swedish costs are as follows:

Table 46 - Cost for vehicle '(complete trains)' – Sweden

Train type	Hour/ton	Kr/hour		Kr/km		Loading or unloading, kr/ton adjusted	
		Ex VAT	Incl. VAT	Ex VAT	Incl. VAT	Ex VAT	Incl. VAT
Diesel, wagon load	0.029	2362	2953	59.61	74.51	193.42	241.77
Diesel, combi	0.004	2431	3039	68.80	85.99	22.35	27.94
Diesel, system	0.001	2579	3223	85.68	107.10	5.14	6.42
Electrical, wagon load	0.029	2252	2814	80.74	100.93	189.39	236.74
Electrical, combi	0.004	2316	2895	58.46	73.08	26.66	33.33
Electrical, system	0.001	2474	3092	74.01	92.51	5.01	6.26

The calculations, although made from different perspectives, show large variations between the Swedish and the Norwegian cost. However, the differences seem to be related mainly to the allocation between time dependent and km dependent cost elements. To investigate how the differences between the two cost models work out, we calculate an example for a container train travelling at 80 km/hr for 500 km. The calculations show that the difference in costs when using electric traction is 2% between the Swedish and Norwegian cost and – 3% when using diesel traction. These results were found when converting costs to a common currency.

A similar comparison between Norwegian timber trains and Swedish system trains gave differences of around 10%. Some factors can be identified that may account for some of the differences. For instance, the calculations for Norway are based on detailed data received from CargoNet and Jernbaneverket. For Norway the time dependent elements are capital cost and wages, while km dependent cost elements are energy and maintenance. For Norway there is no charge for using infrastructure. On the other hand, the wage level used for Norway is quite high.

Swedish costs are based on an update (prolongation) of previously calculated cost from 2002. However, the documentation does not describe the various cost elements in a detailed way, which complicated comparing costs on a detailed level. For Sweden, the costs are calculated on a kr/tonkm basis and the average tonnage used in transfer from kr/tonkm to kr/ton obviously has an impact. In addition, currency fluctuations impact the cost comparisons.

The vehicle definition used for trains is “train” (not wagons). The average payload capacity used for Swedish train types is 350 tons for the wagonload trains, 450 tons for the combi trains and 750 tons for the system trains. For Norwegian trains the average is 655 tons for container trains and 861 tons for timber trains. Maximum payload is estimated at 1000 tons.

Transfer cost

Transfer costs are calculated for the transfer between two vehicles. The transfer may in principle occur according to one of two situations:

1. Direct transfer: goods are moved directly from one vehicle to another. The resources required are in this case not different from one loading and unloading, although time cost for two vehicles have to be taken into account.
2. Indirect transfer: the first vehicle is unloaded after which the goods are stored in a terminal awaiting pick-up by a second vehicle.

Transfer costs according to pattern 1 and 2 are calculated for truck-to-truck transfers, while sea-road and rail-sea are only calculated according to pattern 2. This does not imply that there are no direct transfers between vehicles of different modes. As for the previous calculated loading and unloading cost, the transfer costs also includes time dependent cost for the vehicles involved.

Road – road

The tables below give the direct and indirect transfer cost for Norway and Sweden:

- Table 47: Direct transfer cost Norway road-road
- Table 48: Indirect transfer cost Norway road-road
- Table 49: Direct transfer cost Sweden road-road
- Table 50: Indirect transfer cost Sweden road-road

In these tables the following colour scheme is used:

Not available (n.a.)
Cost for stuffing of container included
Cost for stripping of container included

Table 47 - Direct transfer cost (situation 1) road – road - Norway

Direct transfer Road –> Road	LGV	Light distribution	Heavy distribution Closed unit	Heavy distribution Containers	Articulated semi Total - closed	Articulated semi With container	Tank truck with hanger Oil products	Tank truck with hanger Chemicals	Tank truck with hanger Dry bulk	Semitrailer Tanker oil products	Semitrailer Tanker liquid bulk	Semitrailer Dry bulk products	Semitrailer "Flis"	Timber truck with hanger (4 axles)	"Flis" truck with hanger (4 axles)	Thermo Truck with hanger	Semi, thermo
LGV	616	560	509	n.a	521	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	560	504	453	n.a	465	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution closed unit	509	453	402	n.a	414	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution for containers	n.a	n.a	n.a	15	n.a	15	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - total - closed	521	465	414	n.a	427	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - with container	n.a	n.a	n.a	15	n.a	15	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger oil products	n.a	n.a	n.a	n.a	n.a	n.a	14	n.a	n.a	13	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	14	n.a	n.a	14	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	22	n.a	n.a	22	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	n.a	n.a	n.a	13	n.a	n.a	13	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	14	n.a	n.a	13	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	22	n.a	n.a	21	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	21	n.a	21	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	44	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	21	n.a	22	n.a	n.a
Thermo Truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	325	259
Semi, thermo	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	259	192

Table 48 - Direct transfer cost (situation 1) road – road - Sweden

Road –> Road	LGV	Light distribution	Heavy distribution		Articulated semi trailer		Heavy combination (Sweden)		Tank truck, with hanger		Semitrailer				Truck with hanger			Thermo	
				Container		Container		Container		Liquid bulk	Tank	Liquid bulk	Dry bulk	"flis"	Dry bulk	"flis"	Timber (4-axles)	Hanger	Semi
LGV	508	429	370	379	331	380	344	380	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	429	349	290	300	251	300	264	301	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution	370	290	232	290	193	241	205	242	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution - container	379	300	241	13	202	13	215	14	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi trailer	331	251	193	202	154	83	166	84	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi trailer - container	380	300	241	13	202	13	215	14	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden)	344	264	205	215	166	96	179	97	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden) - container	380	301	242	14	203	14	216	15	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck, with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	12	n.a	12	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck liquid bulk, with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	12	n.a	12	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer - tank	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	12	n.a	11	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	12	n.a	11	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer dry bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	17	n.a	18	n.a	n.a	n.a	n.a
Semitrailer "flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	17	n.a	18	n.a	n.a	n.a
Truck, dry bulk with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	18	n.a	19	n.a	n.a	n.a	n.a
Truck, "flis" with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	18	n.a	19	n.a	n.a	n.a
Truck for timber with 4 axle hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	38	n.a	n.a
Thermo, hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	280	221
Thermo, semi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	221	163

Table 49 - Indirect transfer cost (situation 2) road – road - Norway

Direct transfer Road –> Road	LGV	Light distribution	Heavy distribution		Articulated semi		Tank truck with hanger			Semitrailer				Timber truck with hanger (4-axles)	"Flis" truck with hanger (4-axles)	Thermo Truck with hanger	Semi, thermo
			Closed unit	Containers	Total - closed	With container	Oil products	Chemicals	Dry bulk	Tanker oil products	Tanker liquid bulk	Dry bulk products	"Flis"				
LGV	848	773	710	609	723	609	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	848	698	635	534	648	535	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution closed unit	710	635	572	471	585	472	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution for containers	783	708	471	23	484	24	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - total - closed	723	648	585	484	597	484	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - with container	783	708	472	24	658	18.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger oil products	n.a	n.a	n.a	n.a	n.a	n.a	17.0	n.a	n.a	17.7	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	18.3	n.a	n.a	17.7	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	28.7	n.a	n.a	27.7	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	n.a	n.a	n.a	17.7	n.a	n.a	17.0	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	17.7	n.a	n.a	17.0	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	27.7	n.a	n.a	26.8	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	26.8	n.a	27.5	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	56.2	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	27.5	n.a	28.1	n.a	n.a
Thermo Truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	460	368
Semi, thermo	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	368	277

