Documentation and clarification of Deliverable 4 and the associated program delivery for a logistics module in the Norwegian and Swedish national freight model systems

Deliverable 4a 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 provided clarifications and amendments to a report and computer programs delivered earlier concerning 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 (D4) on the data requirements and further specification of the logistics model was written in 2005 and January/February 2006. A prototype version of the logistics model was programmed for both Norway and Sweden and delivered on 16 February 2006. The current report (D4a) includes the following:

1. Clarifications and amendments on D4 and the programs for the prototype logistics model for Norway and Sweden;
2. Reactions and comment on the outcomes of tests of the model performance and outcome carried out by the clients;
3. Our conclusions for directions of the work in the coming development phases.

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 (D1) and the 2005/2006 report on model development (D4).

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CHAPTER 1 Introduction

1.1 Background

In 2005 and January/February 2006, RAND Europe, together with SITMA, produced Deliverable 4 (D4: Final Progress Report on Model Development) and prototype computer programs for the Samgods group in Sweden and the Work Group for transport analysis in the Norwegian national transport plan. This work was part of a broader study on the development of a logistics module for the Norwegian and Swedish national freight model systems. The first version of the prototype computer program ('*version 0.1*') was delivered in November (Norway) and December (Sweden) 2005.

On 16th February 2006 some initial problems related to the version 0.1 program were fixed according to the agreement made at the meeting in Leiden on 31st January. The most important problems that were fixed are the following:

- The long run-times (for the Swedish program);
- Deviations between the amounts of tonnes in the PWC (base) matrices and the corresponding quantities generated by the model;
- Possible unit errors in the cost functions;
- The fact that the programs could not be operated using a control file.

The program delivery on 16 February 2006 can be seen as a new prototype version ('*version 0.2*'). In addition to these modifications, a flow diagram giving a general overview of the structure of the prototype logistics model was produced.

The clients now wish to attain a higher level of understanding (more detailed and precise) of the properties of the logistics models (for Norway and Sweden) that have been delivered. This is deemed necessary as a basis for the specification of the next steps for the development of the logistic models ('*version 1*').

A further purpose of the current project is to specify and evaluate some additional tests of the model's ability to produce reasonable outcomes for a number of test cases.

These activities together form Phase 2 of the work (three phases in total) to be done before autumn 2006, as described in the minutes of the meeting in Leiden on 31 January 2006.

The Samgods group and the Norwegian NTP have contracted RAND Europe to carry out these Phase 2 activities. This report is called 'Deliverable 4a' and contains the outcomes of the 2006 Phase 2 work. RAND Europe has produced this report together with its subcontractor SITMA (notably Stein Erik Grønland), as was the case for the previous assignment.

1.2 Scope and Objectives

The objectives of the work carried out in this project were:

1. To provide clarifications and amendments on D4 and the programs for the prototype logistics model for Norway and Sweden (a list of these can be found in Chapter 2 on the activities to be carried out);
2. To react and comment on the outcomes of tests of the model performance and outcome carried out by the clients;
3. To communicate to the clients our conclusions for directions of the work in the coming development phases (especially Phase 3).

All activities of Phase 2 have been carried out in close co-operation between RAND/SITMA and representatives of the clients.

1.3 Contents of this report

The following chapters of this report describe in more detail the questions asked by the clients and the outcomes of the work carried out this research project. In Chapter 2 we provide the requested clarifications and amendments to D4. Our reactions and comments on the tests performed by the clients are described in Chapter 3. Conclusions and recommendations for the future development phases can be found in Chapter 4.

CHAPTER 2 Clarifications and amendments

2.1 Overview of requested clarifications and amendments

Clarifications and amendments need to be provided for the following items (in Sections 2.2 – 2.12 the outcomes are discussed item for item):

1. The most recent program delivery (version 0.2) has improved the consistency between the base matrices and the outputs of the logistics model, by treating the disaggregation step as an allocation of the zone-to-zone flows from the PWC base matrices. However, it is still the case that not all the quantities in the input PWC-matrices are retained in the output files from the present logistic models. The existing 2005 model does not include intrazonal flows in the output files. These should be added in the 2006 model. Furthermore, the new disaggregation process is conditional on the availability of transport chains and producing and consuming firms for each zone-to-zone pair in the PWC matrices. The discrepancies between the base matrices and the latest prototype model outputs at the zone-to-zone level will be thoroughly analysed and explanations for these discrepancies will be provided. Also suggestions will be given as to how similar problems may be avoided in future versions of the models. The operation of the provision for "virtual firms" would seem to be a mechanism to ensure that quantities will not be lost due to the fact that there are no producing and/or consuming firms for certain elements of the PWC-matrix. We shall explain how this mechanism operates in practice in the present model and whether this mechanism has failed in any way in the present model to prevent the occurrence of the observed discrepancies.
2. We shall make sure that our approach will give a distribution of consumption of NSTR-commodities by municipality that is broadly consistent to the national use tables. The national use tables show that many sectors consume commodities from several commodity groups.
3. We shall advise how a reporting mechanism of non-allocated flows can be incorporated into the present model (version 0.2) and also implement such a mechanism in the programs.

4. We shall explain how the run-time reductions have been accomplished, and if and to what extent the intended functionality of the models has in any way been reduced by the measures used for run-time reductions.
5. A flow diagram depicting the overall structure of the model has been delivered by RAND as a supplementary delivery. The clients would like to have a considerably more detailed flow diagram, or rather a set of flow diagrams. The new flow diagrams will, for each functional part of the model: explain which specific input data sets are used in each of the sub-modules, what decision rules are applied, what key calculations are carried out, and what output data are produced in each of the sub-modules of the logistics models.
6. An extra sub-model within the prototype logistics module has been used to determine the transfer locations (lorry terminals) of chains that only use road transport. This submodel is briefly described on page 110-111 of D4. A more detailed description of this sub-module will be provided.
7. D4 does not clearly explain if, why, and how the principles for the development of the cost functions for coming development phases might differ from the more or less provisional cost functions that have been used for the current logistics models. This part of the present models will be elaborated and clarified by reacting to the note recently produced by John Bates ('The Cost Specification for the Logistics Model, incl. Stein-Erik Grønland's comments'). We shall also clarify how the present (or other) simplifications and/or approximations of the cost functions are expected to influence the functionality and outcome of the current models and how a feasible, adequate approach for the cost functions is expected to influence the validity of the model.
8. In the 2005 model STAN-based pre-specified transport chains were used as alternatives in a deterministic costs minimisation approach. As a preliminary assumption we postulated that the vehicles/vessels that leave consolidation points are loaded to 90 %. Empty trips were modelled on the basis of vehicle balances, using assumptions for key input parameters. Cargo units were modelled implicitly through the vehicle/vessel types. Ideas for more adequate approaches on these topics for the version 1 model (the next version) will be developed.
9. The assumptions in the provisional model for the number of firm-to-firm relations (see Tables 29-30 of D4) will be discussed. SIKA/SCB will derive lower bounds for the number of receivers per sender from the CFS and register data. SIKA/SCB will also make the modelling of timber transport more realistic. The number of senders will be reduced by using forest statistics. SIKA/NTP will also have a closer look at the stereotypes on logistics decision making in Tables 6-7 and 9-10 (e.g. for timber transport).
10. For a limited set of PWC/product relations (approximately 5-10 for Sweden and 5-10 for Norway) the entire operation of the logistics models will be illustrated, from disaggregation to firms via determination of shipment size and the set of logistic chains that have been considered for selection (including points of modal change). The clients expect that a thorough study of the characteristics of these

examples will contribute significantly to the understanding of the operation, characteristics, and possible strengths and weaknesses of the present model. Each of these examples will be presented with comments. The 5-10 examples will be defined by the clients and for the Swedish case will use real relations from the CFS.

11. The basis for and the actual implementation of the mechanism for the generation of receiving firms (C or C-type W firms) in the present model will be explained and illustrated by suitable examples. It seems as if many firms producing one specific product are using a rather wide range of products as inputs. In the present model we do not assume that receiving firms use as input only the same product classification number as their own output product

2.2 Consistency with PWC base matrices

The program of 16 February 2006 (version 0.2) exactly reproduces the PWC tonnes for a number of commodity types (after correcting for intra-zonal flows). For commodity types and zone-to-zone (z2z) relations where there is no transport chain, production firm or consumption firm available, there still is a difference between the z2z tonnes in the model and the PWC files. In Table 1 we compare the PWC flows and model flows per commodity type and list the importance of these possible causes for deviations for Norway.

Commodities 30 (crude petroleum) and 31 (petroleum gas) have been excluded for Norway, because these include (very large) shipments from the continental shelf that are either using pipeline (not among the available transport chains) or sea transport (but not connected to the network used here). Certainly the latter should be included in the Version 1 model. The missing transport chains for the other commodities mainly concern international flows for which the overseas origin or destination has no road links in the network model. For domestic transport, some transport chains are missing because a zone number has changed.

In the Norwegian version 0.2 model, for almost 60,000 z2z relations the consumption firms are missing. It appears this was not due to malfunctioning of the procedure to generate virtual firms for missing cases, but a result from using an outdated consumption file (that we produce in MS-Access). We checked a number of z2z relations that were missing consumption firms in the 0.2 model and found all relations to have consumption firms.

Table 1 - Comparison of interzonal PWC flows and model tonnages (at PWC level) for Norway

Commodity	Tonnes from P(W) to C(W) in outfile of model	Tonnes in PWC matrices (excl. intrazonal)	Number of relations without a transport chain	Number of relations without a production firm	Number of relations without a consumption firm
1	4215992	4558106	1246	0	179
2	1268430	1437596	949	0	7540
3	501782	559874	804	0	3302
4	1643515	1736552	651	0	378
5	1645008	1855848	1280	0	336
6	1645008	1855848	1280	0	336
7	138103	193424	208	0	5331
8	6860139	7034395	836	0	1321
9	3320312	3503940	1720	0	4619
10	615774	834792	637	0	13787
11	61205	66322	577	0	567
12	38985	135923	50	0	14828
13	10588826	11280512	3577	0	262
14	4763330	5074988	3194	0	309
15	50767228	54127793	4393	0	4993
16	2136293	2208061	467	0	62
17	2136293	2208061	467	0	62
18	496254	512468	223	0	88
19	1408706	1454539	338	0	144
20	9855212	10172924	589	0	54
21	560913	580904	230	0	284
22	29998196	30966835	1127	0	0
23	9463817	9769379	949	0	5
24	641054	661867	628	0	20
25	0	0	0	0	0
26	11751434	12972396	2190	0	13
27	4107877	4534768	1845	0	47
28	11589870	15474665	435	0	0
29	4330905	5782508	382	0	6
30	Nor relevant	Not relevant	4523	0	1
31	Nor relevant	Not relevant	159	0	0
32	8787596	41593123	147	0	16
	185338057	233148411	36101	0	58890

Table 2 - Comparison of inter-zonal PWC flows and model tonnages (at PWC level) for Sweden

Commodity	Tonnes from P(W) to C(W) in outfile of model	Tonnes in PWC matrices	Number of relations without a transport chain	Number of relations without a production firm	Number of relations without a consumption firm
1	2507514	2507514	0	0	0
2	2215226	2215226	0	0	0
3	1785	2011	5191	120	0
4	2013420	2624156	0	720	0
5	29679341	29689664	1641	0	0
6	6643317	7935266	5441	0	0
7	2562444	2641966	0	878	0
8	61424	62722	0	261	0
9	525647	525647	0	0	0
10	21554846	21554846	0	0	0
11	691493	691493	0	0	0
12	2451222	2967531	305	0	0
13	1604798	2400002	156	0	0
14	23980726	24485327	1842	595	0
15	11080861	11311539	0	622	0
16	2960718	2974837	0	220	0
17	16001957	16013417	0	3456	0
18	11381813	11537130	0	991	0
19	4711404	5661070	1668	935	0
20	9117066	9130851	0	2897	0
21	2066674	2233213	0	2280	0
22	478268	478277	308	0	0
23	11772621	12823637	3512	4896	0
24	6415129	7958779	0	3334	0
25	2865795	2865795	0	0	0
26	2440702	2440702	0	0	0
27	986876	994480	0	5588	0
28	10043891	10773434	0	9487	0
29	6338482	6338482	0	0	0
30	18	19	0	204	0
31	7098611	7170570	0	494	0
32	2437040	2437040	0	0	0
33	2992188	2996534	0	241	0
	207683317	216443177	20064	38219	0

In Table 2 is the same information for Sweden. Furthermore, for Sweden, Table 3 gives the number of firm-to-firm (f2f) relations (both in the logfile and the outfile of the program) and the number of z2z relations that is non-zero in the base matrices.

Table 3 - Comparison of number of f2f and z2z relations

Commodity	Firm-to-firm relations in log file	Firm-to-firm relations in outfile	Zone-to zone relations in PWC matrices
1	13070	13052	13052
2	15556	15540	15540
3	21240	12105	6769
4	11118	11114	8410
5	23645	21824	21824
6	102159	96433	96433
7	26991	26704	11247
8	6931	6931	6757
9	179979	179115	65345
10	32512	32223	32223
11	16535	16535	11106
12	505002	502795	69621
13	327	168	167
14	33033	30906	30906
15	6940	6892	4887
16	13465	13254	6800
17	99889	99612	99612
18	19386	19129	19129
19	12183	9975	6200
20	69283	69067	69067
21	63547	63322	34567
22	2999	2573	1812
23	96560	92776	92776
24	17017	16959	16959
25	107618	107329	107329
26	114862	114573	114573
27	804158	801537	95544
28	68737	68537	68537
29	88778	88200	51385
30	4012	4012	3808
31	42737	42499	42499
32	94112	93823	93823
33	9034	8759	8759
	2723415	2688273	1327466

A few f2f relations that are in the logfile are not included in the outfile because no transport chains exist for these relations. This concerns a very small volume (in tonnes).

Also there are flows in the PWC matrix for which no production firm was found (in the sending zone) in the MS-Access production file that we constructed on the basis of information from the CFAR. Since new production companies are generated for flows originating from zones that did not have a firm in the flow's commodity type, all flows should now be linkable to companies producing these flows (and thus these commodities).

The programs delivered on 16 February 2006 contained a bug in the writing of the firm identifiers to the outfile. In cases where there was only one f2f relation for a z2z flow (1.56 million relations in Sweden), the outfile was correct. But for zone pairs with multiple f2f relations, for the second, third, etc. f2f relations the same firm identifiers were written to the file as for the first f2f relation. The bug did not affect the computations (these were done correctly), only the writing of results to the outfile, and it was repaired.

2.3 Consistency with Use matrix

Each sector in Norway and Sweden produces mainly products in a single product category. Therefore, in the program we assign a single product category to each firm at the sending end, as part of step A, the disaggregation to firm-to-firm flows. The Use matrices give the consumption (in product categories) of each sector of the economy. The Use matrices for Norway and Sweden show that each sector consumes products from several product groups: for most sectors, there is not a product group that really dominates in terms of input volume. Therefore it would be good to account in the model for the fact that a single firm might be a receiver of products from several product groups. In the (new) consumption file for Norway, this has already been done. On average there are in this file about six consumption product categories per consuming firm (each firm appears six times in this file - on average) If we distinguish several input commodities for each receiving firm, the effective number of receiving firms will be increased by a factor that is equal to the average number of product categories consumed by a firm. So if (on average) we include the six most important commodities, we get six times as many potential receivers in our calculations. The potential number of receivers in a certain zone then goes up by this factor as well. However, the number of firm-to-firm relations stays the same (see the equations in section 2.5: 'Totalreceivers' and 'Receivers' increase by the same proportion), since we do not have more senders or receivers per sender. Therefore, including multiple consumption product categories per receiving firm does not lead to a longer runtime in the calculation of the optimal transport chains. There is extra runtime involved in drawing of several product categories per firm, and in the determination of the f2f relations.

2.4 Reporting of non-allocated flows

If a PWC flow cannot be allocated, this is written to the logfile. (firm2firm.log) Possible reasons are also given in the logfile (either 'no transport chain available' or 'no consuming firm'). The logfile further contains the following variables: commodity type, origin zone, destination zone, volume. At the end of the logfile 2 tables are listed. The first table gives the numbers of firm-to-firm relations, shipments and tonnes by commodity group. The second table gives the PWC total, the allocated total and the statistics for unallocated flows by commodity group.

2.5 Runtime reductions

We regarded achieving consistency with the PWC matrices and bringing down the run times as the main objectives of the 'quick fix' (2006 project phase 1). Minor objectives concerned checking the units of the costs functions and producing a flow diagram for the operation of the program. Considerably shorter run times (especially for the Swedish program) were necessary for the clients to perform the required tests in due time.

The Norwegian program as delivered before phase 1 of 2006 took 3-7 hours to run; the Swedish program needed up to 48 hours.

We suspected that the main reason for the long run times would be the enormous number of firm-to-firm (f2f) relations that had to be evaluated for determining the shipment size and the transport chain. For Norway we had 24 mln f2f relations and for Sweden 98 mln. In the program this is equivalent to the number of records to be evaluated. Also, it leads to an extremely large output file (5 Gigabyte for Sweden) since in this file, every f2f relation is a record.

To achieve consistency between the model results and the PWC matrices we decided that we should allocate zone-to-zone (z2z) flows from the PWC matrices to f2f flows, instead of creating a new pattern by Monte Carlo simulation that would approach the z2z pattern with increasing sample size. In order to reduce run times as well, for this quick fix version of the model we should decrease the number of f2f relations considerably. This we achieved by implementing the following mechanism:

- If the number of senders in a zone is low, and if the average number of receivers per sender relative to the total number of receivers in the country is low, then we allocate the z2z flow to a single f2f flow;
- Otherwise we allocate to 2, 3, 4, etc. f2f flows, depending positively on the number of senders and also positively on the average number of receivers per sender relative to the total number of receivers in the country.

In equation form this was implemented as:

Allocate the z2z flow to 1 f2f flow if:

$$\text{Senders} * (\text{ReceiversPerSender}/\text{TotalReceivers}) < 1.5$$

Allocate to 2 f2f flows if:

$$1.5 \geq \text{Senders} * (\text{ReceiversPerSender}/\text{TotalReceivers}) < 2.5$$

Allocate to 3 f2f flows if:

$$2.5 \geq \text{Senders} * (\text{ReceiversPerSender}/\text{TotalReceivers}) < 3.5$$

Etc.

In which:

Senders: number of senders in a zone r;

> ReceiversPerSender: average number of receivers per sender: domestic plus international (from Annex 2 of D4).
>
> TotalReceivers: number of receivers in all the zones in the study area (domestic plus international).

For import and export we use the same formulae, but then we only have a single receiver (export) or a single sender (import) to start with, since we had to create virtual firms abroad. For import we use then number senders per receiver for the number of receivers per sender (which was not available).

Given the number of f2f relations that will be used for a particular z2z flow, the specific f2f pairs for a particular z2z relation are selected by randomly drawing f2f pairs (from all f2f pairs available for this z2z pair) proportionally to the product of production (in tonnes) and consumption (in tonnes) of the two firms of each f2f pair. The number of tonnes of the z2z pair (the PWC flow) is then allocated to these f2f pairs proportionally to the share of the same product in the sum of these products for all selected f2f pairs.

The new programs were delivered at the end of Phase 1 (16 February 2006). In these programs the number of tonnes from a zone to another zone by commodity from the PWC base matrices is preserved, unless for a zone pair there is no transport chain available, no production firm available or no consumption firm available (see item 1).

The resulting number of f2f relations for Norway is 2.65 mln and for Sweden 2.72 mln. These are very large reductions, and so was the reduction in runtime: this went down to 15-50 minutes for Norway and 40-180 (depending on the computer used and whether or not the commodities are run sequentially) minutes for Sweden. The lower number of f2f relations (records) leads to considerably fewer computations to be carried out and also to lower memory requirements.

The programs delivered on 16 February have broadly achieved their objectives of restoring consistency with the PWC files (subject to a number of reservations, see Section 2.2) and reducing run times. However, the approach taken for Step A (disaggregation from z2z to f2f flows) is rather crude and the number of f2f relations that results will not be consistent with the average number of receivers per sender) as given in Annex 2 of D4. More specifically, the numbers of receivers per sender in the new programs will be substantially lower than these averages. It can be questioned whether the averages in Annex 2 of D4 are sufficiently reliable for use in the logistics module (this is further discussed in Section 2.10), but it seems very likely that the procedure described above has reduced the number of f2f relations to unrealistically low levels. Therefore we have also designed and implemented a procedure for the allocation to f2f flows that is consistent with the numbers of receivers per sender as given in Annex 2 of D4 while still preserving the PWC flows. This procedure can be used a starting point in the development of the version 1 model in phase 3. It could also work with other average numbers of receivers per sender (if we would be able to get empirical evidence on this). Below this procedure is explained for a hypothetical z2z relation. This example is for a commodity type k, but we drop the subscript k for convenience.

There are 400,000 tonnes going from zone r to s according to the PWC matrices. We should preserve this number. Therefore we should allocate this number to firm-to-firm relations within the zone pair rs instead of drawing destination zones per sender.

We know(from the Access files) that there are 5 firms sending k from r (possibly to all s). We also know (Access files) that there are 10 firms receiving k in s (possibly from all r).

So within rs there could maximally be 5x10=50 firm-to-firm relations.

As exogenous input (Annex 2 of D4) we know that for k there are 500 receivers per sender. In the Access files we find 2,500 receivers for k (all zones s).

We also know the number of senders of k (here: 1500) from all zones r in the Access files. So in total for k there should actually be 500x1500=750,000 relations. As a by-product this gives the implied number of senders per receiver: 750,000/2,500=300.

The potential overall number of relations for k is 2,500x1,500=3,750,000. So 750,000/3,750,000=20% of the potential number of relations materialises.

In equation form:

$$\begin{aligned} fraction &= (ReceiversPerSender*TotalSenders)/(TotalReceivers*TotalSenders) \\ &= ReceiversPerSender/TotalReceivers \end{aligned}$$

In which:

TotalSenders = number of senders in all the zones in the study area (domestic plus international).

Now for rs we use this 20%. With 50 potential relations there should be 10 actual relations:

$$\text{Actual number of relations from zone } r \text{ to zone } s = fraction * (Senders*Receivers)$$

In which:

Receivers: number of receivers in zone s.

We now select these 10 mn relations at random from the 50 available by using proportionality to the product of the production volume of firm m and the consumption volume of firm n for the commodity in question. Then we can divide the 400,000 tonnes over the 10 relations proportionally to the share of a mn relation's product in the sum of the products over all 10 mn relations. The sum of the allocated flows over the 10 relations will equal 400,000 tonnes (preservation of PWC flow).

We call this version 0.3 of the model. The number of f2f relations from this more elaborate procedure is 15 mln for Norway and mln for Sweden. This is rather close to the numbers in D4 and the version 0.1 of the model (24 mln for Norway, 98 mln for Sweden). However, the runtimes are also similar to those of version 0.1, even slightly higher: up to 10 hours for Norway and several days for Sweden.

On the functionality of versions 0.1, 0.2 and 0.3: they can all represent the same decisions (shipment size, transport chain) and produce the same output variables. However, version 0.2 and 0.3 are consistent with the PWC files (with the exceptions discussed above), and version 0.1 is not. Furthermore, version 0.2 differs from 0.1 and 0.3 in that is has a much shorter runtime and generates only a fraction of the number of f2f relations that we obtain in versions 0.1 and 0.3. The latter versions are probably closer to the real number of receivers per sender, though they may be overestimating this number. A smaller number of f2f relations (at the same PWC tonnes, and constant frequencies for some commodities and optimal shipment size that depends on annual demand for other commodities)- will lead to larger shipment sizes. So the average shipment size will be somewhat larger in version 0.3 than in version 0.1, and substantially larger than both in version 2. Predicted shipment sizes can be compared to observed shipment size distributions. This will be further discussed in Sections 2.10 and 3.2

For the transport chain choice versions 0.1, 0.2 and 0.3 give rather similar outcomes (market shares by chain type). This leads to the conclusion that in the present model design, shipment size is not a very important determinant of transport chain choice. For consolidated flows this is easy to see: a small shipment can be transported in a big vehicle/vessel just as well as a large shipment because transport cost only need to be paid for the small shipment’s fraction of total capacity of the vehicle /vessel (or rather 90% of total capacity). So the cost advantage that road-road-road or road-sea-road offer for large shipments, they also offer for small ones. However for direct transport, small vehicles/vessels will be cheaper for small shipments than large vehicle/vessels. The costs functions are more important for the distribution over chain types than the shipment sizes (using the current assumptions about consolidation).

2.6 Detailed flow diagrams

The following flow diagram illustrate how production and consumption from the PWV matrix has been assigned to individual firms. In these flow diagram boxes represent tables, which are interconnected by queries. The boxes coloured light grey function as inputs, the dark grey boxes are the final outputs. The "Final companies and productions" table from Production, has been taken as a starting point in consumption.

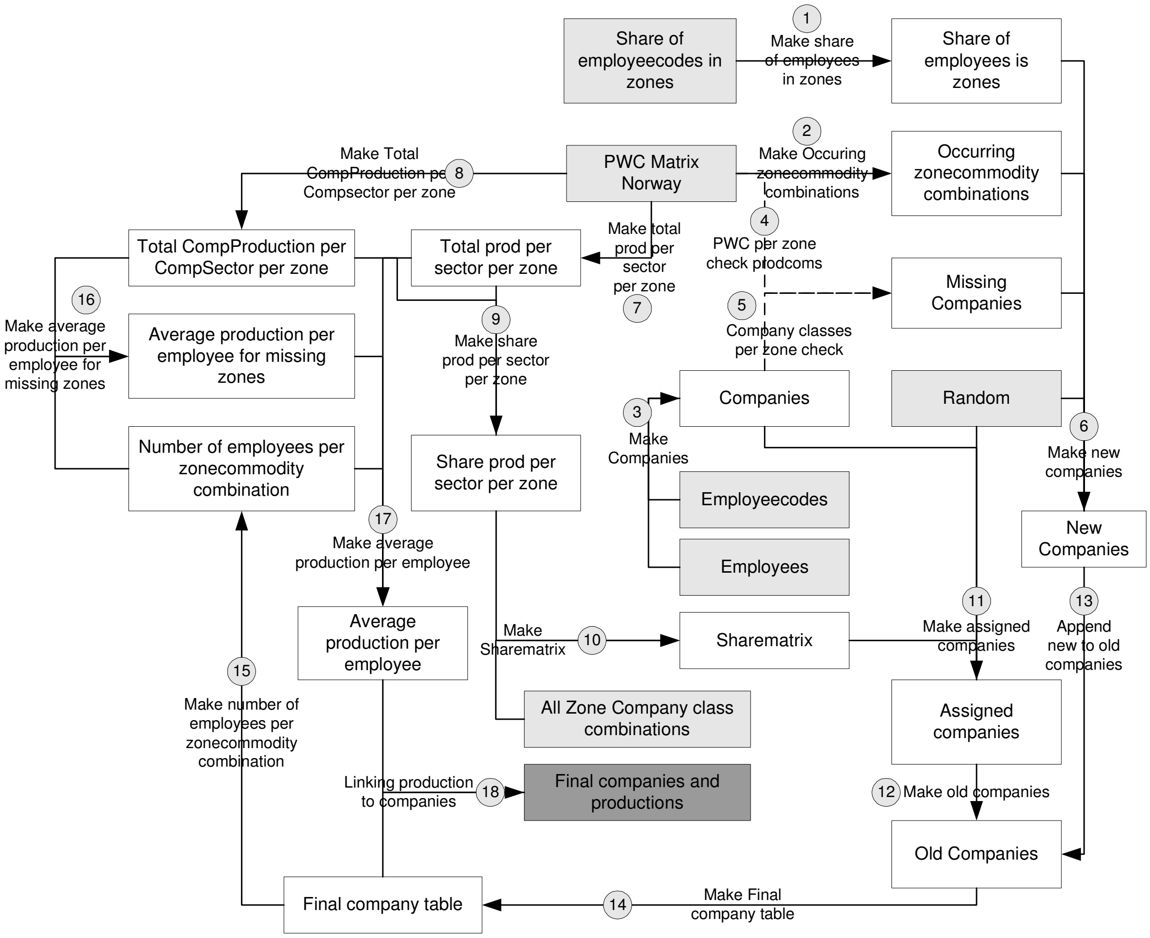


Figure 1 - Detailed flowchart of assigning production to firms in Norway

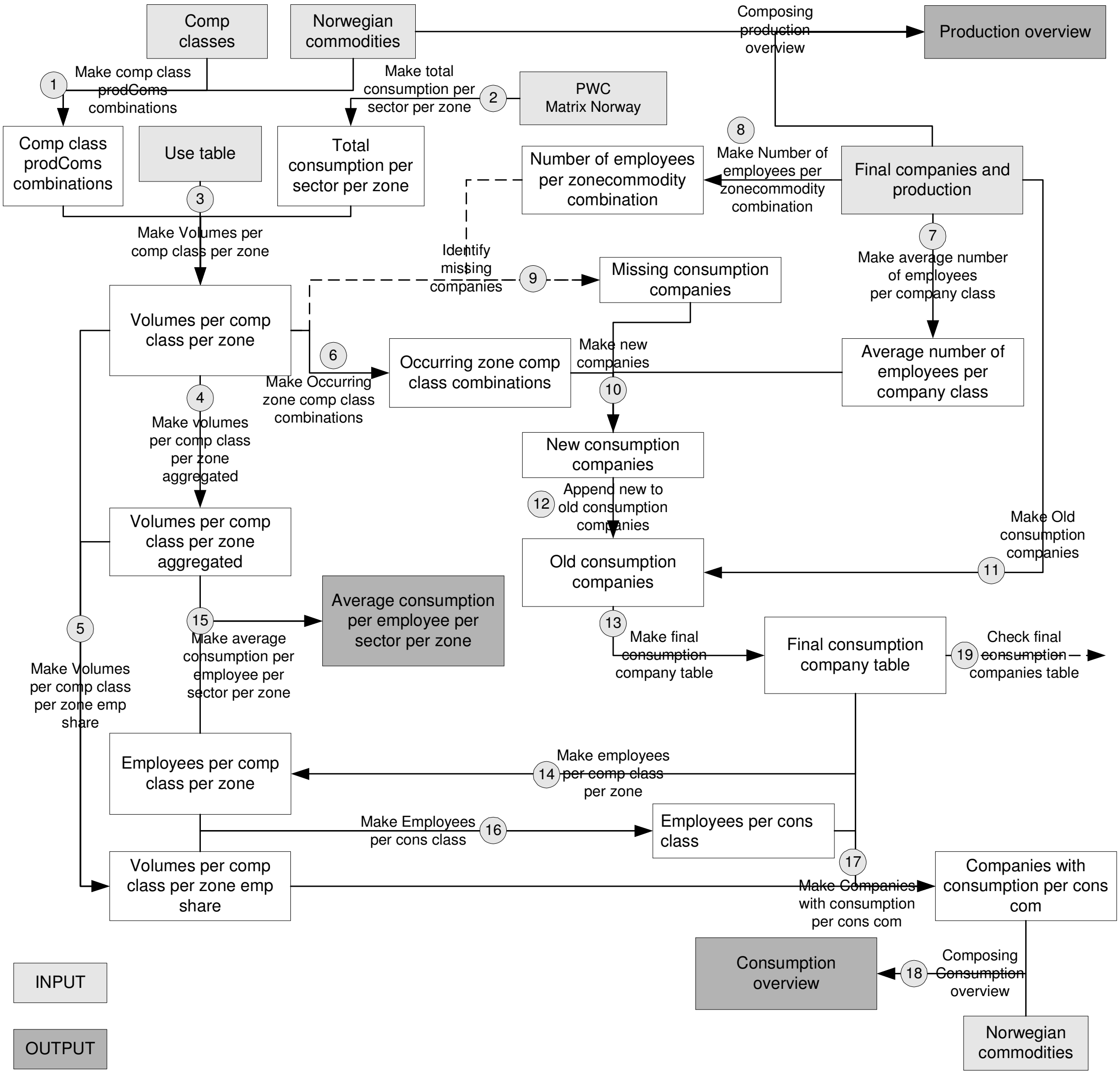


Figure 2 - Detailed flowchart of assigning consumption to firms in Norway

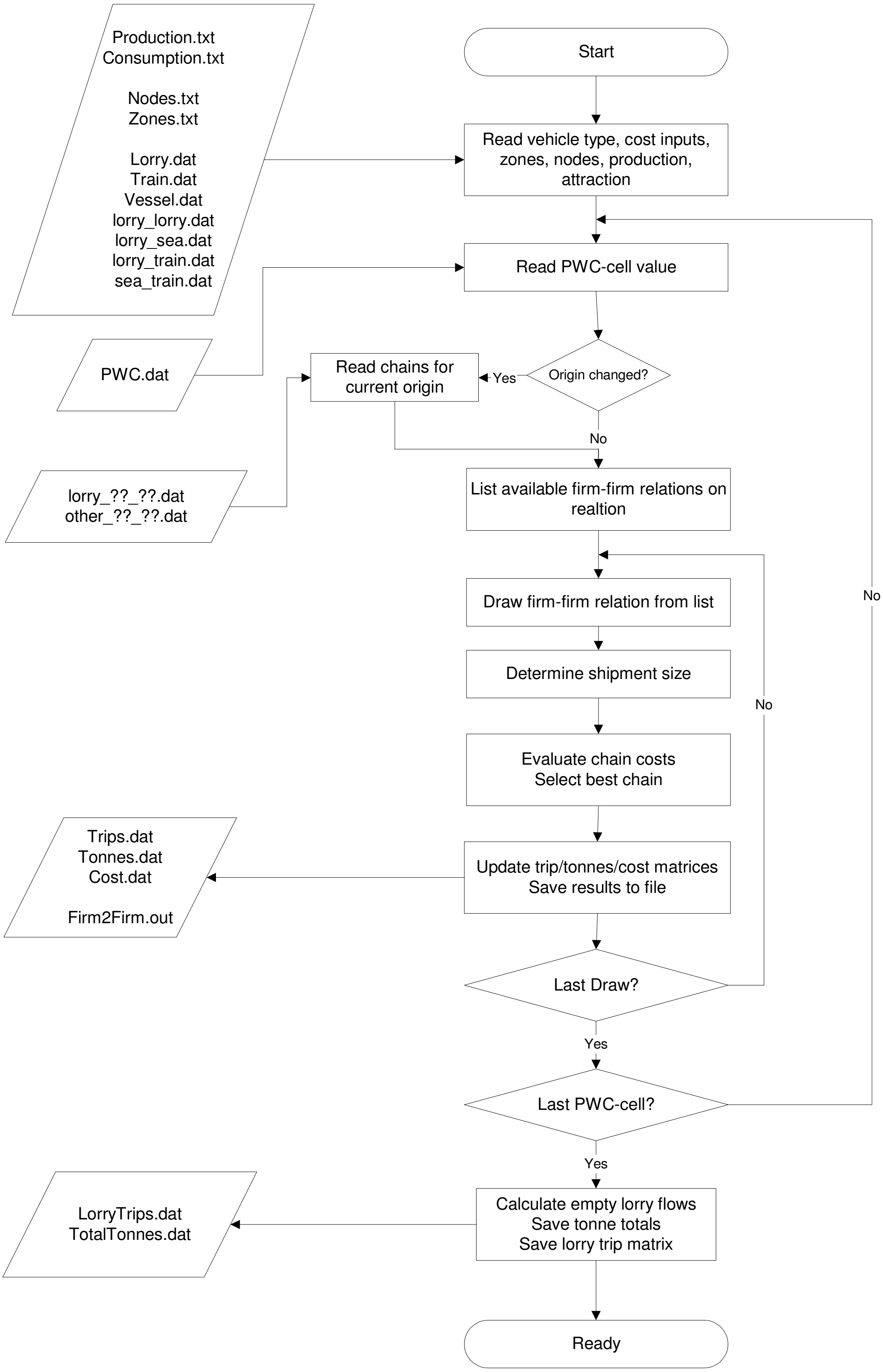


Figure 3 - Flowchart of the firm2firm program

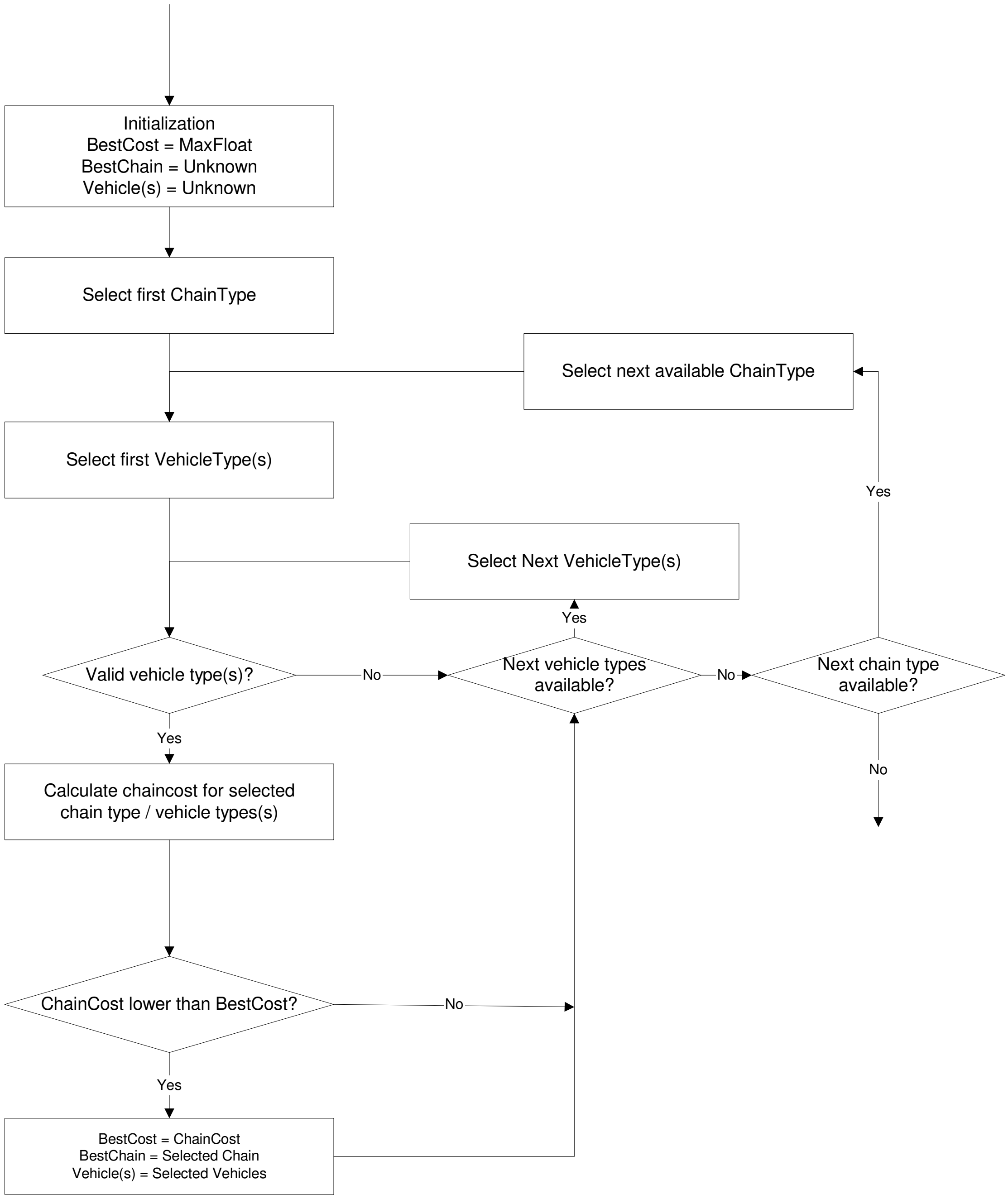


Figure 4 - Detailed flowchart of the "Evaluate chain costs Select best chain" box in figure

