The Specification of Logistics in the Norwegian and Swedish National Freight Model Systems

Model scope, structure and implementation 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 Solving International, Solving Bohlin & Strömberg and Michael Florian of INRO Canada, has produced a specification of a logistics model 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). This report contains the outcomes of a project to specify how a new logistics module for these model systems could look like. It includes both the scope and structure of a logistics model, as well as an implementation plan.

This final 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.

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Glossary

a	a constant to set the safety stock in such a way that there is some fixed probability of not running out of stock
α	parameter to be estimated
b	safety stock
base matrices	P/C matrices or PWC matrices
β	parameter to be estimated.
BTO	build to order
C	consumption (of commodities), including retail and further processing of raw materials and intermediate products
c	consolidation centre
CAPS Supply Chain Designer	commercial software package for strategic logistics analysis
CBA	cost benefit analysis
centroid	centre of gravity of a zone
CFAR	Swedish Business Register
CFS	Commodity Flow Survey (Swedish data set).
Consolidation centre	a location where goods are transhipped and possibly stored, usually located in the vicinity of the production location. Small loads get in from the production locations and larger loads get out.
CT	commercial transport
D	cost of deterioration and damage during transit
d	distribution centre
DC	distribution centre
δ	reorder point
DISTRA	model to be developed for urban freight transport in Sweden
Distribution centre	a location where goods are transhipped and possibly stored, usually in the vicinity of the consumption location. Large loads get in and small loads get out to the consumption locations. In practice the same physical location could serve as a consolidation and distribution centre (for flows in opposite directions).
d_{rs}	distance between r and s (as in a spatial interaction model)
ε	random cost components
EDC	European distribution centre
EOQ	economic order quantity
EU	European Union

Eurostat	European statistical office
f	frequency
FT	freight terminal
FTL	full truck load
G	total annual logistics costs
g	average period to collect a claim (in years)
γ	parameter to be estimated
gravity model	model for interaction between regions, using analogy with gravitation
h	transport mode (can encompass vehicle type and loading unit)
$H(t_d-t_a)$	production costs depending on the time duration available for production
Handling category	the physical way in which the goods are handled during transport (e.g. liquid bulk, unitised).
I	inventory (storage or floorspace) cost, excluding the costs of the safety stock
i	(implied) discount rate (per year)
I/O	input-output
IPF	Iterative Proportional Fitting
IVP	detailed production statistics (Sweden)
j	fraction of the shipment that is lost or damaged
J	consolidation costs
K	capital costs of the goods during the time the goods are stocked
k	commodity group
l	domestic airport
L	available airports
λ	lead time
Lead time	time between placing the order and delivery.
Load	the quantity of goods that is on board of a vehicle (could consist of several small consolidated shipments, could also be only a part of a large shipment).
Loading unit	the unit in which the goods are kept during transport (e.g. containers).
logit model	specific type of model for discrete choice (e.g. mode choice)
loglikelihood value	optimisation and test criterion in particular statistical estimation method (maximum likelihood)
logsum	expected utility from lower level choice
LTL	less-than-truckload
m	firm
M	distribution costs
M_{rs}	flows in tonnes
MMNL	mixed multinomial logit
MNL	multinomial logit
Monte Carlo (MC) simulation	representation method using random draws from a statistical distribution
n	firm

NACE	international commodity classification
NDC	National distribution centre
NEMO	Norwegian national freight transport model system
NL	nested logit
NSTR codes	international commodity classification
NTP	national transport plan (Norway)
NUTS2	European zoning system
O	order costs
o	the constant unit cost per order
OD	origin-destination (matrices)
OD matrix	origin-destination table of goods flows from:
	· Production locations directly to consumption locations
	· Production locations to consolidation centres
	· Consolidation centres to distribution centres
	· Distribution centres to consumption locations
	· Production locations to distribution centres
	· Consolidation centres to consumption centres
P	production (of commodities)
p	domestic port
P(E / s)	probability that a vehicle does not get cargo, given that s has been selected as the next destination of the tour
P(E)	probability of returning empty
P/C	production-consumption (matrices)
P/C matrix	table of goods flows between production and consumption locations (=retailers and producers processing raw materials and intermediate products).
PARAGON	commercial software package for logistics operations
π	profit of the shipper
PINGO	spatial computable general equilibrium model for Norway
PWC matrix	production, wholesale, consumption matrix
PWC matrix	table of goods flows between production locations, wholesalers and consumption locations.
Q	the annual demand (tonnes per year)
q	shipment size
r	location (zone)
$R(t_d+t)$	revenue depending on the arrival time of the goods at the destination
R’t	sensitivity of the client to the product delivery schedule
rAps	regional economic data source in Sweden
RDC	regional distribution centre
RFID	Radio Frequency Identification
s	location (zone)
Samgods	Swedish national freight transport model system.

Samkalk	cost-benefit procedure in Sweden
SAMPERS	Swedish national passenger transport model system.
SCB	Statistics Sweden
SCENES	a transport model (passengers and freight) for Europe
SEK	Swedish Crowns
Shipment	a certain quantity of a good that is ordered and delivered at the same time.
SKU	stock-keeping unit
SLAM	SCENES logistics appended module
SMILE	freight transport and logistics model for The Netherlands
SNI	international sector classification
SP	stated preference
STAN	network software program for freight transport, currently used in NEMO and Samgods
STAN99	a version of the above
T	transport, consolidation and distribution costs
t	transport time
t_a	arrival time
t_d	departure time
TEU	twenty foot equivalent units
$T^i(t_a)$	transport cost for the input
$T^{i'}$ and $T^{o'}$	sensitivity of the production and logistic process to duration
TLUMIP	transport and land use model for Portland, Oregon
$T^o(t)$	transport cost for the output
Transhipment location	a location where goods are transhipped from one mode to another, without a change in the vehicle loads. This term is redundant and can be incorporated in the definition of consolidation and distribution centre.
TSP	travelling salesman problem
u	average time between shipments, in years (u = 1/f = q/Q)
U	utility derived from logistic and transport choices
v	value of the goods that are transported (per tonne)
VMI	vendor managed inventories
VoT	value of time
W	wholesale
w	storage costs per unit per year
X	pure transport costs
x	foreign airport
x_{sr}	loaded trips from s to r

CHAPTER 1 Introduction

1.1 Background and objectives of the project

The Swedish national freight model system (Samgods model) and its Norwegian counterpart NEMO are used for simulating development in goods transport in the short run (representation of the base year, transport policy simulations) as well as the long run (forecasting for scenarios, providing input for the assessment of infrastructure projects).

Both model systems are almost completely based on concepts and considerations different from logistics thinking. The same can be said about almost every regional, national or international freight transport model in the world. Exceptions are the SMILE model for The Netherlands (Tavasszy et al, 1998) and the European SCENES Logistics Appended Module (SCENES consortium, 2001), that include aggregate, but highly segmented, components for the use of distribution centres and the Portland TLUMIP model (PbConsult, 2002), that heavily relies on Monte Carlo simulation to reproduce observed distributions on the outcomes (disaggregate, but largely descriptive modelling).

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

Subsequently, three pre-studies were carried out, one on a logistics module for Samgods (TFK et al., 2002), another one on spatial computable general equilibrium models for goods flows (WSP et al., 2002) and one on the modelling of local/regional distribution and collection traffic (Inregia et al., 2003).

In Norway a process to update and improve the existing national freight model system NEMO has started as well. The Work Group for transport analysis in the Norwegian national transport plan has now, jointly with the Samgods group in Sweden, requested RAND Europe with a number of subcontractors to carry out a research project on specifying a logistics model and how this could be implemented in NEMO and Samgods.

RAND Europe is doing this work together with Solving International, Solving Bohlin & Strömberg and Michael Florian of INRO, Canada.

The objectives of the project are to provide:

1. The theoretical and methodological specification of the design of a logistics model for the Norwegian and Swedish national freight model systems.
2. The specification of the implementation of a logistics model for the Norwegian and Swedish national freight model systems.

The logistic concept is interpreted in a wide sense as to include transport logistics as well as distribution/inventory logistics.