Table 50 - Indirect transfer cost (situation 2) road – road - Sweden

Road –> Road	LGV	Light distribution	Heavy distribution		Articulated semi trailer		Heavy combination (Sweden)		Tank truck, with hanger		Semitrailer				Truck with hanger			Thermo	
				Container		Container		Container		Liquid bulk	Tank	Liquid bulk	Dry bulk	"flis"	Dry bulk	"flis"	Timber (4-axles)	Hanger	Semi
LGV	695	592	519	477	459	578	472	477	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	592	488	415	373	356	475	369	373	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution	519	415	342	300	283	402	296	300	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution - container	477	373	300	21	140	21	140	22	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi trailer	459	356	283	140	224	123	237	123	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi trailer - container	578	475	402	21	241	21	241	22	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden)	472	369	296	140	237	135	249	136	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden) - container	477	373	300	22	140	22	140	23	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck, with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	16	n.a	15	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck liquid bulk, with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	16	n.a	15	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer - tank	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	15	n.a	14	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	15	n.a	14	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer dry bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	22	n.a	23	n.a	n.a	n.a	n.a
Semitrailer "flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	22	n.a	23	n.a	n.a	n.a
Truck, dry bulk with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	23	n.a	24	n.a	n.a	n.a	n.a
Truck, "flis" with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	23	n.a	24	n.a	n.a	n.a
Truck for timber with 4 axle hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	47	n.a	n.a
Thermo, hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	390	312
Thermo, semi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	312	233

Sea – sea

The direct transfer costs for sea-to-sea (Table 52) are regardless of cargo category. Therefore for a given category, a further cost should be added according to Table 51.

Table 51 – Cargo specific transfer cost for sea – sea transfers Norway

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
7.9	11.0	12.5	11.6	11.8	11.8	11.6	11.6	11.9	49.1	12.3	11.7	11.9	11.5	12.3	8.1	8.1	8.3	9.1	10.6	10.1	6.4	7.6	5.7	4.8	9.2	8.5	8.9	11.9	8.3	8.3	7.5

Table 52 – Indirect transfer cost sea – sea Norway

		Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
		500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*5000*	*5300*	*16000*	*27200*	*48000*	*64000*	*3648*	*5000*	*6336*
Lo/lo, general cargo	*500*	64.6	61.6	58.6	57.7	54.0	47.4	46.0	43.4	90.4	235.8	230.1	226.3	226.9	235.6	58.4	59.1	0.0
	1250	61.6	58.5	55.6	54.7	50.9	44.3	43.0	40.3	87.3	232.8	227.0	223.2	223.9	232.5	55.4	56.0	0.0
	2000	58.6	55.6	52.7	51.8	48.0	41.4	40.0	37.4	84.4	229.9	224.1	220.3	221.0	229.6	52.5	53.1	0.0
	3600	57.7	54.7	51.8	50.9	47.1	40.5	39.2	36.5	83.5	229.0	223.2	219.4	220.1	228.7	51.6	52.2	0.0
	6350	54.0	50.9	48.0	47.1	43.3	36.7	35.4	32.7	79.7	225.2	219.4	215.6	216.3	225.0	47.8	48.5	0.0
	10000	47.4	44.3	41.4	40.5	36.7	30.1	28.8	26.1	73.1	218.6	212.8	209.0	209.7	218.4	41.2	41.8	0.0
	14500	46.0	43.0	40.0	39.2	35.4	28.8	27.4	24.8	71.8	217.2	211.5	207.7	208.3	217.0	39.8	40.5	0.0
	20000	43.4	40.3	37.4	36.5	32.7	26.1	24.8	22.2	69.1	214.6	208.9	205.1	205.7	214.4	37.2	37.9	0.0
Sideport vessel	*5000*	90.4	87.3	84.4	83.5	79.7	73.1	71.8	69.1	116.1	261.6	255.8	252.0	252.7	261.4	84.2	84.8	0.0
Container vessel lo/lo	*5300*	235.8	232.8	229.9	229.0	225.2	218.6	217.2	214.6	261.6	59.8	54.0	50.2	50.9	59.5	56.0	56.7	0.0
	16000	230.1	227.0	224.1	223.2	219.4	212.8	211.5	208.9	255.8	54.0	48.3	44.5	45.1	53.8	50.3	50.9	0.0
	27200	226.3	223.2	220.3	219.4	215.6	209.0	207.7	205.1	252.0	50.2	44.5	40.7	41.3	50.0	46.5	47.1	0.0
	48000	226.9	223.9	221.0	220.1	216.3	209.7	208.3	205.7	252.7	50.9	45.1	41.3	42.0	50.6	47.1	47.8	0.0
	64000	235.6	232.5	229.6	228.7	225.0	218.4	217.0	214.4	261.4	59.5	53.8	50.0	50.6	59.3	55.8	56.5	0.0
Ro/ro (cargo)	*3648*	58.4	55.4	52.5	51.6	47.8	41.2	39.8	37.2	84.2	56.0	50.3	46.5	47.1	55.8	52.2	52.9	0.0
	5000	59.1	56.0	53.1	52.2	48.5	41.8	40.5	37.9	84.8	56.7	50.9	47.1	47.8	56.5	52.9	53.6	0.0
	6336	60.6	57.6	54.7	53.8	50.0	43.4	42.0	39.4	86.4	58.2	52.5	48.7	49.3	58.0	54.4	55.1	0.0

		Crude oil tanker		
		100000	*150000*	*300000*
Crude oil tanker	*100000*	5.3	5.1	4.8
	150000	5.1	4.9	4.6
	300000	4.8	4.6	4.3

		Reefer		
		2500	*5000*	*10000*
Reefer	*2500*	113.3	99.9	93.6
	5000	99.9	86.5	80.2
	10000	93.6	80.2	73.9

		Dry bulk							
		500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*
Dry bulk	*500*	13.1	13.9	11.7	10.8	10.5	10.4	10.3	9.8
	1250	13.9	14.7	12.6	11.6	11.3	11.2	11.1	10.7
	2000	11.7	12.6	10.4	9.4	9.1	9.0	8.9	8.5
	3600	10.8	11.6	9.4	8.5	8.1	8.1	7.9	7.5
	6350	10.5	11.3	9.1	8.1	7.8	7.7	7.6	7.2
	10000	10.4	11.2	9.0	8.1	7.7	7.7	7.5	7.1
	14500	10.3	11.1	8.9	7.9	7.6	7.5	7.4	7.0
	20000	9.8	10.7	8.5	7.5	7.2	7.1	7.0	6.6

		Product tanker	
		6416	*40000*
Product tanker	*6416*	16.5	12.1
	40000	12.1	7.6

		Chemicals	
		9500	*17000*
Chemicals	*9500*	212.0	211.1
	17000	211.1	210.2

		LNG	
		28870	*48817*
LNG	*28870*	7.0	6.3
	48817	6.3	5.7

Table 53 - Cargo specific transfer cost for sea – sea transfers Sweden

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10.0	11.0	27.3	23.1	9.4	9.4	6.8	7.6	27.3	21.6	21.6	13.7	14.6	19.9	16.7	16.8	27.3
18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
7.7	11.2	16.4	16.0	13.4	23.4	10.0	27.3	27.3	27.3	10.6	27.3	27.3	7.6	27.3	10.6	9.1