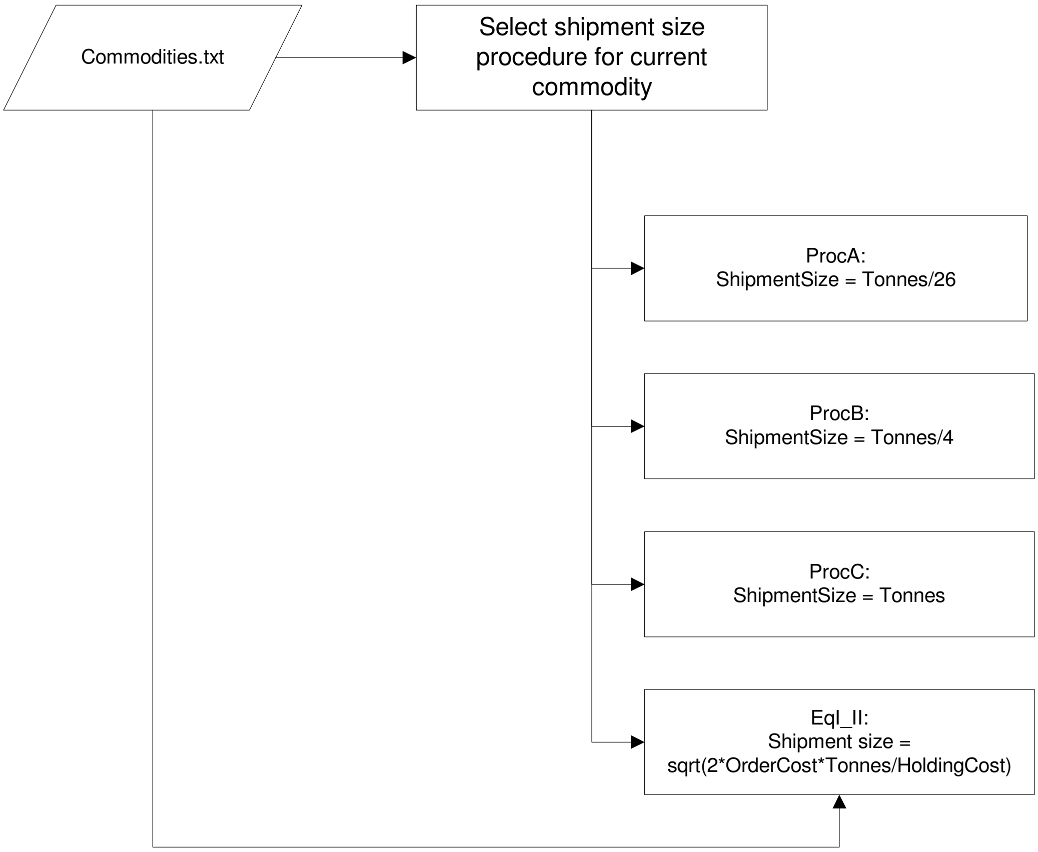


Figure 5 - Detailed flowchart of the "Determine shipment size" box in figure

2.7 Description of the submodel for the choice of terminals in road only chains

The transfer locations between road, rail, combi, sea and air transport are determined by the network models. However, the road terminals (consolidation centres CC and distribution centres DC) for transfers between road vehicle types (road-road, road-road-road) have not been included in the network models yet. This selection takes place within the logistics module as a separate program that produces inputs for the choice set definition of available road transport chains. It produces for every zone pair that is connected through the road network the optimal transport chain for the non-direct road alternatives. The road chains included here are:

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

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 (terminals_submitted_150905.xls) and Sweden (SIKA TERMINAL STRUCTURE.xls) and their availability by commodity type. These files contain information on the municipality in which the terminal is situated. This information was linked to the network data that we had received by using the centroids of the zones (municipalities) as the locations of the terminals. The optimisation was done by enumerating all possible lorry chains with up to 3 legs, while keeping track of the cheapest lorry chain by chain type (1, 11 or 111-chain) for each OD-pair. The 1-leg lorry connections are available from the network models. If the to-node of such a connection is marked as being a transfer-node, the 2-leg chains are obtained by enumerating all lorry connections (again from the network models) starting at this to-node. The 3-leg lorry chains are obtained by similarly extending the 2-leg chains. Each time a node is visited during this process, the chain cost will be compared to the cheapest chain of the relevant chain type that has reached this node so far. If the costs are lower, the "cheapest chain so far" will be updated.

As an example take a shipment of commodity k that has to go from zone 4 to zone 20 (hypothetical numbers). For the road-road chain, we list all zones with a road terminal (available for commodity k) that are connected by road to both zone 4 and 20. We now calculate the link-based costs (combining network time and distance with Tables 35 and 36 from Annex 3 of D4, also including the initial loading and final unloading costs from Tables 37 and 38) from zone 4 to the centroid of each of the potential transfer zones, the transfer costs (for indirect transfers: Tables 49 and 50) and the link-based costs from the centroid of the potential transfer zone to zone 20. We add these costs items for all these alternatives for road chain road-road from zone 4 to zone 20, to get total transport costs per alternative. The alternative (transfer zone) with the lowest transport costs will then be selected for use in the main model, where a road-road transport chain is compared to other chains, such as road-sea-road. All road-road chains considered in the main transport chain choice will use the same road terminal (the one selected in the separate program), but there can be several road-road chains if several road vehicle types are available. For road-road-

road chains, the method is the same, but with two terminal locations, two link-based cost items and two transfer costs items.

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. 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 (full enumeration of choice alternatives). For most commodities there are not many alternatives (the terminal files are small) at the moment: 51 zones in Sweden have a road terminal available and 287 zones in Norway. For Sweden, the clients had decided only to supply information on the bigger terminals. These road terminals may only be suited for a subset of commodities.

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 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 Phase 3 we recommend to differentiate by commodity type here: use a non-containerised small and a non-containerised large vehicle to determine the optimal road transfer locations for commodities that are unlikely to be containerised and a small and a large containerised vehicle for the other commodities.

2.8 The cost functions

2.8.1 Including economies of scale in transport in the determination of shipment size

The cost functions / optimisation should be adapted to handle the question of economy of scale in transportation better than in the prototype.

In the prototype we had several decision methods:

0: Joint minimisation of cost for inventories and transport

1: Cost minimisation for transport only, given time or shipment size constraints: As a first approximation, we suggested the following procedure:

- Use as a constraint (upper-bound) for the shipment size in a P-W, W-C or P-W relation a maximum shipment size (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).

2: Cost minimisation for transport (only): This should in principle lead to economy 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 suggested procedure was then:

- Use as a constraint (upper-bound) for the 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)

Adaptations to 0, joint optimisation:

The optimisation in this situation was based on the following equations:

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

$$\rightarrow$$

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

As a simplification in the prototype, the last part of II (the derivative of the transport cost function) was set to 0, and the optimal shipments were determined through the solution of the former, given the well known EOQ formula. We would however like to take care of the economy of scale for transport in the decision model.

Let us for a given vehicle "x" model the cost for travelling a given OD-combination as follows:

$$(\text{Travelling cost})_{rs\text{-}vehicle\text{-}x} = \text{distance}_{rs}{}^{*}(v_{costperkm\text{-}x} + (v_{costperhour\text{-}x}{}^{*}(1/\text{speed}_{rs\ km/hour - x}))$$

The cost for a given shipment would then, also taking into account the terminal costs, be:

$$T_{rs\text{-}vehicle\text{-}x} = (\text{Travelling cost})_{rs\text{-}vehicle\text{-}x} + q_k{}^{*}(\text{Loading cost}_x \text{ (per ton)} + \text{Unloading cost}_x \text{ (per ton)}_{vehicle\text{-}x}$$

The total transport cost for a given demand over a time period corresponding to Q_k would then be:

$$T_{rskq} = (Q_k/q_k)^{*}T_{rsvehicle\text{-}x} = (Q_k/q_k)^{*}\text{Travelling cost}_{rs\text{-}vehicle\text{-}x} + Q_k{}^{*}(\text{loading cost}_x + \text{unloading cost}_x)$$

Then we get: $\partial T_{rskq}/\partial q_k = -(Q_k/q_k{}^{2})^{*}\text{Travelling cost}_{rs\text{-}vehicle\text{-}x}$

We would then get the adjusted formula for total cost:

$G_{rskmnqh} = o_k{}^*(Q_k/q_k) + (Q_k/q_k)^*T_{rsvehicle\text{-}x} = (Q_k/q_k)^*\text{Travelling cost}_{rs\text{-}vehicle\text{-}x} + Q_k{}^*(\text{loading cost}_x + \text{unloading cost}_x) + i^*j^*g^*v_k{}^*Q_k + (i^*t_{rs}{}^*v_k{}^*Q_k)/365 + (w_k + (i^*v_k))^*(q_k/2) + a * ((LT^*{}_{Q_k}{}^{2}) + (Q_k{}^{2*}{}_{LT}{}^{2}))^{1/2}$ (Ib)

The optimisation procedure would then be:

(a) For each vehicle x find the shipment size from:

$q_{kx}{}^{*} = ((2^*((o_k{}^*Q_k))+\text{Travelling cost}_{rs\text{-}vehicle\text{-}x}))/(w+(i^*v_k))^{1/2}$ if $q_{kx} \leq$ capacity vehicle x; else q_{kx} = capacity vehicle x (IIb)

(b) For each of the alternative vehicles x and q_{kx}, calculate the cost function (I) by using formula (a). The optimum q_k is the q_{kx} that minimises the cost (Ib), that is the given combination of shipment size and vehicle choice.

Adaptations to 1, shipment size or time constraints and 2, cost minimisation for transport only.

No adaptations are required; we can use the same procedure as previously. However, as the upper constraints that were used were rough estimates to test the prototype, it may be that a more differentiated set of rules/constraint levels should be considered. For example the 52 weeks constraint used in situation 2 might be too lax. A first modification of the constraints would be:

max shipment size = min(transport capacity largest feasible vehicle; Q_k*(max period length as part of year))

2.8.2 Effects of time value for cargo, and limited frequencies for certain transport option.

We would in the next phase also include time cost for the cargo. This would basically for a given transport chain from A to B with a yearly quantity Q_k be:

Q_k*(time cost for cargo category)*[∑(transport time each transport leg) + (∑(transfer time each transport leg) + (∑((calculated waiting time in each transfer point)*(additional time cost transfer point)) + (∑((calculated waiting time, first leg before loading at origin)*(additional holding cost at point of origin)) + (∑((calculated waiting time, last leg before consumption, at destination)*(additional holding cost at point of destination))]

This means that the (revised) cost function would have to be further adjusted to include also the time cost for the cargo. The joint time cost would basically be the capital cost for the cargo owner. The additional holding costs would then be inventory holding cost for the various places where the cargo would “wait” in stock. The holding cost elements would then be exclusive of capital cost.

We also suggest (see Chapter 3) estimation/calibration of the model to mode share data (aggregate) by adding a mode-specific constant and an implied interest rate on the inventory in transit to the cost functions and estimating these coefficients.

The effect of alternative frequencies at given points of origin/destination, would be modelled through alternative waiting times at origin and destination, as these would typically be a function of the transport frequency.

This is not a part of the phase 2 delivery, but should be integrated in phase 3, giving some minor adjustments to the cost functions in the logistical model, as well as in the cost data functions delivered to the models.

2.9 Consolidation, empties, cargo units

2.9.1 Consolidation

Consolidation is a key issue for phase 3. Versions 0.1-0.3 allow for consolidation. Consolidated flows are made relatively attractive by the fact that all vehicle/vessel types, including the large ones, are readily available. Also we assume that there is other cargo at the port, railway station of consolidation centre that can be consolidated with the flow studied. Both assumptions need to be relaxed.

Availability of vehicles and vessels

In reality there are only a limited number of large vehicles/vessels in the country and some ports cannot accommodate the largest vessels. So at several ports the availability of vehicle types is actually more restricted than modelled. And if available, using a specific vehicle/vessel will involve waiting time. The model produces too much road-sea-road transport (Norway, especially domestic), but most other multiple leg transport chains (road-road, road-road-road, road-rail-road, road-ferry-road) are given smaller than observed shares. So the fact that vessel availability per port and vessel frequency is not included in the present model can explain the over-prediction of domestic road-sea-road in Norway. Port restrictions in terms of vessel size need to be taken into account. Waiting time in ports needs to be included, based on existing schedules, half-headway and the distribution of vessel types over the zones.

A similar thing may have happened for some chains with rail transport (especially Sweden). Here too we have to include waiting time for the train in the model. This can be based on existing schedules and then we can use half-headway.

In road transport chains the availability (including frequency) of specific vehicle types will be less of an issue than for vessels. Nevertheless it would be good to include a component for waiting time for all multiple-leg chains (which will have an effect through the value of the goods in transit).

Availability of other cargo

The preliminary mechanism for consolidation used in the prototype was to calculate the transport cost as if we had a good capacity utilisation (90%) of a large transport vehicle, regardless of whether the cargo volume from this point of consolidation and the calculated shipment sizes really were consistent with the assumed consolidation. The consolidation mechanism should be developed further.

Consolidation of cargo flows would mostly take place between shipments within the same cargo category, and between shipments with similar characteristics across categories. For containerised cargo, the potential for consolidation across cargo categories would be larger in terms of which category could be combined. A preliminary scheme for potential consolidation patterns between cargo categories is shown in Appendix B.

The steps would then be:

> a) Possible consolidation will be calculated for pairs of road terminals, ports and railway stations. In the current model, consolidation (if there is going to be consolidation at all) will take place at these locations, not at the origins of the PWC flows. At the beginning of step B we also do not know the commodity flows that will go to each consolidation centre. But we might be able to define the size or maximum service areas for each terminal (by commodity type that can be handled in each terminal) and define the maximum consolidation on this basis, using the list in Appendix B of which goods can be combined and a suitable time period.
>
> b) For each cargo category, or grouping of categories, the average flow for a given time period is calculated. The time period most suited should be further evaluated, and may be differentiated between various category groupings.
>
> c) The average flow for a given category or group of categories, gives the maximum for consolidation.
>
> d) The largest feasible vehicle within each mode that has capacity to handle the maximum would then be the upper limit for vehicle choices (and thereby vehicle costing) within that given category for the given pair of terminals/ports/stations.
>
> e) The optimisation of logistics cost as a basis for vehicle choice is then done as previously defined in D4, but the upper limit for the vehicle unit size for a given relation and cargo category, will be the one defined by maximum for consolidation.

By applying this mechanism, the vehicle choices are still done on the basis of the optimisation methodology, but the feasibility space for optimisation is limited to the potential for consolidation. So ports with a small service area or small ports will no longer be able to offer the largest vessel size. By approaching consolidation this way, we on the one hand take into account the costs in a consolidated solution, while still keeping the individual shipments deconsolidated (for calculation purposes).

There is still a risk that we may assume that consolidation takes place in situations where this would not occur in practice, but with the further inclusion of time value for goods and relationships between frequency and time, we should be able to limit this risk to a reasonable level.

2.9.2 **Empties**

For empty vehicles we can use the equations in the report, based on vehicle balances (D4, Section 5.5). This goes clearly beyond the standard approach and will take care of the key directionality problems. But the parameter values need an empirical basis. Maybe we can use these vehicle balances to determine vehicle availability per zone, but probably this would be to computer-time intensive (we don't want to micro-simulate vehicles). Jose Holguin-Veras offered at TRB to send his more sophisticated empty vehicle program. It won't be easy however to fit this into our program and it would need to be calibrated to local data.

In Phase 3, the mechanisms for generating empty flows, and thereby the flows themselves, should be differentiated between the various modes:

- For sea vessels, empty legs for spot or COA (contracted) vessels should be linked to the repositioning of vessels from one contract to another. For vessels under TC contracts, there may also be empty vessels due to unbalances in cargo between destinations, similar to what we would find for other transportation means.
- For rail, the system is to a certain degree "closed": the vehicles components like wagons and locomotives are handled in a closed system. This means that given a transport flow, the flow of empties must balance off the unbalances in flow back and forth on the main OD relations.
- For road, the situation would tend to be more complicated. Part of the empties would be related to repositioning for new contracts. Another part would be related to balancing the differences between required transport capacity in different directions.

Based on this, the calculations on empty vehicles could to a large extent be based on the original concepts fromD4, with some minor modifications. Below, we outline this mode by mode.

Sea vessels:

These could be divided in two groups, liners and others. Liners tend to go in fixed routes, either to and from the same ports, or in some sort of "circle" schedule. In any case, there will not be empty vehicles, rather varying utilisation of the existing vehicles on various legs. For the others, which are running more on a trip basis, there will of course be empty ("ballast") legs, usually to reposition the vessel for new trips. We could handle this by using the following approach:

Set a proposition of the sea traffic to be liners $(1-\xi)$. (The share, $(1-\xi)$, should be consistent with proportion of liner shipments in the calculation of loading cost for sea).

Let μ be the maximum number of cargo categories (Sweden or Norway). Take the total number of arriving and loaded vehicles for a given mode/vehicle type h to be:

$$V^{a}_{hs} = \Sigma_{kr}(\Sigma_{k=1,\mu} T_{hkrs})$$

The corresponding need for loaded vehicles leaving for the same mode would be:

$$V^{L}_{hs} = \Sigma_{kr}(\Sigma_{k=1,\,\mu}T_{hksr})$$

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

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

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

We would then reduce the overcapacity by the liner share (1-ξ), so the overcapacity would be calculated as $\xi * \theta_{hs}$. If we assume that the main tendency is to utilise available capacity first, we may set up the following:

$$\text{If } \xi * \theta_{hs} > 0,\ T_{s,\,k=empty} = \xi * \theta_{hs} + P(E)\Sigma_{r}x_{sr} = \theta_{hs} + (\Sigma_{k=1,\,\mu 2}\alpha_{s}(\Sigma_{hr}T_{hksr}))\ \text{(I)}$$

$$\text{If } \xi * \theta_{hs} = 0,\ T_{s,\,k=empty} = (0 +)\ P(E)\Sigma_{r}x_{sr} = (\Sigma_{k=1,\,\mu}\alpha_{s}(\Sigma_{hr}T_{hksr}))\ \text{(II)}$$

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

We will then get:

$$\text{If } \xi * \theta_{hs} > 0,\ T_{s,\,k=empty} = \xi * \theta_{hs} + P(E)\Sigma_{r}x_{sr} = \theta_{hs} + (\Sigma_{k=1,\,\mu}P(E)*(\Sigma_{hr}T_{hksr}))\ \text{(Ib)}$$

$$\text{If } \xi * \theta_{hs} = 0,\ T_{s,\,k=empty} = (0 +)\ P(E)\Sigma_{r}x_{sr} = (\Sigma_{k=1,\,\mu}P(E)*(\Sigma_{hr}T_{hksr}))\ \text{(IIb)}$$

$$T_{h,k=empty,sr} = [(\Sigma_{k=1,\,\mu)}T_{h,k,rs})/(\Sigma_{kr}(\Sigma_{k=1,\,\mu}T_{hksr}))]*\ T_{s,\,k=empty}\ \text{(III)}$$

Rail:

This is a case where there has to be a balance in the long run. The locomotives for the traction will return either empty or carrying a train which may have all sorts of utilisation. On the other side, a locomotive may both be used for freight or passenger traffic. For the wagons, there should also be a balance in the long turn. We may assume that rail wagons used on directions with overcapacity are filled up with normal loads, and the overcapacity will then consist of empty wagons. In the long run, the locomotive capacity requirements should match the needs to move full and empty wagons.

A suggested approach would then be:

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

$$V^{a}_{hs} = \Sigma_{kr}(\Sigma_{k=1,\,\mu)}T_{hkrs})$$

The corresponding need for loaded vehicles (trains) leaving for the same mode would be:

$$V^{L}_{hs} = \Sigma_{kr}(\Sigma_{k=1,\,\mu}T_{hksr})$$

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

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

$= 0$ (otherwise)

If we assume that the main tendency is to utilise available capacity first, we may set up the following, assuming that the overcapacity is returned to the starting point:

If $\theta_{hs} > 0$, $T_{s,\, k=empty} = \theta_{hs} + P(E)\Sigma_{r}x_{sr} = \theta_{hs} + (\Sigma_{k=1,\, \mu}\alpha_{s}(\Sigma_{hr}T_{hksr}))$ (I)

If $\theta_{hs} = 0$, $T_{s,\, k=empty} = (0 +)\ P(E)\Sigma_{r}x_{sr} = (\Sigma_{k=1,\, \mu}\alpha_{s}(\Sigma_{hr}T_{hksr}))$ (II)

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

If we assume perfect balance, we can disregard in- and outflow of empties from other connections, and use P(E) = 0. With the exception of Oslo, this might be a feasible situation

for Norway. We may for the other connections, Sweden and Oslo use a different value for P(E). We will then get:

Norway, except Oslo:

If $\theta_{hs} > 0$, $T_{s,\, k=empty} = \theta_{hs} + P(E)\Sigma_{r}x_{sr} = \theta_{hs}$ (Ic)

If $\theta_{hs} = 0$, $T_{s,\, k=empty} = (0 +)\ P(E)\Sigma_{r}x_{sr} = 0$ (IIc)

Sweden, Oslo:

If $\theta_{hs} > 0$, $T_{s,\, k=empty} = \theta_{hs} + P(E)\Sigma_{r}x_{sr} = \theta_{hs} + (\Sigma_{k=1,\, \mu 2}P(E)^{*}(\Sigma_{hr}T_{hksr}))$ (Id)

If $\theta_{hs} = 0$, $T_{s,\, k=empty} = (0 +)\ P(E)\Sigma_{r}x_{sr} = (\Sigma_{k=1,12}P(E)^{*}(\Sigma_{hr}T_{hksr}))$ (IId)

$T_{h,k=empty,sr} = [(\Sigma_{k=1,\, \mu)}T_{h,k,rs})/(\Sigma_{kr}(\Sigma_{k=1,\, \mu)}T_{hksr}))]^{*}\ T_{s,\, k=empty}$ (III)

Road:

We would here suggest a mixed approach for the calculation of empties.

1) Transport between zones with an OD distance of less than 50km is to a large extent distribution transport, and based on a fairly low utilisation (= in the equation IV below; might be 0.5, but the values used need to be determined on empirical data if possible). For zones with an OD distance of less than 50km, the number of empties for each vehicle category is calculated as:

$T_{h,k=empty,sr} = \ ^{*} \sum_{k=1,\, \mu} T_{hkrs}$ (IV)

2) For OD-combinations with a longer distance than 50 km, the calculations should be based on the same approach as for the other modes:

$$V^a_{hs} = \Sigma_{kr}(\Sigma_{k=1,\mu}\ T_{hkrs})$$

The corresponding need for loaded vehicles (trains) leaving for the same mode would be:

$$V^L_{hs} = \Sigma_{kr}(\Sigma_{k=1,\mu} T_{hksr})$$

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

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

$= 0$ (otherwise)

If we assume that the main tendency is to utilise available capacity first, we may set up the following, assuming that the overcapacity is returned to the starting point:

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

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

Although we do not have empirical studies of this, it is reason to believe that the α_s values would be falling with increasing distances. As a preliminary approximation, assuming that the share is β at 50 km, falling to χ at a distance of 300km, further assuming the share to be falling linearly (before acquiring empirical data), we might use the following values:

$\alpha_{sr} = \beta - (((\beta - \chi)/300)*distance(r,s))$, $distance(r,s) \leq 300$ km

$= \chi$; $distance(r,s) > 300$ km.

We shall also have to consider the preliminary outcomes on empty road vehicles (see D4), and may have to adjust the above numbers.

This gives:

If $\theta_{hs} > 0$, $T_{s,\ k=empty} = \theta_{hs} + P(E)\Sigma_r x_{sr} = \theta_{hs} + (\Sigma_{k=1,\mu}\alpha_{rs}(\Sigma_{hr}T_{hksr}))$ (Ie)

If $\theta_{hs} = 0$, $T_{s,\ k=empty} = (0 +)\ P(E)\Sigma_r x_{sr} = (\Sigma_{k=1,\mu}\alpha_{rs}(\Sigma_{hr}T_{hksr}))$ (IIe)

$T_{h,k=empty,sr} = [(\Sigma_{k=1,\mu}T_{h,k,rs})/(\Sigma_{kr}(\Sigma_{k=1,\mu}\ T_{hksr}))]*\ T_{s,\ k=empty}$ (III)

Air:

For air transport, the empties would probably best be calculated similarly to rail based on perfect balancing:

$$\text{If } \theta_{hs} > 0,\ T_{s,\ k=empty} = \theta_{hs} + P(E)\Sigma_r x_{sr} = \theta_{hs}\ \text{(Ic)}$$

$$\text{If } \theta_{hs} = 0,\ T_{s,\ k=empty} = (0 +)\ P(E)\Sigma_r x_{sr} = 0\ \text{(IIc)}$$

$$T_{h,k=empty,sr} = [(\Sigma_{k=1,\ \mu} T_{h,k,rs})/(\Sigma_{kr}(\Sigma_{k=1,\ \mu}\ T_{hksr}))]^*\ T_{s,\ k=empty}\ \text{(III)}$$

Risk with errors in estimates

For all modes, the vehicle flows must in some sense balance. By this we mean that no new vehicles are "borne" or that vehicles "die". As the totals are held together by balance equations, the uncertain part would not be the total traffic (loaded and empty vehicles) generated for the vehicles, but rather the distribution between vehicles loaded below capacity and empty vehicles on certain OD-combinations. This again means that some transport in a real situation would perhaps be sold at a discounted price, not necessarily reflected in the optimisation calculations. For traffic calculations, this would not cause any major problems, as the total traffic would be the interesting issue. However, there may be some uncertainty in the modal split. If the cost for transport with a given mode between and O and D, where the OD in question is one with overcapacity, we would use the cost of the largest feasible vehicle (empty or filled up), made available by flows *to* the given "O". This would probably lead to sensible assumptions also for the allocation of the available capacity in an overcapacity situation.

2.9.3 Cargo units

In the model, we would like to keep the variety in terms of cargo units and vehicles down (especially because of the runtime implications). We therefore suggest that we basically use two major groups of cargo units:

- Containers (including flat-racks, both ISO and CEN containers etc.; - including also pallets when these are used inside containers)
- Cargo direct on transport unit, "no cargo unit" (including also palletised goods when taken directly into the transport unit)

To simplify, we have in the prototype defined combinations of container units and transport vehicles as separate categories of vehicles, and defined combinations of "no unit" and vehicles as other categories of vehicles. We suggest that we keep this methodology also in the further calculations. This means that we will not analyse flows of independent containers, but we will keep track of movements of vehicles with containerised cargo. To keep the logic and not "losing or creating" containers, the feasibility definitions for transfer, together with calculations of stuffing or stripping when changes are made to or from containerised cargo must strictly be kept.

2.10 Number of firm-of-firm relationships

The assumptions for the number of receivers per sender in the prototype are very rough and preliminary, and are to be regarded as an indication of the magnitude rather than exact information. There is very little published information giving numbers of receivers or number of customers from the various firms. Some companies regard this as commercial secrets, while other companies would happily give indications in their annual reports or company presentations. The last category is a minority. Lacking the solid information, the numbers used were therefore more loosely based on the following assumptions:

- Case experiences;
- Nature of the business normally associated with the category /for example broad consumer-oriented distribution versus limited distribution to business-to-business customers.

For Sweden, the numbers used for Norway was scaled up by a factor of 1.4 to indicate the on average larger size of firms in Sweden. However, this may be an assumption open to discussions, and we should certainly be open for modifications on the basis of information on this received from SIKA.

The numbers are used to distribute the shipments evenly across the receivers from firms. As we normally would tend to have much more of a Pareto curve ("80/20") distribution, it may be that for the 2006 model, we should adapt the distribution of volumes accordingly.

Another issue is that there will be a tendency towards both larger and increasing numbers of customers with increasing size of firms. It may be that functions should be established to estimate the number of receivers as a function of size of the sending firm.

In Table .. are results from the Swedish Commodity Flow Survey (CFS) 2001 where firms in different sectors have reported either a sample or all their shipments for 1, 2 or 3 weeks (created by SCB, obtained through SIKA). The table gives the number of different receivers per sender (mean, lower bound and upper bound) by broad commodity group and by length of the measurement period. The different receivers were identified by means of their zip area code and industry code. If there were several shipments to the same zip code and industry combination within the measurement period, this was counted as a single receiver. This could lead to some downward bias in the results, but probably not a large one, because it is rather unlikely that a sender from a certain zone will be sending to two different firms in the same area code (16,500 zip codes in Sweden) and industry category.

Table 4 - Number of receivers per sender of shipments in CFS 2001

Stan12	Stan34	Nr of receivers Annex 2	Nr of receivers, 1 week measured			Nr of receivers, 2 weeks measured			Nr of receivers, 3 weeks measured		
			mean	low	high	mean	low	high	mean	low	high
1	1 2 3 4 11	30-800	11	3	19						
2	5 31	25-35	13	13	13						
3	6 7 8	100-500	19	17	20	19	15	23			
4	10	100	131	97	165	49	2	96	9	3	15
5	12 13	5-1000	20	17	23	16	7	24			
6	14 22	40-3000	7	4	10	40	22	58			
7	15 16	150	9	9	9						
8	17	600	30	28	31	38	32	45			
9	24 28 33	30-100	29	27	30	18	12	24	9	2	16
10	18 19 20	40-300	15	12	17	12	9	15			
11	21 23	150-200	67	44	89	49	0	99	22	10	33
12	9 25 26 27 29 30 32 34	700-3000	23	20	26	32	24	40	16	14	18
99			192	143	241	84	42	126	31	23	39
Total			**61**	**52**	**70**	**47**	**32**	**63**	**22**	**18**	**26**

If some commodity is shipped to a receiver at least once a week, the receiver will always show up in the count for a period of one week. But for a commodity that is sent every two weeks, there is a 50% probability that it will be included in the reporting week. A frequency of once per year gives a probability of 1/52 that the receiver will be included in the reporting week. So the above CFS numbers are likely to be underestimating the true number of receivers. However, for a measurement period of two weeks the probability of including the receivers that receive the product once every two weeks goes up to 1 and for once per year it goes up to 2/52. So we would expect that with increasing measurement period, the number of receivers per sender would go up. However, for 6 commodities in the table the number of receivers goes down with increasing measurement period, whereas it goes up for 2 and goes up first and then down for 2 other commodity groups. There is no clear pattern with increasing measurement length, probably because the groups of firms with different measurement length are heterogeneous. If we compare these CFS numbers to those in Annex 2 of D4, the CFS numbers (even the upper bounds) are mostly lower, sometimes considerably lower. Especially for STAN34 commodities 2, 6, 9, 12, 14, 17, 27, 29 and 30 several hundreds of receivers per sender are given in Annex 2. This difference could have to do with the short measurement period in the CFS. It could also be related to the fact that the PWC matrices and the CFS include not only manufacturers but also wholesalers that centralise the producer to consumer flows, thus reducing the number of observed f2f combinations.