The principal idea is that the logistics model will read in P/C (production-consumption) matrices and that it will deliver OD (origin-destination) matrices to be assigned in a network model. In this network model different modes will be represented. Choices covered in the logistics model are on the location and use of transport terminals and distribution centres and on the trade-offs between transport frequency/shipment size, vehicle size and keeping inventories. Additionally, the logistics model might cover mode choice. The work on this project has been coordinated with the work in other projects on base matrices (P/C matrices), as carried out by a consortium headed by Inregia at the same time in Sweden (as a separate study), and in Norway (as part of the NEMO update and improvement). The new logistics model will be able to use the P/C matrices, which will gradually be refined, as inputs and will, together with the network model, provide matrices to the base matrix project on the generalised logistic costs between zones and shortest paths.

This project only refers to the first six months of a logistics model development and implementation that would take about three years in total. The task to be completed in these first six months is the specification of the logistics model, both in terms of model structure and the envisaged implementation.

1.2 Contents of this report

This project consisted of three phases:

- Phase I: Recommendations on the scope of the logistics model;
- Phase II: Design of a model structure for the logistics model;
- Phase III: Design of the model implementation.

This final report provides the outcomes of all three phases. The scope of the logistics model is discussed in chapter 2. Chapter 3 contains our ideas on the model structure. The results on the design of the model implementation are in chapter 4. Finally, chapter 5 contains a summary and conclusions.

Annex 1 contains information on one of the most popular logistics modelling packages for private firms, the CAPS Supply Chain Designer. To find out more about the actual use of distribution centres and freight terminals in Sweden and Norway, Solving Bohlin and Strömberg carried out a limited number of interviews with logistics managers of some of the big players, in various sectors. The outcomes of this are reported in Annex 2. Finally, Annex 3 contains the minutes of seven internal project meetings and Annex 4 minutes of discussion with Statistics Sweden and Statistics Norway, for reasons of transparency to the clients of this project.

Just before chapter 1 a glossary with key definitions and symbols used can be found.

CHAPTER 2 Recommendations on the scope of the logistics model

2.1 Introduction

The new logistics model for Samgods and NEMO will be the interface between the P/C matrices and the network model. In the first phase, the boundary lines between these three models that will operate within one model system were drawn. The objective for phase I was to give recommendations on the boundaries between:

- on the one hand the logistics model and the P/C matrices
- on the other hand, the logistics model and the network model,

and to define their interfaces.

The relationship with the P/C matrices is discussed in section 2.2. After that, in section 2.3, several options for a 'division of labour' between the logistics model and the network models in Samgods and NEMO are discussed.

2.2 The logistics model and the P/C matrices

The P/C matrices give the flows in tonnes[1] between the production locations and the consumption locations (in practical applications: producers processing raw materials and semi-finished goods and retailers: the final step from retailer to consumer is handled in the shopping model in the passenger models[2]. The logistics model then serves to determine

[1] It seems likely that matrices in values can be delivered for Norway and Sweden as well. For the logistics model value matrices are not required, but the value-to-weight transformations used in deriving the base matrix could provide useful information about explanatory variables at the commodity level for logistics choices.

[2] Except for home deliveries, which need to be included in the overall passenger plus freight transport model system. We think that the passenger models (e.g. Sampers in Sweden) are the best place to start with when trying to model the impact of changes in the amount of home deliveries, as is being done in the POET project for the EU.

which flows are covered by direct transports from P to C, and which transports will use distribution centres (DC's) and/or freight terminals (FT's), and how the transport chains will be composed if DC's and or FT's are used. Most flows will probably use direct transport (there is no direct evidence for Sweden or Norway, but in the Dutch SMILE model, 44% of the shipments use a DC). Moreover, the DC or FT will sometimes be in the same zone as the P or C.

In Sweden, the specification of new P/C matrices for the base-year is handled in a separate project, carried out by Inregia, VTI and SINTEF. That project has the same timescale as this project on the specification of the logistics model. In Norway, the development of up-to-date P/C matrices is part of the overall responsibilities of the work group for transport analysis in the Norwegian national transport plan, and carried out by their consultants, such as the Institute of Transport Economics (TØI) in Oslo. The following eight points can be made on the boundaries between the new logistics model for Sweden and Norway and the base matrices for the two countries.

1. Zoning system and basic commodity classification

The base matrix project will supply P/C matrices to the logistics model to be split up in different legs. Both the P/C matrices and OD matrices will use municipalities (290 now in Sweden, 435 in Norway), as well as a number of external zones for international transport. Transit traffic will be treated as well. At present the network models distinguish between 12 (Sweden; plus air freight) and 13 (Norway) commodity types, and the P/C matrices are likely to be at least at the same level of detail (but also see the discussion below under point 8). The base matrices will be in tonnes, but it is likely that information in monetary values (Swedish and Norwegian Crowns) can be provided as well. This can be used in the modelling of logistics decisions, since the value of the goods is an important candidate for the explanatory variables.

2. Treatment of ports and airports

Both in Norway and Sweden, the P/C matrices will not include ports and airports. They give the producing or consuming region within foreign countries for imports or exports, together with the domestic consumption or production zone. The logistics model project should therefore treat ports and airports, to include these in the OD matrices. Foreign trade is relatively important for Norway and Sweden and should receive due attention in both the base matrix work and the logistics module. Including ports and airports in this project requires that these be linked to the existing zoning system (based on municipalities in Norway and Sweden), but it is not necessary that all ports and airports be zones themselves. A change in the zoning system (which would have repercussions for all model components) will probably not be worthwhile, and is not proposed here.

3. Intra-zonal transport

The Norwegian and Swedish P/C matrices both treat intra-zonal transport explicitly. So should the OD matrices to be generated by the new logistics model. In the logistics model, intra-zonal transport can be assumed to be direct transport (no consolidation and distribution centres used), by road. The logistics model should then determine shipment size and road vehicle type, in the same way as it handles this for flows between zones.

4. More detail on commodities

For Norway there is the possibility to provide extra detail in terms of the commodity types beyond the 13 categories of the P/C matrices, since these matrices were based on aggregating more detailed commodity data. This aggregation was carried out by Statistics Norway. TØI have detailed information about the freight volume for each commodity group in different trade links, while Statistics Norway have the detailed industry data that can be aggregated into any commodity grouping. The main work here is to make an up-to-date conversion key between the commodity classifications used in different statistics (Hovi, 2004). For Sweden the original idea of Inregia/VTI/SINTEF was to provide a P/C matrix for the 12 commodity types of the present Samgods. But they are open for suggestions for other (more detailed) commodity classifications and their data on production and consumption is more detailed. The Swedish base matrices will probably use the commodity and service classification of the input/output statistics with 57 groups. To get information on specific firms at the P or C end (e.g. the customer requirements), the base matrix projects cannot be used. For Sweden some of this can come from the Commodity Flow Survey. Such a database does not exist for Norway and will not be developed for a logistics model. In chapter 4 we recommend smaller and more focused additional data collection in Sweden and Norway, to be carried out in the coming years.

5. Treatment of the wholesale sector

Two extreme options and a number of intermediate options exist for the treatment of the wholesale sector:

- Incorporate the wholesale (W) in the base matrices by using flows from W as flows from P and flows to W as flows to C. We call this the <u>PWC matrix option</u>.
- Excluding all flows to and from W from the base matrix. We call this the <u>pure P/C matrix option</u>.

In the intermediate options, a part of the W will be included in the base matrices and the remainder will be treated as part of the logistics model. Both extreme options as well as intermediate options, with their pros and cons, are discussed below.