Table 54 – Indirect transfer cost sea – sea Sweden

		Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
		500	1250	2000	3600	6350	10000	14500	20000	5000	5300	16000	27200	48000	64000	3648	5000	6336
Lo/lo, general cargo	500	76.7	73.1	69.7	68.6	64.1	56.3	54.7	51.5	93.5	190.1	188.7	183.8	185.7	185.3	59.3	59.5	60.6
	1250	73.1	69.5	66.0	65.0	60.5	52.6	51.0	47.9	89.9	186.5	185.1	180.2	182.0	181.7	55.6	55.9	56.9
	2000	69.7	66.0	62.6	61.5	57.0	49.2	47.6	44.4	86.5	183.0	181.6	176.7	178.6	178.2	52.2	52.4	53.5
	3600	68.6	65.0	61.5	60.4	56.0	48.1	46.5	43.4	85.4	182.0	180.5	175.6	177.5	177.2	51.1	51.4	52.4
	6350	64.1	60.5	57.0	56.0	51.5	43.6	42.0	38.9	80.9	177.5	176.0	171.1	173.0	172.7	46.6	46.9	47.9
	10000	56.3	52.6	49.2	48.1	43.6	35.8	34.2	31.0	73.1	169.6	168.2	163.3	165.2	164.8	38.8	39.0	40.1
	14500	54.7	51.0	47.6	46.5	42.0	34.2	32.6	29.4	71.5	168.0	166.6	161.7	163.6	163.2	37.2	37.4	38.5
	20000	51.5	47.9	44.4	43.4	38.9	31.0	29.4	26.3	68.3	164.9	163.5	158.6	160.5	160.1	34.1	34.3	35.4
Sideport vessel	5000	93.5	89.9	86.5	85.4	80.9	73.1	71.5	68.3	110.3	206.9	205.5	200.6	202.5	202.1	76.1	76.3	77.4
Container vessel lo/lo	5300	190.1	186.5	183.0	182.0	177.5	169.6	168.0	164.9	206.9	65.8	64.4	59.5	61.4	61.1	53.8	54.1	55.1
	16000	188.7	185.1	181.6	180.5	176.0	168.2	166.6	163.5	205.5	64.4	63.0	58.1	60.0	59.6	52.4	52.6	53.7
	27200	183.8	180.2	176.7	175.6	171.1	163.3	161.7	158.6	200.6	59.5	58.1	53.2	55.1	54.7	47.5	47.7	48.8
	48000	185.7	182.0	178.6	177.5	173.0	165.2	163.6	160.5	202.5	61.4	60.0	55.1	57.0	56.6	49.4	49.6	50.7
	64000	185.3	181.7	178.2	177.2	172.7	164.8	163.2	160.1	202.1	61.1	59.6	54.7	56.6	56.3	49.0	49.3	50.3
Ro/ro (cargo)	3648	59.3	55.6	52.2	51.1	46.6	38.8	37.2	34.1	76.1	53.8	52.4	47.5	49.4	49.0	41.8	42.0	43.1
	5000	59.5	55.9	52.4	51.4	46.9	39.0	37.4	34.3	76.3	54.1	52.6	47.7	49.6	49.3	42.0	42.3	43.3
	6336	60.6	56.9	53.5	52.4	47.9	40.1	38.5	35.4	77.4	55.1	53.7	48.8	50.7	50.3	43.1	43.3	44.4

		Crude oil tanker		
		100000	150000	300000
Crude oil tanker	100000	6.2	6.0	5.6
	150000	6.0	5.7	5.4
	300000	5.6	5.4	5.0

		Reefer		
		2500	5000	10000
Reefer	2500	164.6	144.2	136.7
	5000	144.2	123.8	116.3
	10000	136.7	116.3	108.8

		Dry bulk							
		500	1250	2000	3600	6350	10000	14500	20000
Dry bulk	500	15.6	16.6	14.0	12.8	12.5	12.3	12.2	11.7
	1250	16.6	17.5	14.9	13.8	13.4	13.3	13.2	12.7
	2000	14.0	14.9	12.3	11.2	10.8	10.7	10.6	10.1
	3600	12.8	13.8	11.2	10.0	9.7	9.6	9.4	8.9
	6350	12.5	13.4	10.8	9.7	9.3	9.2	9.1	8.6
	10000	12.3	13.3	10.7	9.6	9.2	9.1	9.0	8.4
	14500	12.2	13.2	10.6	9.4	9.1	9.0	8.8	8.3
	20000	11.7	12.7	10.1	8.9	8.6	8.4	8.3	7.8

		Product tanker	
		6416	40000
Product tanker	6416	18.0	13.4
	40000	13.4	8.8

		Chemicals	
		9500	17000
Chemicals	9500	250.2	249.5
	17000	249.5	248.8

		LNG	
		28870	48817
LNG	28870	7.9	7.2
	48817	7.2	6.5

Rail – rail

Transfer cost for rail-to-rail transfers applies to transfers between trains with different traction systems or, in some situations, between with different concepts.

Table 55 – Transfer cost train – train, Norway

	Electrical, container	Electrical, timber	Diesel, container	Diesel, timber
Electrical, container	70.66	n.a	69.75	n.a
Electrical, timber	n.a.	475.21	n.a.	471.30
Diesel, container	69.75	n.a	68.84	n.a
Diesel, timber	n.a.	471.30	n.a.	467.38

Table 56 – Transfer cost train – train, Sweden

	Diesel, wagon load	Diesel, combi	Diesel, system	Electrical, wagon load	Electrical, combi	Electrical, system
Diesel, wagon load	386.83	n.a	n.a.	382.81	n.a	n.a
Diesel, combi	n.a.	44.70	n.a.	n.a	49.01	n.a
Diesel, system	n.a.	n.a	10.28	n.a	n.a	10.15
Electrical, wagon load	382.81	n.a	n.a.	378.78	n.a	n.a
Electrical, combi	n.a	49.01	n.a	n.a	53.32	n.a
Electrical, system	n.a	n.a	10.15	n.a	n.a	10.01

Road – sea

The transfer costs for transfers between road and sea are given by the tables below. Again, The transfer costs for road-to-sea are regardless of cargo category. Therefore for a given category, a further cost should be added.

Table 57 – Cargo specific transfer cost for road – sea transfers Norway

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7.9	11.0	12.5	11.6	11.8	11.8	11.6	11.6	11.9	49.1	12.3	11.7	11.9	11.5	12.3	8.1
17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
8.1	8.3	9.1	10.6	10.1	6.4	7.6	5.7	4.8	9.2	8.5	8.9	11.9	8.3	8.3	7.5

Table 58 – Transfer cost road – sea, Norway

	Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
	500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*5000*	*5300*	*16000*	*27200*	*48000*	*64000*	*3648*	*5000*	*6336*
	32.3	29.2	26.3	25.4	21.7	15.1	13.7	11.1	58.1	29.9	24.1	20.3	21.0	29.7	26.1	26.8	28.3
LGV	468.3	465.2	462.3	461.4	457.6	451.0	449.7	447.0	494.0	639.5	633.8	629.9	630.6	639.3	635.7	636.4	637.9
Light distribution	340.3	337.3	334.4	333.5	329.7	323.1	321.7	319.1	366.1	564.6	558.9	555.1	555.7	564.4	387.2	387.9	389.4
Heavy distribution closed unit	251.9	248.8	245.9	245.0	241.3	234.7	233.3	230.7	277.7	501.5	495.8	492.0	492.6	501.3	324.1	324.8	326.3
Heavy distribution for containers,	229.6	226.6	223.7	222.8	219.0	212.4	211.0	208.4	255.4	53.6	47.8	44.0	44.7	53.4	49.8	50.5	52.0
Articulated semi - total - closed	177.7	174.6	171.7	170.8	167.0	160.4	159.1	156.4	203.4	514.1	508.3	504.5	505.2	513.8	336.7	337.3	338.9
Articulated semi - with container	229.8	226.8	223.9	223.0	219.2	212.6	211.2	208.6	255.6	53.8	48.0	44.2	44.9	53.5	50.0	50.7	52.2
Tank truck with hanger oil products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Thermo Truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	271.6	265.9	262.1	262.7	271.4	267.9	268.6	270.1
Semi, thermo	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	180.3	174.5	170.7	171.4	180.1	176.5	177.2	178.7