In version 0.1 we had 108,000 senders in Norway and 24 mln f2f relations. The average number of receivers per sender therefore was 222. For Sweden, with 183,00 senders and 98 mln f2f relations in version 0.1, this would be 536 receivers per sender on average. Using the highest average CFS number in the total row (61) in the logistics program instead of the numbers on D4 would reduce the run times enormously. Using 61 receivers per sender on average, we would get 6.6 mln f2f relations for Norway and 11.2 mln for Sweden. This is much closer to the number of f2f relations in version 0.2 (2.7 mln for both countries). So we could expect much shorter run times if we would use version 0.3 with the numbers of f2f relations from the CFS. For the breakdown to STAN34 categories, either one would have to use the same numbers for each commodity category within a STAN12 category, or to do a 'manual' adjustment, maybe based on the numbers of Annex 2 of D4.

Given the uncertainty about the numbers of receivers per sender from the CFS, and the importance for runtime, a small survey could be made to get information from companies in terms of numbers of receivers, to strengthen the quality of the data. The survey should in principle for each category cover 4-5 companies of various sizes (the same number in Sweden and Norway), and could be done by phone within a limited time span. The goal would be to get an increased base of case data that could be used to modify the preliminary assumptions.

2.11 Illustrations for specific cases

2.11.1 Sweden

For Sweden, SIKA specified seven test cases to be illustrated in more detail. These relate to actual PWC-matrix relations that use a number of different solutions in the delivered logistics model. They cover three different commodity groups and both large and small shipment sizes.

1. Sawn wood (commodity 6) between 916100 and 918000 (domestic flow 182 km);
2. Sawn wood (commodity 6) between 788100 and 625 (export 1721 km);
3. Sawn wood (commodity 6) between 918200 and 556 (export 2534 km);
4. Paper, pulp, waste (commodity 24) between 808200 and 758100 (domestic 593 km);
5. Paper, pulp, waste (commodity 24) between 768200 and 828700 (domestic 311 km);
6. Glassware and ceramic products (commodity 27) between 825700 and 742800 (domestic 493 km);
7. Glassware and ceramic products (commodity 27) between 517 (Fredrikstad) and 719100 (Sigtuna) (Import 1384 km).

General outcomes

In the model delivered on 16th February 2006 the following solutions were obtained. In all cases (except case 6) there is only one f2f relation per PWC-pair.

1. Sawn wood (commodity 6, NSTR 42) between zones 916100 (Ljusdal) and 918000 (Gävle). The total flow in the logistics model is 20 884 tonnes and the shipment size is 86 tonnes. In the logistics model mode 3 (direct Rail) is used.
2. Sawn wood (commodity 6, NSTR 42) between zones 788100 (Nybro) and 625 (Birmingham). The total flow in the logistics model is 13 882 tonnes and the shipment size is 70 tonnes. In the logistics model mode 11 (road via a single road terminal – not two) is used.
3. Sawn wood (commodity 6, NSTR 42) between zones 918200 (Söderhamn) and 556 (Bosnia). The total flow in the logistics model is 0.05 tonnes and the shipment size is 0.05 tonnes. In the logistics model mode 3 (direct Rail) is used.
4. Paper, pulp, waste (commodity 24, NSTR 190) between zones 808200 (Karlshamn) and 758100 (Norrköping). The total flow in the logistics model is 22 654 tonnes and the shipment size is 5 663 tonnes. In the logistics model mode 13 (road-rail) is used.
5. Paper, pulp, waste (commodity 24, NSTR 190) between zones 768200 (Nässjö) and 828700 (Trelleborg). The total flow in the logistics model is 0.0011 tonnes and the shipment size is 0.0003 tonnes. In the logistics model mode 3 (direct Rail) is used.
6. Glassware and ceramic products (commodity 27) between zones 825700 (Östra Göinge) and 742800 (Vingåker). 10 different destination firms from single firm. All relations are very small shipments and flows and are always road-road-road.
7. Glassware and ceramic products (commodity 27) between zones 517 (Fredrikstad) and 719100 (Sigtuna). Flow is 2.13tonnes per year and shipment size is 0.35 tonnes. Transport chain is road-rail-sea -road.

Detailed outcomes

We added the output facilities of the program to include outputs for all individual cost items and obtained the following results for the seven Swedish cases:

Sweden case 1:

```
Orig : 916100
Dest : 918000
Commodity : 6
Frequency : 243
Order cost : 389.00
Holding cost : 2190.00
Shipment Size : 85.95
Chain type : 1
        Vehicle type(s): 15
        Vehicle count : 3.000000
        Nodes : 916100 918000
```

```
        Dist. : 202
        Time : 34
        Loading costs : 2016.28
        Unloading costs: 0.00
        Dist. costs : 4526.82
        Time costs : 3965.45
        Transfer costs : 0.00
        Other costs : 267.00
        Total cost : 10775.55
Chain type : 11
        Cost : N.A.
Chain type : 111
        Vehicle type(s): 15 15 15
        Vehicle count : 3.000000 3.031578 3.000000
        Nodes : 916100 928100 844700 918000
        Dist. : 177 580 377
        Time : 30 82 57
        Loading costs : 2016.28
        Unloading costs: 2016.28
        Dist. costs : 3966.57 13134.61 8448.57
        Time costs : 3498.93 9664.41 6647.97
        Transfer costs : 0.00 4039.43 4039.43
        Other costs : 249.00 475.96 363.00
        Total cost : 58560.42
Chain type : 3
        Vehicle type(s): 7
        Vehicle count : 0.058766
        Nodes : 916100 918000
        Dist. : 182
        Time : 35
        Loading costs : 430.33
        Unloading costs: 430.33
        Dist. costs : 791.57
        Time costs : 508.85
        Transfer costs : 0.00
        Other costs : 4.35
        Total cost : 2165.43
Chain type : 121
        Cost : N.A.
Chain type : 151
```

```
        Cost : N.A.
Chain type : 13
        Cost : N.A.
Chain type : 31
        Cost : N.A.
Chain type : 131
        Cost : N.A.
Chain type : 141
        Cost : N.A.
Chain type : 1231
        Cost : N.A.
Chain type : 1321
        Cost : N.A.
```

Sweden case 2:

```
Orig : 788100
Dest : 625
Commodity : 6
Frequency : 198
Order cost : 389.00
Holding cost : 2190.00
Shipment Size : 70.11
Chain type : 1
        Vehicle type(s): 15
        Vehicle count : 3.000000
        Nodes : 788100 625
        Dist. : 1588
        Time : 453
        Loading costs : 1644.88
        Unloading costs: 0.00
        Dist. costs : 35587.08
        Time costs : 52833.84
        Transfer costs : 0.00
        Other costs : 1335.00
        Total cost : 91400.80
Chain type : 11
        Vehicle type(s): 15 15
        Vehicle count : 3.000000 2.473166
        Nodes : 788100 829000 625
```

```
        Dist. : 198 1523
        Time : 35 436
        Loading costs : 1644.88
        Unloading costs: 1644.88
        Dist. costs : 4437.18 28136.73
        Time costs : 4082.09 41921.08
        Transfer costs : 0.00 3295.37
        Other costs : 270.00 1041.20
        Total cost : 86473.41
Chain type : 111
        Vehicle type(s): 15 15 15
        Vehicle count : 3.000000 2.473166 3.000000
        Nodes : 788100 829000 844700 625
        Dist. : 198 392 1471
        Time : 35 61 426
        Loading costs : 1644.88
        Unloading costs: 1644.88
        Dist. costs : 4437.18 7242.02 32965.11
        Time costs : 4082.09 5865.10 49684.81
        Transfer costs : 0.00 3295.37 3295.37
        Other costs : 270.00 314.09 1221.00
        Total cost : 115961.90
Chain type : 121
        Cost : N.A.
Chain type : 151
        Vehicle type(s): 15 38 3368
        Vehicle count : 3.000000 3.000000 3.000000
        Nodes : 788100 18023 528658 625
        Dist. : 39 1438 201
        Time : 7 445 30
        Loading costs : 1644.88
        Unloading costs: 1644.88
        Dist. costs : 873.99 3395.12 4504.41
        Time costs : 816.42 664919.45 3498.93
        Transfer costs : 0.00 0.00 0.00
        Other costs : 90.00 219.00 186.00
        Total cost : 681793.07
Chain type : 13
        Cost : N.A.
Chain type : 31
```

```
        Cost : N.A.
Chain type : 131
        Cost : N.A.
Chain type : 141
        Cost : N.A.
Chain type : 1231
        Cost : N.A.
Chain type : 1321
        Cost : N.A.
```

Sweden case 3:

```
Orig : 918200
Dest : 556
Commodity : 6
Frequency : 1
Order cost : 389.00
Holding cost : 2190.00
Shipment Size : 0.05
Chain type : 1
        Vehicle type(s): 15
        Vehicle count : 1.000000
        Nodes : 918200 556
        Dist. : 2175
        Time : 464
        Loading costs : 1.17
        Unloading costs: 0.00
        Dist. costs : 16247.25
        Time costs : 18038.93
        Transfer costs : 0.00
        Other costs : 583.00
        Total cost : 34870.35
Chain type : 11
        Cost : N.A.
Chain type : 111
        Vehicle type(s): 15 15 15
        Vehicle count : 1.000000 0.001764 1.000000
        Nodes : 918200 928100 829000 556
        Dist. : 156 884 1661
        Time : 22 130 330
```

```
        Loading costs : 1.17
        Unloading costs: 1.17
        Dist. costs : 1165.32 11.65 12407.67
        Time costs : 855.29 8.91 12829.41
        Transfer costs : 0.00 2.35 2.35
        Other costs : 71.00 0.40 463.00
        Total cost : 27819.70
Chain type : 3
        Vehicle type(s): 7
        Vehicle count : 0.000034
        Nodes : 918200 556
        Dist. : 2534
        Time : 984
        Loading costs : 0.25
        Unloading costs: 0.25
        Dist. costs : 6.41
        Time costs : 8.32
        Transfer costs : 0.00
        Other costs : 0.01
        Total cost : 15.25
Chain type : 121
        Cost : N.A.
Chain type : 151
        Vehicle type(s): 15 38 7545
        Vehicle count : 1.000000 1.000000 1.000000
        Nodes : 918200 18060 517651 556
        Dist. : 36 865 1383
        Time : 7 269 231
        Loading costs : 1.17
        Unloading costs: 1.17
        Dist. costs : 268.92 680.75 10331.01
        Time costs : 272.14 133980.02 8980.59
        Transfer costs : 0.00 0.00 0.00
        Other costs : 30.00 48.00 348.00
        Total cost : 154941.78
Chain type : 13
        Cost : N.A.
Chain type : 31
        Cost : N.A.
Chain type : 131
```

Cost : N.A.

Chain type : 141

Cost : N.A.

Chain type : 1231

Cost : N.A.

Chain type : 1321

Cost : N.A.

Sweden case 4:

Orig : 808200

Dest : 758100

Commodity : 24

Frequency : 4

Shipment Size : 5663.64

Chain type : 1

Vehicle type(s): 6

Vehicle count : 135.000000

Nodes : 808200 758100

Dist. : 393

Time : 55

Loading costs : 60714.22

Unloading costs: 0.00

Dist. costs : 404279.10

Time costs : 281511.45

Transfer costs : 0.00

Other costs : 12015.00

Total cost : 758519.77

Chain type : 11

Cost : N.A.

Chain type : 111

Vehicle type(s): 6 8 6

Vehicle count : 135.000000 178.776520 135.000000

Nodes : 808200 828000 768000 758100

Dist. : 156 309 178

Time : 24 38 24

Loading costs : 60714.22

Unloading costs: 60714.22

Dist. costs : 160477.20 402161.36 183108.60

Time costs : 122841.36 277222.67 122841.36

```
        Transfer costs : 0.00 124600.08 118936.44
        Other costs : 8235.00 13050.69 8370.00
        Total cost : 1663273.18
Chain type : 3
        Vehicle type(s): 7
        Vehicle count : 3.872574
        Nodes : 808200 758100
        Dist. : 1055
        Time : 395
        Loading costs : 28357.85
        Unloading costs: 28357.85
        Dist. costs : 302372.73
        Time costs : 378439.58
        Transfer costs : 0.00
        Other costs : 677.70
        Total cost : 738205.71
Chain type : 121
        Vehicle type(s): 6 8 6
        Vehicle count : 135.000000 0.314647 135.000000
        Nodes : 808200 18018 18057 758100
        Dist. : 4 430 11
        Time : 1 151 3
        Loading costs : 60714.22
        Unloading costs: 60714.22
        Dist. costs : 4114.80 11500.34 11315.70
        Time costs : 5118.39 17812.12 15355.17
        Transfer costs : 0.00 945657.97 945657.97
        Other costs : 2835.00 7.24 2970.00
        Total cost : 2083773.13
Chain type : 151
        Cost : N.A.
Chain type : 13
        Vehicle type(s): 6 6
        Vehicle count : 135.000000 3.872574
        Nodes : 808200 2063 758100
        Dist. : 27 566
        Time : 5 97
        Loading costs : 60714.22
        Unloading costs: 28357.85
        Dist. costs : 27774.90 162220.82
```

```
        Time costs : 25591.95 92933.26
        Transfer costs : 0.00 260810.62
        Other costs : 3375.00 302.06
        Total cost : 662080.69
Chain type : 31
        Vehicle type(s): 3 6
        Vehicle count : 3.872574 135.000000
        Nodes : 808200 2066 758100
        Dist. : 3 388
        Time : 2 54
        Loading costs : 29105.45
        Unloading costs: 60714.22
        Dist. costs : 995.41 399135.60
        Time costs : 1997.47 276393.06
        Transfer costs : 0.00 255656.71
        Other costs : 158.78 9180.00
        Total cost : 1033336.69
Chain type : 131
        Vehicle type(s): 6 6 6
        Vehicle count : 135.000000 3.872574 135.000000
        Nodes : 808200 2063 1941 758100
        Dist. : 27 406 17
        Time : 5 68 5
        Loading costs : 60714.22
        Unloading costs: 60714.22
        Dist. costs : 27774.90 116363.35 17487.90
        Time costs : 25591.95 65149.09 25591.95
        Transfer costs : 0.00 260810.62 260810.62
        Other costs : 3375.00 85.20 3240.00
        Total cost : 927709.02
Chain type : 141
        Vehicle type(s): 6 5 6
        Vehicle count : 135.000000 8.226057 135.000000
        Nodes : 808200 2086 2000 758100
        Dist. : 80 301 14
        Time : 19 40 4
        Loading costs : 60714.22
        Unloading costs: 60714.22
        Dist. costs : 82296.00 144749.48 14401.80
        Time costs : 97249.41 76206.19 20473.56
```

```
        Transfer costs : 0.00 260810.62 260810.62
        Other costs : 4995.00 123.39 3240.00
        Total cost : 1086784.51
Chain type : 1231
        Vehicle type(s): 6 8 4 6
        Vehicle count : 135.000000 0.314647 12.585867 135.000000
        Nodes : 808200 18018 18057 2000 758100
        Dist. : 4 430 9 14
        Time : 1 151 5 4
        Loading costs : 60714.22
        Unloading costs: 60714.22
        Dist. costs : 4114.80 11500.34 9145.65 14401.80
        Time costs : 5118.39 17812.12 14171.69 20473.56
        Transfer costs : 0.00 945657.97 1240110.61 260810.62
        Other costs : 2835.00 7.24 25.17 3240.00
        Total cost : 2670853.39
Chain type : 1321
        Vehicle type(s): 6 4 8 6
        Vehicle count : 135.000000 12.585867 0.314647 135.000000
        Nodes : 808200 2063 18018 18057 758100
        Dist. : 27 35 430 11
        Time : 5 13 151 3
        Loading costs : 60714.22
        Unloading costs: 60714.22
        Dist. costs : 27774.90 35566.40 11500.34 11315.70
        Time costs : 25591.95 36846.38 17812.12 15355.17
        Transfer costs : 0.00 260810.62 1240110.61 945657.97
        Other costs : 3375.00 37.76 7.24 2970.00
        Total cost : 2756160.60
```

Sweden case 5:

```
Orig : 768200
Dest : 828700
Commodity : 24
Frequency : 4
Shipment Size : 0.00
Chain type : 1
        Vehicle type(s): 1
        Vehicle count : 1.000000
```

```
        Nodes : 768200 828700
        Dist. : 376
        Time : 48
        Loading costs : 0.09
        Unloading costs: 0.00
        Dist. costs : 774.56
        Time costs : 1542.05
        Transfer costs : 0.00
        Other costs : 82.00
        Total cost : 2398.70
Chain type : 11
        Cost : N.A.
Chain type : 111
        Vehicle type(s): 1 8 1
        Vehicle count : 1.000000 0.000009 1.000000
        Nodes : 768200 768000 828000 828700
        Dist. : 49 309 43
        Time : 8 38 7
        Loading costs : 0.09
        Unloading costs: 0.09
        Dist. costs : 100.94 0.02 88.58
        Time costs : 257.01 0.01 224.88
        Transfer costs : 0.00 0.00 0.10
        Other costs : 47.00 0.00 46.00
        Total cost : 764.73
Chain type : 3
        Vehicle type(s): 7
        Vehicle count : 0.000000
        Nodes : 768200 828700
        Dist. : 311
        Time : 64
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 0.00
        Time costs : 0.00
        Transfer costs : 0.00
        Other costs : 0.00
        Total cost : 0.01
Chain type : 121
        Vehicle type(s): 1 8 1
```

```
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 768200 18025 519653 828700
        Dist. : 217 200 162
        Time : 33 69 27
        Loading costs : 0.09
        Unloading costs: 0.09
        Dist. costs : 447.02 0.00 333.72
        Time costs : 1060.16 0.00 867.40
        Transfer costs : 0.00 0.07 0.07
        Other costs : 49.00 0.00 51.00
        Total cost : 2808.64
Chain type : 151
        Cost : N.A.
Chain type : 13
        Vehicle type(s): 1 6
        Vehicle count : 1.000000 0.000000
        Nodes : 768200 1946 828700
        Dist. : 10 306
        Time : 2 60
        Loading costs : 0.09
        Unloading costs: 0.00
        Dist. costs : 20.60 0.00
        Time costs : 64.25 0.00
        Transfer costs : 0.00 0.11
        Other costs : 22.00 0.00
        Total cost : 107.06
Chain type : 31
        Vehicle type(s): 6 1
        Vehicle count : 0.000000 1.000000
        Nodes : 768200 2002 828700
        Dist. : 306 6
        Time : 60 1
        Loading costs : 0.00
        Unloading costs: 0.09
        Dist. costs : 0.00 12.36
        Time costs : 0.00 32.13
        Transfer costs : 0.00 0.11
        Other costs : 0.00 21.00
        Total cost : 65.69
Chain type : 131
```

```
        Vehicle type(s): 1 6 1
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 768200 1942 2002 828700
        Dist. : 43 344 6
        Time : 7 63 1
        Loading costs : 0.09
        Unloading costs: 0.09
        Dist. costs : 88.58 0.00 12.36
        Time costs : 224.88 0.00 32.13
        Transfer costs : 0.00 0.11 0.11
        Other costs : 26.00 0.00 21.00
        Total cost : 405.36
Chain type : 141
        Vehicle type(s): 1 5 1
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 768200 1942 2002 828700
        Dist. : 43 344 6
        Time : 7 61 1
        Loading costs : 0.09
        Unloading costs: 0.09
        Dist. costs : 88.58 0.01 12.36
        Time costs : 224.88 0.01 32.13
        Transfer costs : 0.00 0.11 0.11
        Other costs : 26.00 0.00 21.00
        Total cost : 405.36
Chain type : 1231
        Vehicle type(s): 1 8 4 1
        Vehicle count : 1.000000 0.000000 0.000001 1.000000
        Nodes : 768200 18025 519653 2002 828700
        Dist. : 217 200 76 6
        Time : 33 69 15 1
        Loading costs : 0.09
        Unloading costs: 0.09
        Dist. costs : 447.02 0.00 0.00 12.36
        Time costs : 1060.16 0.00 0.00 32.13
        Transfer costs : 0.00 0.07 0.06 0.11
        Other costs : 49.00 0.00 0.00 21.00
        Total cost : 1622.10
Chain type : 1321
        Vehicle type(s): 1 1 8 1
```

Vehicle count : 1.000000 0.000001 0.000000 1.000000

Nodes : 768200 1946 18057 18014 828700

Dist. : 10 177 521 7

Time : 2 27 179 2

Loading costs : 0.09

Unloading costs: 0.09

Dist. costs : 20.60 0.01 0.00 14.42

Time costs : 64.25 0.00 0.00 64.25

Transfer costs : 0.00 0.11 0.06 0.07

Other costs : 22.00 0.00 0.00 21.00

Total cost : 206.96

Sweden case 6:
(first f2f relation):

Orig : 825700

Dest : 742800

Commodity : 27

Frequency : 1

Order cost : 389.00

Holding cost : 9855.00

Shipment Size : 0.00

Chain type : 1

Vehicle type(s): 1

Vehicle count : 1.000000

Nodes : 825700 742800

Dist. : 431

Time : 56

Loading costs : 0.00

Unloading costs: 0.00

Dist. costs : 887.86

Time costs : 1799.06

Transfer costs : 0.00

Other costs : 83.00

Total cost : 2769.92

Chain type : 11

Cost : N.A.

Chain type : 111

Vehicle type(s): 1 8 1

Vehicle count : 1.000000 0.000000 1.000000

```
        Nodes : 825700 829300 886100 742800
        Dist. : 39 392 64
        Time : 8 62 13
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 80.34 0.00 131.84
        Time costs : 257.01 0.00 417.64
        Transfer costs : 0.00 0.00 0.00
        Other costs : 46.00 0.00 50.00
        Total cost : 982.84
Chain type : 121
        Vehicle type(s): 1 8 1
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 825700 18015 18057 742800
        Dist. : 56 632 90
        Time : 9 215 18
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 115.36 0.00 185.40
        Time costs : 289.13 0.00 578.27
        Transfer costs : 0.00 0.00 0.00
        Other costs : 27.00 0.00 34.00
        Total cost : 1229.18
Chain type : 151
        Cost : N.A.
Chain type : 131
        Vehicle type(s): 1 3 1
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 825700 1801 1900 742800
        Dist. : 284 32 119
        Time : 34 4 19
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 585.04 0.00 245.14
        Time costs : 1092.28 0.00 610.39
        Transfer costs : 0.00 0.01 0.01
        Other costs : 47.00 0.00 35.00
        Total cost : 2614.88
Chain type : 141
        Vehicle type(s): 1 5 1
```

```
        Vehicle count : 1.000000 0.000000 1.000000
        Nodes : 825700 2086 2000 742800
        Dist. : 81 301 78
        Time : 13 40 14
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 166.86 0.00 160.68
        Time costs : 417.64 0.00 449.76
        Transfer costs : 0.00 0.01 0.01
        Other costs : 30.00 0.00 31.00
        Total cost : 1255.96
Chain type : 1231
        Vehicle type(s): 1 8 4 1
        Vehicle count : 1.000000 0.000000 0.000000 1.000000
        Nodes : 825700 18015 18002 2414 742800
        Dist. : 56 657 10 142
        Time : 9 220 1 25
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 115.36 0.00 0.00 292.52
        Time costs : 289.13 0.00 0.00 803.15
        Transfer costs : 0.00 0.00 0.00 0.01
        Other costs : 27.00 0.00 0.00 40.00
        Total cost : 1567.19
Chain type : 1321
        Vehicle type(s): 1 4 8 1
        Vehicle count : 1.000000 0.000000 0.000000 1.000000
        Nodes : 825700 2033 18015 18057 742800
        Dist. : 55 1 632 90
        Time : 8 0 215 18
        Loading costs : 0.00
        Unloading costs: 0.00
        Dist. costs : 113.30 0.00 0.00 185.40
        Time costs : 257.01 0.00 0.00 578.27
        Transfer costs : 0.00 0.01 0.00 0.00
        Other costs : 27.00 0.00 0.00 34.00
        Total cost : 1195.00
```

Sweden case 7:

Orig : 517

Dest : 719100

Commodity : 27

Frequency : 6

Order cost : 389.00

Holding cost : 9855.00

Shipment Size : 0.35

Chain type : 1

- Vehicle type(s): 1
- Vehicle count : 1.000000
- Nodes : 517 719100
- Dist. : 519
- Time : 99
- Loading costs : 123.36
- Unloading costs: 0.00
- Dist. costs : 1069.14
- Time costs : 3180.47
- Transfer costs : 0.00
- Other costs : 117.00
- Total cost : 4489.97

Chain type : 11

- Cost : N.A.

Chain type : 111

- Vehicle type(s): 1 8 4
- Vehicle count : 1.000000 0.011206 1.000000
- Nodes : 517 848800 711400 719100
- Dist. : 214 404 16
- Time : 46 59 4
- Loading costs : 123.36
- Unloading costs: 3.72
- Dist. costs : 440.84 32.96 98.88
- Time costs : 1477.80 26.98 138.06
- Transfer costs : 0.00 3.90 7.81
- Other costs : 76.00 0.96 43.00
- Total cost : 2474.27

Chain type : 121

- Vehicle type(s): 1 8 1
- Vehicle count : 1.000000 0.000020 1.000000
- Nodes : 517 518651 18002 719100

```
        Dist. : 104 1091 72
        Time : 19 345 19
        Loading costs : 123.36
        Unloading costs: 123.36
        Dist. costs : 214.24 1.83 148.32
        Time costs : 610.39 2.55 610.39
        Transfer costs : 0.00 101.86 101.86
        Other costs : 35.00 0.00 35.00
        Total cost : 2108.17
Chain type : 151
        Vehicle type(s): 1 9 3368
        Vehicle count : 1.000000 1.000000 1.000000
        Nodes : 517 518651 18002 719100
        Dist. : 104 1091 72
        Time : 19 345 19
        Loading costs : 123.36
        Unloading costs: 123.36
        Dist. costs : 214.24 57.82 148.32
        Time costs : 610.39 113390.46 610.39
        Transfer costs : 0.00 0.00 0.00
        Other costs : 35.00 57.00 35.00
        Total cost : 115405.35
Chain type : 31
        Vehicle type(s): 3 1
        Vehicle count : 0.000243 1.000000
        Nodes : 517 518415 719100
        Dist. : 38 494
        Time : 12 94
        Loading costs : 1.82
        Unloading costs: 123.36
        Dist. costs : 0.79 1017.64
        Time costs : 0.75 3019.84
        Transfer costs : 0.00 136.86
        Other costs : 0.01 93.00
        Total cost : 4394.08
Chain type : 131
        Vehicle type(s): 1 3 1
        Vehicle count : 1.000000 0.000243 1.000000
        Nodes : 517 5807 1300 719100
        Dist. : 439 27 57
```

```
        Time : 82 4 14
        Loading costs : 123.36
        Unloading costs: 123.36
        Dist. costs : 904.34 0.56 117.42
        Time costs : 2634.33 0.25 449.76
        Transfer costs : 0.00 136.86 136.86
        Other costs : 84.00 0.00 31.00
        Total cost : 4742.10
Chain type : 141
        Vehicle type(s): 1 5 1
        Vehicle count : 1.000000 0.000516 1.000000
        Nodes : 517 518401 2394 719100
        Dist. : 92 371 177
        Time : 17 78 29
        Loading costs : 123.36
        Unloading costs: 123.36
        Dist. costs : 189.52 11.18 364.62
        Time costs : 546.14 9.31 931.65
        Transfer costs : 0.00 137.18 137.18
        Other costs : 33.00 0.01 42.00
        Total cost : 2648.52
Chain type : 1231
        Vehicle type(s): 1 8 4 4
        Vehicle count : 1.000000 0.000020 0.000789 1.000000
        Nodes : 517 518651 18067 9070 719100
        Dist. : 104 1233 0 44
        Time : 19 398 0 12
        Loading costs : 123.36
        Unloading costs: 3.72
        Dist. costs : 214.24 2.07 0.00 271.92
        Time costs : 610.39 2.94 0.00 414.18
        Transfer costs : 0.00 101.86 83.87 16.27
        Other costs : 35.00 0.00 0.00 29.00
        Total cost : 1908.82
Chain type : 1321
        Vehicle type(s): 4 4 8 1
        Vehicle count : 1.000000 0.000789 0.000020 1.000000
        Nodes : 517 518415 518651 18002 719100
        Dist. : 29 74 1091 72
        Time : 6 18 345 19
```

```
Loading costs : 3.72
Unloading costs: 123.36
Dist. costs : 179.22 4.71 1.83 148.32
Time costs : 207.09 3.20 2.55 610.39
Transfer costs : 0.00 16.27 83.87 101.86
Other costs : 25.00 0.00 0.00 35.00
Total cost : 1546.39
```

Observations and comments

Case 1

The shipment size of 85.95 tonnes was determined as follows: shipment size = sqrt(2*OrderCost*Tonnes/HoldingCost) = sqrt(2*389*20885/2190) = 86.13 tonnes. To obtain an integer number for the frequency the shipment sise is set to 85.95 tonnes.

For chain type 1 (direct road transport), the unloading costs should not be zero, but the same as the loading costs. This needs to be corrected in the program.

Chain type 11 (road-road) is only available for large receivers (not the case here).

For chain type 111 (road-road-road) the second leg uses 3.03 vehicles of type 15. This is internally consistent, since we assume 90% capacity use for consolidated flows. However, 3 vehicles are sufficient to carry the shipment size (a fourth vehicle, with other cargo as well will never be used in practice for the second leg). In reality there will be no consolidation for such a convoy of trucks. This chain is unattractive because of the long detour (no nearby road terminals available for this commodity type).

Chain 3 (direct rail) is available here, since both municipalities have rail access, but whether it would be available for both firms (own sidings) is doubtful. This needs to be improved in version 1 (more restrictions on rail accessibility in the network model). This chain uses a fraction of a train (consolidation), which makes rail cheap (it is the chosen transport chain). The assumptions that this train is immediately available and that there is other cargo need to be relaxed (see Chapter 2).

Case 2

The shipment size of 70.11 is determined as follows: shipment size = sqrt(2*OrderCost*Tonnes/HoldingCost) = sqrt(2*389* 13883/2190) = 70.22 tonnes. To obtain an integer number for the frequency the shipment sise is set to 70.11 tonnes.

This is a transport from Sweden to Birmingham. The chains 1, 11 and 111 turn out to be road+ferry chains, not pure road chains. This is a miscommunication between the logistics team and SIKA. As a result, we have calculated transport chain costs for 1, 11 and 111 on the basis of road+ferry time and distance but combined with pure road costs functions. The same problem occurred for rail and combi, which can mean rail+ferry and combi+ferry in the paths provided to us. Henrik Edward's program can be changed to deliver pure road legs, pure rail legs and pure combi legs, and this should be done for all road, rail and combi legs: for Sweden, road means road vehicles only, rail means rail vehicles only and combi means combi vehicles only. Sea, ferry and air should be three separate modes in the network output for the logistics model. For Norway these problems did not happen.

Chain 11 is available here, because the receiver is a large firm.

In chain 111 we can see that 2.47 vehicles of type 15 are used in the second leg, which is in line with the model assumptions on consolidation. Two remarks can be made here. First, for a convoy of three trucks, only one of the trucks can take a consolidated load. The other trucks will not need transfer costs (which are calculated here). Also, consolidation is not very likely in reality for a convoy of three trucks.

See transport chains are not available here, because for this commodity only one truck type (timber truck with hanger) is available. For this truck type there is no transfer available to any of the vessel types (see Annex 3 of D4). This is too restrictive and will be revised in the next phase.

Rail transport chains are not available either, again due to too restrictive availability constraints. There will be relaxed as well.

The time costs for the ferry leg in 151 appear to be too high by a factor of 10. This is an error in the program (the network times were in hours*10, and this was taken into account everywhere in the program except in the calculation of the ferry cost. This has to be revised in the next phase. Also in the program, costs for a truck on a ferry cannot be shared with other cargo; the trucks drive onto the ship, without loading other cargo (no consolidation, as opposed to sea transport, where there can be consolidation). We propose to leave this as it is.

Case 3

This is a very small transport, because the PWC flow is very small (number of f2f relations and frequency are both equal to one). In practice it is hard to imagine that someone will transport 50 kg of wood from Sweden to Bosnia.

The model makes consolidation (e.g. 111) relatively attractive, because it assumes that other cargo will pay (up top 90% of vehicle capacity) most of the bill. The last leg is very long, which is not realistic, but the result of restricting ourselves to a set of road terminals in Sweden only.

Case 4

In transport chain 111 the vehicle types used are 6, 8 and 6. The second leg takes place with vehicles that are smaller than on the first and second leg This is possible in principle, because it could lead in some (albeit unlikely) cases to lower costs. But as mentioned earlier, consolidation is not at all likely for a convoy. The model could be changed to rule out 11 and 111 if the shipment size exceeds the biggest available vehicle (convoy)

Case 5

This shipment is very small: 0.3 kg (could perhaps be a report delivered by a courier), due to the small PWC flow, which was divided by a frequency of 4 (using a single f2f relation).

Case 6

This case concerns a PWC flow that leads to 10 f2f flows (one sender, 10 receivers). Again it is a very small flow (of glass and ceramic products). We only presented the calculations for the first f2f relation.

Case 7

Again the time-based ferry costs are too high by a factor 10.

2.11.2 **Norway**

The cases that we received to be worked out for Norway are:

1. Fresh fish (commodity 4) from Ålesund (1504) to Paris (5201);
2. Machinery and equipments (commodity 9) from Kongsvinger (402) to Helsinki (3001);
3. General cargo-other inputs (commodity 14) from Stavanger (1171) to Bergen (1271);
4. General cargo-consumption (commodity 15) from Oslo (301) to Stavanger (1171);
5. General cargo-consumption (commodity 15) from Stockholm (50) to Oslo (301);
6. Pulpwood (commodity 17) from Oslo (301) to Hamburg (5101);
7. Paper intermediates (commodity 19) from Hønefoss (605) to Halden (101);
8. Fertilizers (commodity 27) from Porsgrunn (805) to Kambo (104);
9. Aluminium (commodity 29) from Sunndalsøra (1563) to Raufoss (529).