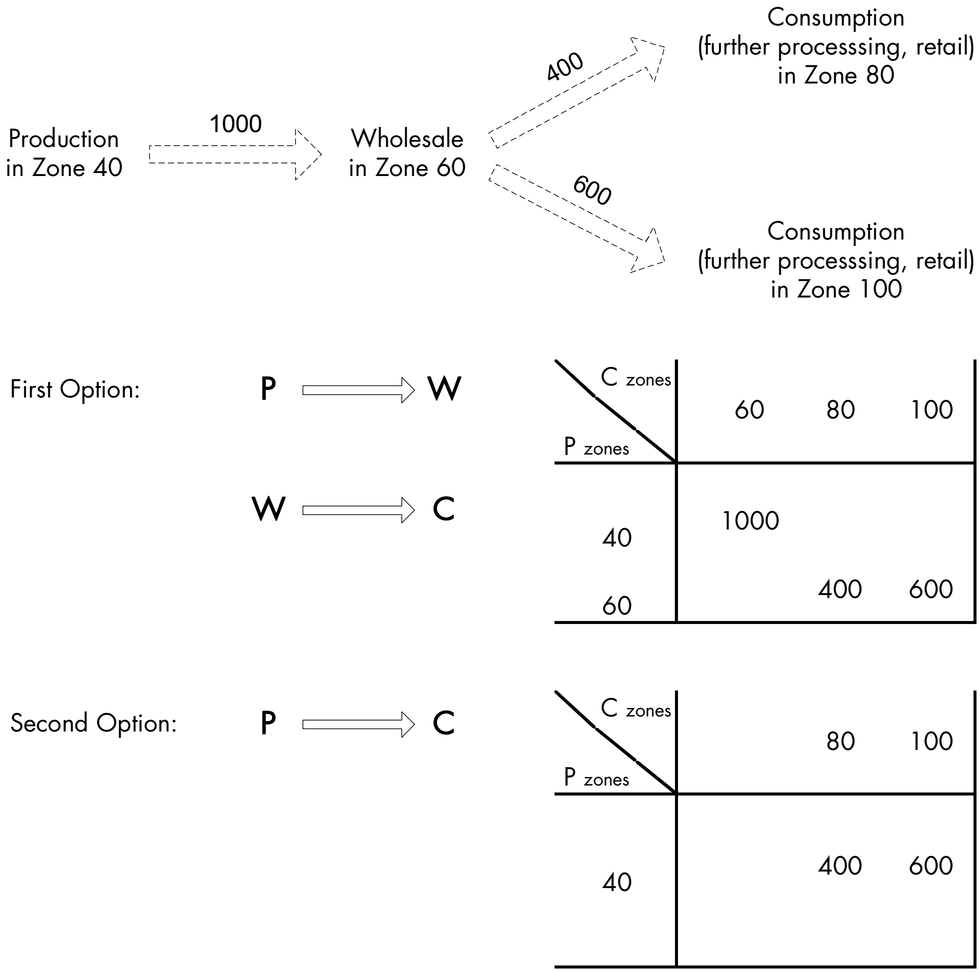

Figure 1 – P/C and P/W/C models

In the pure P/C matrix option, the wholesale sector is regarded as a sector that exclusively, or at least predominantly, performs logistic activities such as consolidation, storage and distribution, activities that are an integral part of the logistics decision-making in the supply chain. These are exactly the decisions that we study in the logistics model (see chapter 3). If the wholesale sector is viewed like this, it is most appropriate to treat the activities of the wholesale sector within the logistics model (see chapter 3). However this does not imply that all logistics decisions are taken by wholesalers; there are also decisions on consolidation, distribution and inventories made by transport firms (carriers), and to some extent also by manufacturers and retailers. For short-run applications, the existing locations of consolidation and distribution centres can be taken as given; in the long run private intermediate locations can be explained by the logistics model (facility location choice).

In the PWC matrix option, the logistics model explains the decisions on inventories consolidation and distribution centres for P/C relations as well as for P/W and W/C relations (maybe with different parameters governing the decisions in these three kinds of flows). The wholesale locations are used as location of the sender and/or receiver. This implies that the choice of these locations (facility location choice) and their use is taken as given in the logistics model. What remains to be explained by the logistics model is the use of consolidation and distribution centre within the P/C, P/W and W/C flows. For a short run model this might not be a problem. In the long run, this implies that the location of wholesale is fixed (unless the base matrix methodology would allow for changes of location in the wholesale), which seems undesirable.

However, there are the following three arguments in favour of using a PWC matrix, at least in the short run:

- It can be questioned whether the wholesale sector can be fully reflected by the consolidation and distribution centres.
- The Swedish commodity flow survey (CFS) includes many shipments that involve wholesale.
- The present Norwegian base matrix is not pure P/C, but PWC.

These arguments are worked out below. The first argument is a definitional problem of a more general nature (would also be relevant to a greater or lesser degree for other countries), the second and third argument are specific for Sweden and Norway.

The wholesale sector is performing more functions/activities besides storing and reselling goods. In addition manufacturing, assembling and packing are increasingly commonplace in the wholesale sector. This leads to increased value added in this sector and gives reason to adjust the modelling to incorporate these functions. This raises both conceptual problems (as discussed above) and data problems (in the economic statistics, all roles of wholesale that add value, are included). According to Inregia (the leader of the base matrix project for Sweden) the supply table in the Swedish National Accounts for the year 2001 shows that the product mix of the wholesale sector consists for 90% (in value terms) of wholesale products (sales of commodities to producers and retailers, packing, assembling). The remaining 10% mainly consists of services, not manufacturing. So at least in Sweden, the wholesale sector does not carry out a significant fraction of manufacturing activities. This could be investigated for Norway as well. Also in Sweden it is still possible that the wholesale sector is heavily involved in packing and assembling, and not only in consolidation and distribution activities. Other sectors (e.g. transport companies, retailers) perform logistics activities as well.

The Swedish commodity flow survey (CFS) includes many shipments that involve wholesale, maybe more than would be the case if it only did consolidation and distribution. If the base matrix were to be pure P/C, then these observations could not be used in building the base matrix (loss of information), or additional assumptions would be needed to use these observations (see the report on the base matrices by the consortium led by Inregia, Inregia et al., 2004).

The present Norwegian base matrix is not pure P/C, but PWC. The Norwegian client will consider building a pure P/C matrix by allocating flows to/from W to P or C if the logistics model project would recommend this. The Norwegian client does not regard the flows between different business links (such as the share of producer to wholesaler transport) in the PWC as very reliable. According to TØI, it is possible to exclude the wholesale sector from both marginals of the Norwegian PWC matrix (Hovi, 2004). The row and column totals (marginals) come from trade data (after conversion from values to tonnes), and the cell values are produced with the help of a gravity model, calibrated on the basis of questionnaire-based OD surveys (origin, destination, costs, commodity) for truck, rail and sea (the latter are rather old). Hovi (2004) remarks that after the exclusion of the wholesalers from the marginals, the gap between the data foundation of the base material and the calibration data (the transport counts) would increase: the quality of the calibration would diminish. However, if the calibration to the traffic data was done before the wholesale is excluded, and the wholesale was excluded from the calibrated PWC matrix, it could be possible to circumvent this problem and derive an initial PWC matrix. After this, the wholesale sector can be removed from the row and column totals and the matrix rebalanced, to get a preliminary P/C matrix for use in the logistics model. Also, the calibration to the traffic counts should be redone after having applied the logistics model, because this is the stage in the transport model where transport chain predictions (OD matrices) become available that can be compared to observed OD information. In any case, this procedure for removing the W from the Norwegian PWC would constitute a considerable amount of extra work. The present procedure in Norway should be seen as a very approximate calibration of the flows (which might get somewhat worse without the W information). But more generally, the final calibration should wait until the logistics model can provide OD information instead of P/C or PWC. This means starting with a provisionally calibrated P/C matrix, then deriving the OD, deriving a new assignment matrix, then going back to the calibration of the P/C model, etc: iterative calibration.

An alternative –but not one we would recommend- would be to develop a logistics model for Sweden that also models the wholesale activities on the basis of a pure P/C matrix and a rather different logistics model for Norway that would accept producer to wholesale relations and wholesale to consumption (i.e. retail) relations as given by the base PWC matrices. Given the amount of inconsistency that would arise between the Swedish and Norwegian logistics model, we find this 'separate ways' alternative for treating the wholesale sector unattractive and advise against it.

It might also be possible to make the wholesale sector partly exogenous (given as part of the PWC) and partly endogenous (in the logistics model). These are the intermediate solutions in which one tries to split the logistics activities of the wholesale sector from the manufacturing-like activities (manufacturing, packing and assembling). The former can then be included in the logistics model, the latter in the base matrices. Maybe the production statistics can give insight into the different activities of wholesale. This depends on the commodity: if the commodity stays the same, it is just consolidation and distribution; if it changes, it becomes P and/or C. But the commodity classification might not be fine enough to discern whether or not there is a change. Even for manufacturers, the output is often in the same commodity group as the input. We see two possible ways to implement an intermediate option:

- <u>Intermediate option A</u>: In some sectors there are complicated series of chains from raw materials to retail. Some steps involve logistics functions (consolidation, distribution), some are production, packaging or assemblage. These need to be split into P/C flows.

The criterion can be value added. For instance if more than 15 or 20% value is added (these numbers are just chosen for illustrative purposes), it is production (and consumption), even if in the data it is classified as wholesale. This cut-off point needs to be determined from the data. This would be easy if the distribution is bimodal: there are many non-producers and many full producers. The base matrix consortium could then make this split.