	Reefer			Product tanker		Crude oil tanker			Chemicals		Dry bulk								LNG	
	2500	*5000*	*10000*	*6416*	*40000*	*100000*	*150000*	*300000*	*9500*	*17000*	*500*	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*28870*	*48817*
	56.7	43.3	37.0	8.2	3.8	2.7	2.5	2.1	106.0	105.1	6.6	7.4	5.2	4.2	3.9	3.8	3.7	3.3	3.5	2.8
LGV	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution closed unit	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution for containers,	254.0	240.6	234.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - total - closed	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - with container	254.2	240.8	234.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger oil products	n.a	n.a	n.a	21.2	21.2	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	20.1	20.1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	21.2	21.2	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	20.1	20.1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	24.6	21.8	19.5	18.6	18.3	18.2	18.1	17.6	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	22.6	20.8	18.6	17.6	17.3	17.2	17.1	16.7	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Thermo Truck with hanger	298.4	285.0	278.7	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semi, thermo	207.1	193.7	187.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Table 59 - Cargo specific transfer cost for sea – sea transfers Sweden

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10.0	11.0	27.3	23.1	9.4	9.4	6.8	7.6	27.3	21.6	21.6	13.7	14.6	19.9	16.7	16.8	27.3
18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
7.7	11.2	16.4	16.0	13.4	23.4	10.0	27.3	27.3	27.3	10.6	27.3	27.3	7.6	27.3	10.6	9.1

Table 60 – Transfer cost road – sea, Sweden

	Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
	500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*5000*	*5300*	*16000*	*27200*	*48000*	*64000*	*3648*	*5000*	*6336*
	38.4	34.7	31.3	30.2	25.7	17.9	16.3	13.2	55.2	32.9	31.5	26.6	28.5	28.1	20.9	21.1	22.2
LGV	400.1	396.5	393.0	392.0	387.5	379.6	378.0	374.9	416.9	513.5	512.1	507.1	509.0	508.7	501.5	501.7	502.8
Light distribution	339.7	336.1	332.6	331.5	327.0	319.2	317.6	314.5	356.5	453.1	451.6	446.7	448.6	448.3	322.2	322.4	323.5
Heavy distribution closed unit	286.6	282.9	279.5	278.4	273.9	266.1	264.5	261.4	303.4	399.9	398.5	393.6	395.5	395.2	269.1	269.3	270.4
Heavy distribution for containers,	181.9	178.3	174.8	173.8	169.3	161.4	159.8	156.7	198.7	57.7	56.2	51.3	53.2	52.9	45.6	45.9	46.9
Articulated semi - total - closed	301.7	298.0	294.6	293.5	289.0	281.2	279.6	276.4	318.4	415.0	413.6	408.7	410.6	410.2	284.2	284.4	285.5
Articulated semi - with container	182.2	178.5	175.1	174.0	169.5	161.7	160.1	157.0	199.0	57.9	56.5	51.6	53.5	53.1	45.9	46.1	47.2
Heavy combination (Sweden)	335.2	331.6	328.1	327.1	322.6	314.7	313.1	310.0	352.0	448.6	447.2	442.3	444.2	443.8	317.8	318.0	319.0
Heavy combination (Sweden) - container	182.8	179.2	175.7	174.7	170.2	162.3	160.7	157.6	199.6	58.5	57.1	52.2	54.1	53.7	46.5	46.7	47.8

Tank truck with hanger oil products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Thermo Truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	242.3	240.9	236.0	237.9	237.5	230.3	230.5	231.6
Semi, thermo	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	163.9	162.5	157.6	159.5	159.1	151.9	152.1	153.2

	Reefer			Product tanker		Crude oil tanker			Chemicals		Dry bulk								LNG	
	2500	*5000*	*10000*	*6416*	*40000*	*100000*	*150000*	*300000*	*9500*	*17000*	*500*	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*28870*	*48817*
	82.3	61.9	54.4	9.0	4.4	3.1	2.9	2.5	125.1	124.4	7.8	8.8	6.2	5.0	4.7	4.5	4.4	3.9	4.0	3.3
LGV	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Light distribution	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution closed unit	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy distribution for containers,	225.9	205.5	198.0	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - total - closed	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Articulated semi - with container	226.1	205.7	198.2	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Heavy combination (Sweden) - container	226.7	206.3	198.8	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger oil products	n.a	n.a	n.a	294.3	294.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	293.6	293.6	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	294.9	294.9	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	294.3	294.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	23.4	20.9	18.3	17.1	16.8	16.7	16.5	16.0	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	21.2	19.9	17.2	16.1	15.7	15.6	15.5	15.0	n.a	n.a
Timber truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
"Flis" truck with hanger (4 axles)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semitrailer, "Flis"	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Thermo Truck with hanger	291.7	271.3	263.8	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Semi, thermo	213.3	192.9	185.4	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Road – rail

Transfer cost and feasibility for road – rail combinations are given in the tables below:

Table 61 – Transfer cost road – rail, Norway

	Electrical, container	Electrical, timber	Diesel, container	Diesel, timber
LGV	633	n.a	632	n.a
Light distribution	558	n.a	557	n.a
Heavy distribution closed unit	495	n.a	494	n.a
Heavy distribution for containers,	47.02	n.a	46.11	n.a
Articulated semi - total - closed	508	n.a	507	n.a
Articulated semi - with container	47.21	n.a	46.30	n.a
Tank truck with hanger oil products	n.a	n.a	n.a	n.a
Semitrailer, tanker oil products	n.a	n.a	n.a	n.a
Tank truck with hanger (chemicals)	n.a	n.a	n.a	n.a
Semitrailer, tanker liquid bulk	n.a	n.a	n.a	n.a
Tank dry bulk truck with hanger	n.a	n.a	n.a	n.a
Semitrailer, dry bulk products	n.a	n.a	n.a	n.a
Timber truck with hanger (4 axles)	n.a	265.72	n.a	261.81
"Flis" truck with hanger (4 axles)	49.39	n.a	48.48	n.a
Semitrailer, "Flis"	48.75	n.a	47.84	n.a
Thermo Truck with hanger	n.a	n.a	n.a	n.a
Semi, thermo	n.a	n.a	n.a	n.a

Table 62 – Transfer cost road – rail, Sweden

	Electrical, container	Electrical, timber	Diesel, container	Diesel, timber
LGV	502	n.a	501	n.a
Light distribution	441	n.a	440	n.a
Heavy distribution	388	n.a	387	n.a
Heavy distribution - container	45.82	n.a	44.90	n.a
Articulated semi trailer	403	n.a	402	n.a
Articulated semi trailer - container	46.05	n.a	45.14	n.a
Heavy combination (Sweden)	437	n.a	436	n.a
Heavy combination (Sweden) - container	47	n.a	46	n.a
Tank truck, with hanger	n.a	n.a	n.a	n.a
Semitrailer - tank	n.a	n.a	n.a	n.a
Tank truck liquid bulk, with hanger	n.a	n.a	n.a	n.a
Semitrailer liquid bulk	n.a	n.a	n.a	n.a
Truck, dry bulk with hanger	n.a	n.a	n.a	n.a
Semitrailer dry bulk	n.a	n.a	n.a	n.a
Truck for timber with 4 axle hanger	n.a	261	n.a	257
Truck, "flis" with hanger	47	n.a	46	n.a
Semitrailer "flis"	46	n.a	46	n.a
Thermo, hanger	n.a	n.a	n.a	n.a
Thermo, semi	n.a	n.a	n.a	n.a

Sea – rail

The transfer costs for transfers between road and sea are given by the tables below. Again, The transfer costs for road-to-sea are regardless of cargo category. Therefore for a given category, a further cost should be added.