Detailed outcomes

We added the output facilities of the program to include outputs for all individual cost items and obtained the following results for the nine Norwegian cases:

Norway case 1:

```
Orig : 1504
Dest : 5201
Commodity : 4
Frequency : 26
Shipment Size : 310.85
Chain type : 1
      Vehicle type(s): 6
      Vehicle count : 8.000000
      Nodes : 1504 5201
      Dist. : 2502
```

```
     Time : 349
     Loading costs : 3692.85
     Unloading costs: 0.00
     Dist. costs : 122297.76
     Time costs : 120929.90
     Transfer costs : 0.00
     Other costs : 10400.00
     Total cost : 257320.51
Chain type : 11
     Cost : N.A.
Chain type : 111
     Vehicle type(s): 6 6 6
     Vehicle count : 8.000000 8.223443 8.000000
     Nodes : 1504 1531 101 5201
     Dist. : 30 662 1806
     Time : 5 93 253
     Loading costs : 3692.85
     Unloading costs: 3692.85
     Dist. costs : 1466.40 33262.35 88277.28
     Time costs : 1732.52 33124.92 87665.51
     Transfer costs : 0.00 5688.48 5688.48
     Other costs : 0.00 0.00 10400.00
     Total cost : 274691.66
Chain type : 121
     Vehicle type(s): 4 25 6
     Vehicle count : 20.000000 0.054511 8.000000
     Nodes : 1504 21910 52124 5201
     Dist. : 2 1636 204
     Time : 0 686 27
     Loading costs : 3633.79
     Unloading costs: 3692.85
     Dist. costs : 196.40 15786.78 9971.52
     Time costs : 0.00 23662.83 9355.61
     Transfer costs : 0.00 19757.38 19816.44
     Other costs : 0.00 0.71 0.00
     Total cost : 105874.31
Chain type : 131
     Vehicle type(s): 6 1 6
     Vehicle count : 8.000000 0.451483 8.000000
     Nodes : 1504 21921 52016 5201
```

```
          Dist. : 113 2258 22
          Time : 16 533 3
          Loading costs : 3692.85
          Unloading costs: 3692.85
          Dist. costs : 5523.44 32082.06 1075.36
          Time costs : 5544.06 134967.33 1039.51
          Transfer costs : 0.00 14675.05 14675.05
          Other costs : 0.00 5.87 0.00
          Total cost : 216973.43
Chain type : 141
          Vehicle type(s): 6 6 6
          Vehicle count : 8.000000 8.000000 8.000000
          Nodes : 1504 21822 40301 5201
          Dist. : 601 241 1352
          Time : 85 111 182
          Loading costs : 3692.85
          Unloading costs: 3692.85
          Dist. costs : 29376.88 964.00 66085.76
          Time costs : 29452.84 63838.32 63063.73
          Transfer costs : 0.00 0.00 0.00
          Other costs : 192.00 104.00 0.00
          Total cost : 260463.23
Chain type : 151
          Vehicle type(s): 6 2 6
          Vehicle count : 8.000000 2.892668 8.000000
          Nodes : 1504 20219 54042 5201
          Dist. : 524 1460 514
          Time : 72 19 69
          Loading costs : 3692.85
          Unloading costs: 3692.85
          Dist. costs : 25613.12 274514.24 25124.32
          Time costs : 24948.29 419987.69 23908.78
          Transfer costs : 0.00 156977.31 156977.31
          Other costs : 0.00 0.00 0.00
          Total cost : 1115436.75
Chain type : 1231
          Vehicle type(s): 4 25 1 6
          Vehicle count : 20.000000 0.054511 0.451483 8.000000
          Nodes : 1504 21910 52125 52016 5201
          Dist. : 2 1460 264 22
```

```
    Time : 0 613 53 3
    Loading costs : 3633.79
    Unloading costs: 3692.85
    Dist. costs : 196.40 14088.44 3750.96 1075.36
    Time costs : 0.00 21144.78 13420.77 1039.51
    Transfer costs : 0.00 19757.38 26857.11 14675.05
    Other costs : 0.00 0.71 0.00 0.00
    Total cost : 123333.10
Chain type : 1321
    Vehicle type(s): 6 3 25 6
    Vehicle count : 8.000000 0.451483 0.054511 8.000000
    Nodes : 1504 21805 21921 52124 5201
    Dist. : 121 1 1767 204
    Time : 17 0 741 27
    Loading costs : 3692.85
    Unloading costs: 3692.85
    Dist. costs : 5914.48 23.60 17050.88 9971.52
    Time costs : 5890.57 0.00 25560.00 9355.61
    Transfer costs : 0.00 14392.18 26428.14 19816.44
    Other costs : 0.00 0.00 0.71 0.00
    Total cost : 141789.83
```

Norway case 2:

```
Orig : 402
Dest : 3001
Commodity : 9
Frequency : 26
Shipment Size : 6.92
Chain type : 1
    Vehicle type(s): 2
    Vehicle count : 1.000000
    Nodes : 402 3001
    Dist. : 2106
    Time : 293
    Loading costs : 1823.61
    Unloading costs: 0.00
    Dist. costs : 8255.52
    Time costs : 11308.04
    Transfer costs : 0.00
```

```
    Other costs : 0.00
    Total cost : 21387.17
Chain type : 11
    Cost : N.A.
Chain type : 111
    Vehicle type(s): 4 6 4
    Vehicle count : 1.000000 0.183150 1.000000
    Nodes : 402 236 1841 3001
    Dist. : 49 1502 1338
    Time : 8 224 191
    Loading costs : 80.93
    Unloading costs: 80.93
    Dist. costs : 240.59 1680.81 6569.58
    Time costs : 324.38 1776.94 7744.48
    Transfer costs : 0.00 166.15 166.15
    Other costs : 0.00 0.00 0.00
    Total cost : 18830.95
Chain type : 121
    Vehicle type(s): 4 21 4
    Vehicle count : 1.000000 0.000160 1.000000
    Nodes : 402 21825 39501 3001
    Dist. : 96 1625 2
    Time : 14 687 0
    Loading costs : 80.93
    Unloading costs: 80.93
    Dist. costs : 471.36 32.31 9.82
    Time costs : 567.66 64.88 0.00
    Transfer costs : 0.00 391.64 391.64
    Other costs : 24.00 0.00 0.00
    Total cost : 2115.17
Chain type : 131
    Vehicle type(s): 4 1 4
    Vehicle count : 1.000000 0.010055 1.000000
    Nodes : 402 21762 39901 3001
    Dist. : 5 974 1
    Time : 1 258 0
    Loading costs : 80.93
    Unloading costs: 80.93
    Dist. costs : 24.55 308.21 4.91
    Time costs : 40.55 1455.04 0.00
```

```
        Transfer costs : 0.00 325.52 325.52
        Other costs : 0.00 0.13 0.00
        Total cost : 2646.30
Chain type : 141
        Vehicle type(s): 4 4 4
        Vehicle count : 1.000000 1.000000 1.000000
        Nodes : 402 14065 38016 3001
        Dist. : 463 289 171
        Time : 72 95 23
        Loading costs : 80.93
        Unloading costs: 80.93
        Dist. costs : 2273.33 54.91 839.61
        Time costs : 2919.38 4860.20 932.58
        Transfer costs : 0.00 0.00 0.00
        Other costs : 0.00 13.00 0.00
        Total cost : 12054.88
Chain type : 151
        Vehicle type(s): 4 2 4
        Vehicle count : 1.000000 0.064425 1.000000
        Nodes : 402 20219 10019 3001
        Dist. : 68 762 1780
        Time : 11 10 239
        Loading costs : 80.93
        Unloading costs: 80.93
        Dist. costs : 333.88 3190.95 8739.80
        Time costs : 446.02 4923.08 9690.73
        Transfer costs : 0.00 3489.23 3489.23
        Other costs : 0.00 0.00 0.00
        Total cost : 34464.78
Chain type : 1231
        Vehicle type(s): 4 21 3 4
        Vehicle count : 1.000000 0.000160 0.010055 1.000000
        Nodes : 402 21825 39501 39901 3001
        Dist. : 96 1625 1 1
        Time : 14 687 0 0
        Loading costs : 80.93
        Unloading costs: 80.93
        Dist. costs : 471.36 32.31 0.53 4.91
        Time costs : 567.66 64.88 0.00 0.00
        Transfer costs : 0.00 391.64 540.21 319.22
```

```
        Other costs : 24.00 0.00 0.00 0.00
        Total cost : 2578.58
Chain type : 1321
        Vehicle type(s): 4 1 20 4
        Vehicle count : 1.000000 0.010055 0.000283 1.000000
        Nodes : 402 21762 14065 39501 3001
        Dist. : 5 478 493 2
        Time : 1 106 204 0
        Loading costs : 80.93
        Unloading costs: 80.93
        Dist. costs : 24.55 151.26 14.54 9.82
        Time costs : 40.55 597.81 22.00 0.00
        Transfer costs : 0.00 325.52 545.33 387.14
        Other costs : 0.00 0.00 0.00 0.00
        Total cost : 2280.38
```

Norway case 3:

```
Orig : 1171
Dest : 1271
Commodity : 14
Frequency : 68
Order cost : 500.00
Holding cost : 1467.00
Shipment Size : 45.15
Chain type : 1
        Vehicle type(s): 6
        Vehicle count : 2.000000
        Nodes : 1171 1271
        Dist. : 388
        Time : 78
        Loading costs : 536.35
        Unloading costs: 0.00
        Dist. costs : 4741.36
        Time costs : 6756.83
        Transfer costs : 0.00
        Other costs : 638.00
        Total cost : 12672.54
Chain type : 11
        Cost : N.A.
```

```
Chain type : 111
        Vehicle type(s): 6 6 6
        Vehicle count : 2.000000 1.194367 2.000000
        Nodes : 1171 1172 1274 1271
        Dist. : 3 378 13
        Time : 1 77 2
        Loading costs : 536.35
        Unloading costs: 536.35
        Dist. costs : 36.66 2758.49 158.86
        Time costs : 86.63 3983.33 173.25
        Transfer costs : 0.00 826.19 826.19
        Other costs : 0.00 369.06 20.00
        Total cost : 10311.35
Chain type : 121
        Vehicle type(s): 6 20 4
        Vehicle count : 2.000000 0.001844 3.000000
        Nodes : 1171 21854 21868 1271
        Dist. : 3 320 2
        Time : 1 144 0
        Loading costs : 536.35
        Unloading costs: 527.77
        Dist. costs : 36.66 61.55 29.46
        Time costs : 86.63 101.27 0.00
        Transfer costs : 0.00 2515.59 2506.56
        Other costs : 0.00 0.00 0.00
        Total cost : 6401.85
Chain type : 131
        Vehicle type(s): 4 1 4
        Vehicle count : 3.000000 0.065573 3.000000
        Nodes : 1171 21799 21804 1271
        Dist. : 2 958 1
        Time : 0 192 0
        Loading costs : 527.77
        Unloading costs: 527.77
        Dist. costs : 29.46 1976.91 14.73
        Time costs : 0.00 7061.33 0.00
        Transfer costs : 0.00 2122.81 2122.81
        Other costs : 0.00 0.00 0.00
        Total cost : 14383.60
Chain type : 141
```

```
        Vehicle type(s): 4 4 4
        Vehicle count : 3.000000 3.000000 3.000000
        Nodes : 1171 21852 21868 1271
        Dist. : 77 657 2
        Time : 11 399 0
        Loading costs : 527.77
        Unloading costs: 527.77
        Dist. costs : 1134.21 21681.00 29.46
        Time costs : 1338.05 48478.50 0.00
        Transfer costs : 0.00 0.00 0.00
        Other costs : 0.00 2475.31 0.00
        Total cost : 76192.07
Chain type : 151
        Vehicle type(s): 6 2 6
        Vehicle count : 2.000000 0.420129 2.000000
        Nodes : 1171 20960 20001 1271
        Dist. : 17 2096 17
        Time : 3 28 3
        Loading costs : 536.35
        Unloading costs: 536.35
        Dist. costs : 207.74 57238.37 207.74
        Time costs : 259.88 89892.81 259.88
        Transfer costs : 0.00 22799.26 22799.26
        Other costs : 0.00 0.00 20.00
        Total cost : 194757.64
Chain type : 1231
        Vehicle type(s): 6 20 3 4
        Vehicle count : 2.000000 0.001844 0.065573 3.000000
        Nodes : 1171 21854 21868 21804 1271
        Dist. : 3 320 1 1
        Time : 1 144 0 0
        Loading costs : 536.35
        Unloading costs: 527.77
        Dist. costs : 36.66 61.55 3.43 14.73
        Time costs : 86.63 101.27 0.00 0.00
        Transfer costs : 0.00 2515.59 3475.87 2081.73
        Other costs : 0.00 0.00 0.00 0.00
        Total cost : 9441.58
Chain type : 1321
        Vehicle type(s): 4 1 20 4
```

```
     Vehicle count : 3.000000 0.065573 0.001844 3.000000
     Nodes : 1171 21799 21845 21868 1271
     Dist. : 2 229 521 2
     Time : 0 46 223 0
     Loading costs : 527.77
     Unloading costs: 527.77
     Dist. costs : 29.46 472.56 100.22 29.46
     Time costs : 0.00 1691.78 156.83 0.00
     Transfer costs : 0.00 2122.81 3538.18 2506.56
     Other costs : 0.00 0.00 0.00 0.00
     Total cost : 11703.40
```

Norway case 4 (first f2f relation):

```
Orig : 301
Dest : 1171
Commodity : 15
Frequency : 8
Order cost : 500.00
Holding cost : 992.00
Shipment Size : 7.67
Chain type : 1
     Vehicle type(s): 4
     Vehicle count : 1.000000
     Nodes : 301 1171
     Dist. : 549
     Time : 79
     Loading costs : 89.68
     Unloading costs: 0.00
     Dist. costs : 2695.59
     Time costs : 3203.21
     Transfer costs : 0.00
     Other costs : 0.00
     Total cost : 5988.48
Chain type : 11
     Cost : N.A.
Chain type : 111
     Vehicle type(s): 6 6 6
     Vehicle count : 1.000000 0.202939 1.000000
     Nodes : 301 306 1172 1171
```

```
      Dist. : 7 555 3
      Time : 1 80 1
      Loading costs : 91.13
      Unloading costs: 91.13
      Dist. costs : 42.77 688.18 18.33
      Time costs : 43.31 703.19 43.31
      Transfer costs : 0.00 140.38 140.38
      Other costs : 0.00 0.00 0.00
      Total cost : 2002.12
Chain type : 121
      Vehicle type(s): 4 21 4
      Vehicle count : 1.000000 0.000178 1.000000
      Nodes : 301 21825 21854 1171
      Dist. : 2 584 3
      Time : 0 261 1
      Loading costs : 89.68
      Unloading costs: 89.68
      Dist. costs : 9.82 12.87 14.73
      Time costs : 0.00 27.31 40.55
      Transfer costs : 0.00 436.79 436.79
      Other costs : 0.00 0.00 0.00
      Total cost : 1158.21
Chain type : 131
      Cost : N.A.
Chain type : 141
      Vehicle type(s): 4 4 4
      Vehicle count : 1.000000 1.000000 1.000000
      Nodes : 301 10383 21833 1171
      Dist. : 114 65 424
      Time : 25 29 59
      Loading costs : 89.68
      Unloading costs: 89.68
      Dist. costs : 559.74 715.00 2081.84
      Time costs : 1013.67 1174.50 2392.27
      Transfer costs : 0.00 0.00 0.00
      Other costs : 0.00 148.78 30.00
      Total cost : 8295.16
Chain type : 151
      Vehicle type(s): 4 2 4
      Vehicle count : 1.000000 0.071386 1.000000
```

Nodes : 301 20219 20960 1171

Dist. : 48 1905 17

Time : 6 25 3

Loading costs : 89.68

Unloading costs: 89.68

Dist. costs : 235.68 8839.31 83.47

Time costs : 243.28 13637.49 121.64

Transfer costs : 0.00 3866.23 3866.23

Other costs : 0.00 0.00 0.00

Total cost : 31072.69

Chain type : 1231

Cost : N.A.

Chain type : 1321

Cost : N.A.

Norway case 5:

Orig : 50

Dest : 301

Commodity : 15

Frequency : 177

Order cost : 500.00

Holding cost : 992.00

Shipment Size : 177.34

Chain type : 1

Vehicle type(s): 6

Vehicle count : 5.000000

Nodes : 50 301

Dist. : 532

Time : 83

Loading costs : 2106.85

Unloading costs: 0.00

Dist. costs : 16252.60

Time costs : 17974.90

Transfer costs : 0.00

Other costs : 120.00

Total cost : 36454.35

Chain type : 11

Cost : N.A.

Chain type : 111

```
        Vehicle type(s): 6 6 6
        Vehicle count : 5.000000 4.691657 5.000000
        Nodes : 50 402 306 301
        Dist. : 456 93 7
        Time : 71 13 1
        Loading costs : 2106.85
        Unloading costs: 2106.85
        Dist. costs : 13930.80 2665.94 213.85
        Time costs : 15376.11 2641.73 216.57
        Transfer costs : 0.00 3245.41 3245.41
        Other costs : 0.00 112.60 0.00
        Total cost : 45862.12
Chain type : 121
        Vehicle type(s): 6 21 4
        Vehicle count : 5.000000 0.004105 12.000000
        Nodes : 50 14065 21825 301
        Dist. : 11 1440 2
        Time : 1 610 0
        Loading costs : 2106.85
        Unloading costs: 2073.16
        Dist. costs : 336.05 733.50 117.84
        Time costs : 216.57 1475.79 0.00
        Transfer costs : 0.00 10131.70 10098.00
        Other costs : 0.00 0.00 0.00
        Total cost : 27289.46
Chain type : 131
        Cost : N.A.
Chain type : 141
        Vehicle type(s): 6 6 6
        Vehicle count : 5.000000 5.000000 5.000000
        Nodes : 50 10383 21833 301
        Dist. : 542 65 129
        Time : 72 29 18
        Loading costs : 2106.85
        Unloading costs: 2106.85
        Dist. costs : 16558.10 162.50 3940.95
        Time costs : 15592.68 10424.05 3898.17
        Transfer costs : 0.00 0.00 0.00
        Other costs : 0.00 65.00 120.00
        Total cost : 54975.16
```

```
Chain type : 151
        Vehicle type(s): 6 2 6
        Vehicle count : 5.000000 1.650332 5.000000
        Nodes : 50 10019 20219 301
        Dist. : 36 762 48
        Time : 5 10 6
        Loading costs : 2106.85
        Unloading costs: 2106.85
        Dist. costs : 1099.80 81740.92 1466.40
        Time costs : 1082.82 126111.74 1299.39
        Transfer costs : 0.00 89559.04 89559.04
        Other costs : 0.00 0.00 120.00
        Total cost : 396252.87
Chain type : 1231
        Cost : N.A.
Chain type : 1321
        Cost : N.A.
```

Norway case 6:

```
Orig : 301
Dest : 5101
Commodity : 17
Frequency : 39
Order cost : 500.00
Holding cost : 718.00
Shipment Size : 52.05
Chain type : 1
        Vehicle type(s): 13
        Vehicle count : 2.000000
        Nodes : 301 5101
        Dist. : 4105
        Time : 563
        Loading costs : 1463.68
        Unloading costs: 0.00
        Dist. costs : 47043.30
        Time costs : 52177.71
        Transfer costs : 0.00
        Other costs : 0.00
        Total cost : 100684.70
```

```
Chain type : 11
        Cost : N.A.
Chain type : 111
        Vehicle type(s): 13 13 13
        Vehicle count : 2.000000 1.807336 2.000000
        Nodes : 301 602 1833 5101
        Dist. : 54 1381 3344
        Time : 8 208 460
        Loading costs : 1463.68
        Unloading costs: 1463.68
        Dist. costs : 618.84 14301.69 38322.24
        Time costs : 741.42 17420.03 42631.88
        Transfer costs : 0.00 2925.28 2925.28
        Other costs : 0.00 86.75 0.00
        Total cost : 122900.78
Chain type : 121
        Cost : N.A.
Chain type : 131
        Cost : N.A.
Chain type : 141
        Vehicle type(s): 13 13 13
        Vehicle count : 2.000000 2.000000 2.000000
        Nodes : 301 21822 40301 5101
        Dist. : 59 241 541
        Time : 9 111 73
        Loading costs : 1463.68
        Unloading costs: 1463.68
        Dist. costs : 676.14 183.16 6199.86
        Time costs : 834.10 15120.42 6765.49
        Transfer costs : 0.00 0.00 0.00
        Other costs : 0.00 26.00 0.00
        Total cost : 32732.54
Chain type : 151
        Cost : N.A.
Chain type : 1231
        Cost : N.A.
Chain type : 1321
        Cost : N.A.
```

Norway case 7:

Orig : 605

Dest : 101

Commodity : 19

Frequency : 4

Shipment Size : 1.00

Chain type : 1

  Vehicle type(s): 1

  Vehicle count : 1.000000

  Nodes : 605 101

  Dist. : 180

  Time : 26

  Loading costs : 283.39

  Unloading costs: 0.00

  Dist. costs : 302.40

  Time costs : 997.52

  Transfer costs : 0.00

  Other costs : 24.00

  Total cost : 1607.31

Chain type : 11

  Cost : N.A.

Chain type : 111

  Vehicle type(s): 4 6 4

  Vehicle count : 1.000000 0.026455 1.000000

  Nodes : 605 301 105 101

  Dist. : 63 90 34

  Time : 10 13 5

  Loading costs : 11.69

  Unloading costs: 11.69

  Dist. costs : 309.33 14.55 166.94

  Time costs : 405.47 14.90 202.73

  Transfer costs : 0.00 24.00 24.00

  Other costs : 24.00 0.00 0.00

  Total cost : 1209.30

Chain type : 121

  Vehicle type(s): 4 20 4

  Vehicle count : 1.000000 0.000041 1.000000

  Nodes : 605 21827 21820 101

  Dist. : 52 130 2

  Time : 8 67 0

```
    Loading costs : 11.69
    Unloading costs: 11.69
    Dist. costs : 255.32 0.55 9.82
    Time costs : 324.38 1.04 0.00
    Transfer costs : 0.00 53.09 53.09
    Other costs : 0.00 0.00 0.00
    Total cost : 720.67
Chain type : 131
    Vehicle type(s): 4 1 4
    Vehicle count : 1.000000 0.001452 1.000000
    Nodes : 605 21779 21820 101
    Dist. : 2 221 2
    Time : 0 44 0
    Loading costs : 11.69
    Unloading costs: 11.69
    Dist. costs : 9.82 10.10 9.82
    Time costs : 0.00 35.84 0.00
    Transfer costs : 0.00 47.02 47.02
    Other costs : 0.00 0.00 0.00
    Total cost : 183.00
Chain type : 141
    Vehicle type(s): 1 1 1
    Vehicle count : 1.000000 1.000000 1.000000
    Nodes : 605 21833 10383 101
    Dist. : 135 65 11
    Time : 19 29 12
    Loading costs : 283.39
    Unloading costs: 283.39
    Dist. costs : 226.80 91.00 18.48
    Time costs : 728.95 1113.60 460.39
    Transfer costs : 0.00 0.00 0.00
    Other costs : 0.00 30.70 0.00
    Total cost : 3236.71
Chain type : 151
    Vehicle type(s): 4 2 1
    Vehicle count : 1.000000 0.009306 1.000000
    Nodes : 605 20219 10019 101
    Dist. : 102 762 585
    Time : 15 10 88
    Loading costs : 11.69
```

```
        Unloading costs: 283.39
        Dist. costs : 500.82 460.92 982.80
        Time costs : 608.20 711.11 3376.21
        Transfer costs : 0.00 504.00 921.00
        Other costs : 0.00 0.00 0.00
        Total cost : 8360.14
Chain type : 1231
        Vehicle type(s): 4 20 3 4
        Vehicle count : 1.000000 0.000041 0.001452 1.000000
        Nodes : 605 21827 21822 21820 101
        Dist. : 52 52 78 2
        Time : 8 28 16 0
        Loading costs : 11.69
        Unloading costs: 11.69
        Dist. costs : 255.32 0.22 5.92 9.82
        Time costs : 324.38 0.44 12.49 0.00
        Transfer costs : 0.00 53.09 74.56 46.11
        Other costs : 0.00 0.00 0.00 0.00
        Total cost : 805.72
Chain type : 1321
        Vehicle type(s): 4 1 20 4
        Vehicle count : 1.000000 0.001452 0.000041 1.000000
        Nodes : 605 21779 21834 21820 101
        Dist. : 2 179 96 2
        Time : 0 36 43 0
        Loading costs : 11.69
        Unloading costs: 11.69
        Dist. costs : 9.82 8.18 0.41 9.82
        Time costs : 0.00 29.33 0.67 0.00
        Transfer costs : 0.00 47.02 75.94 53.09
        Other costs : 0.00 0.00 0.00 0.00
 Total cost : 257.66
```

Norway case 8:

```
Orig : 805
Dest : 104
Commodity : 27
Frequency : 1
Shipment Size : 144.00
```

```
Chain type : 1
        Vehicle type(s): 6
        Vehicle count : 4.000000
        Nodes : 805 104
        Dist. : 226
        Time : 33
        Loading costs : 1710.72
        Unloading costs: 0.00
        Dist. costs : 5523.44
        Time costs : 5717.32
        Transfer costs : 0.00
        Other costs : 192.00
        Total cost : 13143.48
Chain type : 11
        Cost : N.A.
Chain type : 111
        Vehicle type(s): 6 6 6
        Vehicle count : 4.000000 3.809524 4.000000
        Nodes : 805 806 105 104
        Dist. : 23 235 36
        Time : 4 34 5
        Loading costs : 1710.72
        Unloading costs: 1710.72
        Dist. costs : 562.12 5469.90 879.84
        Time costs : 693.01 5610.06 866.26
        Transfer costs : 0.00 2635.20 2635.20
        Other costs : 0.00 182.86 0.00
        Total cost : 22955.89
Chain type : 121
        Vehicle type(s): 12 16 12
        Vehicle count : 4.000000 0.008000 4.000000
        Nodes : 805 21836 21822 104
        Dist. : 2 161 2
        Time : 0 80 1
        Loading costs : 1928.16
        Unloading costs: 1928.16
        Dist. costs : 47.84 91.95 47.84
        Time costs : 0.00 201.99 181.76
        Transfer costs : 0.00 3627.36 3627.36
        Other costs : 0.00 0.00 0.00
```

```
    Total cost : 11682.42
Chain type : 131
    Vehicle type(s): 4 1 4
    Vehicle count : 10.000000 0.209150 10.000000
    Nodes : 805 21836 21747 104
    Dist. : 2 241 2
    Time : 0 48 0
    Loading costs : 1683.36
    Unloading costs: 1683.36
    Dist. costs : 98.20 1586.25 98.20
    Time costs : 0.00 5630.66 0.00
    Transfer costs : 0.00 6770.88 6770.88
    Other costs : 0.00 0.00 0.00
    Total cost : 24321.80
Chain type : 141
    Vehicle type(s): 6 6 6
    Vehicle count : 4.000000 4.000000 4.000000
    Nodes : 805 21833 10383 104
    Dist. : 45 65 59
    Time : 6 29 18
    Loading costs : 1710.72
    Unloading costs: 1710.72
    Dist. costs : 1099.80 7722.00 1441.96
    Time costs : 1039.51 5022.80 3118.54
    Transfer costs : 0.00 0.00 0.00
    Other costs : 120.00 10247.20 0.00
    Total cost : 33233.25
Chain type : 151
    Vehicle type(s): 6 2 6
    Vehicle count : 4.000000 1.340034 4.000000
    Nodes : 805 20219 10019 104
    Dist. : 214 762 632
    Time : 31 10 95
    Loading costs : 1710.72
    Unloading costs: 1710.72
    Dist. costs : 5230.16 66371.86 15446.08
    Time costs : 5370.81 102400.00 16458.94
    Transfer costs : 0.00 72720.00 72720.00
    Other costs : 96.00 0.00 0.00
    Total cost : 360235.29
```

```
Chain type : 1231
      Cost : N.A.
Chain type : 1321
         Cost : N.A.
```

Norway case 9 (first f2f relation):

```
Orig : 1563
Dest : 529
Commodity : 29
Frequency : 4
Shipment Size : 0.20
Chain type : 1
      Vehicle type(s): 1
      Vehicle count : 1.000000
      Nodes : 1563 529
      Dist. : 346
      Time : 49
      Loading costs : 55.93
      Unloading costs: 0.00
      Dist. costs : 581.28
      Time costs : 1879.93
      Transfer costs : 0.00
      Other costs : 0.00
      Total cost : 2517.15
Chain type : 11
      Cost : N.A.
Chain type : 111
      Vehicle type(s): 1 5 1
      Vehicle count : 1.000000 0.005222 1.000000
      Nodes : 1563 1502 412 529
      Dist. : 91 429 51
      Time : 14 61 7
      Loading costs : 55.93
      Unloading costs: 55.93
      Dist. costs : 152.88 13.69 85.68
      Time costs : 537.12 13.16 268.56
      Transfer costs : 0.00 104.22 104.22
      Other costs : 0.00 0.00 0.00
      Total cost : 1391.40
```

```
Chain type : 121
      Vehicle type(s): 4 8 1
      Vehicle count : 1.000000 0.000011 1.000000
      Nodes : 1563 21926 21825 529
      Dist. : 2 1171 114
      Time : 0 511 17
      Loading costs : 2.31
      Unloading costs: 55.93
      Dist. costs : 9.82 0.92 191.52
      Time costs : 0.00 1.77 652.22
      Transfer costs : 0.00 43.40 62.84
      Other costs : 0.00 0.00 0.00
      Total cost : 1020.73
Chain type : 131
      Cost : N.A.
Chain type : 141
      Vehicle type(s): 1 1 1
      Vehicle count : 1.000000 1.000000 1.000000
      Nodes : 1563 10383 21833 529
      Dist. : 578 65 218
      Time : 91 29 31
      Loading costs : 55.93
      Unloading costs: 55.93
      Dist. costs : 971.04 91.00 366.24
      Time costs : 3491.31 1113.60 1189.35
      Transfer costs : 0.00 0.00 0.00
      Other costs : 0.00 16.49 0.00
      Total cost : 7350.90
Chain type : 151
      Vehicle type(s): 1 2 1
      Vehicle count : 1.000000 0.001837 1.000000
      Nodes : 1563 10019 20219 529
      Dist. : 800 762 104
      Time : 120 10 15
      Loading costs : 55.93
      Unloading costs: 55.93
      Dist. costs : 1344.00 90.97 174.72
      Time costs : 4603.92 140.36 575.49
      Transfer costs : 0.00 181.78 181.78
      Other costs : 0.00 0.00 0.00
```

```
          Total cost : 7404.90
Chain type : 1231
          Cost : N.A.
Chain type : 1321
               Cost : N.A.
```

The same comments that were made on the Swedish results are also valid for the Norwegian case outcomes, notably:

- The unloading costs for road transport should be equal to the loading costs;
- Because foreign road terminals are missing, the third and last leg of an international road transport can be longer than the second leg;
- Consolidation at ports, railway stations and road terminals is often too easy, due to the lack of availability constraints.

Some specific findings for Norway are:

- Transport of timber (sawlogs and pulpwood; commodities 16 and 17) can in terms of road transport only use the timber truck vehicle. Transfers from this vehicle to sea transport (121) are not allowed in the model. This should be made possible in the next version. Also, because of a shift in the train availabilities by commodity, train transport is erroneously not available for pulpwood. As a result of all these non-availabilities, sawlogs often go by rail transport (131) and pulpwood by ferry (141);
- The same shift also made rail (131) non-available for commodity 15. This will also be fixed;
- For Norway (unlike Sweden) the program calculates the time-based ferry costs properly (no factor 10 difference).

2.12 The generation of receiving firms

For zones that did not comprise a firm in all of the company classes for which they receive goods, new firms have been generated. This is done is Step 9 of the flowchart in Figure 2. First a comparison is made of which company classes are present in each zone and which should be present in order to receive all types of commodities coming in to that specific zone. Second, from this comparison a matrix is complied presenting the zones in which a specific company class is required and should be generated. As the queries that make up these analyses do not automatically create new tables, these queries are represented by dotted lines.

CHAPTER 3 Reactions and comments to tests

3.1 Tests on model performance and outcome

Within this Phase 2 the clients carried out a set of tests. The reactions and comments by RAND Europe and SITMA on the outcomes of these tests can be found in the following Sections. The tests include:

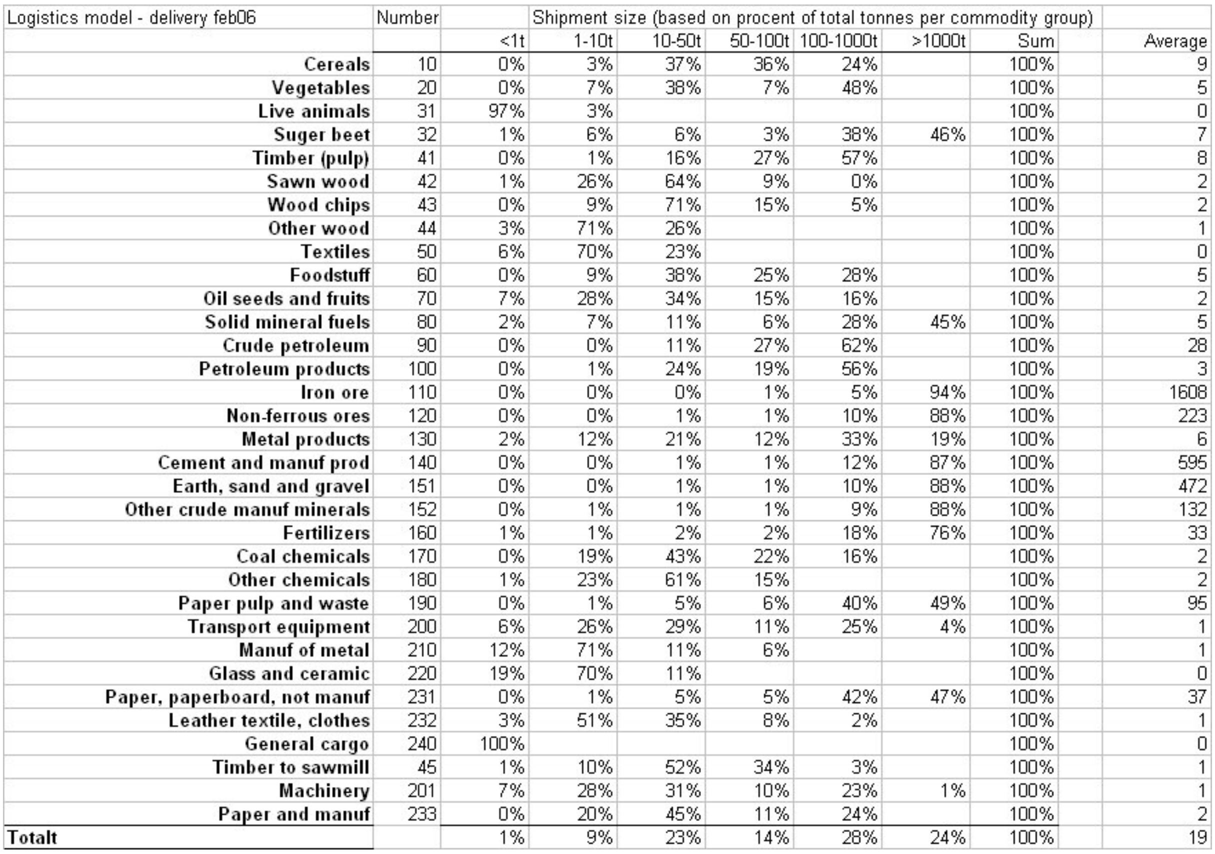
1. One or more sets of descriptive tables giving shipment size variation (in suitable classes) depending on total quantity of the PWC-matrix element, number of firm to firm relations defined for the element and the distance associated with the PWC matrix element relation.
2. Comparison of the shipment sizes generated by the model and the observed shipment sizes of the CFS.
3. Distribution of goods flows between the various types of terminals that are defined for the Norwegian or the Swedish version of the logistics model. Since scale advantages in transport and consolidation are not part of the present logistics model, the routing via terminals are only governed by the structural properties of the available transport chains. We shall provide comments on the models' distribution of goods between terminals as well as on the likely effects of scale advantages in transport and consolidation.
4. The models' distribution of goods flows between different vehicle types will be tabulated with suitable pivot tables. The factors driving the distribution will be discussed and commented.
5. Finally, tests that have already been carried out on the distribution of goods volumes between different transport chains, have shown that the model allocates unexpectedly large flows to direct rail while most other modes are under-predicted. This could be due to characteristics of the cost functions but also to assumptions on accessibility inherent in the transport chain definitions. Comments and observations on this topic and suggestions for the future phases will be given

3.2 Test on shipment size

3.2.1 Sweden

For Sweden, information on shipment size has been extracted from both the logistics model delivered on 16th February 2006 and the CFS 2001 database. This can be found in Table 5 (model) and Table 6 (CFS 2001). In Figure 6 both sources are compared.