- Intermediate option B: This P/C versus PWC issue is also related to the level of detail in the commodity classification that we shall use in step B of the logistics model (see chapter 3). Hopefully in step A we can also go to a finer level than 12 or 13 commodities. At the 12/13 level, for many firms incoming and outgoing shipments will belong to the same commodity group. But if in the disaggregation we can go to many (hundreds of) commodities, then input and output will be in different groups and we can also see wholesalers where changes in commodity take place. Then it becomes a matter of coordination with the base matrix project. If a detailed disaggregation by commodity type could be done, flows to and from wholesale can be included in the initial P/C matrix and some fraction of these will then be taken out after the disaggregation step, to get a 'pure' P/C matrix (including production, packaging and assembling activities of wholesale). The locations taken out will then serve as information on consolidation and distribution centres. But note that this option depends on getting a detailed distribution by commodity type.

Our interpretation of the currently available data for carrying out these intermediate options is that it will be very difficult to find data that give a reliable, consistent and sufficiently detailed picture on both the inputs and the outputs of the wholesale sector to apply either one of the intermediate solutions. Maybe in a few years time (e.g. with the CFS 2004/2005 in Sweden) such an analysis would become possible.

In the meantime, we could exclude these options and, therefore, see the choice as one between the two extreme options: P/C or PWC. On conceptual grounds (as discussed above), we prefer to use P/C matrices, but there are definitional, data and model development strategy issues (also discussed above) that lead us to recommend to start with a logistics model that reads in PWC matrices. For applications that do not involve wholesale location choice (representation of the base year, short and medium run policy simulations), the PWC approach is much more practical and still acceptable from a conceptual modelling perspective. For applications where the locations of wholesale activities can be expected to change (medium to long run forecasting), the pure P/C matrix option appears the better option, unless this wholesale location choice can be dealt within the development of future year base matrices (that should also handle the long run issues of relocation of P and C, maybe in a multi-regional input-output or a spatial computable general equilibrium model). A logistics model that uses pure P/C matrices as inputs, will have to provide the PWC flows itself as an intermediate output of the logistics model. In the long run this will be the most desirable option: the wholesale activities and the locations at which these take place would then be explained by the models. Furthermore, this model would provide the linking between the P to W flows and the W to C flows (unlike the PWC option). From a model development perspective however, this seems a risky and possibly over-ambitious option, which is not suitable for making the next modelling step. It is safer to start with a less far reaching logistics model first. Given this line of reasoning, we recommend that a research program be set up, in which PWC matrices are produced first and then combined with a new logistics model for the base year. The next step then would then be further investigation of the possibilities for building pure P/C matrices or performing a split of wholesale activities, for the development of a new model system for long run forecasting.

6. Base year and future years

The base matrix project is by nature limited to the base year (presumably 2001); it will not deal with forecasting for say 2020 or 2030. The logistics model project focuses on developing a mechanism that can provide logistics outcomes (such as OD matrices, modes, vehicles, shipment sizes) from any (present as well as future) given P/C or PWC matrix and set of conditions on the networks. The first base matrix to be taken on board will be the 2001 matrix. There are no projects (yet) for improving other forecasting modules; the Samgods group wanted to start with the present two projects. For the future year trade flows, the existing Samgods (for Sweden) and NEMO and the spatial computable general equilibrium model PINGO (for Norway) will be used.

7. Cost matrices

The logistics model should not only use the P/C matrices as inputs, but should also, together with the network model, provide matrices to the base matrix project on the generalised logistic costs between zones and (generalised) paths. Developments in logistics are not fully exogenous to the transport sector; these decisions depend –among other things- on the transport costs by mode and route, including transhipment costs. From the network models, the logistics model needs at least generalised costs for different paths through the network. The network model will provide the shortest paths through the networks and the corresponding generalised transport costs. The logistics model then should add other logistics costs (e.g. for keeping inventories and costs of DC's and FT's), and maybe also (this depends on the validation method, see chapter 3) information on how the legs that are in the OD matrix combine to transport chains (which could include the use of DC's and FT's) between the production locations P and the consumption locations C. Whether these are the logistics costs of the existing distribution centre structure or the optimised locations (see chapter 3), depends on the timescale of a particular application of the model system. For short-term policy analysis, the former can be used, for long-term forecasting and evaluation of major infrastructure projects, the predicted locations of private logistic facilities and their (future) costs are most appropriate.

8. Treatment of air transport

For one of the modes, air transport, the flows in terms of tonnes are relatively small (the value-to-weight ratio is high). The P/C matrix will be in tonnes and can be regarded as a double constraint (at the P and at the C end) for the logistics model (or the network model) that will include mode choice. If a certain flow is very small (perhaps even smaller than the uncertainty with which the constraints are calculated), then an unconstrained direct demand model may be more useful for that small flow than the combination of P/C matrices, network model and logistics model, containing a mode choice model. This could be the case for air cargo, at least within certain commodity groups. This would imply that air transport would be treated outside the P/C matrices and the logistics model. However, since it is clearly undesirable to have incomplete P/C matrices, we propose to make the split between air freight (here we mean freight transport that actually takes place by air, not just notional air freight that is trucked for instance from Sweden to Kastrup or Schiphol) and other freight transport early in the logistics module. The P/C matrices will therefore cover all modes (without distinguishing by mode). The logistics model could take the form of a nested logit model, with the choice between air and non-air at the top and other mode choices lower in the tree. This would imply that the level of substitution between air and the other modes would be less than between two non-air modes. The fact that air transport has small volume shares when the unit of measurement is tonnes is not much of a problem for the development of a new freight transport model, since we propose that the logistics model will work at the level of the shipment as the unit of observation (see the next chapter). In the latest version of the Norwegian freight transport model, air transport is also included as a mode available in mode choice for two commodity groups ('fresh fish' and 'high value commodities'; Hovi, 2004)

2.3 The logistics model and the network models

Several options exist for the boundaries between the logistics model and the network models. These are described and compared in this section. The network models in NEMO and Samgods are currently using the STAN software (though for local/regional flows in Sweden, the passenger transport model SAMPERS will do the assignment), developed by INRO Consultants.

It has not been decided which network software will be used in the future by NEMO and Samgods. Nevertheless, it is relevant to be aware of how the current STAN software operates, and how it could be combined in the future with a new logistics model.

2.3.1 STAN

The STAN software carries out a system-optimal assignment (minimizing total costs) as the default option and requires the following inputs:

- Product OD matrices by mode or subset of modes. The demand for any one product may be subdivided into several OD matrices that can each be moved by a mode or a subset of modes. This is usually the result of the mode choice step: the cost functions for each product by each mode must be specified; the OD demand is specified in tonnes and the quantity transported is converted into a number of vehicles or convoys (trains, barges, etc…) depending on the weight/vehicle and the total convoy weight. These vehicles and/or convoys are used as parameters of the delay cost functions. The demand for a product may use more than one mode if the proper transfers have been defined between modes; i.e. the road-rail-ship mode combination can find such a path only if the proper transfers are defined from road to rail and from rail to ship, etc…

- A multi-modal network. The multi-modal network permits modal parallel links between adjacent nodes if there is more than one mode serving the two nodes; each such link has its own mode and corresponding cost functions.
- Cost functions. The delay and/or cost functions become part of the STAN data bank. The STAN software can carry out a user-optimal assignment by modifying the cost functions in an appropriate way.

2.3.2 The options for combining the logistics and the network model

The present development of a logistics module is not dependent on the continuation of the use of STAN as the network model, however we do comment on the possibilities of using STAN in conjunction with the new logistics demand model: how would one model the interface in a particular combination-variant with the network model? We distinguish three options for combining the logistics model and the network model. These options are depicted in Figure 2 and described in detail below.