Table 63 – Cargo specific transfer cost for road – sea transfers Norway

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7.9	11.0	12.5	11.6	11.8	11.8	11.6	11.6	11.9	49.1	12.3	11.7	11.9	11.5	12.3	8.1
17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
8.1	8.3	9.1	10.6	10.1	6.4	7.6	5.7	4.8	9.2	8.5	8.9	11.9	8.3	8.3	7.5

Table 64 – Transfer cost sea – rail, Norway

	Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
	500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*5000*	*5300*	*16000*	*27200*	*48000*	*64000*	*3648*	*5000*	*6336*
Electrical, container	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	76.4	70.7	66.9	67.5	76.2	72.7	73.3	74.9
Electrical, timber	277.5	274.4	271.5	270.6	266.8	260.2	258.9	256.2	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Diesel, container	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	75.0	69.3	65.5	66.1	74.8	71.3	71.9	73.5
Diesel, timber	273.1	270.0	267.1	266.2	262.4	255.8	254.5	251.9	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

	Reefer			Product tanker		Crude oil tanker			Chemicals		Dry bulk								LNG	
	2500	*5000*	*10000*	*6416*	*40000*	*100000*	*150000*	*300000*	*9500*	*17000*	*500*	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*28870*	*48817*
Electrical, container	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Electrical, timber	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Diesel, container	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Diesel, timber	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Table 65 - Cargo specific transfer cost for sea – sea transfers Sweden

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10.0	11.0	27.3	23.1	9.4	9.4	6.8	7.6	27.3	21.6	21.6	13.7	14.6	19.9	16.7	16.8	27.3
18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
7.7	11.2	16.4	16.0	13.4	23.4	10.0	27.3	27.3	27.3	10.6	27.3	27.3	7.6	27.3	10.6	9.1

Table 66 – Transfer cost sea – rail, Sweden

	Lo/lo, general cargo								Sideport vessel	Container vessel lo/lo					Ro/ro (cargo)		
	500	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*5000*	*5300*	*16000*	*27200*	*48000*	*64000*	*3648*	*5000*	*6336*
Diesel, wagon load	239	235	231	230	226	218	216	213	255	n.a	n.a	n.a	n.a	n.a	262.1	262.1	262.1
Diesel, combi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	61	59	54	56	56	83	83	83
Diesel, system	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	41	40	35	37	37	64	64	64
Electrical, wagon load	234	231	227	226	222	214	212	209	251	n.a	n.a	n.a	n.a	n.a	258.1	258.1	258.1
Electrical, combi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	65	63	58	60	60	87	87	87
Electrical, system	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	40	38	33	35	35	62	62	62

	Reefer			Product tanker		Crude oil tanker			Chemicals		Dry bulk								LNG	
	2500	*5000*	*10000*	*6416*	*40000*	*100000*	*150000*	*300000*	*9500*	*17000*	*500*	*1250*	*2000*	*3600*	*6350*	*10000*	*14500*	*20000*	*28870*	*48817*
Diesel, wagon load	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Diesel, combi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Diesel, system	64	64	64	64	64	n.a	n.a	n.a	64	64	64	64	64	64	64	64	64	64	13	12
Electrical, wagon load	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Electrical, combi	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Electrical, system	62	62	62	62	62	n.a	n.a	n.a	62	62	62	62	62	62	62	62	62	62	11	10

Road – air

Table 67 – Transfer cost road – air, Norway

	Freight plane	
	Airbus A300B4-200F	Boeing 747-400F
LGV	1070	1062
Light distribution	942	934
Heavy distribution closed unit	853	845
Heavy distribution for containers,	512	504
Articulated semi - total - closed	779	626
Articulated semi - with container	513	505
Tank truck with hanger oil products	na	na
Semitrailer, tanker oil products	na	na
Tank truck with hanger (chemicals)	na	na
Semitrailer, tanker liquid bulk	na	na
Tank dry bulk truck with hanger	na	na
Semitrailer, dry bulk products	na	na
Timber truck with hanger (4 axles)	na	na
"Flis" truck with hanger (4 axles)	na	na
Semitrailer, "Flis"	na	na
Thermo Truck with hanger	730	722
Semi, thermo	639	631

Table 68 – Transfer cost road – air, Sweden

	Freight plane	
	Airbus A300B4-200F	Boeing 747-400F
LGV	1061	1052
Light distribution	1001	991
Heavy distribution closed unit	948	938
Heavy distribution for containers,	605	596
Articulated semi - total - closed	963	953
Articulated semi - with container	605	596
Heavy combination (Sweden)	996	987
Heavy combination (Sweden) - container	606	597
Tank truck with hanger oil products	na	na
Semitrailer, tanker oil products	na	na
Tank truck with hanger (chemicals)	na	na
Semitrailer, tanker liquid bulk	na	na
Tank dry bulk truck with hanger	na	na
Semitrailer, dry bulk products	na	na
Timber truck with hanger (4 axles)	na	na
"Flis" truck with hanger (4 axles)	na	na
Semitrailer, "Flis"	na	na
Thermo Truck with hanger	790	780
Semi, thermo	711	702

Ferry cost

Ferries are used to transport vehicles such as trucks or trains across sea legs. In principle, the cost modelling might treat ferry cost in one of two ways. The first would be to calculate them as an additional cost to the truck costs for a given OD-relation. The second way would be to calculate the costs for a given combination of vehicles and ferries. We have used the second approach, since this better connects to the logistics model.

Road ferries

Road ferries are mainly used in Norway. Ferries are used to cross fjords and sea legs and are part of the main road system. User costs are based on tariff pricing for “Riksvegfergene”. In TØI-report 581/2002, a model is developed for ferry prices, giving a cost per ton and a distance dependent cost per tonkm. We base our model on this previous work, corrected for inflation, but adapt it to the structure used for the other vehicles by splitting it into a time dependent and a distance dependent element. For the distance dependent element, for each road vehicle an average capacity utilisation of 50% is used as a basis for converting the cost from per tonkm to per km. The time dependent element is the sum of the cost per hour for the road vehicle used. In addition, there is a fixed cost element per ton, which results in the following costs:

Table 69 – Road ferry cost, Norway. The costs are combined cost for the road vehicle and the ferry.