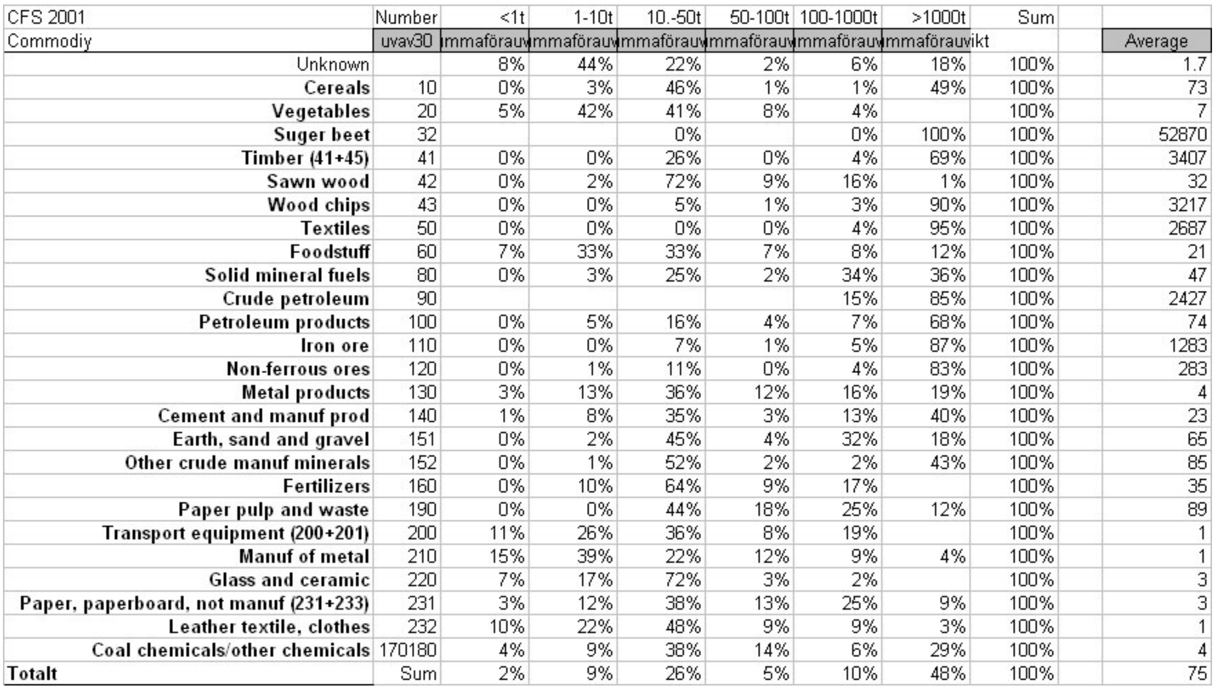
Table 5 – Shipment size distribution from the Logistics model for Sweden



Logistics model - delivery feb06	Number		Shipment size (based on procent of total tonnes per commodity group)							
		<1t	1-10t	10-50t	50-100t	100-1000t	>1000t	Sum		Average
Cereals	10	0%	3%	37%	36%	24%		100%		9
Vegetables	20	0%	7%	38%	7%	48%		100%		5
Live animals	31	97%	3%					100%		0
Suger beet	32	1%	6%	6%	3%	38%	46%	100%		7
Timber (pulp)	41	0%	1%	16%	27%	57%		100%		8
Sawn wood	42	1%	26%	64%	9%	0%		100%		2
Wood chips	43	0%	9%	71%	15%	5%		100%		2
Other wood	44	3%	71%	26%				100%		1
Textiles	50	6%	70%	23%				100%		0
Foodstuff	60	0%	9%	38%	25%	28%		100%		5
Oil seeds and fruits	70	7%	28%	34%	15%	16%		100%		2
Solid mineral fuels	80	2%	7%	11%	6%	28%	45%	100%		5
Crude petroleum	90	0%	0%	11%	27%	62%		100%		28
Petroleum products	100	0%	1%	24%	19%	56%		100%		3
Iron ore	110	0%	0%	0%	1%	5%	94%	100%		1608
Non-ferrous ores	120	0%	0%	1%	1%	10%	88%	100%		223
Metal products	130	2%	12%	21%	12%	33%	19%	100%		6
Cement and manuf prod	140	0%	0%	1%	1%	12%	87%	100%		595
Earth, sand and gravel	151	0%	0%	1%	1%	10%	88%	100%		472
Other crude manuf minerals	152	0%	1%	1%	1%	9%	88%	100%		132
Fertilizers	160	1%	1%	2%	2%	18%	76%	100%		33
Coal chemicals	170	0%	19%	43%	22%	16%		100%		2
Other chemicals	180	1%	23%	61%	15%			100%		2
Paper pulp and waste	190	0%	1%	5%	6%	40%	49%	100%		95
Transport equipment	200	6%	26%	29%	11%	25%	4%	100%		1
Manuf of metal	210	12%	71%	11%	6%			100%		1
Glass and ceramic	220	19%	70%	11%				100%		0
Paper, paperboard, not manuf	231	0%	1%	5%	5%	42%	47%	100%		37
Leather textile, clothes	232	3%	51%	35%	8%	2%		100%		1
General cargo	240	100%						100%		0
Timber to sawmill	45	1%	10%	52%	34%	3%		100%		1
Machinery	201	7%	28%	31%	10%	23%	1%	100%		1
Paper and manuf	233	0%	20%	45%	11%	24%		100%		2
Totalt		1%	9%	23%	14%	28%	24%	100%		19

Table 5 shows the distribution of tonnes in the logistics model by commodity group and shipment size class. In order to be able to judge this data similar tables have been extracted from the CFS2001 database. Not all commodity groups are defined specifically in the CFS2001. There can be some difference in definition of shipment size between these sources. Table 6 shows the CFS2001 result.

Table 6 - Shipment size distribution from the CFS2001 for Sweden CFS2001



CFS 2001	Number	<1t	1-10t	10.-50t	50-100t	100-1000t	>1000t	Sum		
Commodiy	uvav30	mmaförauv	mmaförauv	mmaförauv	mmaförauv	mmaförauv	mmaförauvikt			Average
Unknown		8%	44%	22%	2%	6%	18%	100%		1.7
Cereals	10	0%	3%	46%	1%	1%	49%	100%		73
Vegetables	20	5%	42%	41%	8%	4%		100%		7
Suger beet	32			0%		0%	100%	100%		52870
Timber (41+45)	41	0%	0%	26%	0%	4%	69%	100%		3407
Sawn wood	42	0%	2%	72%	9%	16%	1%	100%		32
Wood chips	43	0%	0%	5%	1%	3%	90%	100%		3217
Textiles	50	0%	0%	0%	0%	4%	95%	100%		2687
Foodstuff	60	7%	33%	33%	7%	8%	12%	100%		21
Solid mineral fuels	80	0%	3%	25%	2%	34%	36%	100%		47
Crude petroleum	90					15%	85%	100%		2427
Petroleum products	100	0%	5%	16%	4%	7%	68%	100%		74
Iron ore	110	0%	0%	7%	1%	5%	87%	100%		1283
Non-ferrous ores	120	0%	1%	11%	0%	4%	83%	100%		283
Metal products	130	3%	13%	36%	12%	16%	19%	100%		4
Cement and manuf prod	140	1%	8%	35%	3%	13%	40%	100%		23
Earth, sand and gravel	151	0%	2%	45%	4%	32%	18%	100%		65
Other crude manuf minerals	152	0%	1%	52%	2%	2%	43%	100%		85
Fertilizers	160	0%	10%	64%	9%	17%		100%		35
Paper pulp and waste	190	0%	0%	44%	18%	25%	12%	100%		89
Transport equipment (200+201)	200	11%	26%	36%	8%	19%		100%		1
Manuf of metal	210	15%	39%	22%	12%	9%	4%	100%		1
Glass and ceramic	220	7%	17%	72%	3%	2%		100%		3
Paper, paperboard, not manuf (231+233)	231	3%	12%	38%	13%	25%	9%	100%		3
Leather textile, clothes	232	10%	22%	48%	9%	9%	3%	100%		1
Coal chemicals/other chemicals	170180	4%	9%	38%	14%	6%	29%	100%		4
Totalt	Sum	2%	9%	26%	5%	10%	48%	100%		75

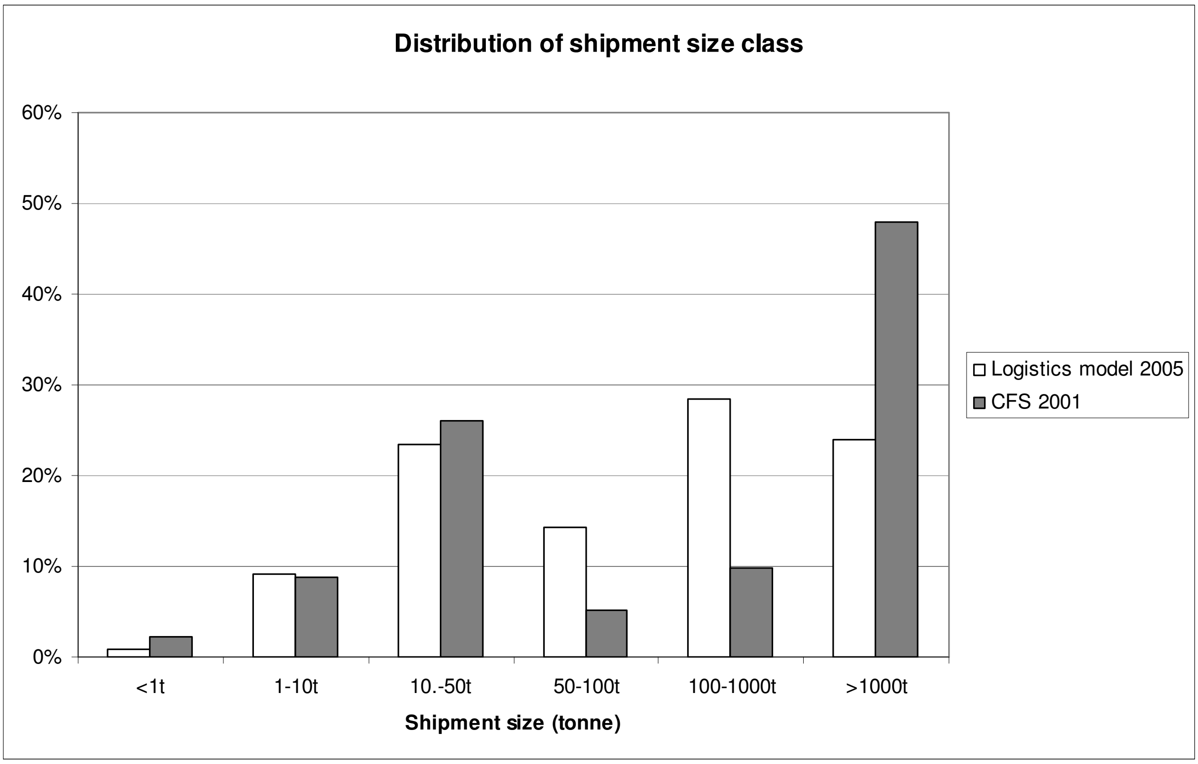
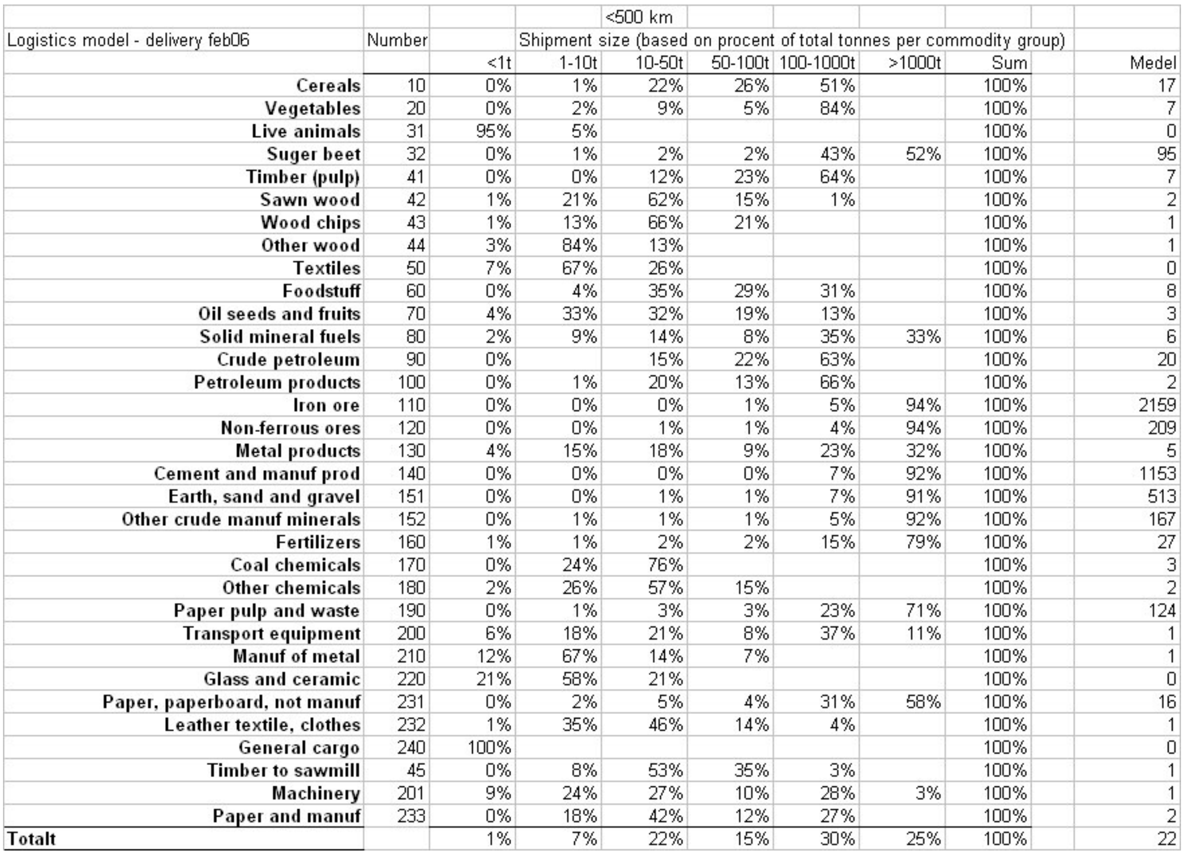


Figure 6 - Shipment size class comparison between logistics model and CFS2001

As can be seen in Figure 6, the CFS has more large shipments (over 1000 tonnes) and less in the size 50 to 1000 tonnes. The sources match well on total amount of shipments under 50 tonnes. When looking at the results of the logistics model in terms of shipment size by distance the following tables were produced.

Table 7 and Table 8 give the shipments by size, according to the logistics model, with a distinction between under and over 500km (based on PC distance).

Table 7 - Shipment size distribution from the logistics model for Sweden, distances under 500 km



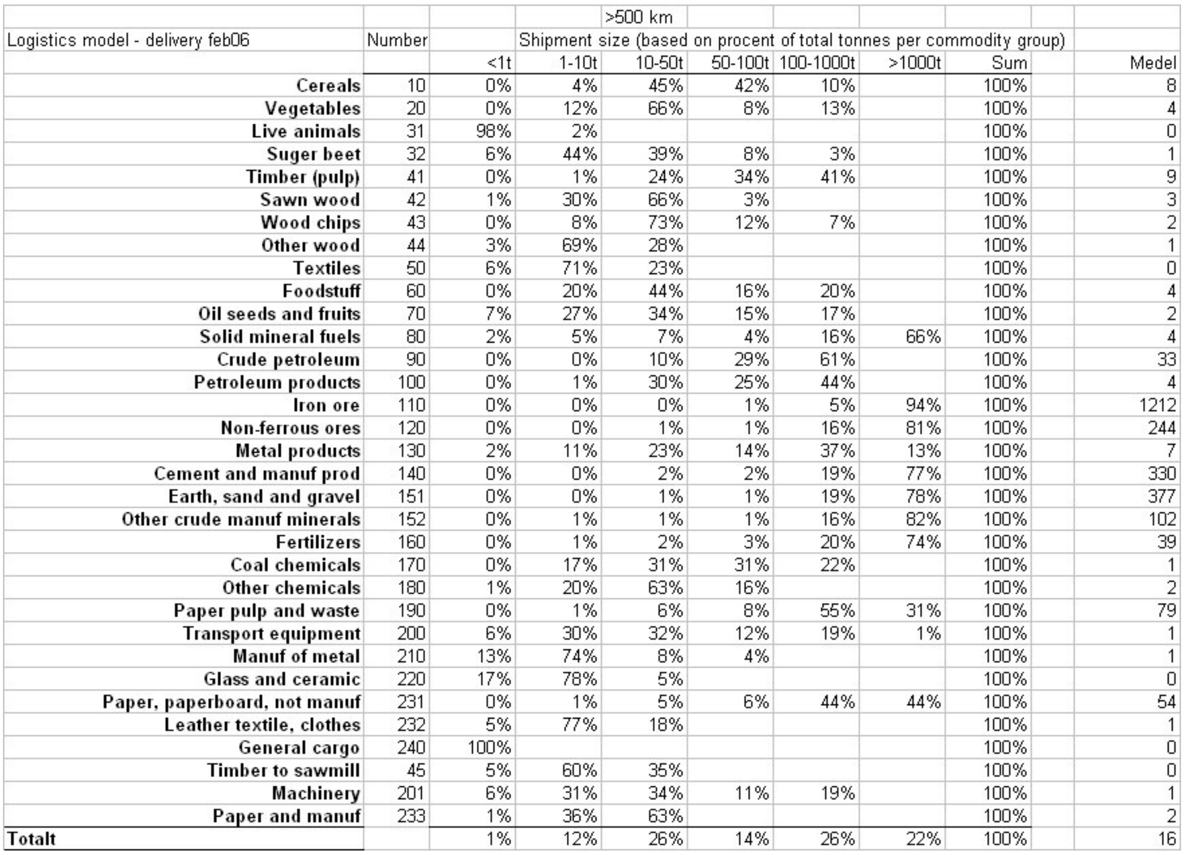
				<500 km						
Logistics model - delivery feb06	Number		Shipment size (based on procent of total tonnes per commodity group)							
		<1t	1-10t	10-50t	50-100t	100-1000t	>1000t	Sum		Medel
Cereals	10	0%	1%	22%	26%	51%		100%		17
Vegetables	20	0%	2%	9%	5%	84%		100%		7
Live animals	31	95%	5%					100%		0
Suger beet	32	0%	1%	2%	2%	43%	52%	100%		95
Timber (pulp)	41	0%	0%	12%	23%	64%		100%		7
Sawn wood	42	1%	21%	62%	15%	1%		100%		2
Wood chips	43	1%	13%	66%	21%			100%		1
Other wood	44	3%	84%	13%				100%		1
Textiles	50	7%	67%	26%				100%		0
Foodstuff	60	0%	4%	35%	29%	31%		100%		8
Oil seeds and fruits	70	4%	33%	32%	19%	13%		100%		3
Solid mineral fuels	80	2%	9%	14%	8%	35%	33%	100%		6
Crude petroleum	90	0%		15%	22%	63%		100%		20
Petroleum products	100	0%	1%	20%	13%	66%		100%		2
Iron ore	110	0%	0%	0%	1%	5%	94%	100%		2159
Non-ferrous ores	120	0%	0%	1%	1%	4%	94%	100%		209
Metal products	130	4%	15%	18%	9%	23%	32%	100%		5
Cement and manuf prod	140	0%	0%	0%	0%	7%	92%	100%		1153
Earth, sand and gravel	151	0%	0%	1%	1%	7%	91%	100%		513
Other crude manuf minerals	152	0%	1%	1%	1%	5%	92%	100%		167
Fertilizers	160	1%	1%	2%	2%	15%	79%	100%		27
Coal chemicals	170	0%	24%	76%				100%		3
Other chemicals	180	2%	26%	57%	15%			100%		2
Paper pulp and waste	190	0%	1%	3%	3%	23%	71%	100%		124
Transport equipment	200	6%	18%	21%	8%	37%	11%	100%		1
Manuf of metal	210	12%	67%	14%	7%			100%		1
Glass and ceramic	220	21%	58%	21%				100%		0
Paper, paperboard, not manuf	231	0%	2%	5%	4%	31%	58%	100%		16
Leather textile, clothes	232	1%	35%	46%	14%	4%		100%		1
General cargo	240	100%						100%		0
Timber to sawmill	45	0%	8%	53%	35%	3%		100%		1
Machinery	201	9%	24%	27%	10%	28%	3%	100%		1
Paper and manuf	233	0%	18%	42%	12%	27%		100%		2
Totalt		1%	7%	22%	15%	30%	25%	100%		22

Taking into account the lack of constraints in the prototype, the structure of the shipments sizes in the prototype and in the CFS are not that far apart. There are some strange results for some categories where CFS actually had much larger proportions of shipments above 1000 tons than we had in the prototype. These are mainly the following:

- Wood chips (90 % in CFS);
- Textiles (95 %);
- Foodstuff (12 %);
- Crude Petroleum (85 %);
- Petroleum products (68 %).

Also, the shipments sizes seems to be larger on longer distances and smaller on shorter – however this is not consistent across cargo categories, perhaps due to market conditions. A more consistent picture should be expected with upgraded cost models in the next version.

Table 8 - Shipment size distribution from the logistics model for Sweden, distances over 500 km



				>500 km						
Logistics model - delivery feb06	Number		Shipment size (based on procent of total tonnes per commodity group)							
		<1t	1-10t	10-50t	50-100t	100-1000t	>1000t	Sum		Medel
Cereals	10	0%	4%	45%	42%	10%		100%		8
Vegetables	20	0%	12%	66%	8%	13%		100%		4
Live animals	31	98%	2%					100%		0
Suger beet	32	6%	44%	39%	8%	3%		100%		1
Timber (pulp)	41	0%	1%	24%	34%	41%		100%		9
Sawn wood	42	1%	30%	66%	3%			100%		3
Wood chips	43	0%	8%	73%	12%	7%		100%		2
Other wood	44	3%	69%	28%				100%		1
Textiles	50	6%	71%	23%				100%		0
Foodstuff	60	0%	20%	44%	16%	20%		100%		4
Oil seeds and fruits	70	7%	27%	34%	15%	17%		100%		2
Solid mineral fuels	80	2%	5%	7%	4%	16%	66%	100%		4
Crude petroleum	90	0%	0%	10%	29%	61%		100%		33
Petroleum products	100	0%	1%	30%	25%	44%		100%		4
Iron ore	110	0%	0%	0%	1%	5%	94%	100%		1212
Non-ferrous ores	120	0%	0%	1%	1%	16%	81%	100%		244
Metal products	130	2%	11%	23%	14%	37%	13%	100%		7
Cement and manuf prod	140	0%	0%	2%	2%	19%	77%	100%		330
Earth, sand and gravel	151	0%	0%	1%	1%	19%	78%	100%		377
Other crude manuf minerals	152	0%	1%	1%	1%	16%	82%	100%		102
Fertilizers	160	0%	1%	2%	3%	20%	74%	100%		39
Coal chemicals	170	0%	17%	31%	31%	22%		100%		1
Other chemicals	180	1%	20%	63%	16%			100%		2
Paper pulp and waste	190	0%	1%	6%	8%	55%	31%	100%		79
Transport equipment	200	6%	30%	32%	12%	19%	1%	100%		1
Manuf of metal	210	13%	74%	8%	4%			100%		1
Glass and ceramic	220	17%	78%	5%				100%		0
Paper, paperboard, not manuf	231	0%	1%	5%	6%	44%	44%	100%		54
Leather textile, clothes	232	5%	77%	18%				100%		1
General cargo	240	100%						100%		0
Timber to sawmill	45	5%	60%	35%				100%		0
Machinery	201	6%	31%	34%	11%	19%		100%		1
Paper and manuf	233	1%	36%	63%				100%		2
Totalt		1%	12%	26%	14%	26%	22%	100%		16

The tests of shipment size against the CFS data are based on model version 0.2. Versions 0.1 and 0.3 have much more f2f relations and will therefore have much more small shipments. So the match with the observations on shipment size will be best for version 0.2, a version that does not use the numbers of receivers per sender from Annex 2 of D4. Should we use the CFS numbers of receivers per sender (see Section 2.10) in combination with version 0.3 of the model, we would obtain a number of relations that comes considerably closer to that in version 0.2. This combination therefore has the advantages of a relatively good match with shipment size data, consistency with observed data on the number of receivers per sender and an acceptable runtime (see Section 2.5).

3.2.2 **Norway**

The outcomes on shipments size from the logistics model for Norway are in Table 9 and Table 10.

Table 9 - Shipment sizes from the logistics model for Norway

No	Commodity	Shipment size, percentage of total tonnes (except overseas because of missing transport chain)							
		<1t	1-10t	10-50t	50-100t	100-1000t	>1000t	SUM	Average (ton)
1	Bulk food	1%	9%	38%	27%	25%	0%	100%	20.57
2	Consumption food	6%	53%	36%	5%	0%	0%	100%	2.82
3	Beverages	14%	63%	23%	0%	0%	0%	100%	1.49
4	Fresh fish	4%	15%	27%	16%	36%	2%	100%	4.39
5	Frozen fish	1%	17%	51%	24%	6%	0%	100%	11.84
6	Other fish (conserved)	1%	17%	51%	24%	6%	0%	100%	11.84
7	Thermo input	5%	61%	34%	0%	0%	0%	100%	3.52
8	Thermo consumption	2%	8%	15%	12%	50%	14%	100%	9.30
9	Machinery and equipments	4%	14%	21%	13%	41%	7%	100%	3.43
10	Vehicles	17%	38%	33%	11%	1%	0%	100%	0.43
11	Gen cargo, high value	84%	16%	1%	0%	0%	0%	100%	0.03
12	Gen cargo, living animals	63%	32%	6%	0%	0%	0%	100%	0.08
13	Gen cargo, building materials	0%	9%	37%	26%	28%	0%	100%	22.65
14	Gen cargo, inputs	1%	17%	50%	21%	10%	0%	100%	12.15
15	Gen cargo, consumption	1%	11%	38%	22%	28%	0%	100%	14.34
16	Sawlogs	0%	8%	47%	29%	16%	0%	100%	23.08
17	Pulpwood	0%	7%	47%	29%	16%	0%	100%	23.23
18	Pulp and chips	2%	11%	23%	16%	45%	2%	100%	10.45
19	Paper intermediates	1%	5%	13%	11%	50%	20%	100%	22.64
20	Wood products	0%	3%	24%	30%	43%	0%	100%	43.77
21	Paper products and printed matters	2%	38%	60%	0%	0%	0%	100%	6.80
22	Mass commodity	0%	0%	0%	0%	3%	96%	100%	2298.54
23	Coal, ore and scrap	0%	0%	1%	1%	7%	91%	100%	919.35
24	Cement, plaster and cretaceous	0%	2%	5%	5%	33%	55%	100%	98.81
26	Chemical products	0%	2%	11%	12%	70%	5%	100%	81.11
27	Fertilizers	0%	1%	3%	3%	18%	75%	100%	137.35
28	Metals and metal products	0%	1%	7%	7%	27%	57%	100%	121.84
29	Aluminium	1%	3%	5%	3%	16%	73%	100%	24.20
32	Refined products	0%	0%	4%	7%	53%	37%	100%	201.43

Table 10 - Average shipment size for each size group from the logistics model for Norway

No	Commodity	Shipment size, percentage of total tonnes (except overseas because of missing transport chain)						
		<1t	1-10t	10-50t	50-100t	100-1000t	>1000t	Average (tonne)
1	Bulk food	1.00	4.70	23.29	68.78	161.13		20.57
2	Consumption food	0.36	3.43	17.70	60.86			2.82
3	Beverages	0.31	2.88	17.22				1.49
4	Fresh fish	0.22	3.32	21.20	70.13	224.19	1257.31	4.39
5	Frozen fish	0.67	4.29	22.07	67.22	126.71		11.84
6	Other fish (conserved)	0.67	4.29	22.07	67.22	126.71		11.84
7	Thermo input	0.51	3.76	14.37				3.52
8	Thermo consumption	0.23	3.40	22.17	70.54	263.93	1540.62	9.30
9	Machinery and equipments	0.18	3.18	21.35	69.57	242.88	1230.27	3.43
10	Vehicles	0.08	3.02	20.35	65.99	105.21		0.43
11	Gen cargo, high value	0.03	2.15	16.52				0.03
12	Gen cargo, living animals	0.05	2.26	16.53				0.08
13	Gen cargo, building materials	1.00	4.66	23.49	70.08	158.56		22.65
14	Gen cargo, inputs	0.71	4.41	21.99	67.47	139.83		12.15
15	Gen cargo, consumption	0.34	4.21	22.73	69.27	165.70		14.34
16	Sawlogs	1.00	4.95	24.73	69.38	125.36		23.08
17	Pulpwood	1.00	4.93	24.73	69.29	125.56		23.23
18	Pulp and chips	0.45	3.62	22.64	69.75	238.64	1185.00	10.45
19	Paper intermediates	0.45	3.65	22.82	70.87	259.05	1652.78	22.64
20	Wood products	1.00	5.23	26.05	70.56	160.75		43.77
21	Paper products and printed matters	0.70	4.42	18.50				6.80
22	Mass commodity	1.00	4.93	25.87	72.42	368.42	15183.07	2298.54
23	Coal, ore and scrap	1.00	4.65	24.60	71.17	351.51	8231.75	919.35
24	Cement, plaster and cretaceous	1.00	4.40	23.96	71.61	313.25	2706.88	98.81
26	Chemical products	1.00	5.08	25.73	71.10	283.86	1092.04	81.11
27	Fertilizers	1.00	4.30	23.59	71.15	297.45	5771.00	137.35
28	Metals and metal products	1.00	4.81	25.74	71.42	206.83	2669.89	121.84
29	Aluminium	0.22	3.36	22.19	70.22	274.14	11907.44	24.20
32	Refined products	0.57	5.21	27.85	73.45	299.76	1674.79	201.43

In Table 11 the average shipments sizes by commodity group from the model are compared to information on observed shipment size for Norwegian export and import.

Table 11 - Average shipment size in Norwegian export and import data and in the model output

Nemo32	Commodity Name	Average weight per shipment (tonnes)		
		EXPORT	IMPORT	Model
11	Bulk food	66	21	20.57
12	Consumption food	2.7	2.1	2.82
13	Beverages	8.8	4.0	1.49
21	Fresh fish	3.8	21	4.39
22	Frozen fish	51	23	11.84
23	Other fish (conserved)	10	3.7	11.84
31	Thermo input			3.52
32	Thermo consumption	4.3	3.1	9.3
41	Machinery and equipments	1.1	0.4	3.43
42	Vehicles	3.7	1.3	0.43
51	Gen cargo, high value	1.5	0.2	0.03
52	Gen cargo, living animals	0.4	0.3	0.08
53	Gen cargo, building materials	12	7.2	22.65
54	Gen cargo, inputs	4.0	1.4	12.15
55	Gen cargo, consumption	0.9	0.3	14.34
61	Sawlogs			23.08
62	Pulpwood	472	1156	23.23
63	Pulp and chips	76	39	10.45
64	Paper intermediates	31	10	22.64
65	Wood products	18	13	43.77
66	Paper products and printed matters	3.4	1.4	6.8
71	Mass commodity	2788	99	2298.54
72	Coal, ore and scrap	739	566	919.35
73	Cement, plaster and cretaceous	296	56	98.81
74	Non-traded goods			
81	Chemical products	81	10	81.11
82	Fertilizers	1382	400	137.35
91	Metals and metal products	29	5.1	121.84
92	Aluminium	38	20	24.2
101	Raw oil	64559	39011	
102	Petroleum gas	6184	161	
103	Refined products	1436	80	201.43
Average		*144*	*4.4*	

The match is rather good, given that the model includes domestic as well as international transport and the observed data only export and import (which probably have larger average shipment sizes). Commodities with large observed shipments sizes also get large modelled shipment sizes and vice versa. The most salient deviations are for general cargo (high value), general cargo (living animals), general cargo (consumption) and pulpwood. Except for the third category, the model under-predicts shipment size. For commodity 51 (general cargo, high value) the assumption on the number of receivers per sender (1,000) might be too high. For the other groups mentioned, the number of receivers per sender used in the program is not extremely high.

3.3 Test on use of terminals

No test results received on this.

3.4 Test on use of vehicle/vessel types

3.4.1 Sweden

Here is a quick review of the situation related to choice of vehicle per commodity group and transport chain from the logistics model delivered on 16th February 2006. Pivot tables were used to produce the aggregations. We first repeat the commodity and vehicle vessel codes used in the logistics model for Sweden.