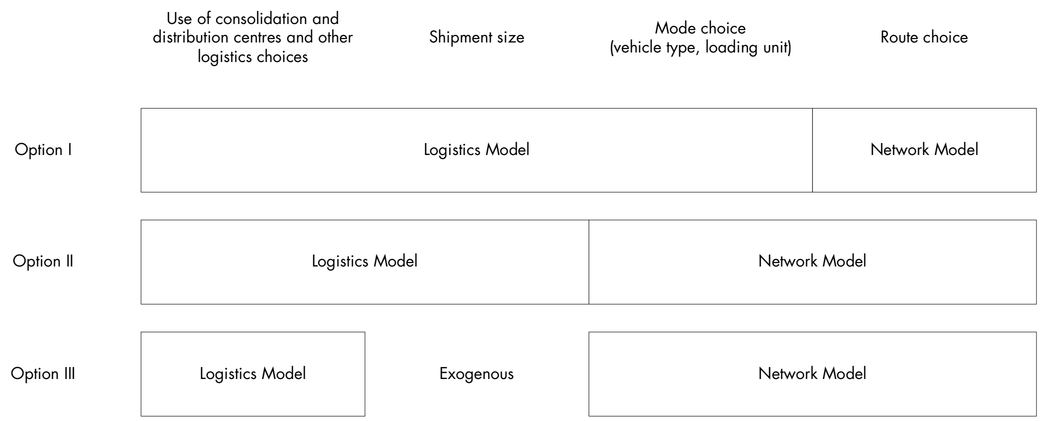

Figure 2 - Three options for combining the logistics and the network model

Option I: simple network model for assigning OD matrices to routes; the logistics model covers the conversion from P/C matrices to OD matrices as well as mode choice.

We start with the case in which the network model only provides the optimal routes: the shortest paths between the origins and destinations of the OD matrix and the generalised transport costs of these optimal paths. This role can be performed by any network program, given that it can handle the right amount of zones, links and nodes (please note that if the network has some congestion one needs to use representative link delays and costs for the shortest path calculations).

In this case, the logistics model would cover the decisions on modes and transfers between modes (fully or partly) and provide matrices for the legs in terms of vehicles: OD matrices of flows in number of vehicles between P and C locations and intermediate logistics centres with the mode (and maybe vehicle type) specified for each of these legs. In the present NEMO and Samgods systems, the network model receives its inputs in the form of flows in tonnes. This by definition will not include OD matrices for empty vehicles and partially loaded vehicles. At present, these modelling aspects are handled in a simple way in the network model (a load factor of 0.5 is assumed also to include the empty trips, leading to half-empty trips in both directions, instead of full trips to the destination and empty trips back). If the logistics model would deliver OD matrices in terms of vehicles to the network model, then the logistics module should also include the re-positioning of vehicles (such as empty or partially loaded return trips) and the shipment to vehicle transformations (load factors). It is necessary to develop an empty vehicle model where the vehicles that arrive at destinations are re-allocated to origins (e.g. a spatial interaction model or a classical transportation model; see section 3.6.4).

However, it is important to maintain the association with "products" in order to be able compute the corresponding tonnes by product and still produce these as an output of the model system. A number of trucks or railway cars does not provide any information on the global product flows, as is required for many purposes (outputs in tonne-kilometres by commodity type are used as key forecasting results, and also used in cost-benefit analysis). If the vehicles are partially loaded, then one needs to determine the OD pattern of such shipments and the corresponding products. This would imply an addition to the OD matrices of the corresponding products. If the vehicles are empty then one needs to determine where they should return. If one were to use STAN, this implies that another product would have to be added to the STAN data bank. This product is "empty vehicles". The corresponding "empty vehicle" OD matrix is added to the multi-product, multi-product assignment. If one is going to generate the demand in vehicle units by product, then the resulting flows will be vehicle flows. The assigned vehicle volumes must be converted back to tonnes in order to have results in tonnes and tonne-kilometres by commodity type. The flows by vehicle type do not convey the information of product flows unless one identifies the vehicle by product in a great level of detail: all vehicle types by all products. This may become onerous.

If STAN were to be used for the assignment and the demand is specified in vehicles for a given product, one must specify an average “weight” of 1(one). Then, after the assignment has been done, one must convert the vehicle flows into tonnes by doing the reverse of the standard STAN procedure: by using the average weight by vehicle one can compute the corresponding tonnes. The possible problem is that vehicle/product flows must be kept by vehicle type (small, medium, large), each becoming a distinct mode. This would increase the number of flow vectors that must be kept in the STAN data bank. If one has 12 products in the data bank, then one would have to keep perhaps 36 flow vectors, if the average number of different vehicle types by product is 3. INRO-Montreal is planning to increase the number of products that can be assigned simultaneously in STAN from 15 to 30. This may alleviate the need for more vehicle types.

Option II: The network model provides mode and route choice; the logistics model covers the transfer from P/C matrices to OD matrices and differentiates by shipment size.

In option II we have a multimodal assignment in the network part, as can be handled by the STAN software. The logistics model splits the P/C matrices into 'legs' measured in terms of tonnes between P's, DC/FT's and C's (the OD matrix). But it also gives a split of the tonnes by shipment size. For different shipment sizes, different modes and vehicle sizes may be available, and the relative costs of the various available modes and vehicle sizes for different shipment sizes may be different. STAN, or another multimodal assignment routine, would carry out the assignment for each shipment size class on the available modes, vehicle sizes and routes. It may well be that the assignment results for different shipment sizes shipped between the same zones can be different as predicted by the logistics demand model. Within STAN, this requires that the OD matrices should be split into several matrices by average shipment size. In STAN, one can have more than one demand matrix for a given product. There are up to 999 matrices that can be used in one data bank, even though this limit is rarely attained. For each OD matrix that corresponds to a particular average shipment or shipment size, one can specify the modes that can be used (e.g. also distinguishing between less-than-truckload and full-truckload trucking). So, for each such OD matrix in option II, different modes can be specified with corresponding different costs and different average weight per vehicle. The treatment of empty and partially loaded vehicles would not be done by the logistics model, but would be carried out according to current practice in the network model (by using fixed load factors, though these can be differentiated by commodity type and also in option II by shipment size). The link flow results of this option would be reported in tonnes or vehicles or both.

Option III: The network model provides mode and route choice; the logistics model covers the transfer from P/C matrices to OD matrices.

In this option, the logistics model splits the P/C matrices into 'legs' measured in terms of tonnes between P's, DC/FT's and C's. The network model does the multimodal assignment. For the network part, the current STAN procedures can be used and therefore we refer to this as the 'benchmark' option. Intermediate destinations are identified in the logistics model and then become origins for the delivery from the warehouse to the final destination. The OD matrices are in tonnes, not in vehicle units, and the average weight per vehicle is specified in the network model. Then, at the assignment stage, the tonnes are converted into vehicles and these are used to determine costs, congestion effects, etc.. Empty vehicles and partially loaded vehicles are not treated in the logistics model, but in the network model, as is the case presently. The final results for link flows are in tonnes or vehicles or both. More constraints are specified for the formation of convoys (trains), be they railway cars or barges. All the delay is computed with vehicles, but the result of an assignment is a number of tonnes.

2.3.3 Evaluation of the options

We do not think that a viable alternative would be to let STAN (or other network software) read in the P/C matrices and determine the consolidation and distribution activities and its locations in the network model. STAN does include the functionality to determine the location of intermediate modal transfers (transfer nodes) for a combined mode trip. The possible locations for these transfers need to be specified exogenously. If one can define the demand that uses the combined modes, say "truck-rail-truck", one can compute intermediate origin-destination matrices which route the demand from one mode to another. But at the present time it is not possible to specify particular logistic chains in STAN; it cannot give the use of storage and warehousing facilities. These logistic choices can much better be treated in a random utility framework (as proposed for the new logistics model in chapter 3).

A variant of option I is to include a stochastic route assignment in the logistics model and use the network model only for the calculation of generalised costs per alternative route. We do not think this is a viable alternative either: this would place much too heavy a burden on the logistics model, which already needs to consider many choices (see chapter 3). The route choice can be more adequately handled by cost minimisation in the network model, and if required, a stochastic route assignment can be incorporated within the network model itself (using new versions of STAN, or STAN macros that include stochastic assignment[3], or other software packages). This could actually be done in all three options: all have route choice included in the network model and in all three options this can be made stochastic. However, it is important to identify which of the network components are to be considered to be stochastic.

If we move from I to III the model system as a whole becomes less complicated (and potentially less interesting). The number of tasks to be covered by the logistics model also decreases. In all three options, the transport chains are no longer produced by the cost-minimising multi-modal assignment, but by the logistics model. Option II is slightly more complicated than Option III for the network model, because multiple shipment sizes have to be dealt with. For implementation in the network model, Option I requires most changes, because it deviates the most from the current application. We do note that the choice of network modelling software is not constrained to STAN. In principle, other packages could be used.

[3] The STAN software currently used in Samgods and NEMO does not include stochastic assignment. Quite recently, a STAN macro for stochastic assignment (logit, probit, Burrell) was developed.