Vehicle:	kr/km	kr/hour	kr/ton
LGV	1.4	384	17.7
Light distribution	5.9	386	17.7
Heavy distribution closed unit	11.0	373	17.7
Heavy distribution for containers, spec. Cont	11.0	405	17.7
Articulated semi - total - closed	29.7	413	17.7
Articulated semi - with container	29.7	433	17.7
Tank truck with hanger	28.2	533	17.7
Semitrailer, tanker oil products	24.9	467	17.7
Tank truck with hanger (chemicals)	36.5	533	17.7
Semitrailer, tanker liquid bulk	32.3	467	17.7
Tank dry bulk truck with hanger	33.5	514	17.7
Semitrailer, dry bulk products	29.6	454	17.7
Timber truck with hanger (4 axles)	22.6	463	17.7
"Flis" truck with hanger (4 axles)	20.9	497	17.7
Semitrailer, "Flis"	20.9	449	17.7
Thermo Truck with hanger	21.2	485	17.7
Semi, thermo	22.6	456	17.7

International ferries

International ferries tend to be RoPax ferries that combine passenger traffic and freight lorries on the same vessels and sailings. More than half of the incomes for these ferries are generated by shops and restaurants and there are elements of internal subsidising from passenger traffic towards freight in terms of contributions to cost coverage for the ferries. As a basis for estimation of the user cost, the best would be to use the actual pricing. For ferries to and from Norway, a price model has been developed in TØI 581/2002 estimating average cost per ton and km and per ton and hour for trucks on international ferries to and from Norway. These costs are corrected for inflation and the cost per km is calculated based on an average capacity utilisation of the vehicles of 50%. The time dependent part is the sum of the time dependent cost for the ferry transport based on the same assumption for average utilisation as for the km dependent cost plus the time dependent cost for the vehicle.

The limitations to what cargo can be taken on board a RoPax ferry are indicated in the comment column of the table below.

Table 70 – Cost for international ferries – Norway. The costs are combined cost for the road vehicle and the ferry

Vehicle:	kr/km	kr/hour	Comment
LGV	0.02	397.3	
Light distribution	0.10	443.1	
Heavy distribution closed unit	0.19	479.1	
Heavy distribution for containers, spec. Cont	0.19	511.6	
Articulated semi - total - closed	0.50	699.1	
Articulated semi - with container	0.50	718.9	
Tank truck with hanger	0.48	803.7	If applicable
Semitrailer, tanker oil products	0.42	706.2	If applicable
Tank truck with hanger (chemicals)	0.62	883.9	If applicable
Semitrailer, tanker liquid bulk	0.55	777.0	If applicable
Tank dry bulk truck with hanger	0.57	835.4	
Semitrailer, dry bulk products	0.50	738.8	
Timber truck with hanger (4 axles)	0.38	681.1	If applicable
"Flis" truck with hanger (4 axles)	0.35	697.3	If applicable
Semitrailer, "Flis"	0.35	649.9	If applicable
Thermo Truck with hanger	0.36	689.4	
Semi, thermo	0.38	673.9	

For the Swedish foreign ferries, a similar work was presented in SIKA 2002:15. Based on the same principles as above, the ferry cost for combination of trucks and international ferries to/from Sweden is calculated as below:

Table 71 – Cost for international ferries – Sweden. The costs are combined cost for the road vehicle and the ferry

Vehicle type	Cost per km	Cost per hour	Comment
LGV	0.0534	328.7	
Light distribution	0.2242	354.3	
Heavy distribution closed unit	0.4163	364.6	
Heavy distribution for containers, spec. Cont	0.4163	403.0	
Articulated semi - total - closed	1.1208	511.0	
Articulated semi - with container	1.1208	534.8	
Tank truck with hanger	1.0621	628.8	If applicable
Semitrailer, tanker oil products	0.9394	538.5	If applicable
Tank truck with hanger (chemicals)	1.3770	672.5	If applicable
Semitrailer, tanker liquid bulk	1.2169	577.0	If applicable
Tank dry bulk truck with hanger	1.2623	635.3	
Semitrailer, dry bulk products	1.1155	549.4	
Timber truck with hanger (4 axles)	0.8540	523.5	If applicable
"Flis" truck with hanger (4 axles)	0.7872	550.7	If applicable
Semitrailer, "Flis"	0.7872	498.1	If applicable
Thermo Truck with hanger	0.8006	539.9	
Semi, thermo	0.8540	515.1	
Heavy combination	1.3343	649.1	If applicable
Heavy combination with container	1.3343	654.7	If applicable

Railway ferries

The railway ferries are mainly a Swedish issue. We will base the cost models for combinations of trains and ferries on SIKA 2002:15. The cost parameters are corrected for inflation. For the load on the various train categories, the same assumptions are used as for the calculation of rail costs (SIKA 2002:15).

Table 72 – Cost for railway ferries – Sweden. The costs are combined cost for the train and the ferry

Train category	Kr/km	Kr/hour
Wagonload train, electrical	155	4746
System train, electrical	333	7818
Combi trains, electrical	200	5522
Wagonload train, diesel	155	4856
System train, diesel	333	7923
Combi trains, diesel	200	5638

Airfreight

We have calculated cost parameters for freight planes based on a revision of the calculations made in SIKA 2002:15 for two alternative sized freight planes. The detailed level of the previous calculations facilitated a detailed approach of the adjustments. The largest change from the 2002 calculations is in the cost per km due to the rather steep increase in fuel prices, which has taken place. Although this increase was found in Swedish data, it was also applied to the Norwegian cost. In addition to the calculated costs, start and landing fees for the specific airports are taken from the network model.

Table 73 – Cost model air freight – Norway

Freight plane:	Average load (tons)	Max load	kr/km	kr/hour	Loading cost/ton
Airbus A300B4-200F	43.96	60.6	42	39802	501
Boeing 747-400F	86.59	119.4	65	76416	493

Table 74 – Cost model air freight – Sweden

Freight plane:	Average load (tons)	Max load	kr/km	kr/hour	Loading cost/ton
Airbus A300B4-200F	43.96	60.6	49	46891	595
Boeing 747-400F	86.59	119.4	77	90035	585

For feasibility of airfreight, see the section on road-air in the chapter on transfer cost.

Relationship with cost models in the network models

The cost functions in the network models are split in several components:

uv1: Cost per tonkm

uv2: Cost per ton and hour

These costs are calculated for the different modes, based on averages across vehicle types and cargo groups. Furthermore, there are specific linkage costs to handle specific costs on an OD link:

/wbyveh: where is the additional link cost, and wbyveh is the "weight by vehicle", (average) load per trip on the link. The costs are further adjusted with factors to establish the relationships between cost and expected price paid by the user, calibration factors for the suitability of the mode, factors for expected delays, and also level factors for adjusting to specific costs on links, regions and countries.

For the logistics model the costs are directly linked to the vehicles used. The model allocates cargo to vehicles based on lot-size and cost considerations. The cost parameters calculated for each vehicle are:

C_{kmv}: Cost per km for the vehicle

C_{hrv}: Cost per hour for the vehicle

The costs are calculated for the transport vehicles based on average loads and market prices. The actual cost per tonkm for the goods carried depends on the capacity utilisation for the respective cargo. In principle however, there is a relationship between the way costs are calculated for the network model and for the vehicles:

$$uv1 = C_{kmv}/(average\ tonnage)$$

$$uv2 = C_{hrv}/(average\ tonnage)$$

For both cases the costs are built up bottom-up. This means that they are based on more detailed calculations under specific assumptions for different vehicles. However, while the network costs are based on aggregation across different vehicles and cargo groups, the logistics model's costs remain on a disaggregated level. The aggregations in the network models are generally based on fewer vehicles than the vehicle models with a few significant exceptions. Table 75 gives some of the characteristics of the calculations:

Table 75 - Relationships between costs in network and logistics model

Aspect	Network cost	Logistics model cost
Level	Aggregated on a modal basis	Disaggregated on a vehicle basis
Adaptation to cargo groups	Implicit in aggregation	Controlled by feasibility tables between cargo groups and vehicles. Explicit in optimisation
Alternatives, trucks	Few - (Variations between Norwegian and Swedish model)	17-19
Alternative ships	Few (Variations between Norwegian and Swedish model)	37 (+ ferries)
Alternative trains	Few (Variations between Norwegian and Swedish model)	Same number used in the Swedish model as in the network model. (Same basis) 4 categories used in Norwegian model
Alternatives, ferries	Few	Same number used as in the network model
Alternatives, air	Few	Same number used as in the network model
Direct relationships between cost models	-	For road and sea, the cost models are basically developed separately with a few exceptions: The largest Swedish trucks are based on the same data used in calculating the network costs. For rail, the Swedish costs are based on an adjustment of the network cost, while the Norwegian costs are calculated separately. For ferries and air, the costs are based on adjustments of previous calculations made for establishing network costs.
Other link cost	Included in separate parameters	Not included. Must be extracted from the network model, and added to OD cost for a given mode.