Table 12 - Commodity Codes used for Sweden

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

Table 13 - Lorry Codes used for Sweden

Code	Label	Code	Label
1	LGV	11	Tank truck with hanger (chemicals)
2	Light distribution	12	Semitrailer, tanker liquid bulk
3	Heavy distribution closed unit	13	Tank dry bulk truck with hanger
4	Heavy distribution for containers, spec. Cont	14	Semitrailer, dry bulk products
5	Articulated semi - total - closed	15	Timber truck with hanger (4 axles)
6	Articulated semi - with container	16	"Flis" truck with hanger (4 axles)
7	Heavy combination	17	Semitrailer, "Flis"
8	Heavy combination with container	18	Thermo Truck with hanger
9	Tank truck with hanger	19	Semi, thermo
10	Semitrailer, tanker oil products		

Table 14 - Train Codes used for Sweden

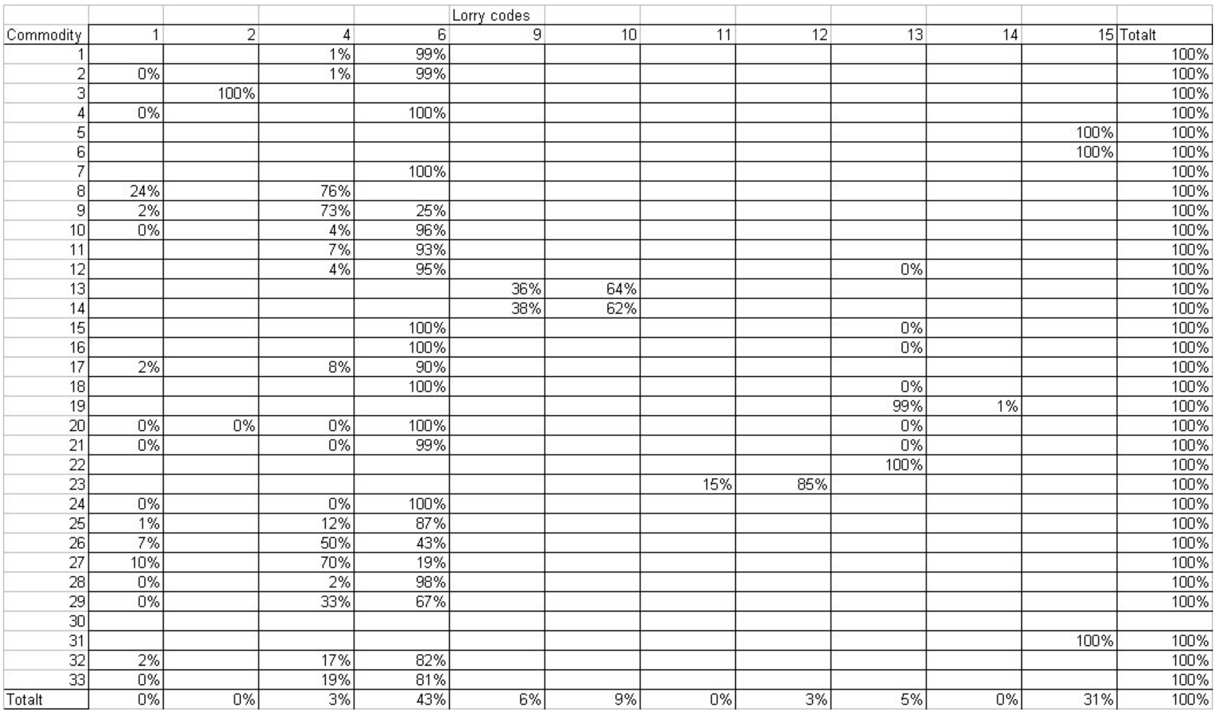
Code	Label	Code	Label	Code	Label
1	Diesel, wagon load	3	Diesel, system	5	Electrical, combi
2	Diesel, combi	4	Electrical, wagon load	6	Electrical, system

Table 15 - Vessel Codes used for Sweden

Code	Label	Code	Label
1	Lo/lo, general cargo 500 Tonne	20	Container vessel lo/lo 27200 Tonne
2	Lo/lo, general cargo 1250 Tonne	21	Container vessel lo/lo 48000 Tonne
3	Lo/lo, general cargo 2000 Tonne	22	Container vessel lo/lo 64000 Tonne
4	Lo/lo, general cargo 3600 Tonne	23	Ro/ro (cargo) 3648 Tonne
5	Lo/lo, general cargo 6350 Tonne	24	Ro/ro (cargo) 5000 Tonne
6	Lo/lo, general cargo 10000 Tonne	25	Ro/ro (cargo) 6336 Tonne
7	Lo/lo, general cargo 14500 Tonne	26	Reefer 2500 Tonne
8	Lo/lo, general cargo20000 Tonne	27	Reefer 5000 Tonne
9	Dry bulk 500 Tonne	28	Reefer 10000 Tonne
10	Dry bulk 1250 Tonne	29	Product tanker 6416 Tonne
11	Dry bulk 2000 Tonne	30	Product tanker 40000 Tonne
12	Dry bulk 3600 Tonne	31	Crude oil tanker 100000 Tonne
13	Dry bulk 6350 Tonne	32	Crude oil tanker 150000 Tonne
14	Dry bulk 10000 Tonne	33	Crude oil tanker 300000 Tonne
15	Dry bulk 14500 Tonne	34	Liquid bulk - Chemicals 9500 Tonne
16	Dry bulk 20000 Tonne	35	Liquid bulk - Chemicals 17000 Tonne
17	Sideport vessel 5000 Tonne	36	LNG 28870 Tonne
18	Container vessel lo/lo 5300 Tonne	37	LNG 48817 Tonne
19	Container vessel lo/lo 16000 Tonne		

Road only transport chains

Table 16 – Distribution over lorry types for road chains for Sweden from logistics model



	Lorry codes											
Commodity	1	2	4	6	9	10	11	12	13	14	15	Totalt
1			1%	99%								100%
2	0%		1%	99%								100%
3		100%										100%
4	0%			100%								100%
5											100%	100%
6											100%	100%
7				100%								100%
8	24%		76%									100%
9	2%		73%	25%								100%
10	0%		4%	96%								100%
11			7%	93%								100%
12			4%	95%					0%			100%
13					36%	64%						100%
14					38%	62%						100%
15				100%					0%			100%
16				100%					0%			100%
17	2%		8%	90%								100%
18				100%					0%			100%
19									99%	1%		100%
20	0%	0%	0%	100%					0%			100%
21	0%		0%	99%					0%			100%
22									100%			100%
23							15%	85%				100%
24	0%		0%	100%								100%
25	1%		12%	87%								100%
26	7%		50%	43%								100%
27	10%		70%	19%								100%
28	0%		2%	98%								100%
29	0%		33%	67%								100%
30												
31											100%	100%
32	2%		17%	82%								100%
33	0%		19%	81%								100%
Totalt	0%	0%	3%	43%	6%	9%	0%	3%	5%	0%	31%	100%

1. Only 11 of 19 road vehicles are used in the model;
2. Vehicle number 6 (Articulated semi – with container) is dominant with 43% of all direct road tonnes;
3. Vehicle type 15 (Timber truck with hanger (4 axles)) has the second highest amount with 31%.

Comments on the findings for road only supply chains:

Ad 1. Only 11 of road vehicles are used.

There are probably several reasons for this:

- 18 and 19 are thermo trucks. They will cost-wise be dominated by other alternatives. In Sweden, there is no category only limited to thermo (like frozen fish in Norway). In the revised model, we should for the Swedish foodstuff categories distinguish what portion of the flows would need refrigerated trucks, and what portion can go on general trucks. Otherwise, the general truck will always dominate the refrigerated truck in a cost minimisation.
- Why container trucks always seem to beat non-container (leading to the elimination of truck types 3 and 5) must be a cost issue, together with the fact that we have so far in the model not put in any restrictions, for example restricting the use of containers.
- The reason why categories 16 and 17 are not used is that so far no cargo category has been opened to "flis trucks" as feasible. When the work on the cost models started, the expectation was that 'flis' (small pieces of wood and sawdust)

would become a separate commodity group. In the commodity classification that was finally agreed, 'flis' is not a separate category. We recommend to estimate which portion of the wood products categories is 'flis' and allow the truck types 16 and 17 only for this portion.

- Why the very large special trucks for Sweden (7 and 8) are not included is a little bit more intriguing, but it may have something to do with the cost models for those trucks.

Ad 2. Vehicle number 6 is dominating.

This is not surprising given the remark at the second bullet point above. With constraints both on size and frequencies included at a later stage, this should be taken care of. As it is, this is just a consequence of minimising cost. Also the distribution on various vehicle sizes should be better once we include time cost values for different cargos into the cost functions.

Ad 3. Second highest amount on timber truck with hanger.

The explanation probably is that timber (categories 5 and 6) has a major share of the total volumes.

Rail only transport chains

All direct rail transport is by vehicle type 6 (Electric, system train). This is of course far too much.

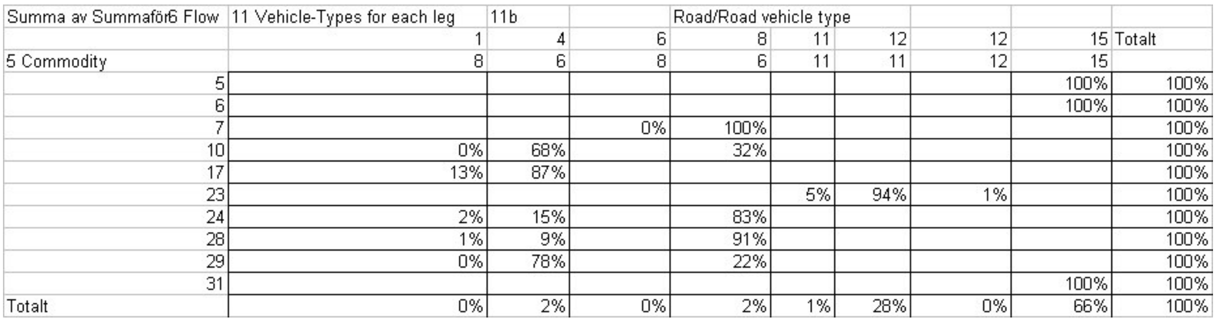
Comments on the findings for rail only chains:

The reason why there is such a large share of electric trains is that so far no constraints are introduced which regulate which line will use electric and which will use diesel. This must of course be done in the future model.

The second issue, why wagonloads are not used, is probably because so far constraints have not been introduced which would give a choice for smaller shipments with wagonloads. On a cost basis, with full capacity utilisation of the system train vehicle, this would always be cheaper and preferred. However, once the optimisation takes into account that there may only be partial utilisation of a system train, wagonloads should become more "competitive" in the calculations.

Road-Road transport chains

Table 17 – Distribution over lorry types for road-road chains for Sweden from logistics model

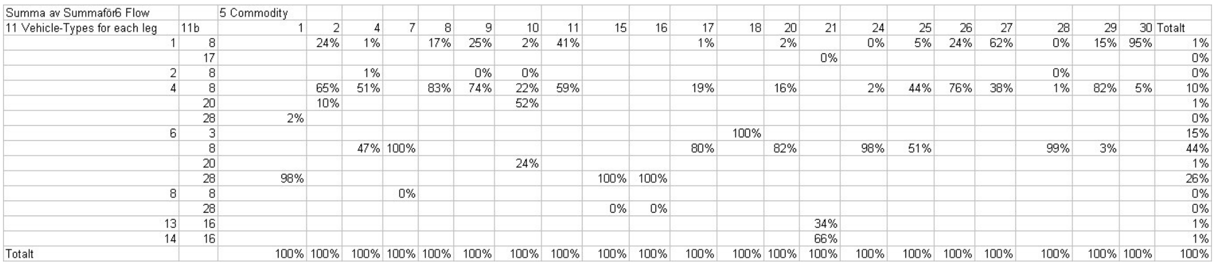


Summa av Summaför6 Flow	11 Vehicle-Types for each leg	11b		Road/Road vehicle type					
	1	4	6	8	11	12	12	15	Totalt
5 Commodity	8	6	8	6	11	11	12	15	
5								100%	100%
6								100%	100%
7			0%	100%					100%
10	0%	68%		32%					100%
17	13%	87%							100%
23					5%	94%	1%		100%
24	2%	15%		83%					100%
28	1%	9%		91%					100%
29	0%	78%		22%					100%
31								100%	100%
Totalt	0%	2%	0%	2%	1%	28%	0%	66%	100%

Two thirds of all tonnes using road-road transport chains use vehicle type 15 (Timber truck with hanger (4 axles)) as both vehicles, which is probably not correct. Timber is usually sent direct and not via terminals. Not even one percent of tonnes use a light gods vehicle (types 1 or 2). 28% use chemical tank truck and liquid bulk tanker – terminals should not be used for such goods. No general cargo seems to use a terminal.

Road-Sea transport chains

Table 18 – Distribution over vessel types for Sweden from logistics model



Summa av Summaför6 Flow		5 Commodity																					
11 Vehicle-Types for each leg	11b	1	2	4	7	8	9	10	11	15	16	17	18	20	21	24	25	26	27	28	29	30	Totalt
1	8		24%	1%		17%	25%	2%	41%			1%		2%		0%	5%	24%	62%	0%	15%	95%	1%
	17														0%								0%
2	8			1%			0%	0%												0%			0%
4	8		65%	51%		83%	74%	22%	59%			19%		16%		2%	44%	76%	38%	1%	82%	5%	10%
	20		10%					52%															1%
	28	2%																					0%
6	3												100%										15%
	8			47%	100%							80%		82%		98%	51%			99%	3%		44%
	20							24%															1%
	28	98%								100%	100%												26%
8	8				0%																		0%
	28									0%	0%												0%
13	16														34%								1%
14	16														66%								1%
Totalt		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

55% of tonnes by ship use vessel type 8 (Lo/lo, general cargo20000 Tonne). 27% use vessel type 28 (Reefer 10000 Tonne). In both cases this is the largest possible vessel size.

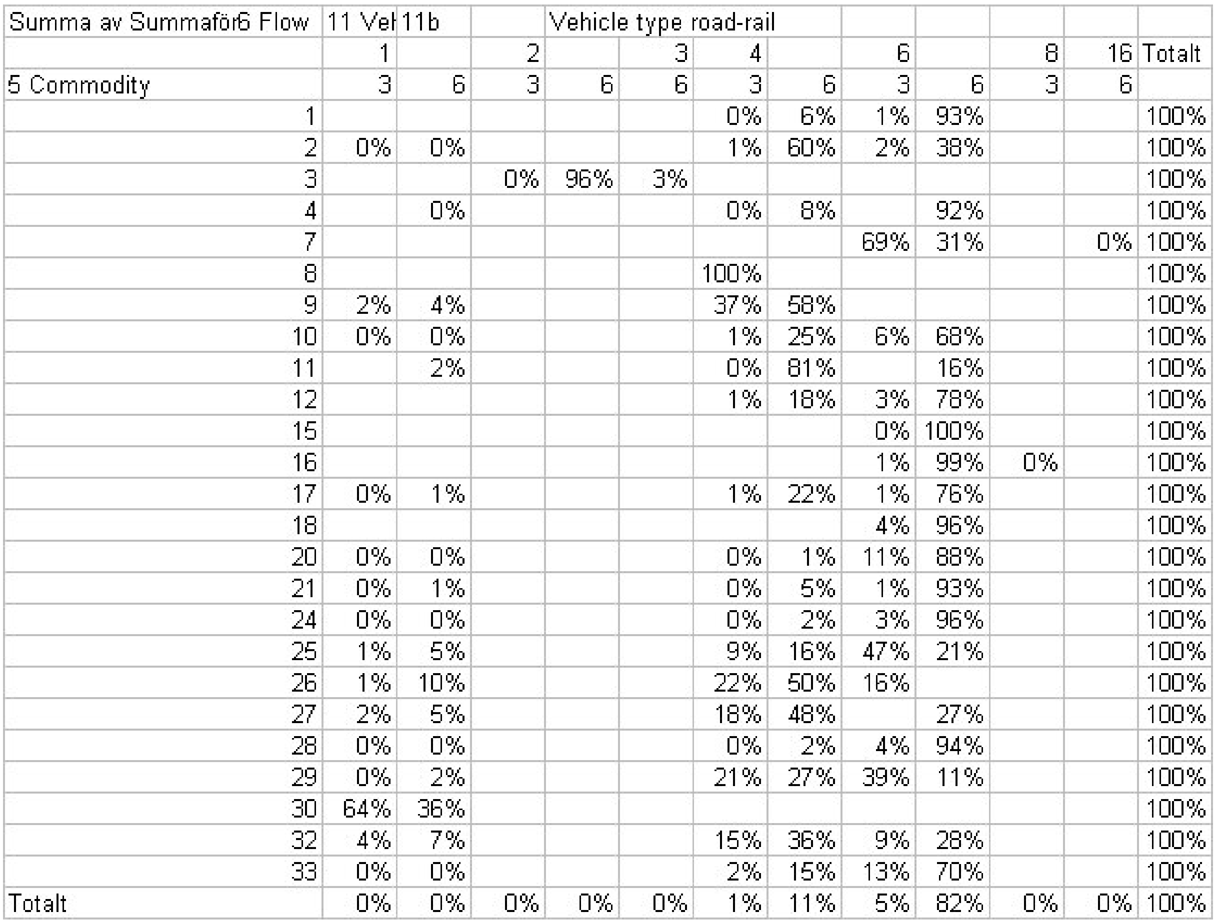
85% of tonnes by road use vehicle type 6 (Articulated semi - with container).

Comments on the findings for road – sea:

In the current model, reefer vessels are used heavily, as reefer goods is feasible in combination with container on road. Since Swedish food categories are not distinguishing between what should be taken with reefers, and what should be taken ordinarily, a lot is put into reefers that should not be there. Further, as there are no capacity limitations in the model so far, the largest (overseas) vessel is chosen. This should change when capacity limitations are introduced. The feasibility for container/reefer combinations should be changed in the new version of the cost models. Reefer should be chosen as a solution only in combination with thermo trucks for road.

Road-Rail transport chains

Table 19 – Distribution over train types for Sweden from logistics model



Summa av Summaför6 Flow	11 Vel	11b		Vehicle type road-rail								
	1		2		3	4		6		8	16	Totalt
5 Commodity	3	6	3	6	6	3	6	3	6	3	6	
1						0%	6%	1%	93%			100%
2	0%	0%				1%	60%	2%	38%			100%
3			0%	96%	3%							100%
4		0%				0%	8%		92%			100%
7								69%	31%		0%	100%
8						100%						100%
9	2%	4%				37%	58%					100%
10	0%	0%				1%	25%	6%	68%			100%
11		2%				0%	81%		16%			100%
12						1%	18%	3%	78%			100%
15								0%	100%			100%
16								1%	99%	0%		100%
17	0%	1%				1%	22%	1%	76%			100%
18								4%	96%			100%
20	0%	0%				0%	1%	11%	88%			100%
21	0%	1%				0%	5%	1%	93%			100%
24	0%	0%				0%	2%	3%	96%			100%
25	1%	5%				9%	16%	47%	21%			100%
26	1%	10%				22%	50%	16%				100%
27	2%	5%				18%	48%		27%			100%
28	0%	0%				0%	2%	4%	94%			100%
29	0%	2%				21%	27%	39%	11%			100%
30	64%	36%										100%
32	4%	7%				15%	36%	9%	28%			100%
33	0%	0%				2%	15%	13%	70%			100%
Totalt	0%	0%	0%	0%	0%	1%	11%	5%	82%	0%	0%	100%

82% of goods use road vehicle 6 (Articulated semi - with container) and train type 6 (Electrical, system). 8% of rail uses train type 3 (Diesel, system) The choice between electric versus diesel train should not be used on costs minimisation, but on the classification of each rail link as either for electric or for diesel trains.. No wagonload train type is used.

Comments on the findings for road-rail:

See the comments for road and rail – the same issues trigger the solutions in the road-rail combinations.

Other transport chain combinations

The other transport chain combinations (3 and 4 mode combinations) are only 9% of the total tonnes and are not shown in this paper.

General comments on the findings on the vehicle/vessel type distribution:

The results are not that surprising taking into account what is still missing in the prototype in terms of capacity constraints, and what is missing in terms of time cost for cargo, frequency effects on shipments sizes, and some further refinement of feasibility in cost models. Further, for Sweden it may be necessary to introduce some further distinction between refrigerated goods and standard goods.

3.5 Tests on use of transport chains

3.5.1 Sweden

Tonnes

Table 20 gives the percentage share per transport chain type by commodity group.

Table 20 – Distribution over transport chains in logistics model for Sweden (R=road, W=rail, S=sea, C=combi, F=ferry)

Del Feb06	R	W	R-R	R-S	R-W	S-R	W-R	RRR	RSR	RWR	RCR	RFR	RSWR	RWSR		
Total tonnes	1	3	11	12	13	21	31	111	121	131	141	151	1231	1321	Totalt	Total tonnes
Cereals	22%	26%		30%	11%	1%	4%						2%		100%	2 507 514
Vegetables	44%	26%			2%	7%	5%		11%				1%	3%	100%	2 215 226
Live animals		50%			28%		4%			7%		10%			100%	1 785
Suger beet	72%	10%		2%	10%		4%		1%						100%	2 013 420
Timber (pulp)	50%	49%													100%	29 679 341
Sawn wood	34%	42%	16%					7%							100%	6 643 317
Wood chips	15%	59%				6%			16%						100%	2 562 444
Other wood		62%		4%		1%			27%		1%		3%		100%	61 424
Textiles	7%	57%		3%	1%	7%		1%	9%		8%		2%	3%	100%	525 647
Foodstuff	44%	38%			8%	1%	5%			1%					100%	21 554 846
Oil seeds and fruits		59%		2%	7%	9%	16%		3%						100%	691 493
Solid mineral fuels	35%	34%			12%		14%			4%					100%	2 451 222
Crude petroleum	50%	50%													100%	1 604 798
Petroleum products	41%	59%													100%	23 980 726
Iron ore	6%	81%		5%	6%		1%								100%	11 080 860
Non-ferrous ores	30%	22%			16%	16%	14%								100%	2 960 718
Metal products	6%	57%		4%	11%		13%		4%	3%					100%	16 001 957
Cement and manuf prod	42%	28%		7%	15%		5%			2%					100%	11 381 813
Earth, sand and gravel	71%	29%													100%	4 711 404
Other crude manuf minerals	42%	34%			13%	2%	5%		3%						100%	9 117 066
Fertilizers	22%	40%		4%	5%		8%		21%						100%	2 066 674
Coal chemicals	21%	67%						12%							100%	478 268
Other chemicals	20%	62%	5%					14%							100%	11 772 621
Paper pulp and waste	14%	59%		5%	7%	1%	10%		4%						100%	6 415 129
Transport equipment	10%	56%		9%	1%	3%	1%	2%	8%		5%		2%	2%	100%	2 865 795
Manuf of metal	14%	46%		2%	3%	4%	2%	10%	5%	1%	9%		2%	2%	100%	2 440 702
Glass and ceramic	10%	46%		1%	5%	3%	1%	9%	9%	1%	8%		3%	3%	100%	986 876
aper, paperboard, not manuf	4%	54%		13%	10%		7%		5%	6%					100%	10 043 891
Leather textile, clothes	36%	37%		2%	3%	4%	1%	4%	4%		5%		1%		100%	6 338 482
General cargo		59%		9%					5%		6%		9%	11%	100%	18
Timber to sawmill	62%	36%						2%							100%	7 098 611
Machinery	21%	49%			2%	6%	2%	3%	6%		8%			2%	100%	2 437 040
Paper and manuf	49%	25%			18%		5%			2%					100%	2 992 188
Totalt	34%	48%		2%	5%	1%	4%	1%	2%						100%	207 683 319

Tonne-kilometres

The following table gives the model output converted to tonne-kilometres.

Table 21 – Total number of tonne-kilometres by commodity and main mode – Model delivery 16th Feb06

Commodity	tonkm-truck	tonkm-sea	tonkm-wagonload	tonkm-combi	tonkm-ferry	Sum
1	146,449,670	174,860,280	453,592,874	3,999,825	0	778,902,648
2	83,791,418	133,828,044	412,085,746	332,921	0	630,038,129
3	89,344	0	710,490	0	226,262	1,026,096
4	132,318,308	17,331,202	178,230,085	399,667	0	328,279,262
5	2,537,601,763	0	6,011,245,058	0	277,144	8,549,123,965
6	2,196,676,121	0	2,254,975,263	0	12,019,256	4,463,670,640
7	127,923,509	191,731,325	803,140,289	0	0	1,122,795,122
8	2,024,675	8,210,271	22,707,443	137,071	0	33,079,460
9	20,373,797	28,900,205	156,738,193	14,679,576	0	220,691,771
10	815,726,029	218,150,844	5,000,412,626	12,514,602	0	6,046,804,102
11	16,849,857	26,663,705	299,375,183	2,122,110	0	345,010,855
12	177,064,214	0	765,183,383	0	91,911	942,339,509
13	412,043,531	0	344,875,834	0	0	756,919,366
14	2,851,583,188	0	6,462,414,473	0	43,623,752	9,357,621,413
15	293,814,615	530,336,017	7,495,973,417	0	0	8,320,124,048
16	364,482,565	419,610,961	1,103,950,765	0	0	1,888,044,291
17	546,316,237	731,478,991	7,788,073,018	64,827,016	0	9,130,695,263
18	884,901,233	176,617,328	2,640,894,495	0	0	3,702,413,055
19	564,739,200	0	489,683,487	0	694,002	1,055,116,689
20	459,082,156	156,533,499	1,939,868,996	2,167,854	0	2,557,652,505
21	93,983,297	188,015,194	462,285,133	0	0	744,283,625
22	64,544,259	0	147,220,489	0	89	211,764,837
23	1,496,843,209	0	3,762,253,813	0	16,897,873	5,275,994,895
24	267,208,949	224,070,458	2,485,312,506	25,015,941	0	3,001,607,854
25	153,990,702	163,544,784	841,393,080	53,923,728	0	1,212,852,293
26	228,781,488	122,484,957	745,047,100	73,463,143	0	1,169,776,688
27	75,265,452	57,649,171	282,883,481	27,029,013	0	442,827,118
28	414,272,159	649,485,022	4,350,855,795	67,122,227	0	5,481,735,203
29	357,610,228	182,203,999	1,291,836,846	120,939,640	0	1,952,590,713
30	670	1,703	6,380	313	0	9,066
31	734,896,803	0	718,864,322	0	0	1,453,761,125
32	144,904,901	94,586,310	639,723,223	64,945,341	0	944,159,775
33	142,508,482	2,397,209	560,910,557	8,685,237	0	714,501,485
Sum	16,808,662,030	4,498,691,478	60,912,723,843	542,305,226	73,830,289	82,836,212,866
Extract from Samgods 2001	41,000,000,000	38,000,000,000	16,542,000,000	2,458,000,000	700,000,000	98,700,000,000
Factor	0.41	0.12	3.68	0.22	0.11	0.84

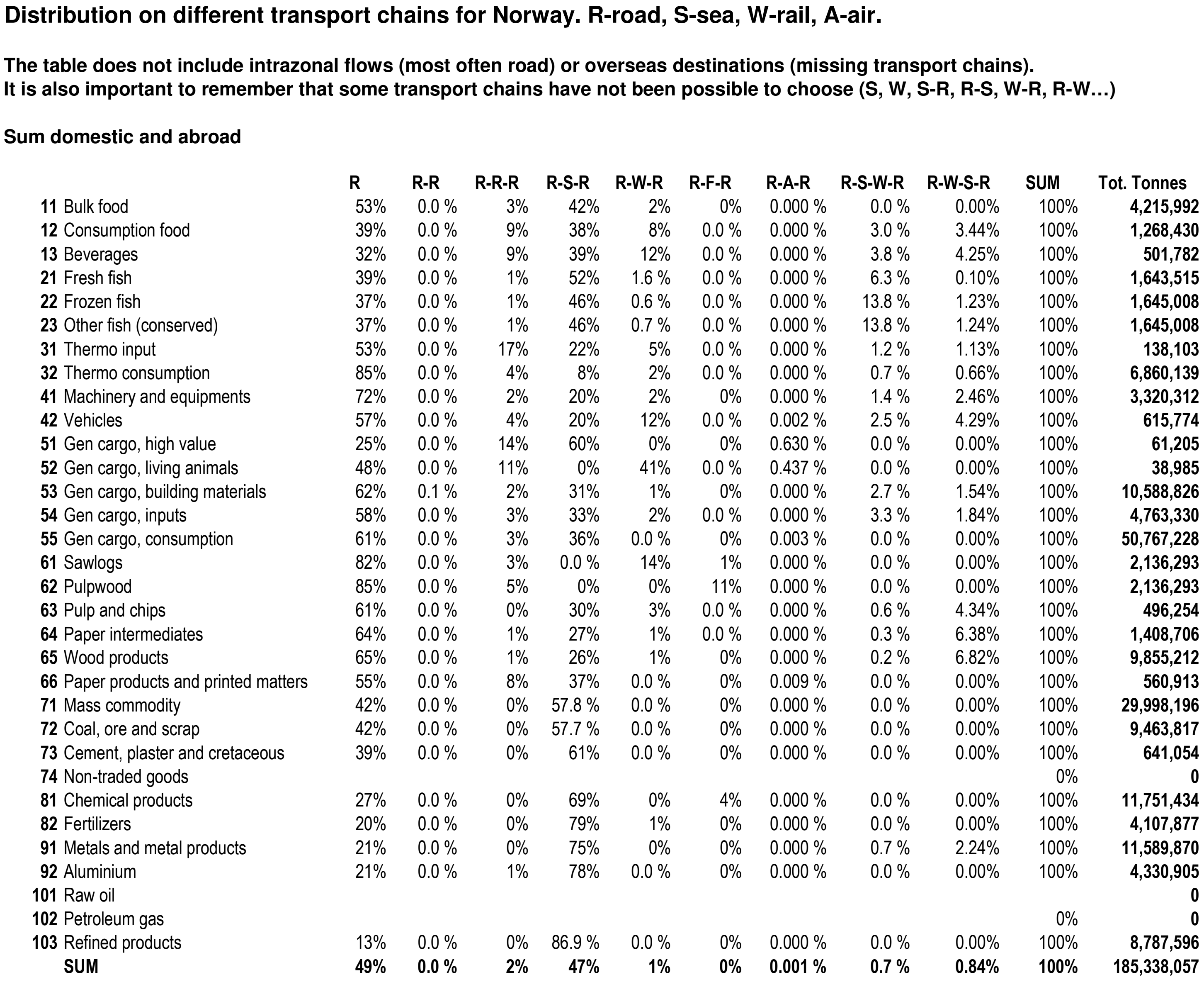
The Swedish results are discussed together with the Norwegian results in section 3.5.3.

3.5.2 **Norway:**

Tonnes

The following table gives the percentage share per transport chain type by commodity group for Norway.

Table 22 – Distribution over transport chains in logistics model for Norway (R=road,



Distribution on different transport chains for Norway. R-road, S-sea, W-rail, A-air.

The table does not include intrazonal flows (most often road) or overseas destinations (missing transport chains).
It is also important to remember that some transport chains have not been possible to choose (S, W, S-R, R-S, W-R, R-W...)