We have a preference for option I. The choice of the location and use of DC's (and FT's) is usually made at the company level, by taking into account all of the transport operations of the firm, but mostly not those of other firms (though inter-company cooperation is expanding). As a result, some firms have set up their own distribution structures, whereas others use hired and shared facilities or have contracted these tasks to logistic service providers. Consequently, it will often happen in practice that, for the same P/C combination, several 'competing' O-D combinations are used (by different firms). If this were to be modelled in a network model as cost-minimisation per P/C flow or even per O-D flow, all flows for the same zone pairs would use the same modes and routes. The same deficiency would result if some deterministic cost minimisation model would be used as a location choice model for the location or use of the DC's and FT's in the new logistics model. This can be made more realistic by including a segmentation by shipment size (see under Option II above); but even within shipment size classes, multiple routes through the multimodal network are likely to be used in practice. A more fundamental solution would be to use a discrete choice random utility model for modes and other choices in the logistics model. This and the other options for a combination between the logistics model and the network model are developed in chapter 3.

CHAPTER 3 Ideas on the structure for the logistics model

3.1 Introduction

The objective of Phase II of this project was to deliver a model structure (definition of endogenous and key exogenous variables and their links, and the unit of observation) for the new logistics model, or rather alternative structures with different levels of sophistication for a step-by-step approach.

According to our interpretation of the Terms of Reference, it is required that the new logistics model will contain submodels for the following choices:

- Location of distribution centres and freight terminals, and their use in the formation of logistic chains (consecutive series of flows between production locations, intermediate locations and consumption locations): consolidation and distribution of shipments;
- Choice of mode and vehicle type/size or restrictions on this choice for each leg of the logistic chain, to give transport chains (flows between zones taking account of changes of mode and vehicle type/size);
- Partly endogenous, partly exogenous: transport frequency/shipment size (trade-off between keeping inventory costs and transport costs: more frequent delivery leads to higher transport costs but lower inventory costs).

The explanatory variables for these choices will include:

- Shipment size and frequency;
- Requirements of different agents (also for the same P/C), e.g. in terms of lead time, delivery time windows and reliability;
- Inventory levels and economies of scale in transport and logistic services;
- Commodity types.

Knowledge from private sector models for similar logistics choices (distribution centre location planning for private firms, inventory policy, transport cost minimisation) can be used to guide the development of the new logistics model.

The output of the logistics model will consist of factors to transform the P/C or PWC matrices into OD matrices, with a distinction by shipment size and possibly also by customer requirements and other attributes of the shipment, as well as restrictions or choice information on modes and vehicle types. The time unit to be used is that of a year: the flows in the P/C, PWC and OD matrices are on an annual basis.

It could be worthwhile for the national model systems to cover seasonal variation, which exists for some products both in the amount of production (e.g. agricultural products), consumption (e.g. foods and drinks) and the availability of modes (in winter, the Northern Baltic Sea often freezes). The Italian National Model for passenger transport for instance has a summer and a winter mode. The idea was that the P/C matrices should be annual amounts, but data such as traffic counts might be season-specific. At least one needs to be aware of this issue to remove seasonality from the data. After discussion with the clients, it was decided not to study seasonal variation in this project.

It could be possible to identify some singular flows in goods transport in Norway and Sweden (e.g. iron ore form Kiruna to Narvik by rail, or car parts from southern Sweden to Göteborg by rail), that could be singled out. These are large flows that have their special characteristics, and modelling on the basis of these flows plus the other smaller flows could lead to misleading results and problems of interpretation. Some commodity groups could be subtracted before using the data for building a more general logistics model. The model would then be based on the remaining large numbers of flows (so that the law of large numbers can be invoked). After discussion with the clients it was decided not to treat large flows and big firms separately.

The unit of observation in the logistics model can be a firm, a shipment, or aggregates of these (e.g. flows between zone pairs by shipment size, handling characteristics, etc.). Generally speaking, the more disaggregate the unit of observation, the better it is, since aggregation may lead to loss of information. We propose to go down to the level of the unit that makes the logistics decisions: the firm. But data availability needs to be incorporated as well, and this will be discussed in chapter 4.

3.2 Overall structure of the national model systems for freight

Our preferred model structure for the entire national freight model system is that of an 'aggregate-disaggregate-aggregate' model: the P/C flows are determined in an aggregate fashion, the logistics decisions are treated in disaggregate models, and the assignment of OD flows to routes (network model) is at the aggregate level again. 'Disaggregate' in the first place means that the unit of observation in the models is that of the decision-maker (the firm). The two aggregate models are for flows between zones, not distinguishing between firms. But the commodity classification of the disaggregate models may also be more detailed than the 12 or 13 commodity groups that will probably be used in both the

P/C matrices and the network models. The P/C or PWC matrices for the base-year to be used in this project will probably be for 13 commodity groups in Norway and 12 in Sweden (though some information on more detailed commodity types or sectors at the P and C end could be provided). For the network model it is also best to have no more than 10-15 commodity types to keep the model (results) traceable (for the user, not the computer program). In the logistics model, we might use more segments if that is required to account for the heterogeneity in logistic decisions for different products.

Figure 3 is a schematic representation of the envisaged structure for the national model systems (the boxes indicate model components).

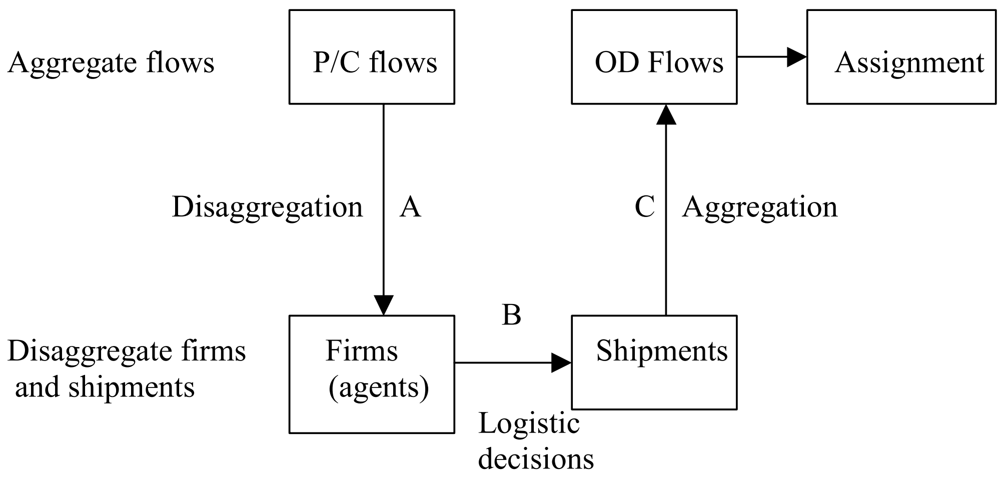

Figure 3 - Envisaged structure of the national model systems

The logistics model then consists of three steps (each of which will be discussed below).

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

B. Models for the logistics decisions by the firms

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

3.3 Step A: Disaggregation from flows to firms

This is not a choice model, but rather a prerequisite to get down to the level of the decision-making unit, so that the nature of the industry can be captured at the actor level. It could be modelled as a discrete choice model (including choice of sender by receiving firms or the other way around), with Monte Carlo (MC) simulation on the basis of the modelled probabilities, or one could use descriptive random sampling (both are discussed later in this section). Using information on the existing distributions of producing and consuming firms (the latter including retail) by commodity type/sector and zone, and on their size distribution, in the disaggregation step, one can use random draws to allocate flows in tonnes (not shipments yet) to individual firms at both the P end and the C end. Instead of trade between zones we shall get trade between firms. These firms are manufacturers or retailers: shippers in transport terms. Wholesalers and carriers come into the picture in the second step. If a P/C matrix is used as the starting point, the role of wholesale is defined as consolidation and distribution (but carriers and shippers can perform these activities in the model as well), and modelled within the logistics model. If a PWC matrix is used as an input into the logistics model, then the focus of the model will be on consolidation and distribution by carriers and shippers with own account transport. Preferably the commodity types used in this simulation would be more detailed than the 12-13 currently used in Samgods and NEMO. Some of the above information on firms may only be available at the national level. To go to the regional level, Iterative Proportional Fitting (IPF) can be used.

MC simulation means that assumptions are made (on the basis of the available data) on the statistical distribution functions for the distribution of firms in the aggregate commodity segments in the producing and consuming zones, these distributions are parameterised on available data, and then individual firms are drawn from these distributions. Alternatively, we could use the observed distribution in terms of a frequency distribution for each available alternative, and generate firms in the same proportions as the observed frequencies. This might be computationally faster, and has the advantage that different runs with the same input data and parameters lead to the same results.