Even if the costs are based on the same background material, there will be differences in levels and actual costs calculated due, among other things, to the following:

- Changes in main cost factors as fuel prices, labour and general costs;
- Changes in interest levels;
- Currency fluctuations (SEK/USD; NOK/USD).

Another difference is that the vehicle costs do not include any time cost or other cost for the cargo itself. (This is included in the optimisation based on inventory holding costs of the cargo).

The cost model also includes loading and unloading costs. These are calculated based on the following:

- Assumptions on methods and capacities in loading / unloading a vehicle based on the feasibility matrices vehicles/cargo groups, size of vehicles and data on equipment cost and labour cost;
- Time cost for the vehicle involved.

The direct cost are calculated in kr/ton. The same goes for the vehicle time cost which are added to the kr/ton based on the following relationship:

Time cost vehicle = C_{hr}*/(loading(unloading) capacity per hour)*

For sea vessels, cargo fees and berth fees are included. In general, other fees such as “farledsavgifter” and for air “airport fees” etc. are not included in the logistics cost model and should be imported in that model from the network model. Transfer costs in the logistics model generally consist of combinations of loading and unloading costs for the two vehicles between which the transfer takes place.

Inventory cost

Inventory cost is divided in two groups: inventory holding cost and order cost. The inventory holding cost consists of two elements:

Inventory holding cost = Capital cost + Other holding cost

The capital cost is based on the interest of current inventory levels. The other holding cost depends on cargo type calculated for use of area, staff and administration. Depending on cargo types, different sort of areas and stockholding methods are assumed (for example closed warehouses for general cargo, tank facilities for petroleum products and bulk shelters for dry bulk products).

For the order cost, in practice there may be large variations due to individual business processes applied by the companies. We use some typically cost levels based on case studies and expert judgements. The resulting costs model then is:

Table 76 – Inventory cost – Norwegian model

New Nemo category	Description	Inventory holding cost per day	Estimated order cost
11	Bulk food	1.42	500
12	Consumptions food	4.08	500
13	Beverages	4.06	500
21	Fresh fish	5.69	500
22	Frozen fish	8.96	500
23	Other fish	8.96	500
31	Thermo input	6.00	500
32	Thermo consumption	4.42	500
41	Machinery and equipment	16.29	500
42	Vehicles	22.44	500
51	General cargo - high value goods	77.34	750
52	General cargo - live animals	13.80	500
53	General cargo - building materials	2.73	500
54	General cargo - other inputs	4.02	500
55	General cargo - consumptions goods	2.72	500
61	Timber - "Saw logs"	2.00	500
62	Timber - "Round logs"	1.97	500
63	Pulp	2.90	500
64	Paper intermediates	3.36	500
65	Wood products	2.59	500
66	Paper products	6.86	500
71	Mass commoditites	0.68	500
72	Coal, ore and scrap	0.76	750
73	Cement, plaster and cretaceous	1.10	750
74	Non-traded goods	0.66	200
81	Chemical products	1.06	750
82	Fertilizers	0.83	750
91	Metals and metal goods	1.91	750
92	Aluminium	4.07	750
101	Raw oil	0.79	750
102	Petroleum gas	0.74	750
103	Refined petroleum products	0.84	750

Table 77 – Inventory cost – Swedish model

New Stan category	Description	Inventory holding cost per day	Estimated order cost
1	Cereals	0.99	389
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	4.59	389
3	Live animals	4.46	389
4	Sugar beet	2.82	389
5	Timber for paper industry (pulpwood)	2.26	389
6	Wood roughly squared or sawn lengthwise, sliced or peeled	2.59	389
7	Wood chips and wood waste	2.31	389
8	Other wood or cork	2.28	389
9	Textiles, textile articles and manmade fibres, other raw animal and vegetable materials	9.13	389
10	Foodstuff and animal fodder	4.62	389
11	Oil seeds and oleaginous fruits and fats	3.37	389
12	Solid mineral fuels	0.80	584
13	Crude petroleum	0.75	584
14	Petroleum products	0.97	584
15	Iron ore, iron and steel waste and blast-furnace dust	0.81	584
16	Non-ferrous ores and waste	0.84	584
17	Metal products	4.04	389
18	Cement, lime, manufactured building materials	0.92	584
19	Earth, sand and gravel	0.76	584
20	Other crude and manufactured minerals	0.79	584
21	Natural and chemical fertilizers	3.03	584
22	Coal chemicals, tar	0.89	584
23	Chemicals other than coal chemicals and tar	3.04	584
24	Paper pulp and waste paper	3.09	389
25	Transport equipment, whether or not assembled, and parts thereof	11.32	389
26	Manufactures of metal	7.94	389
27	Glass, glassware, ceramic products	5.20	389
28	Paper, paperboard; not manufactures	3.40	389
29	Leather textile, clothing, other manufactured articles than paper, paperboard and manufactures thereof	6.22	389
30	Mixed and part loads, miscellaneous articles etc	6.91	389
31	Timber for sawmill	2.26	389
32	Machinery, apparatus, engines, whether or not assembled, and parts thereof	19.98	389
33	Paper, paperboard and manufactures thereof	6.03	389
34	Used packaging materials	3.72	156

Annex 4. The data used for calibrating the 2005 logistics model

The aggregate calibration data refer to the mode shares. For Norway we only had available calibration data in terms of tonnes transported (received from TØI).

Table 78 - Norway: domestic flows in tonnes (x 1,000)

NEMO10 Commodity type number (NEMO32)	Commodity description	Road transport	Rail transport	Sea transport
1 (11-13)	Bulk food, consumption food, beverages	12,389	272	108
2 (21,22)	Fish	1,272	36	22
3 (31,32)	Thermo products	9,863	75	6
4 (41,42)	Machinery and equipment	7,285	-	67
5 (51-55)	General cargo	66,455	2,962	1,197
6 (61-66)	Sawlogs, pulpwood, pulp, paper intermediates, wood products, paper products and printed	9,537	804	2,082
7 (71-74)	Mass commodity, coals, ore, scrap, cement, plaster, non-traded goods	112,870	-	8,696
8 (81,82)	Chemical products, fertilisers	5,345	25	860
9 (91,92)	Metals, metal products, aluminium	6,046	-	343
10 (101-103)	Crude oil, petroleum gas and refined products	9,633	-	5,679
Total		240,695	4,173	19,059

Table 79 - Norway, export and import flows in tonnes (x 1,000), by NEMO10 commodity group

Import	1	2	3	4	5	6	7	8	9	10	11[32]	SUM
Truck	181	15	159	365	1843	1159	199	546	30	169		4658
Rail	21	0	29	27	355	295	20	63	5	12		825
Ship	813	314	148	464	3075	1883	5164	2567	4494	5482		24419
Ferry	118	9	142	174	530	19	31	175	33	29		1255
Sum	1132	338	479	1030	5802	3356	5415	3352	4561	5691		31157
Export												
Truck	54	78	33	101	1440	347	47	843	40	22	204	3231
Rail	1	2	0	3	295	147	188	83	10	0	0	729
Ship	202	848	17	107	6503	114	12813	8133	563	14439	181	43849
Ferry	19	45	9	79	559	243	9	326	13	7	140	1446
Sum	276	973	59	289	8796	851	13058	9385	625	14468	525	49254

For Sweden, we have calibration data by mode in terms of tonnes, tonne-kilometres, vehicle kilometres and transports. For consistency with Norway, we used data in tonnes for calibration.