Sum domestic and abroad

	R	R-R	R-R-R	R-S-R	R-W-R	R-F-R	R-A-R	R-S-W-R	R-W-S-R	SUM	Tot. Tonnes
11 Bulk food	53%	0.0 %	3%	42%	2%	0%	0.000 %	0.0 %	0.00%	100%	**4,215,992**
12 Consumption food	39%	0.0 %	9%	38%	8%	0.0 %	0.000 %	3.0 %	3.44%	100%	**1,268,430**
13 Beverages	32%	0.0 %	9%	39%	12%	0.0 %	0.000 %	3.8 %	4.25%	100%	**501,782**
21 Fresh fish	39%	0.0 %	1%	52%	1.6 %	0.0 %	0.000 %	6.3 %	0.10%	100%	**1,643,515**
22 Frozen fish	37%	0.0 %	1%	46%	0.6 %	0.0 %	0.000 %	13.8 %	1.23%	100%	**1,645,008**
23 Other fish (conserved)	37%	0.0 %	1%	46%	0.7 %	0.0 %	0.000 %	13.8 %	1.24%	100%	**1,645,008**
31 Thermo input	53%	0.0 %	17%	22%	5%	0.0 %	0.000 %	1.2 %	1.13%	100%	**138,103**
32 Thermo consumption	85%	0.0 %	4%	8%	2%	0.0 %	0.000 %	0.7 %	0.66%	100%	**6,860,139**
41 Machinery and equipments	72%	0.0 %	2%	20%	2%	0%	0.000 %	1.4 %	2.46%	100%	**3,320,312**
42 Vehicles	57%	0.0 %	4%	20%	12%	0.0 %	0.002 %	2.5 %	4.29%	100%	**615,774**
51 Gen cargo, high value	25%	0.0 %	14%	60%	0%	0%	0.630 %	0.0 %	0.00%	100%	**61,205**
52 Gen cargo, living animals	48%	0.0 %	11%	0%	41%	0.0 %	0.437 %	0.0 %	0.00%	100%	**38,985**
53 Gen cargo, building materials	62%	0.1 %	2%	31%	1%	0%	0.000 %	2.7 %	1.54%	100%	**10,588,826**
54 Gen cargo, inputs	58%	0.0 %	3%	33%	2%	0.0 %	0.000 %	3.3 %	1.84%	100%	**4,763,330**
55 Gen cargo, consumption	61%	0.0 %	3%	36%	0.0 %	0%	0.003 %	0.0 %	0.00%	100%	**50,767,228**
61 Sawlogs	82%	0.0 %	3%	0.0 %	14%	1%	0.000 %	0.0 %	0.00%	100%	**2,136,293**
62 Pulpwood	85%	0.0 %	5%	0%	0%	11%	0.000 %	0.0 %	0.00%	100%	**2,136,293**
63 Pulp and chips	61%	0.0 %	0%	30%	3%	0.0 %	0.000 %	0.6 %	4.34%	100%	**496,254**
64 Paper intermediates	64%	0.0 %	1%	27%	1%	0.0 %	0.000 %	0.3 %	6.38%	100%	**1,408,706**
65 Wood products	65%	0.0 %	1%	26%	1%	0%	0.000 %	0.2 %	6.82%	100%	**9,855,212**
66 Paper products and printed matters	55%	0.0 %	8%	37%	0.0 %	0%	0.009 %	0.0 %	0.00%	100%	**560,913**
71 Mass commodity	42%	0.0 %	0%	57.8 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**29,998,196**
72 Coal, ore and scrap	42%	0.0 %	0%	57.7 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**9,463,817**
73 Cement, plaster and cretaceous	39%	0.0 %	0%	61%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**641,054**
74 Non-traded goods										0%	**0**
81 Chemical products	27%	0.0 %	0%	69%	0%	4%	0.000 %	0.0 %	0.00%	100%	**11,751,434**
82 Fertilizers	20%	0.0 %	0%	79%	1%	0%	0.000 %	0.0 %	0.00%	100%	**4,107,877**
91 Metals and metal products	21%	0.0 %	0%	75%	0%	0%	0.000 %	0.7 %	2.24%	100%	**11,589,870**
92 Aluminium	21%	0.0 %	1%	78%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**4,330,905**
101 Raw oil											**0**
102 Petroleum gas										0%	**0**
103 Refined products	13%	0.0 %	0%	86.9 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**8,787,596**
SUM	**49%**	**0.0 %**	**2%**	**47%**	**1%**	**0%**	**0.001 %**	**0.7 %**	**0.84%**	**100%**	**185,338,057**

W=rail, S=sea, F=ferry, A=air), domestic and abroad

Table 23 – Distribution over transport chains in logistics model for Norway (R=road, W=rail, S=sea, F=ferry, A=air), domestic

Domestic

		R	R-R	R-R-R	R-S-R	R-W-R	R-F-R	R-A-R	R-S-W-R	R-W-S-R	SUM	Tot. Tonne
11	Bulk food	63%	0.0 %	4%	32%	2%	0%	0.000 %	0.0 %	0.00%	100%	**3,545,**
12	Consumption food	47%	0.0 %	10%	30%	10%	0.0 %	0.000 %	1.0 %	1.73%	100%	**1,056,**
13	Beverages	38%	0.0 %	11%	33%	14%	0.0 %	0.000 %	1.6 %	2.50%	100%	**419,**
21	Fresh fish	53%	0.0 %	2%	42%	1.9 %	0.0 %	0.000 %	0.8 %	0.12%	100%	**1,195,**
22	Frozen fish	51%	0.0 %	2%	46%	0.8 %	0.0 %	0.000 %	0.9 %	0.14%	100%	**1,182,**
23	Other fish (conserved)	51%	0.0 %	1%	46%	1.0 %	0.0 %	0.000 %	0.9 %	0.15%	100%	**1,182,**
31	Thermo input	54%	0.0 %	17%	22%	5%	0.0 %	0.000 %	0.9 %	0.64%	100%	**136,**
32	Thermo consumption	86%	0.0 %	4%	8%	1%	0.0 %	0.000 %	0.4 %	0.23%	100%	**6,766,**
41	Machinery and equipments	82%	0.0 %	2%	13%	2%	0%	0.000 %	0.6 %	0.51%	100%	**2,937,**
42	Vehicles	66%	0.0 %	5%	16%	11%	0.0 %	0.002 %	1.3 %	1.40%	100%	**534,**
51	Gen cargo, high value	30%	0.0 %	17%	53%	0%	0%	0.006 %	0.0 %	0.00%	100%	**50,**
52	Gen cargo, living animals	62%	0.0 %	14%	0%	24%	0.0 %	0.045 %	0.0 %	0.00%	100%	**30,**
53	Gen cargo, building materials	74%	0.1 %	2%	22%	1%	0%	0.000 %	0.2 %	0.31%	100%	**8,850,**
54	Gen cargo, inputs	69%	0.0 %	3%	25%	2%	0.0 %	0.000 %	0.3 %	0.45%	100%	**3,981,**
55	Gen cargo, consumption	73%	0.0 %	3%	24%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**42,430,**
61	Sawlogs	94%	0.0 %	4%	0.0 %	1%	0%	0.000 %	0.0 %	0.00%	100%	**1,663,**
62	Pulpwood	95%	0.0 %	5%	0%	0%	0%	0.000 %	0.0 %	0.00%	100%	**1,663,**
63	Pulp and chips	79%	0.0 %	0%	17%	3%	0.0 %	0.000 %	0.3 %	0.42%	100%	**385,**
64	Paper intermediates	82%	0.0 %	2%	15%	1%	0.0 %	0.000 %	0.1 %	0.15%	100%	**1,095,**
65	Wood products	83%	0.0 %	1%	15%	1%	0%	0.000 %	0.0 %	0.03%	100%	**7,665,**
66	Paper products and printed matters	70%	0.0 %	10%	19%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**435,**
71	Mass commodity	75%	0.0 %	0%	25.5 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**16,980,**
72	Coal, ore and scrap	75%	0.0 %	0%	25.4 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**5,356,**
73	Cement, plaster and cretaceous	70%	0.0 %	0%	30%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**362,**
74	Non-traded goods											
81	Chemical products	77%	0.1 %	2%	22%	0%	0%	0.000 %	0.0 %	0.00%	100%	**3,397,**
82	Fertilizers	64%	0.0 %	0%	35%	1%	0%	0.000 %	0.0 %	0.00%	100%	**1,188,**
91	Metals and metal products	74%	0.0 %	1%	24%	1%	0%	0.000 %	0.3 %	0.15%	100%	**3,303,**
92	Aluminium	73%	0.0 %	2%	25%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**1,233,**
101	Raw oil											
102	Petroleum gas											
103	Refined products	33%	0.0 %	0%	66.9 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**3,466,**
	SUM	**73%**	**0.0 %**	**2%**	**24%**	**1%**	**0%**	**0.000 %**	**0.1 %**	**0.11%**	**100%**	**122,498,**

Table 24 – Distribution over transport chains in logistics model for Norway (R=road, W=rail, S=sea, F=ferry, A=air), import

Import

		R	**R-R**	**R-R-R**	**R-S-R**	**R-W-R**	**R-F-R**	**R-A-R**	**R-S-W-R**	**R-W-S-R**	**SUM**	**Tot. Tonnes**
11	Bulk food	0%	0.0 %	0%	98%	2%	0%	0.000 %	0.0 %	0.00%	100%	**544,061**
12	Consumption food	0%	0.0 %	0%	81%	2%	0.0 %	0.000 %	2.6 %	14.24%	100%	**171,962**
13	Beverages	0%	0.0 %	0%	77%	2%	0.0 %	0.000 %	4.9 %	15.56%	100%	**67,202**
21	Fresh fish											**0**
22	Frozen fish	6%	0.0 %	0%	82%	0.0 %	0.0 %	0.000 %	0.0 %	12.67%	100%	**145,187**
23	Other fish (conserved)	6%	0.0 %	0%	82%	0.0 %	0.0 %	0.000 %	0.0 %	12.67%	100%	**145,187**
31	Thermo input	0%	0.0 %	0%	25%	14%	0.0 %	0.000 %	4.8 %	56.68%	100%	**1,191**
32	Thermo consumption	0%	0.0 %	0%	33%	13%	0.0 %	0.000 %	4.5 %	49.28%	100%	**58,246**
41	Machinery and equipments	0%	0.0 %	0%	74%	2%	0%	0.000 %	2.0 %	21.61%	100%	**298,379**
42	Vehicles	0%	0.0 %	0%	49%	20%	0.0 %	0.000 %	1.3 %	28.80%	100%	**63,111**
51	Gen cargo, high value	0%	0.0 %	0%	97%	0%	0%	2.712 %	0.0 %	0.00%	100%	**3,491**
52	Gen cargo, living animals	6%	0.0 %	0%	0%	93%	0.0 %	0.753 %	0.0 %	0.00%	100%	**3,054**
53	Gen cargo, building materials	0%	0.0 %	0%	77%	1%	0%	0.000 %	0.3 %	21.62%	100%	**601,886**
54	Gen cargo, inputs	0%	0.0 %	0%	74%	2%	0.0 %	0.000 %	0.8 %	23.41%	100%	**270,807**
55	Gen cargo, consumption	1%	0.0 %	0%	99%	0.0 %	0%	0.003 %	0.0 %	0.00%	100%	**2,886,903**
61	Sawlogs	36%	0.0 %	0%	0.0 %	61%	3%	0.000 %	0.0 %	0.00%	100%	**365,938**
62	Pulpwood	45%	0.0 %	4%	0%	0%	51%	0.000 %	0.0 %	0.00%	100%	**365,938**
63	Pulp and chips	0%	0.0 %	0%	79%	0%	0.0 %	0.000 %	0.5 %	20.13%	100%	**85,393**
64	Paper intermediates	1%	0.0 %	0%	62%	0%	0.0 %	0.000 %	0.1 %	35.87%	100%	**242,086**
65	Wood products	0%	0.0 %	0%	60%	0%	0%	0.000 %	0.0 %	39.33%	100%	**1,692,012**
66	Paper products and printed matters	1%	0.0 %	0%	99%	0.0 %	0%	0.003 %	0.0 %	0.00%	100%	**96,705**
71	Mass commodity	0%	0.0 %	0%	100.0 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**3,535,793**
72	Coal, ore and scrap	0%	0.0 %	0%	100.0 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**1,115,431**
73	Cement, plaster and cretaceous	0%	0.0 %	0%	100%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**75,500**
74	Non-traded goods											**0**
81	Chemical products	6%	0.0 %	0%	93%	0%	2%	0.000 %	0.0 %	0.00%	100%	**2,385,015**
82	Fertilizers	1%	0.0 %	0%	98%	1%	0%	0.000 %	0.0 %	0.00%	100%	**833,613**
91	Metals and metal products	0%	0.0 %	0%	97%	0%	0%	0.000 %	0.0 %	3.25%	100%	**7,816,793**
92	Aluminium	0%	0.0 %	0%	100%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**2,921,667**
101	Raw oil											**0**
102	Petroleum gas											**0**
103	Refined products	1%	0.0 %	0%	99.4 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**970,854**
	SUM	**2%**	**0.0 %**	**0%**	**91%**	**1%**	**1%**	**0.001 %**	**0.1 %**	**5.05%**	**100%**	**27,763,405**

Table 25 – Distribution over transport chains in logistics model for Norway (R=road, W=rail, S=sea, F=ferry, A=air), export

Export

		R	R-R	R-R-R	R-S-R	R-W-R	R-F-R	R-A-R	R-S-W-R	R-W-S-R	SUM	Tot. Tonnes
11	Bulk food	0%	0.0 %	0%	97%	2%	0%	0.000 %	0.0 %	0.00%	100%	**126,656**
12	Consumption food	0%	0.0 %	0%	39%	2%	0.0 %	0.000 %	57.5 %	2.22%	100%	**39,860**
13	Beverages	0%	0.0 %	0%	37%	1%	0.0 %	0.000 %	58.8 %	2.63%	100%	**15,535**
21	Fresh fish	0%	0.0 %	0%	78%	0.6 %	0.0 %	0.000 %	20.9 %	0.04%		**447,866**
22	Frozen fish	0%	0.0 %	0%	32%	0.0 %	0.0 %	0.000 %	68.0 %	0.06%	100%	**317,145**
23	Other fish (conserved)	0%	0.0 %	0%	32%	0.0 %	0.0 %	0.000 %	68.0 %	0.06%	100%	**317,145**
31	Thermo input	0%	0.0 %	0%	36%	13%	0.0 %	0.000 %	48.8 %	2.46%	100%	**691**
32	Thermo consumption	0%	0.0 %	0%	37%	9%	0.0 %	0.000 %	52.1 %	1.87%	100%	**35,424**
41	Machinery and equipments	0%	0.0 %	0%	67%	2%	0%	0.002 %	28.6 %	2.53%	100%	**84,349**
42	Vehicles	0%	0.0 %	0%	30%	24%	0.0 %	0.011 %	41.7 %	4.21%	100%	**18,280**
51	Gen cargo, high value	1%	0.0 %	0%	95%	0%	0%	4.232 %	0.0 %	0.00%	100%	**6,794**
52	Gen cargo, living animals	0%	0.0 %	0%	0%	98%	0.0 %	2.273 %	0.0 %	0.00%	100%	**5,891**
53	Gen cargo, building materials	1%	0.0 %	0%	74%	1%	0%	0.000 %	23.6 %	0.47%	100%	**1,136,668**
54	Gen cargo, inputs	1%	0.0 %	0%	70%	1%	0.0 %	0.000 %	27.3 %	1.18%	100%	**511,421**
55	Gen cargo, consumption	4%	0.0 %	0%	96%	0.0 %	0%	0.027 %	0.0 %	0.00%	100%	**5,449,423**
61	Sawlogs	50%	0.0 %	0%	0.0 %	47%	3%	0.000 %	0.0 %	0.00%	100%	**106,892**
62	Pulpwood	56%	0.0 %	3%	0%	0%	41%	0.000 %	0.0 %	0.00%	100%	**106,892**
63	Pulp and chips	0%	0.0 %	0%	74%	10%	0.0 %	0.000 %	5.0 %	10.80%	100%	**25,087**
64	Paper intermediates	0%	0.0 %	0%	92%	2%	0.0 %	0.000 %	4.2 %	1.92%	100%	**71,223**
65	Wood products	0%	0.0 %	0%	93%	2%	0%	0.000 %	4.3 %	0.94%	100%	**498,014**
66	Paper products and printed matters	0%	0.0 %	0%	100%	0.0 %	0%	0.172 %	0.0 %	0.00%	100%	**28,463**
71	Mass commodity	0%	0.0 %	0%	100.0 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**9,482,352**
72	Coal, ore and scrap	0%	0.0 %	0%	100.0 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**2,991,649**
73	Cement, plaster and cretaceous	0%	0.0 %	0%	100%	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**202,793**
74	Non-traded goods											
81	Chemical products	7%	0.0 %	0%	86%	0%	7%	0.000 %	0.0 %	0.00%	100%	**5,968,483**
82	Fertilizers	2%	0.0 %	0%	97%	1%	0%	0.000 %	0.0 %	0.00%	100%	**2,086,199**
91	Metals and metal products	3%	0.0 %	0%	82%	0%	0%	0.000 %	14.2 %	0.02%	100%	**469,181**
92	Aluminium	4%	0.0 %	0%	96%	0.0 %	0%	0.005 %	0.0 %	0.00%	100%	**175,274**
101	Raw oil											
102	Petroleum gas											
103	Refined products	0%	0.0 %	0%	100.0 %	0.0 %	0%	0.000 %	0.0 %	0.00%	100%	**4,350,670**
	SUM	**2%**	**0.0 %**	**0%**	**93%**	**0%**	**1%**	**0.006 %**	**3.2 %**	**0.07%**	**100%**	**35,076,320**

3.5.3 Discussion of results for on transport chains Sweden and Norway

All these results have been produced by an un-calibrated model (though some simple multiplicative calibration factors by aggregate mode and commodity type have been derived). By definition, a calibrated model would produce a much better representation of observed shares (e.g. mode shares). A model estimated on aggregate data could even give a perfect representation of the observed shares, provided that constants would be included for all the modes minus one. Therefore we recommend that the version 1 model will be calibrated on data on the mode shares (not the detailed vehicle/vessel types for which there are no observed data, but road, sea, rail, ferry and air) using formal optimisation or statistical estimation procedures.

A question from looking at these results is why there are not enough road-road and road-road-road flows (especially Sweden)? This is mainly because there are just a few road terminal locations (especially Sweden); in Norway we use considerably more road terminals.

Another issue is why there are so many direct rail transports in Sweden We think direct rail should not be available for so many relations. For most relations there will be road-rail-road chains available, not direct rail. This means own sidings. Road access or road egress to/from a railway station within the same zone should not be represented as direct rail, but as chains with road and rail transport, with subsequent costs. If there would be no knowledge on road time and distance to/from the station, but no own sidings either, we have to assume an average road time and distance.

Sea transport is used too much, and also for goods (high value goods) where one would not expect this, especially in the Norwegian model. This is due to the assumptions on consolidation (possibility of sharing the cost with other cargo, availability of big vessels at all ports, no waiting times). Restrictions on the availability of vessels by port have to be built in, as well as on the frequency of ships (to include time costs, which may be important for high value goods) and the availability of other cargo.

For Norway the (international) ferry has been treated as a separate mode, with information on it coming from the networks (leading to chains such as road-ferry-road). For Sweden there is ferry transport in the road chains (e.g. road, road-road, road-road-road), but this does not show up in the tables above. We recommend that for Sweden as well ferry will be treated a separate network model. In the current Swedish results, we rather artificially included a separate ferry mode, but made it too expensive.

Air transport should be included in Sweden too.

The present device of ruling out road-road, except for large receivers is not acceptable. We should use consolidation (cost sharing) only for second leg in road-road-road. Maybe we can include restrictions on large trucks in urban areas.

CHAPTER 4 Conclusions for the directions in the coming development phases

Finally in this chapter we give our conclusions, based on the work carried out as described above, for the development of future versions of the logistics module, particularly for the development of version 1 that is expected to take place April-September 2006 (Phase 3 for 2006). In Sections 4.1-4-3 we summarise the conclusions from Phase 2. In Section 4.4 we describe which improvements to the 2005 prototype model we think are feasible for the version 1 model, and which improvements we think should be carried later or not at all (because of data that is not yet available, limited importance of the improvement, or because a disproportionately large effort would be involved).

4.1 Step A and shipment size

Several variants are available for the disaggregation step (step A) from zone-to-zone (z2z) flows to firm-to-firm (f2f) flows:

- Version 0.1:
    - Uses the PWC flows as the starting point for a probabilistic process that when aggregated over firms can give differences from the PWC flows, especially for small numbers of firms;
    - Uses the number of receivers per sender from Annex 2 of D4;
    - Has a long runtime;
    - Would generate too many small shipments.
- Version 0.2:
    - Preserves the PWC flows (with some exceptions that need to be treated differently in Phase 2 to achieve full consistency);
    - Uses a number of f2f relations that is rather artificially kept low;
    - Is inconsistent with the number of receivers per sender in Annex 2 of D4;
    - Has a short runtime;
    - Produces a reasonably good match with the observed shipment size data.
- Version 0.3:

- Preserves the PWC flows (with some exceptions that need to be treated differently in Phase 2 to achieve full consistency);
- Uses a number of f2f relations is consistent with the number of receivers per sender in Annex 2 of D4;
- Has a long runtime;
- Would generate too many small shipments.

Neither of these versions is an ideal starting point for Phase 3. The best starting point would be to use version 0.3 with a lower number of receivers per sender . The Swedish Commodity Flow Survey produces some indications that these numbers could be considerably lower, but the CFS information on this is very uncertain. We recommend a small new survey on the number of receivers per sender. This version 0.3 with a lower number of receivers per sender would ensure consistency with the PWC files, the assumptions on the number of receivers per sender and lead to runtimes that would probably not be much longer than those of version 0.2. It would also generate a shipment size distribution similar to the one of version 0.2 that matched the observations relatively well.

Several consumption commodity categories can be used for the same consumption firm, to do justice to the national Use tables. Consumption files with this feature have already been developed.

Shipment size can be made dependent on transport costs (using economies of scale in transport) using equations derived in Chapter 2.

4.2 Cost functions and use of network models

In our view, the costs in the 2006 model should still be based on vehicle costs, calculated per km and hour for given vehicles. The distance and time elements should be gathered from the network model on an OD-basis, so that each vehicle type will have the appropriate distance in an OD-pair, and the time for travelling that distance based on what would be a reasonable average speed.

In addition we would still for loading and unloading at the first and last leg in a transport chain add the vehicle specific costs. For transfer between different vehicles in the transport chain, we would use vehicle (combination) specific transfer cost. For some vehicle combinations, the transfer and loading/unloading cost also have a cargo specific cost element. That should be kept.

In this respect, the principles applied for the prototype should still be used for the 2006 model. The interface between the transport chains generated externally and the logistics model should also probably be kept for the new version of the model, although with more possibilities for transport chains generated. However, it should be considered further if more detailed cost functions should be used for the external generation of transport chains, or if some of the generation (more of the generation) of transport chains should be made inside the logistics model. There should be a high level of consistency between the cost functions in the logistics model and the assumptions made for possible transport chains.

Improvements in the cost models from the prototype should be:

- Inclusion of capital cost/time cost for the cargo, both in transit and in terminals (not just in the inventories) – that would mean that we would also need to calculate total time for the cargo, and probably also in some cases establish frequency/time relationships in the model;
- There are also some minor improvements in terms of adding a few vehicles, for example should tank lorries without hangers also be included (for more local distribution of petroleum products), or transfer possibilities (from timber truck to sea and rail transport).
- We should also add an additional cost element for mobilisation/positioning of transport unit.
- In other cases we should build in more restrictions on the availability of vehicle/vessel types by commodity, e.g. only use thermo trucks and reefer vessels for refrigerated goods. This requires that the portion of refrigerated goods (within foodstuffs) be distinguished separately in the PWC matrices. Also the proportion of 'flis' (small pieces of wood and sawdust)_within wood products need to be distinguished separately, so that the special 'flis' truck can be made available for these goods. Tanker trucks should not be allowed to consolidate (within road transport).

The consequences of not making the suggested improvements would be:

- The choices of vehicles for high value goods may tend to choose low cost transport instead of high frequency/fast transport to a larger extent than in practice;
- We may overrate the availability of certain types of vehicles.

There also is the issue of what the network models should provide, what the cost functions should do and what the logistics costs minimisation should cover. We suggest to keep using Henrik Edwards' program for the determination of the optimal transfer locations. This program can use unimodal results from a network model as inputs, so it does not depend on particular (commercial) assignment packages. It can locate the transfer locations on the network, which is better than using the centroids as is being done now for the optimal road transfer location within the logistics model. If possible (would need a distinction between several road vehicle types and coding of road terminals in the network) Henrik Edwards' program could take over the determination of optimal road transfer location. This is only important if the locations of terminals are studied in greater detail than linking a terminal to a municipality. Also in the determination of the road transfer locations we should distinguish between commodities with containerised chains and commodities with non-containerised chains.

On the other hand it is important to make the optimisation within Henrik Edwards' program more consistent with the costs functions, e.g. by using the same cost items or even using the numbers for particular vehicle/vessel types). The logistics model will continue to do the choice between the different available transport chains and detailed vehicle/vessel type for each leg.

From this program we need data on unimodal level-of-service and transfers between these modes; road and rail transport should not include ferries, these should be treated as separate modes. For Norway we should make sure that all foreign zones are connected to Norwegian zones by at least some mode. Also the number of available transport chains in both countries needs to be extended (e.g. air transport chains in Sweden).

Preferably the network output would not only include distance and transport time for each leg as well as the transfer locations, but also the frequency of the modal service for the specific link (as a link attribute). On this basis we could calculate wait time as half-headway. Also the network inputs for the logistics model should ideally include tolls (e.g. Öresund), fairway and pilot dues, network restrictions (e.g. for heavy trucks, rail axle loads), and distinguish links for diesel and links for electric trains.

4.3 **Transport chain choice and consolidation**

At the moment consolidation at ports, railway terminals and road terminals is often too easy in the model and more restrictions should be build in to make the mode more realistic. This is especially relevant for ports, where we should characterise each port by the vessel types that can reach the port. Also we should include waiting times (see above) for vessel types that can reach the port, but in reality do not leave every time of the day on every day. Finally we should include in the model that some goods can be combined and others cannot, and that at a port, station or road terminal (a small one or one with a limited service area) there might not be enough other cargo to fill a large vehicle (up to 90%).

Direct rail transport in reality is only available to a small minority of firms (those with own sidings). If it would be possible to obtain firm-specific data on this, we could attach this as a firm characteristic. If not, we could use zone-specific fractions of direct rail accessibility, which we could use for proportional draws for each firm. This will reduce the number of firms that can choose direct rail (which is now over-predicted, especially in Sweden). For the other firms, indirect rail transport (with rail access/egress) will be available, but this adds access/egress and transfer costs. For access/egress to/from a station within the same zone (but not at own sidings) we could add a constant amount or an amount that increases with zone size.

Within roads transport, consolidation should not be allowed for convoys, in the sense that as soon as the shipment exceeds the largest available vehicle capacity, consolidation within road transport will no longer be possible.

Empty vehicles have been treated using vehicle balances to account for the directionality of the flows. However, assumptions have been used for the coefficients in the functions governing this, which should if possible be replaced by direct empirical observations on the share of empty vehicles.

All these results have been produced by an un-calibrated model (though some simple multiplicative calibration factors by aggregate mode and commodity type have been derived). By definition, a calibrated model would produce a much better representation of observed shares (e.g. mode shares). A model estimated on aggregate data could even give a perfect representation of the observed shares, provided that constants would be included for all the modes minus one. Therefore we recommend that the version 1 model will be calibrated on data on the mode shares (not the detailed vehicle/vessel types for which there are no observed data, but the shares for road, sea, rail, ferry and air) using formal optimisation or statistical estimation procedures. Disaggregate data will not be used for version 1 (this will happen later), but there is data available on the observed mode shares (say for 2001) at the OD level by commodity type, from the road, rail, air and maritime statistics. It might be possible to obtain data that will give the mode shares at the OD level between aggregates of zones (e.g. counties, foreign countries), either directly from the statistics, or from combining the current national models with the statistics. We could then add mode-specific constants (e.g. for rail, sea, ferry, air) and one or more other coefficients, such as one for the implied discount rate on capital tied up in goods in transit, to the cost functions. The optimisation in the logistics model and the aggregation of transport chain outputs at the OD level then give the predicted mode shares. Then we define an objective function (e.g. minimising the squared difference between the observed mode shares and the predicted mode shares) and we could find the values for the mode-specific constants and other coefficients by minimising this objective function (by grid search or gradient search).

4.4 Improvements for Phase 3 (2006) and after

At the meeting in Leiden on 31 January, a number of possible improvements were discussed. Below these potential improvements are reiterated (in *italics*) and we indicate which improvements could best be incorporated in Version 1 of the model, to be delivered at the end of Phase 3 (September 2006) and which improvements would have to be dealt with at a later stage or might be considered not worth the effort required.

1. *The disaggregation procedure needs to be revisited. A situation in which the PWC flows are exactly maintained after the determination of firm-to-firm flows is preferred. Also the assumptions on the number of receivers per sender (and the other way around) need to be replaced by empirical data as much as possible (e.g. from the CFS 2004/2005, the LG data). Furthermore we have to make sure that firms from all relevant sectors (including oil, agricultural sector, retail) are included (esp. for Norway). For Sweden the CFS 2004/2005 might be used for step A as well, as could turnover data instead of employment data.*

   A large part of this work (restoring consistency with PWC flows, investigating options and sensitivity with regards to the number of receivers per sender) has already been done in Phases 1 and 2 of 2006. Most of the remaining tasks (collect and use empirical information on the number of receivers per sender, use turnover data for Sweden if preferred to employment) should be done in Phase 3 (however, there may not be sufficient time in Phase 3 to include the 2004/2005 CFS production-consumption pattern).

2. *For some commodities, shipment size and frequency are treated as given; for others they follow from an optimization that does not include economies of scale in transport. This needs to be revisited and empirical data on frequency needs to be found and used.*

This issue was treated in this report, and a procedure to include economies of scale in transport in the determination of shipment size was sketched. But the issue of more empirical data on this is important for Phase 3, and might be combined with a short survey on the number of receivers per sender.

3. *Estimate transport chain model on disaggregate data. This requires extra chain data at the shipment level.*

We regards this as a very important issue for the final quality of the model, but it is not for Phase 3 of 2006, but for the phases immediately after this.

4. *Gather additional empirical costs information.*

We hope this can also be done as part of the Phase 3 work.

5. *The logistic behaviour in the implemented model should differentiate between P-W, W-C and P-C. But this should also be known for the base matrices.*

This will probably have to wait until after Phase 3, but is too important to be skipped entirely.

6. *The determination of CC and DC (road transport) now depends on two vehicle types. Needs to be revisited.*

For Phase 3,we suggest to use four vehicle types: two (one small, one large) for containerised commodities and two (one small, one large) for non-containerised commodities. It might be possible to extend this later.

7. The choice of intermodal transfer location should follow from a disaggregate random utility model. The network model needs to generate several alternative locations as the choice set.

See issue 3.

8. *Base the empty flows procedures to a greater extent on observed data (percentage empty by commodity, weight-in-motion data). Maybe use for non-road transport as well.*

This should be done in Phase 3, depending on existing data.

9. *Consider having different shipment sizes for a single firm-to-firm flow, and also different transport chains.*

This cannot be done within Phase 3, but we feel that this complication is not worth the effort and runtime complications involved in later phases either.

10. *Include intrazonal transport. But then also need costs inputs or distance.*

This needs to be done (in a simple way) in Phase 3, and can be improved later.

11. *Transit traffic needs to be included. Need list of eligible flows from base matrix.*

Same comment as for issue 10.

12. *The list of available mode chains for Sweden needs to be extended (sea-sea, air, road and rail ferry).*

This is very important for Phase 3 and cannot wait.

13. *The list of available mode chains for Norway needs to be extended (not necessarily starting/ending with road, also add sea-sea).*

This is very important for Phase 3 and cannot wait.

14. *The load factors for consolidated flows need to be based on empirical data.*

Consolidation needs to be treated differently (this is a broader issue than just the load factors used). This report contains proposals for this, that we want to implement in Phase 3.

15. *Both road-road and road-road-road should be available alternatives.*

This is for Phase 3 as well.

16. *Maybe bulk containers should be added as a choice alternative.*

Some small changes to the vehicle/vessel types can be made in Phase 3.

17. *The preliminary model for Norway overestimates intrazonal flows (unlike the one for Sweden). This needs to be investigated.*

This has been taken care of already.

18. *For Norway the zoning system in PWC flows and network inputs need to be made consistent.*

This needs to be done in Phase 3.

19. *In the costs functions, sea transport might be too cheap (Norway) and ferry too expensive. For air transport a specific high time sensitivity segment is required. In Sweden rail might be represented as too cheap in the costs functions.*

All these issues should be visited in Phase 3. The cases described in this report have provided more insights into the outcomes for the various modes (including vehicle/vessel types)

20. Transports from the continental shelf should be included.

Needs to be done in the Phase 3 model.

21. *Need to add more road terminals in Sweden.*

The Swedish clients prefer to use the main road terminals only. For Phase 3, this will not be changed, but we might have to revisit this issue after that.

Annex A Specification of cost functions

The Cost Specification for the Logistics Model – A note intended to clarify the current approach

John Bates, 16 February 2006

Commented by Stein Erik Grønland and Gerard de Jong

Introduction

I have been meaning to get to grips with this for a long time, but it has been delayed by other things! I intend what follows as a partial contribution to the task which Henrik S and I have of extending the "Common Understanding", and in part this builds on our earlier note.

At the same time, I have been concerned about possible confusion in the notation, despite the considerable efforts made earlier by RAND, and I have tried to move this on, while not necessarily finishing the job.

In addition, I have tried to present an exposition of some of the logistics concepts. Since I am not very well acquainted with these, part of what I say may be seen as rather obvious, but it does seem useful to try and spell out the ideas for those who (like myself) do not have the background experience in this area.

The General Approach

We begin with some text from the Common Understanding document (§2.2):

"The "pure transport" opportunities between any two relevant locations will be represented by relatively conventional networks. However, because of the possibilities of intermediate unloading and loading, the actual matrices of demand (on an "Origin-Destination" basis) may differ substantially from the underlying PWC demand represented in the Base Matrices. It is the essential function of the logistics model to serve as the **interface** between the Base Matrices and the modal O-D matrices which can be directly assigned to the networks. In this respect, it should be noted that the word "mode" is being used in quite a wide sense, and includes questions of vehicle type and cargo units, as well as the more conventional differences between road, rail, sea and air.

“Thus, the logistics model takes the estimate of demand for freight transport between municipalities as represented by the Base Matrices, splits it up into appropriate consignments, and for each such consignment chooses an appropriate “logistic chain” – either direct, or making use of a number of intermediate loading/unloading locations. As a result of these choices, “modes” are chosen for the individual “legs” of the chain, and this allows the Base Matrices to be transformed into a series of modal O-D matrices. It is also possible, at this stage, to take the output O-D road matrices by vehicle type, and disaggregate them further by more detailed zones. Procedures have been developed for doing this, and it is intended to make them, as far as possible, compatible with the allocation of flows between municipalities to representative firms (Step A …).

“The choice of consignment size and of mode and logistic chain is decided on the basis of the total logistics cost (G), which consists of the following elements:

- order costs (O);
- (pure) transport costs (X);
- transshipment costs (J);
- cost of deterioration and damage during transit (D);
- capital goods of goods during transit (Y);
- inventory costs (storage costs) (I);
- capital costs of inventory (K);
- stockout costs (Z).

“The choice of consignment size, for a given level of demand, implies a **frequency**, so that there is a trade-off between delay in meeting the demand and the possibility of realising economies of scale in transport by moving larger consignments. Whatever consignment size is chosen, the total (annual) demand must be met. The transport (and other) costs will depend on the consignment size, and this will also influence the range of modes (including vehicle size etc) that is available. Thus it is necessary to model the complex interconnections between consignment size and mode and logistics chain.”

Because of the way that the order costs have been defined, it is implicit that this cost relates to the total **annual demand** between an appropriate pair of firms (m in r, n in s).

If we begin by ignoring the transport chain complications, we have proposed that the basic costs, as a function of shipment size q, can be written:

$$G^{rskmn}_q = O^k_q + T^{rsk}_q + D^k + Y^{rsk} + I^k_q + K^k_q + Z^{rsk}_q \qquad (1')$$

In this equation, the “pure transport” costs X and the transhipment costs J have been combined into a single term T.

Note that, while it has not been so notated, **all** the items on the RHS are implicitly functions of q (though it is unclear in the case of D how this will be dealt with): in some cases, the relationship is via t^{rs}, the transport time, which is dependent on the shipment size.

We will now consider the various items one by one. We may note that in D4 §5.3 it is stated :

"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."

Non-Transport costs

The order costs (which we will now write as O^{kmn}_q to make its relation to the mnk demand clear) are assumed to be a function of frequency only, so that

$$O^{kmn}_q = o_k \, . \, (Q^k_{mn} / q^k_{mn}) \qquad \text{(1a from D1: revised)}$$

where:

o : the constant unit cost per order

Q: the annual demand (tonnes per year)

q : the average shipment size.

This assumes that orders are placed **regularly**, with a frequency $f^k_{mn} = Q^k_{mn} / q^k_{mn}$

Note that in D4, it is acknowledged that an order could encompass more than one product. We ignore this complication for the sake of simplicity (and note that it is in any case unclear how it could be used within the model). If used, it would have had an impact on frequencies and lot-sizes through a consolidation effect (reduced shipment sizes for each shipment). For the more mathematical implications, see notes on disaggregation effects, as the effect of multiproduct situations would be analogue. I suggest we keep ignoring this complication, at least for this year's work. I agree.

The order costs are set out in Annex 3 Tables 76 (NO) and 77 (SE): they vary to a very limited extent with the commodity group k. The reason it that they at this stage is estimated on experience as an indication of the level of magnitude. As previously stated, it might be beneficial to gather more empirical data for these cost elements. I think this should be done (but not in the phase 2 contract). Agree. We might gather some more information on this, but not in phase 2.

The key trade-off, which underlies the concept of the "economic order quantity" (EOQ), is that between the cost of placing the orders (which, for a given total demand Q, will increase if a smaller consignment q is ordered), and the costs of holding stock in inventory (which will increase if the consignment size goes up). If we assume, in the first place, that the rate of demand is fixed, and that transport costs are zero are delivery instantaneous, then the only other relevant costs, apart from the order, are those associated with I and K.

The inventory cost I^k_q is defined as the storage or floor space costs, excluding the costs of the safety stock. The unit storage costs w^k depend on the commodity type, though D1 notes that “In practice these are not so much dependent on the weight of the goods (shipment size is measured in weight units), but on their volume.”

The total storage costs also depend on the level of the inventory and therefore on the shipment size q. On average, half the shipment size is stored at any time over the year (assuming constant shipment rates over time). I^k_q then becomes:

$$I^k_q = w^k.(q^k/2) \qquad (1d)$$

In D4, the storage costs are given in units of costs per tonne per year (§5.1). Hence, this term is correctly composed in terms of units. For notational consistency, we will slightly revise this equation to:

$$I^{kmn}_q = w^k.(q^{kmn}/2) \qquad (1d\text{ - revised})$$

The <u>capital costs of inventory</u> K^k_q are defined as the capital costs of the goods during the time the goods are stocked. These are the interest costs on the capital that is tied up in storage, which depend on the average level and value of the inventory (and therefore on shipment size q and commodity type k).

$$K^k_q = i.v^k.(q^k/2) \quad (1e)$$

The rationale here is more or less identical to that for item I, as again on average, half the shipment size is stored at any time over the year. For consistency, we will slightly revise this equation to:

$$K^{kmn}_q = i.v^k.(q^{kmn}/2) \qquad (1e\text{ - revised})$$

In Annex 3 the two items I and K are combined to a single quantity referred to as “Inventory holding cost”: the values are in Tables 76 (NO) and 77 (SE).