More specifically, the disaggregation could work as follows. For a specific commodity group k (preferably defined at a finer level than the 12/13 commodity groups, otherwise we may also have to sample in step A to get finer commodity groups) we know from the P/C matrix that some amount of tonnes, say 1 million, goes from production zone r to consumption zone s. At the production end the question now is how likely it is that firm m is the producer. If we should have data on the amounts produced of good k by zone and by firm (or rather by local production unit), we can use the share of firm m in the total production of good k in zone r as the probability that m is the producer. For example we may know that there are three producers of good k in zone r, and that m produces 30%, and the other firms 30% and 40% respectively. If we would not know the shares in the production of k by zone, but only that there are three firms in r in the sector that produces k, we could use the share of m in the total turnover of these firms (or, as a further approximation, in the number of employees). This procedure gives us the split in the production of good k in zone r that goes to s over three firms: 300,000 tonnes, 300,000 tonnes and 400,000 tonnes.

At the consumption end the question is how likely it is that firm n is the consumer of good k in zone s. This requires data on the consumption of good k by firms by zone. If there would be data on which firms are consuming a certain good in a zone, but not on the amount consumed of this good, the turnover or number of employees can be used as approximation. Again we use the shares of a firm in the total of all relevant firms. For example, the data tell us that there are five firms in zone s that are consuming good k and that they have equal consumption shares. Then we split the flow of 1 million tonnes over the five firms as five times 200,000 tonnes. Firm n consumes 200,000 tonnes of good k that comes from zone r.

What is left to determine is what goes from firm m to firm n. Assuming independence of the production and consumption flows, this will be 0.3 x 0.2 x 1 million = 60.000 tonnes per year. This firm-to-firm transport flow of commodity type k is the starting point of step B. The first thing to determine now is the frequency or size of the shipments (this happens in step B, see section 3.4.2). The procedure is repeated until we have covered all the 1 million tonnes of good k that need to go from r to s, and similarly for all other commodity types and zone pairs.

The assumption that the firm to firm flows will then be formed on the basis of independence between the P and C allocation could lead to problems. For a certain commodity group there might be three producing firms in zone r and five consuming firms in zone s (as above). Because of the independence assumption there will then be fifteen firm to firm flows between r and s, the sum of which will be equal to the given P/C flow (in tonnes). This is repeated for every zone to zone flow. In reality many of these firm to firm flows are zero: a consumer does not purchase from all suppliers located in each zone that is observed to supply to the zone where the consumer is located. The number of fifteen could be regarded as the maximum number of firm to firm flows for the commodity k between r and s. This procedure therefore can lead to unrealistic results when the EOQ model is applied next. An alternative would be a supplier model for the purchasing firm or some form of sampling from the above maximum number of flows. A supplier choice model[4] is conditional on the locations of potential suppliers and provides for a given receiver the probability that a certain firm is the supplier. In this case, the determination of receiving firms could be as above, but the supplying firm is sampled from the distribution of suppliers given the receiver. For each receiving firm only one (or just a few) suppliers could be drawn for each P zone in the base matrix. This firm to firm combination would then represent all flows of the specific commodity from r to the receiving firm in s. By aggregating over the receiving firms, all the tonnes from r to s of this commodity are represented.

The question is whether there are statistics on the number of suppliers (or the number of receivers) that a firm uses (by commodity type). In the absence of official statistics, logistics experts might be able to give some guidance here. Data is available on the number of shipments by commodity group for Sweden from the CFS, as well as the weight of these. This gives the observed average shipment size per commodity group, which can be used to calibrate the EOQ model together with the step A model (which fraction of the maximum number of firm to firm flows is realised?).

The use of MC simulation/descriptive random sampling for disaggregation is similar to the approach followed in the Commercial Transport (CT) component of the TLUMIP model for Portland, Oregon (Pbconsult, 2002). But in this CT component, MC simulation is used to go from trade flows to discrete shipments (in **Figure 3** that would be a diagonal arrow from the upper left box to the bottom right box); an allocation to firms is done later in the CT component. We propose to go to firms first, because we would like to develop a behavioural model of logistics (step B).

[4] To estimate a supplier choice model, the Swedish commodity flow survey (CFS) can be an important source of information. However, in the main data file of the CFS, the receiving firm is not identified (only the zone where it is located and the commodity group that it receives). But this can be regarded as data where the specific receiving firms have been aggregated. This can be modelled by integrating over attributes of the firms (e.g. size, which might come from business register data), as in a latent variable or mixed logit model.

It should be kept in mind that the disaggregation to firms (and in step B also to shipments) is not done to predict at the individual firm or shipment level. In step C we aggregate again to arrive at predictions for specific segments. Here the law of large numbers can be evoked and one can get rid of a large amount of noise. One could also use replications in the Monte Carlo simulation to reduce the noise. Therefore, the fact that the original P/C information will only be a rough approximation of the actual trade flows is not more of a problem for the proposed logistics approach than it would be for an aggregate logistics model.

3.4 Step B: Models for the logistic decisions of firms

3.4.1 Decisions in Step B

The decisions that would ideally be covered in this step are:

- Which agent (=a firm) controls the relevant supply chain?

  Choice set: the manufacturer at the P end, the retailer or manufacturer at the C end.

- Lead time.

  The choice set could contain as alternatives: within 24 hours, within 48 hours, within a week, more than a week.

- Frequency/shipment size (so inventory decisions are endogenous).

  The choice set for shipment size could be based on a categorisation in tonnes. Alternatively a functional classification (e.g. less-than-truckload, more-than- truckload) could be used. The latter will probably provide more insight.

- Whether the shipping firm carries out the transport and logistics itself or it contracts out to carriers/logistic service providers (one could go even further and distinguish several types of outsourcing).

  Choice set: do it yourself versus contracting out.

- Choice of loading unit

  Choice set: especially the distinction between containerised versus non-containerised

- Use (and location) of distribution centres, freight terminals, ports and airports and the related consolidation and distribution of shipments and formation of tours (batching shipments at consolidation centres, multi-stop deliveries).

  Choice set: chains of zones, with a specific activity (e.g. origin, consolidation, distribution and destination) at each zone. For the decision of the optimal location of consolidation and distribution centres only a limited number of candidate sites might be available. Some locations might not be accessible for some of the modes (e.g. by ship in winter), or there might be uncertainty about their accessibility.

- Mode used for each tour leg.

Choice set: air transport, road transport (possibly several vehicle types), rail transport (possibly with different train types, such as regular trains, block trains and intermodal rail transport), and maritime transport (possibly with different vessel types).

The models that are used for logistics decisions by private enterprises, such as the CAPS Supply Chain Designer (described in Annex 1, just as an example, not with the idea to use this software in the future Samgods or NEMO) can be useful here. These are cost minimising network models that differ in one important aspect from the national planning network models (such as the STAN models in NEMO and Samgods): they take the service requirements (e.g. lead time, frequency) of the receivers into account. But these requirements are usually given exogenously (for different commodity types), whereas in the logistics module to be developed we would prefer to make these endogenous: they are the outcome of a choice process on inventories and of bargaining between the parties involved in a shipment, which depend on factors like the fluctuation in demand and production[5]. In some CAPS Supply Chain Designer applications, lead times were not taken as given but considered as part of the choice problem (this is only possible if one has cost functions that distinguish between different lead times). There also is an interaction between the actual lead time and mode choice (e.g. road transport can usually guarantee shorter lead times than rail transport).

It will be infeasible to simulate all the individual shipments that take place in a year in a country. In the models that are used for the logistics decisions of individual firms, a simulation of all the individual shipments of the firm will not be carried out either. Especially if one would also model which individual shipments are combined with which other shipments (consolidation), one would get trillions of permutations. What is being proposed for step B of the logistics model is to generate a distribution of shipment types (e.g. shipment size in a discrete number of size classes) per firm. Especially for the shipments that are less-than-truckload (LTL), a fraction that will be consolidated needs to be determined (for each available company-internal and company-external consolidation centre; this gives a profile of such shipments). This can be based on transport and logistics costs, that vary by shipment size, but it is not necessary to keep track of which shipment is combined with which other shipments.