[32] Fresh fish.

Table 80 - Sweden, domestic flows in tonnes (x 1,000), 2001

NSTR commodity group number	Description	STAN34 number	Road transport[33]	Rail transport[34]	Sea transport[35]
1	Cereals	1	5,519	16	280
2	Potatoes, vegetables, fruit	2	2,182	126	-
3	Live animals, sugar beets	3, 4	1,862	-	239
4	Wood	5-8, 31	62,105	6,469	342
5	Textiles	9	1,304	10	2
6	Foodstuffs	10	25,334	697	34
7	Oil seeds	11	453	23	13
8	Solid mineral fuels	12	953	532	52
9	Crude petroleum	13	42	-	-
10	Petroleum products	14	15,808	779	6,930
11	Iron ore	15	8,000	23,428	1,311
12	Non-ferrous ores	16	1,344	283	-
13	Metal products	17	5,993	7,999	18
14	Cement, building materials	18	13,279	306	1,125
15	Crude and manufactured minerals	19, 20	79,719	661	859
16	Fertilisers	21	1,704	84	39
17	Coal chemicals	22	35	7	1
18	Other chemicals	23	5,612	1,026	330
19	Pulp and waste paper	24, 34	6,062	1,867	27
20	Machinery and equipment	25, 32	10,188	659	2
21	Manufactures of metal	26	1,215	103	-
22	Glass, ceramics	27	649	73	-
23	Paper, clothing	28, 29, 33	12,415	4,729	68
24	Part loads	30	42,489	4,157	57
Total			304,300	54,032	12,207

[33] Transport with origin and destination in Sweden by Swedish lorries (SIKA and SCB, 2005). International goods transport by Swedish lorries: 6.642 million tonnes in 2001.

[34] All goods transport on Swedish rail tracks, of which 34.795 million tonnes domestic consignments and 20.411 million tonnes for cross-border consignments (SIKA and National Rail Administration, 2003). The cross-border consignments are dominated by the iron ore transports from Kiruna: after subtracting 15-20 mln tonnes from category 11 in the table, we obtain a reasonable impression of the domestic rail pattern.

[35] Shipping between Swedish ports (volume unloaded, which is almost equal to the volume unloaded). The source is SIKA (2004).

Table 81 - Sweden, import and export flows by sea in tonnes (x 1,000), 2001

Mode	Unloaded in Sweden	Loaded in Sweden
Sea vessel only	55,301	41,154
Lorry on ship	13,940	14,396
Train on ship	1,436	2,231
Total	70,677	57,781

The air transport volume is only 171,000 tonnes for international airfreight plus 5,000 tonnes domestic freight plus 35,700 tonnes airmail in 2001 (SIKA, 2002), and is not relevant for calibration.

Annex 5. Comparison of PWC and singular flows

In this Annex we give examples of the comparison of flows by commodity type from Table 14 and Table 15 (singular flows) with the PWC flows for Norway and Sweden.

Kiruna-Narvik

Singular flows: 15.5 million tonnes for commodity type 15/72 (iron ore). Total PWC flow (all senders) of 71 from Kiruna: 2.7 million tonnes.

Tana-Iceland/Bremanger

Singular flows: 308,000 tonnes for commodity type 72 (silica). Total PWC flow (all senders) of 72 from Tana: 101,000 tonnes.

Spain-Orkdal

Singular flows: 100,000 tonnes for commodity type 72 (silica). Total PWC flow (all receivers) of 72 to Orkdal: 111,000 tonnes.

Surinam-Farsund

Singular flows: 174,000 tonnes for commodity type 71 (alumina). Total PWC flow (all receivers) of 71 to Farsund: 38,000 tonnes.

Surinam-Mosjøen

Singular flows: 365,000 tonnes for commodity type 71 (alumina). Total PWC flow (all receivers) of 71 to Mosjoen: 14,000 tonnes.

Mosjøen-Rotterdam

Singular flows: 210,000 tonnes for commodity type 92. Total PWC flow (all senders) of 71 to Mosjøen: 14,000 tonnes.

Surinam/Brasil/Jamaica-Karmøy

Singular flows: 199,800 tonnes for commodity type 71 (alumina) from Brasil, 110,700 tonnes from Jamaica and 118,800 tonnes from Surinam. Total PWC flow (all receivers) of 71 to Karmøy: 1,445,000 tonnes.

Karmøy-Rotterdam

Singular flows: 317,000 tonnes for commodity type 92. Total PWC flow of 92 from Karmøy: 64,000 tonnes.

Surinam/Brasil/Jamaica-Sunndal

Singular flows: 154,000 tonnes for commodity 71 from Surinam, 259,000 tonnes from Brasil and 143,500 tonnes from Jamaica. Total PWC flow of 71 to Sunndal: 225,000 tonnes.

Sunndal-Rotterdam

Singular flows: 349,000 tonnes for commodity type 92. Total PWC flow of 92 from Sunndal: 29,000 tonnes.

Porsgrunn-overseas

Singular flows: 1,180,000 tonnes for commodity type 82 to destinations outside Europe, 249,000 tonnes to the UK and 212,00 tonnes to France/Spain. Total PWC flow (all senders) of 82 from Porsgrunn: 25,000 tonnes.

Kårstø/Bergen-Porsgrunn

Singular flows: 137,000 tonnes for commodity type 102 from Kårstø and 344,000 tonnes from Bergen. Total PWC flow of 92 from Porsgrunn: 0 tonnes

Oxelösund/Luleå -Borlänge

Singular flows: 700,000 tonnes for commodity type 17 from Oxelösund and 2,100,000 tonnes from Luleå. Total PWC flow of 17 Oxelösund-Borlänge: 4,000 tonnes. Total flow from Oxelösund for 17: 600,000, and 718,000 tonnes from Luleå. Total PWC flow for 17 to Borlänge: 524,000 tonnes

Halmstad-Gothenburg

Singular flows: 400,000 tonnes for commodity type 28. Total PWC flow of 28 from Halmstad: 73,000 tonnes

Karlstad-Gothenburg

Singular flows: 400,000 tonnes for commodity type 28. Total PWC flow of 28 from Karlstad: 76,000 tonnes

Borlänge -Malmö/Gothenburg

Singular flows: 600,000 tonnes for commodity type 17 to Malmö and 200,000 to Gothenburg. Total PWC flow of 17 from Borlänge : 2,953,000 tonnes

Borlänge –Gothenburg

Singular flows: 600,000 tonnes for commodity type 6. Total PWC flow of 6 from Borlänge : 23,000 tonnes.

Given these differences, we suggest that the logistics model team and the base matrix teams together carry out a check of the PWC flows against the singular flows, to remove inconsistencies that cannot be justified. The three largest OD flows (all by train) that seem to be missing from the PWC files are:

- Kiruna – Narvik, commodity 15 (Sweden) and 72 (Norway): 15.5 million tonnes;
- Kiruna – Luleå, commodity 15: 5 million tonnes;
- Luleå – Borlänge, commodity 17: 2.1 million tonnes.