If no other costs relating to q are involved, then the optimum consignment size (EOQ) is readily found from the condition:

$$\partial/\partial q\ [O^{kmn}_q + I^{kmn}_q + K^{kmn}_q] = 0$$

which is readily seen to yield:

$$-\quad o_k\ .\ Q^k_{mn} /(q^k_{mn})^2 + [w^k + i.v^k] /2 = 0$$

whence $q^k_{mn} = \sqrt{(\ 2.o_k\ .\ Q^k_{mn} / [w^k + i.v^k]\ )}$

The <u>costs of deterioration or damage during the trip</u> was notated as D^k in Deliverable 1, and given as:

$D^k = i.j.g.v^k.Q^k$ (1b)

where:

i: the discount rate (per year)

j: the fraction of the shipment that is lost or damaged

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

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

“Here we are assuming that the carrier will pay the direct damage, but the capital costs on the time to collect the claim are part of the logistics costs of the shipper.”

Note that while the explanation of j relates to the **shipment**, there is no implication that the fraction varies according to shipment size. In that case, Q does not depend on q (or transport costs) and could therefore be dropped. It would of course be possible to develop more functionality – for example, probability of damage could be a function of transit time, and this would be an indirect function of q. I would not do this for the 2006 model. I also agree that we should not include this in the 20o6 model. If there were substantial differences between modes in terms of damage it might have been an idea, but for modern transport I wouldn’t expect this to have any major difference. As for shipment size, any relationship would be hard to find. So again – I agree.

As noted earlier, up to now no estimates of the components contributing to D have been used, though in Chapter 7 it is stated:

“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, which is equivalent to a 5% interest per year and 0.1 years to collect the claim.” We did not use this in determining shipment size or transport chain, but we used it in the cost calculation (for cost outputs to base matrices) at the end. If that is needed for generalised cost to the base matrix that is of course OK, otherwise I agree with your earlier statement on this issue.

The capital cost of the goods during the time the transport takes was notated Y^{rsk} in D1. These costs depend on the transport time compared to a full year and on the value of the goods:

$Y^{rsk} = (i.t_{rs}.v^k.Q^k)/365$ (1c)

Where:

t: the average transport time (in **days**).

In this case, the dependency on q is indirectly through the transport time. For consistency, we will slightly revise this equation to:

$Y^{rskmn} = [i.t_{rs}(q^k{}_{mn}).v^k.Q^k{}_{mn}]/365$ (1c - revised)

For the moment we use the same interest rate as for K (though in practical model estimation a distinction will/may be made). Up till now, this term has not been used, though it would appear that the components of the calculation are available. If capital cost interest is an expression of the cargo owners expected return on alternative investments, it might be that they in fact should be the same. Could include this component in 2006 model (in EOQ and transport chain choice). Yes, we could do this. I can comment further on this in the note regarding cost representation in 2006 model.

There are some important questions relating to the specification of t. Even if transport costs were zero, the item Y essentially relates to the time between placing the order (when we may assume that payment is made) and the time that the consignment arrives at its (final) destination, since this is (like the capital costs of inventory) a non-productive period. This suggests that we are not only talking about the actual transit time but all associated delays (loading, intermediate storage, waiting for departure of ships etc., plus allowances for driving time regulations).

It is helpful to illustrate this using a space-time diagram. Initially we confine to the simplest case of direct transport, but below we will amplify this to consider more complex chaining cases.

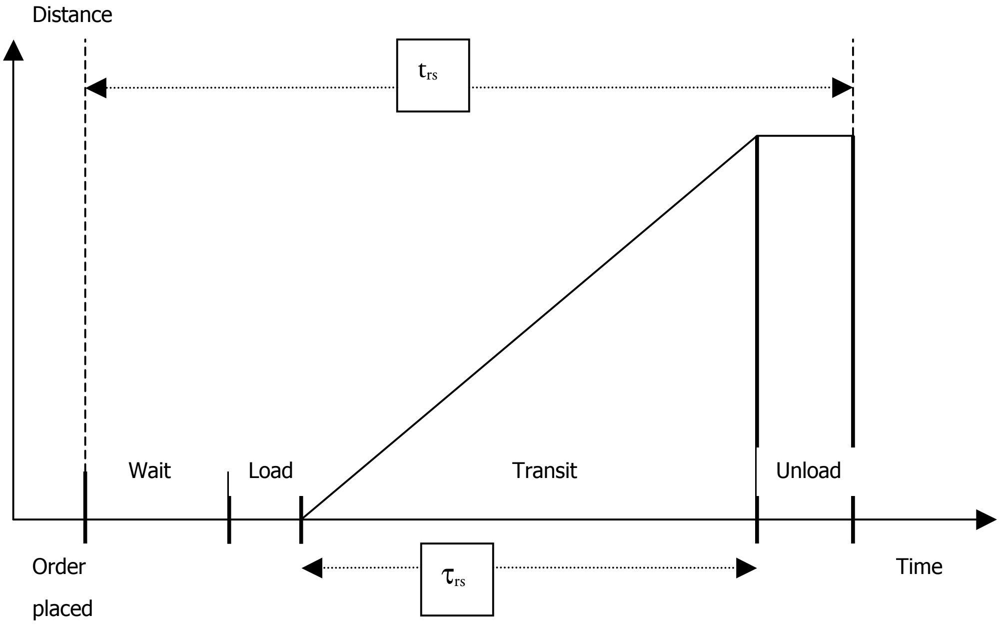


Figure 7 - Space-time diagram for Direct Transport

It will be essential that all the additional elements of time, over and above the “pure” network O-D times τ_{rs}, are included in the calculations. This will need to be spelled out in detail. In particular, the item “wait” in the diagram could relate to the frequency with which particular forms of transport depart, or the time needed to position a vehicle. At present, it appears that no information on frequency is available: quite apart from the correct allocation of time, it is also necessary that the frequency of **consignments** is conformable with the frequency of vessels etc, to avoid the conflict of frequent deliveries choosing routes with infrequent sailings etc.

If neither the **total** annual transport costs nor the total travel time (tonne-hours) are a function of the consignment size, in other words if

$$(Q^{k}_{mn} / q^{k}_{mn}).C(q^{k}_{mn}) = \text{constant}\ \forall\ q^{k}_{mn}$$

and

$$(Q^{k}_{mn} / q^{k}_{mn}).\ [q^{k}_{mn}.\ t_{rs}(q^{k}_{mn})] = \text{constant}\ \forall\ q^{k}_{mn}$$

where $C(q^{k}_{mn})$ denotes the transport cost of a single consignment q, then neither the transport costs T not the transit capital costs Y will not affect the optimum consignment size, and the joint optimum of choice of consignment size and choice of transport can be decomposed. However, if there are economies of scale relating either to unit cost or time, this is no longer the case.

Aside from an explicit consideration of transport costs, we have now dealt with all items apart from those relating to **uncertainty**. Here essentially two components have been identified – variations in the rate of demand, and variations in the time taken between order and delivery. Both these can in principle be dealt with by the concept of “safety stock”, implying that an additional “buffer” inventory needs to be kept, necessitating a further addition to the quantity which drives the “inventory holding cost” (I and K).

So far, this has not been very clearly specified. In principle, given the probability distributions of the demand rate and the (total) transit time, together with the associated costs of a) holding additional stock and b) not being able to service demand, it should be possible to calculate the optimum “buffer” (presumably based on minimising expected costs).

The additional cost associated with this buffer is described as the <u>stockout costs</u> Z^{rsk}_{q}, defined as the cost of being out of stock, which depends on the type of good. For a retailer, these are the costs of loss of sale. For a manufacturer these are the costs of disruptions in the production process. In both cases the annual costs of stockout depend on the risk of being out of stock during a reorder period and the costs of a stockout. The risk can be selected by the management by choosing a level for the safety stock (the higher the safety stock the lower the risk of stockout). The reasons for stockout stem from uncertainty in the demand for the good and in the transport service. There is a trade-off between the costs of storing and carrying safety stock on the one hand and the stockout costs on the other hand.

Originally, the formulation, as presented in (Eq 1f) in D1, was based on a seminal paper by Baumol and Vinod (1970), who assume a Poisson distribution for demand, and derive the safety stock b as:

$$b_{rsk} = a_k.((u_k+t_{rs}).Q_k)^{½} \quad (1f)$$

Where:

Q: total annual demand (product units transported)

u: the average time between shipments, in years ($u = 1/f = q/Q$)

t: average transport time per shipment, in years

a: a constant to set the safety stock in such a way that there is some fixed probability of not

running out of stock

u is the possible delay when an order just misses a shipment, and t is the (unavoidable) delay in transport.

Therefore u+t is the maximal delay is filling an order, and (u+t).Q is an estimate of the

unsatisfied demand during this period of delay. The safety stock cost is simply :

$$Z_{rskq} = (w_k+i.v_k).b_{krs} = (w_k+i.v_k).a_k((u_k+t_{rs}).Q_k)^{½} \quad (1g)$$

Where:

w: again is the storage costs per unit per year.

If transport time is reduced or increased, the shipper will be affected through the carrying costs of the “inventory on wheels” (Y) and the size of the safety stock. If the transport rates decrease with shipment size (economies of scale in transport), there is a trade-off between lower transport costs, ordering costs, and costs of the safety stock on the one hand, and higher warehousing costs on the other hand. The problem with using the Poison distribution is that it would normally only hold for low frequency items, which do not constitute the major parts of the material flows. See also technical notes in the report.

The formula has been changed from what was presented in D1, and is now given as follows in §3.4.1 of D4:

(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

This formula appears to be due to Silver & Peterson (1985)[1], though this should be confirmed. The formula is a standard formulation for safety stocks, which may be found in many textbooks in the field. See for example Stock and Lamberts Strategic Logistics Management (4.ed 2002; first ed. 1982); Chaper and Meindel Supply Chain Management 2004, Grønland Logistikk og Materialadministrasjon 1992. In addition, more explanation should be provided of the derivation, as the following text from D4 is not very clear:

"The expression under the square root is the variance in the inventory level, at the end of a replenishment cycle. The first contribution is the variance caused 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 (covariance between lead time and demand is normally disregarded)." The explanation may perhaps be a little popular, the basic idea is that it is derived from the properties in the Normal distribution, taking into account that both lead-times and demand are (independent) normally distributed. It can be extended to cover situations with co-variances, but this is a complication beyond our scope. The calculation is based on service level as CSL ("Cycle Service Level"). If instead using fill rates, additional calculations will be needed as outlined in a technical note in the report.

In particular, it needs to be clarified whether what is notated as LT is the same as t_{rs}, and whether the change in the formula results merely from a change in the assumption of the underlying distributions (from Poisson to Normal), or from other considerations as well. It is currently unclear to what extent this term also is potentially dependent on the transport possibilities. I think we can say that LT is the same as the t_{rs} in the figures in this note. Strictly speaking, there is a distinction between lead-time (LT(and transit time (t_{rs}), as the first one would also include administrative lead-time, time for loading/unloading etc. As the safety stock does not enter into the optimisation, but could be an input to the final cost calculation, we should perhaps skip administrative lead-time, but otherwise include the total time from sender to receiver, including transfer times and loading/unloading times.(In real-life calculation, also administrative lead-time is taken into account, but we don't know have data for this).

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[1] Decision systems for inventory management and production planning. New York: Wiley.

Having said this, we note that this item is not currently included in the logistics cost calculation. The reason for this being that these cost are independent of the shipment sizes, one major difference between the high frequency and the low frequency case.

Transport costs

We now turn to the most difficult item – the transport costs. The possible mode combinations for transport chains are given in Tables 26 (SE) and 27 (NO) in D4. Note that throughout this section we are talking about the costs for a given consignment q: this means that they will need to be multiplied by the frequency Q/q to bring them to annual costs, consistent with the non-transport items.

We begin with the direct transport case. Even here, we have a choice over three quantities – (strict) mode, which we notate as h, vehicle type (within mode), which we notate as v, and cargo unit, which we notate as g. Note that, at least for the 2005 model, it seems that cargo units have been more or less integrated with vehicle types: it is unclear whether this is intended to be permanent (see Annex A2 for relevant excerpts from D4). Cargo units have been integrated with vehicle/vessel types. I would not mind leaving it like this. What about you? I also think we should leave it as it is (to be commented further in separate note).

In practice, a large number of these choice combinations are ruled out on grounds of "feasibility": we will discuss these in more detail below. In the first place, however, we will aim to give a general account.

The space-time diagram given earlier for the direct case indicates the essential components. As already noted, there is currently no account of "frequency"/waiting time (NB while this most clearly applies to **non-road** modes, it may also be an issue for some of the more specialised road vehicle types). It is important to note that waiting time, or headway, should be used as a **general** indicator of service, as opposed to a literal interpretation of e.g. how soon the lorry arrives before the ferry departs etc. If we make the conventional assumption that waiting time is half the headway (compatible with a random distribution of order times), then it will be necessary to assess what money items within **transport** costs are associated with this waiting time (the capital costs within Y are automatically taken care of by all components which contribute to t_{rs}).

We will expect the network model(s) to deliver the distance d_{rs} and transit time, which we write as τ_{rs}. These will vary by mode and, to a limited extent, by vehicle type. For non-road modes, direct routes will only be available for a small subset of {rs}, and there may be further limitations on the set of vehicle types (eg when some ports are limited in the size of vessels that they can accept We'll try to build this into the 2006 model. Yes. However, the data for this must to a large extent come from the network models(?)). For road modes, it is proposed that only a very limited number of vehicle types need to have explicit routes chosen, mainly to take account of possible weight etc. restrictions on specific links. Generally, we can write these as d_{rshv}, τ_{rshv}: they will be the distances and times between rs along the optimum route (according to some criterion to be defined) for a particular {hv} combination.

It is important to note that for road transport the times will **not** take account of legally imposed rest-times etc. for drivers. Therefore some adjustment is likely to be necessary (another possibility is that there is more than one driver, with consequent implications for cost).

To convert these into vehicle money costs, the times and distances need to be multiplied by the relevant coefficients in Annex 3. The values are differentiated by mode h and vehicle type v. For road vehicles, the costs per distance and time are given in Tables 35 (NO) and 36 (SE): the distance units are in Km, but the time units are not made clear (hours? Please confirm. Yes - confirmed). Writing these as y^d_{hv} and y^t_{hv} respectively, we derive the vehicle operating costs for the direct rs movement as:

$$y^d_{hv}.\ d_{rshv} + y^t_{hv}.\ \tau_{rshv}$$

The corresponding values for y^d_{hv} and y^t_{hv} for the other modes are given as follows:

Sea:	Tables 41 (NO) and 42 (SE)
Rail:	Tables 44 (NO) and 46 (SE)
Air:	Tables 73 (NO) and 74 (SE)

Note that in some cases, costs are given inclusive or exclusive of VAT, and inclusive or exclusive of profit. It is not clear how and when these alternatives will be used. The ones that includes VAT are redundant information, as all calculations are made excl. of VAT.

For road vehicles, some investigations have been made of the impact of weight of load on operating costs. While they do not appear to be very large, Tables 39 (NO) and 40 (SE) indicate the variation between empty and fully loaded vehicles.

Restrictions on feasibility

There are a number of aspects of this. In the first place, of course, there are the network restrictions, whereby there will be no distance and time components for modes (and to a limited extent, vehicle types within modes) which cannot offer a service between r and s. These are implicit in the previous section, and will return an appropriate value for time and distance (approximating to ∞).

Secondly, based on judgment, there are restrictions on the use of certain vehicle types for certain commodities. We will notate these as ϕ_{khv}, and assume that a value of 1 means that vehicle type v within mode h is feasible for commodity k, and a value of 0 means that it is infeasible.

For road, these feasibility matrices are given in Tables 32 (NO) and 33 (SE) [Note: for NO the colour coding red/green seems to comply with the table values na/ok, but this is not the case for SE – is this an error or is something else intended? The colour coding is not explained.]. For sea, the feasibility values are implied by the loading/unloading costs: an entry of “na” means that the vehicle/vessel type is infeasible. The values are given in

Tables 43 (NO) and 44 (SE). For rail, the feasibility for NO is given in Table 45, but there is no corresponding table for SE. SEG, can you add this? Yes – a can add this in update for cost models, or earlier if this is needed. For air, there is no direct indication of feasibility SEG, need to add? I am a little bit unsure, but perhaps it would be a good thing. There are some limitations towards what cargo can be taken on air, for safety reasons as well as for technical and economical reasons. The latter (for example excluding bulk) might also be included for reduction of unnecessary options, though Tables 67 (NO) and 68 (SE) imply restrictions on the **transfer** between certain kinds of road vehicles and cargo planes. For Sweden (table 33), the colouring is wrong, but the values are right (a slight misprint).

Thirdly, there will be restrictions based on the capacity of the vehicle type (in tonnes), so that smaller vehicles will be ruled out if the consignment exceeds their capacity. For road vehicles, the capacities are given in Tables 35 (NO) and 36 (SE): note that in some cases, the maximum is explicit, and in some cases both maximum and average are given, for reasons which are not clear. The reason is that this is an appendix, based on a working document, and has not been completely rinsed of unnecessary information. The max capacity is the interesting number, but if someone should have a need outside the model to calculate average cost in certain situations, average tonnage may come handy. Units are presumably in tonnes Yes. For sea, the capacity is not given explicitly, but Tables 41 (NO) and 42 (SE) give the vessel size in terms of "deadweight" (DWT) tonnes, and the definition is: "DWT is the ship's total carriage capacity of cargo, bunker, fresh water, stores and crew, defined normally for loading to summer freeboard." For rail, it is noted: "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." Nothing is said about airfreight capacity I've seen max loads in the report for air. Yes that is correct – capacity numbers are in there.

For vessels, max tonnage is not far from the DWT, and it may be approximated from this. For trains, the max capacity will also be dependent on the link, and can not be given as one simple number. (But should of course be taken into consideration in the further modelling). For air, the numbers for max capacity should of course be added.

Based on this information, it is not clear how the capacity restrictions will be applied in practice.

The final aspect of feasibility relates to the frequency, and this has been discussed above.

Other costs associated with transport

Loading and Unloading costs are described separately for each vehicle type within mode. For road, Tables 37 (NO) and 38 (SE) give a direct cost per tonne (independent of commodity) plus a loading time per tonne (in hours), which is multiplied by a cost per hour for the transport. Taken together, these appear to give the "Adjusted cost per ton" column. To explain (and this goes for all vehicles): The adjusted cost per tonn is the direct loading cost per ton + (vehicle cost per hour / loading time per ton). So this cost already contains the time cost for the vehicle and further calculations of time for terminal operations of the vehicle should not be done. (However, if one chooses in the further modelling, this can of course be arranged differently in 2006.)

It would seem appropriate I think we should do this in the 2006 model – I think we should discuss this a little bit. At present, the time (and time cost for vehicle) for the direct loading and unloading is included in the loading/unloading cost, as well as in the transfer costs. The part missing is the time cost for the cargo (capital cost) which is commented elsewhere. If the loading/unloading time went into the time calculation for the vehicle, we would have to adjust the cost for loading to deduct this part (which we of course could do). The part not included so far is only the time cost for the cargo itself. to include the implied hours for loading/unloading within the overall calculation of t_{rs}, thus adding it to the pure transport time τ_{rshv}, though it is not clear whether this is being proposed. It would seem that both this time and the associated costs must be calculated **twice**, once for loading and once for unloading. Note in addition that, on the assumption that the time-dependent costs in Tables 35 and 36 are on a per **hour** basis,, it is not clear why they do not agree with the "Cost per hour, transport means" data in Tables 37 and 38. [For example, for NO LGV costs from Table 37 are given as 365, and these are described as "Incl. profit and ex. VAT". In Table 35 the "time-dependent" cost for LGV, also described as "ex. VAT, incl. profit", is 383.66.] Good point. The numbers in table 37 are from a previous version and by some slip were not updated in the report (same also applies for the Swedish numbers). They will be updated together with an update of the direct cost (see previous e-mail distributing new terminal cost. However, it might be needed with a further refreshment here.

Not entirely clearly, it is stated in Annex 3:

"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."

This seems to imply that the additional costs should be added to the loading/unloading costs when containers are used. It is also implied that the term "loading/unloading" only applies at the start and end point of the consignment (P/C basis). In transfer costing, the stuffing and stripping is included when appropriate.

For sea transport, it is stated that "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." Tables 43 (NO) and 44 (SE) appear also to give the hours per tonne (reciprocal of "Loading capacity per hour") and multiply it by a (loading) cost per hour. To this must also be added the hire cost for the vessel for the number of hours required. See comments bottom page 11. However, figures are presented which vary by commodity group, and the derivation of these is not clear – neither is the row of italicised numbers immediately below the commodity numbers. The italics are cargo dependent port costs. The derivation of the cargo dependent numbers are a combination of direct loading cost for a given vessel type and the cargo dependent port costs.

Once again, it would seem that the loading time needs to be explicitly calculated and added to the "pure" transport time, once for loading and once for unloading. In addition, the same remarks apply to stuffing and stripping (?"in the port"). See pervious comments bottom page 11 and bottom page 12.

For rail transport, we again get a loading time (hours per tonne) which can be multiplied by an hourly rate (?for the train). It is however unclear how the final figures (described as "Loading or unloading, kr/ton adjusted") are derived (Tables 44 (NO) and 46 (SE)). See pervious comments bottom page 11

For air, a "loading cost per ton" is provided (Tables 73 (NO) and 74 (SE)), but no indication of the time to load is given. See pervious comments bottom page 11. The indication of time is redundant information in all tables where it appears, and is only included as an additional piece of information. For the sake of consistency, it might also be included for air.

In addition to the costs of loading and unloading, there are port dues (given in Tables 43 (NO) and 44 (SE), on what appears to be a per tonne basis, but varying with vessel type), cargo dues (which seem to be incorporated in the same Tables, but in a way which is not clear), and for air, start and landing fees (which it is claimed are taken from the network model for the specific airports). See above for port dues. For air, start and landing fees are considered part of the network cost that should be added separately, and it is accordingly not included in this report.

Overall transport costs and times

On the basis of this discussion, it would seem that the transport elements **per consignment** for direct transport can be specified as follows (recall again that these items needs to be scaled up to annual costs for compatibility with the non-transport costs):

Table 26 - Monetary elements

loading/unloading	vary with vehicle size and consignment
stuffing/stripping (where appropriate)	vary with consignment
transport costs	vary with vehicle size, time and distance
port dues (sea transport)	vary with vehicle size
cargo dues (sea transport)	vary with consignment and commodity
start and landing fees (air transport)	see comment above
pilot and fairway dues for ships, infrastructure fees	(not discussed in Annex 3 – since it is a link cost)

Table 27 - Time elements (affecting Y, capital cost of the goods during the time the transport takes)

loading/unloading	vary with vehicle size and consignment
stuffing/stripping (where appropriate)	included in transfer cost when appropriate. Might also be included explicitly in future versions of tables for direct loading and unloading
transport	from network, could vary with vehicle size
waiting time	related to frequency etc. (not currently included) Include in 2006 model, Probably yes
rest time (road transport)	What is meant by this? Time for rest for drivers etc., or remaining time (rest of time) ? The former. We might then add some time elements for this for longer transports. This should then be an addition to the time calculations on an OD basis.

One set of elements that should be added (I will suggest this for the update of the cost model) is also what I would call positioning costs for the vehicle: Moving it from a depot to the first loading point, perhaps also inclusive of some mobilisation cost elements.

Essentially, of all options hv|q, there will be a number which are infeasible, due to:

- no network connection;
- unsuitable for the commodity;
- insufficient capacity;
- inappropriate frequency (not in current model).

For the remaining options, we will expect that given q, the best option (for direct transport) will usually be the smallest vehicle type (within mode) which has sufficient capacity. It would therefore be extremely interesting to see (on an illustrative basis, for a small number of rs pairs and commodities) what **total** costs are predicted for the combinations of hv and q, both in order to ensure that realistic vehicle choices are being made, **and** to see how the economies of scale are likely to affect the choice of consignment size.

Note that on this basis it might be possible to optimise the consignment size based on **direct** transport only: given the consignment size q, it might then be possible to consider how the transport costs **and** the capital cost of the goods during the time the transport takes (Y) could be reduced by the use of transport chains, to which we now turn.

Transport chains

The identified transport chains are set out in Annex A1, below. In what follows, we try to make the general case, using two "legs" as an illustration. We assume the transfer point is t, and we develop the space-time diagram accordingly:

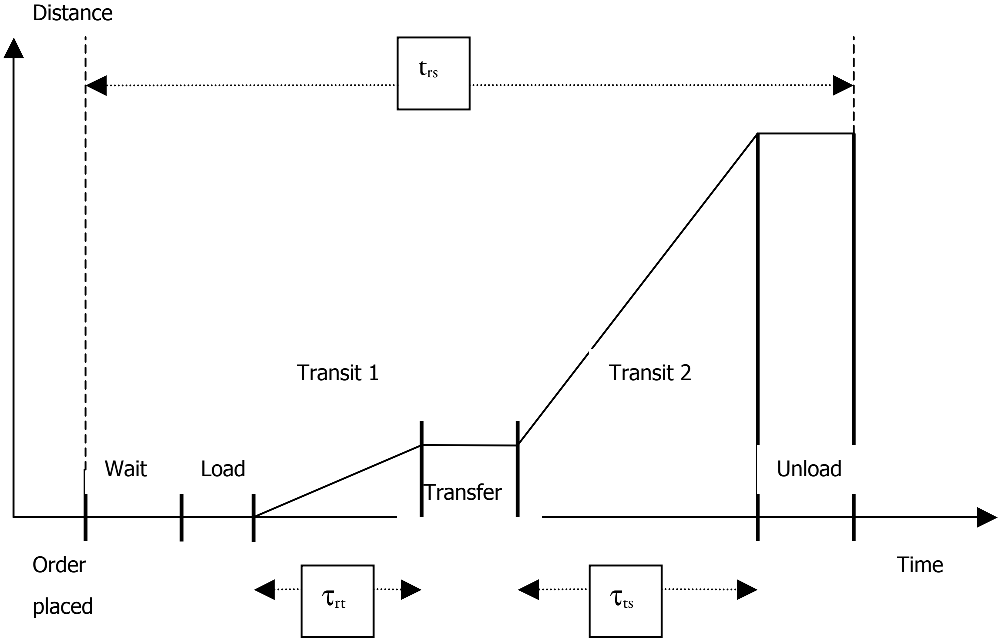

Figure 8 - Illustrative Space-time diagram for non-Direct Transport

The chief modification is the transfer costs (and associated time). The costs are dealt with in some detail in Annex 3, according to the modes involved.

The following text from Annex 3 is important:

"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.

It is not clear **why** using pattern 2 for sea-road and rail-sea "does not imply that there are no direct transfers between vehicles of different modes". ." What is meant, perhaps expressed somewhat awkwardly, is that although the model will base itself on indirect transfer for the described situation, this does not exclude that we could find the more efficient direct transfers in some practical situations. In addition, a little more information on the calculation relating to the "vehicles involved" would be helpful. It is assumed that no "frequency" effect is taken into account, though this could be related to the storage element. That is right. That must be handled in other parts of the calculations.

"Direct" road-to-road transfer costs are given in Tables 47 (NO) and 48 (SE), and "Indirect" road-to-road transfer costs are given in Tables 49 (NO) and 50 (SE). These vary according to the combination of vehicle types (vv′) – many being judged infeasible. The units are not clear – are they per tonne? Yes A "colour coding" is used to indicate whether the transfer cost includes stuffing and stripping – presumably when no colour is given (as for NO in Table 47), it does not? Yes

For NO, the feasible combinations for Indirect transfer are somewhat more than for Direct, which seems sensible, and where both are possible, the indirect costs are always higher. For SE, the feasible combinations seem to be the same for both direct and indirect transfer, and in some cases the indirect transfer costs are **lower** than the direct costs (e.g. Articulated semi-trailer/Heavy distribution container: direct 202, indirect 140). This difference between NO and SE requires more explanation. The reason is that the headings for the two tables are mixed up in the edit. (See also the revised spreadsheets sent out) In the prototype model we used only the indirect (normal) road-road transfer costs. I think we should keep it that way unless someone comes up with special chains where direct transfer is obviously the case.

No indication is given of the **time** required, either for he transfer operation or for storage in the indirect case. Of course this may be added, it follows directly from the time data in the loading and unloading cost per vehicle. NB: As for loading and unloading, also the transfer cost includes the time cost for the vehicles involved.

For (indirect) sea-sea transfers the costs are given, according to the combination of vehicle types (vv′), in Tables 52 (NO) and 54 (SE). Again, the units are unclear. Stuffing and stripping of containers is allowed for. No explicit non-feasibility is given, but this time the matrix (vv′) is partitioned between broad categories which appear to be:

- general cargo and containers;
- crude oil tankers;
- reefers;
- dry bulk;
- product tankers;
- chemicals;
- LNG.

and no allowance is made for transfers **between** these categories. In addition, a commodity-specific cost is given (again, units unclear) in Tables 51 (NO) and 53 (SE).

Again, no indication given of the **time** required, either for the transfer operation or for storage. In this case, it seems reasonable that the storage time should be related to the frequency of the second vessel. Storage considerations is in another part of the calculations. But intermediate storage time (not at receiver), is that included? Not so far. But I think we should include this in the 2006 model.

For rail-rail transfers, costs (again, with no units stated) are given in Tables 55 (NO) and 56 (SE). No indication of time is given.

For road-sea transfers, costs are given on a (vv′) basis (with many being infeasible) in Tables 58 (NO) and 60 (SE), plus a commodity-specific “add-on” in Tables 57 (NO) and 59 (SE). Stuffing and stripping of containers is allowed for. The same comments about units and times apply. Presumably the costs are intended to apply in both directions – i.e. road-sea **and** sea-road? Yes

Road-rail transfer costs are given on a (vv′) basis in Tables 61 (NO) and 62 (SE): the same comments about direction, units and times apply. See previous comments.

For sea-rail transfers, costs are given on a (vv′) basis (with many being infeasible) in Tables 64 (NO) and 66 (SE), plus a commodity-specific “add-on” in Tables 63 (NO) and 65 (SE). Stuffing and stripping of containers is **not** discussed. The same comments about direction, units and times apply. See previous comments.

Road-air transfers costs (again, with no units stated) are given in Tables 67 (NO) and 68 (SE). Stuffing and stripping of containers is allowed for. No indication of time is given. It must be assumed that the costs apply in both directions.

No transfer costs are given for the mode combinations rail-air, sea-air and air-air. While this seems reasonable in the first two cases, it might be thought necessary for air-air transfers?

Ferries

Annex 3 notes that there are two ways in which ferries could be treated. "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."

It is not entirely clear what this means, however. The question seems to be whether the ferry is already included as a "link" in the network of another mode (think not-"not" is also the assumption used for the cost model), and this will need to be clarified. What is meant is the following: One could either calculate the cost for the ferry only, and then in the model add this together with the time cost for the vehicle on board. Or, one could add this cost explicitly before entering them into the model. In the tables shown, the last alternative is chosen.

In the case of road ferries, costs are given on a per Km, per hour **and** per tonne basis (Table 69 for NO), separately for each road vehicle type, and it is stated that the costs are the **combined** costs of the road vehicle and the ferry. This will need to be set out carefully in terms of the network quantities.

For international ferries, costs are given as Kr/Km and Kr/hour, again the **combined** costs of the road vehicle and the ferry, separately for each road vehicle type (Tables 70 (NO) and 71 (SE)). It does not seem that there is any allowance for loading the ferry or waiting. It is noted that in some cases there may be restrictions on the allowable commodities. This is based on previous work by TØI. When referring to restrictions on cargo, this may for example apply to dangerous goods.

Finally for rail ferries, separately for each vehicle type, costs are given as Kr/Km and Kr/hour, again the **combined** costs of the train and the ferry (Table 72 for SE).

While it seems that international ferries can be effectively dealt with as a variant of road-sea chains, it is less clear what should be done about the other two types of ferries.

Consolidation

On the basis of the remarks above in respect of direct transport, it would seem unlikely, on a single consignment basis, that costs could ever be reduced by a transport chain (except where no direct transport is possible, or where the direct land connection is extremely circuitous). Well – you might find examples where for example a road – sea – road combination may give lower cost than a direct road transport, for example for a large quantity shipment. Thus the whole basis of transport chains seems to depend on the possibility for **sharing costs** between different consignments. This is clearly acknowledged in D4: §5.3 [emphasis added]:

"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[2]. We are assuming that for legs directly from a sending firm, there are no possibilities for consolidating this flow with other goods[3]. 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 (usually 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 smaller vehicles. This is usually not correct however, because in most cases the different consolidated shipments in the larger vehicle 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

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[2] **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.**

[3] 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).

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-road 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 Report D4 does not appear to indicate how the costs of consolidated transport are allocated among the constituent consignments, though in discussion it appeared that this were done *pro rata* by weight, based on the 90% capacity rule quoted above True. We should certainly look more into the mechanisms for consolidation (see separate note for this). A 90% assumptions valid for all goods regardless of total volumes etc. is too simplistic, and we must refine this. This appears to mean that if the vehicle cost is Z, say, and its capacity is 100 tonnes, then a 10 tonne consignment will be assigned 10/90 of the vehicle cost.

This is done without any knowledge of whether a full (90%) load can actually be made up, or of the time taken to consolidate the load. At the least, it might be necessary to develop some formula to indicate the "waiting time", perhaps as a function of the proportion of the consignment to the vehicle capacity, so that smaller consignments take longer to "find partners". I agree this is the biggest problem. Consolidation can also depend on the number of vehicles/vessels for each vehicle/vessel types that is available in the country as a whole (and maximum vessel size of the port). Agree. See also previous comment.

What is certainly clear is that this is a key topic for further discussion, and while the current assumptions can be accepted for the initial (2005) version, they are not obviously satisfactory for the final model.

While the choice of the **location** of transfer points remains a difficult issue, the treatment of consolidation is, if anything, more important. It would therefore, again, be very useful to have an illustration, for a small number of rs pairs and commodities, of what consignment costs are predicted for the candidate chains, compared with the direct transport costs, in order to ensure that realistic choices are being made. We'll work on this. Yes!

Annex A1 Transport chains

Table 28 - 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 29 - 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

Annex A2 Discussion of Cargo Units from D4

Table 30 - 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 31 - 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 32 - 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.

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.

Annex B Potential consolidation groups for cargo

The following tables need to be interpreted as follows:

Commodity 41 for Norway can be consolidated with 51, .., but 12 can only be consolidated with 12.

Table 33 - Consolidation groups for Norway

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

Table 34 - Consolidation groups for Sweden

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