The trade-off between transport and keeping inventories (large inventories reduce the risk of not being able to serve demand or use the required inputs in a production process; small and frequent deliveries lead to higher transport and stockout costs but lower inventory costs) will be part of this model. This could be treated as part of a cost minimisation, as in operations research applications for optimal inventory decisions (the classic 'saw-tooth'

[5] The model described here is the 'ideal' model. When considerations on the availability of data and computational complexity are be taken into account as well, we may have to compromise. This could include making lead time per commodity type exogenous, depending –among other things- on how much variation there is in practice in lead time requirements, within (not between) commodity classes or sectors. Solving International has evidence for substantial relative variation in lead times within a sector (can differ by 100%). The trend over time generally has been a reduction in lead times in the past decades (so some convergence in lead times has taken place). For some commodities (e.g. fresh food, newspapers), the lead time is not negotiable and can best be treated as exogenous.

model and its extensions). For the decision-making on logistics, it matters which agent (if any) has the dominant position in the supply chain, so as to effectively control it. A receiver might have to keep a larger inventory if the sender (manufacturer) controls the supply chain; smaller buyers have to keep (relatively) large stocks. For company-internal transports, it is easy to determine the key decision-maker, but when several firms are involved, the dominant agent (responsible for the logistic decision-making, including the decision to contract out to third parties) might be the sender or the receiver, depending on the market under investigation, or there might be a split of responsibilities. Both extremes exist today, and there are divergent tendencies, both towards control of the chain by the retailer ('factory gate pricing' in the food sector; Potter et al., 2003) and control by the sender ('vendor managed inventories' in for instance the petrochemical sector; Waller et al., 1999; Disney et al., 2003). But in both cases, the information on which the size of the inventory is based comes from the receiver: the demand for his products or the peculiarities of his production process are the key determinant of stock size and shipment size. Below we shall assume that the inventories are kept at the C end. The decisions on these inventories, however, are influenced by who is in control of the supply chain. This choice can, in the absence of specific observations on the controlling agent, be modelled as a latent class model (Chintagunta et al., 1991), since it has an impact on other choices. Explanatory variables can be the market form and number of firms at different stages of the supply chain and the size of the firms (e.g. from step A). If this would not be feasible, assumptions on supply chain dominance would have to be made by commodity type.

The behavioural mechanism of the model could be that of minimisation of the sum of the expected inventory, distribution centre and transport costs. The model could be estimated as a discrete choice model (similar to Chiang, Roberts and Ben-Akiva, 1981, but with a greater range of choice alternatives; or the modal share and quality perceptions model of Park, 1995) or a joint discrete/continuous model (since shipment size can be treated as a continuous variable similar to McFadden, Winston and Boersch-Supan, 1985).

The step B model differs from what is being done in the CT component of the Portland model. We understand that many steps in this CT component use existing distributions (e.g. to generate discrete shipments, allocate shipments to establishments, generate transhipment stops) based observed data (such as the US Commodity Flow Survey), from which random draws are made. This does not give a causal model in which endogenous variables are explained by exogenous variables, but a random process that just tries to replicate observed outcomes (descriptive model) without explaining them. Also in this approach there will be no policy variables that can be used to perform a policy simulation.

For different types of commodities the complexity of this model could be different. It could be considered to take bulk out, but for a lot of bulk transports there still is a choice of port to be made and therefore these flows need to be included in the logistics model. An important distinction to be made is also that between domestic (or within-Scandinavia) transports and international (overseas) transports (both can be further subdivided). These two types of transports may be governed by different factors and/or different behavioural coefficients. The modes available and transhipment locations involved are also different. The number of market segments (in particular commodity types) to be used in the logistics model could be made dependent on the estimation results for the logistics model. In estimation one could test for differences in the behavioural parameters for a number of a priori defined segments in terms of commodity types and shipper/carrier and shipment (product weight, volume, value, handling characteristics) attributes (observed heterogeneity), and keep the segmentations that produce significant differences.

The model could use the existing locations of ports, airports, distribution centres and freight terminals. As in assignment, the network is given exogenously, and can be changed manually by the user. We can take the locations for transhipment and stocking as given and add/remove locations manually. Alternatively we could try to model this as well (the optimal locations for consolidation, warehousing and distribution, given a list of pre-selected candidate sites), as part of the above big decision problem, based on cost minimisation. The location of the ports and airports will, even in long-run applications, be taken as given (it will be possible to test different scenarios for this).

3.4.2 Shipment size and related logistics decisions

We are assuming that decisions on production and the location of production have already been taken. Also the location of demand (intermediate and final) is given. It is not needed to model both the shipment size and the frequency of ordering (and thus transporting) a good. If the total annual demand for the good Q is known (from the P/C matrices and the application of step A we know the annual flows by commodity type), then $Q = f.q$, in which f is the frequency of ordering and transporting the good and q is the shipment size. Here we seek to model shipment size; and frequency will follow once we determine the optimal shipment size.

The inventory problem is usually studied at the level of a company serving a demand or using the product in a production process and ordering the product from a sender. In our terms this means that the inventory is kept at the consumption end, by the producer processing raw materials or intermediate goods or by the retailer. The shipment size to be determined, consequently, is the shipment size as it arrives at the destination end C. We shall assume that corresponding amounts of this good are produced at the P end, but in transport from the P zone, these amounts (shipments) may be combined to larger vehicle loads. A shipment is a certain quantity of the good that is ordered at the same time and delivered at the same time. It can exceed a full truckload, and, in the case of road transport, can consist of several trucks (‘convoy’).

The reason we are assuming that inventories are being kept at the C end is that the models that have been developed in logistics to explain the shipment size (the economic order quantity model, EOQ) are about a firm ordering from a producer[6]. The inventory decisions might in the model be taken at the P end, but these refer to the inventory at the C location (vendor managed inventories: the producer carries out the management of the inventories of his client). In reality there are of course also inventories kept at the P end

[6] There is a variant of the EOQ model that does not concern goods that are ordered from a producer, but goods that are produced internally. This is called the ‘continuous-rate EOQ model’ (Winston, 1987), where there is not only a demand rate at which the inventory in depleted, but also a production rate over time at which the inventory is generated. This variant is not relevant for our model, since it is not related to P/C flows.

and between P and C. Furthermore, in several sectors there are tendencies to push the inventories back to the suppliers (e.g. as a result of Just-in-Time practices). But these inventories are not really important for our modelling problem, since they do not determine the shipment size (frequency in transport). The inventories at the C end determine the order quantity. Inventories at the P end are determined by production considerations ('production-smoothing inventories', see Shirley and Winston, 2004 for more information about this distinction). In the new freight model systems for Norway and Sweden, we need not go into production scheduling and the trade-off between production costs and inventories, since we do not model production. What we are interested in is the trade-off between transport and inventories, which is modelled in the EOQ model.

The EOQ model was first formulated by Harris of Westinghouse Corporation in 1915 (Winston, 1987). As the shipment size increases, transport costs decrease, while inventory costs increase. The optimal shipment size is found by minimising the sum of those costs. The solution is called the 'economic order quantity'. This can also be written as the optimal shipment size. Inventory theoretic models have been derived for this problem (see for example Baumol and Vinod, 1970; Chiang, Roberts and Ben Akiva, 1981; Vieira, 1990 or Park, 1995). The general idea is that the lead time λ (time between placing the order and arrival of the shipment, thus including the transport) and/or annual demand are uncertain. Therefore the reorder point δ (measured in terms of amounts of the good) is set at a level that is high enough to prevent the situation where the stock would have been reduced to zero before the next shipment arrives. The next order is placed when the inventory reaches the reorder point. In a world without uncertainty, it could be sufficient to reorder at the point where all of the commodity would be used during the lead time. However, both the demand fluctuations over time and the actual lead time are not known with certainty. Therefore, the reorders are placed sooner than this. In other words, a safety stock b is used as buffer: $b = \delta - E(Q).E(\lambda)$; the safety stock is the reorder point minus the product of expected use Q and the expected lead time. When the lead time is equal to zero (no time needed to place the order, to process it, or to transport it), the EOQ model is simplified. In this case it does not reduce to a situation without inventories, but to $b = \delta$. Even then, there still would be a trade-off between annual ordering costs (decreasing with order size) and inventory costs (increasing with order size), leading to a positive optimal shipment and inventory size. Positive lead times lead to bigger inventories. The EOQ model that we propose to use here is of the continuous review type (orders can be placed at any time), which does not require dynamic programming, unlike the periodic review models (Winston, 1987).

This problem can be modelled as one of minimising the total logistics costs (by the shipper). The purchase costs of the goods need not be added here (although Chiang, Roberts and Ben-Akiva, 1981 include this), since the senders and receivers of the goods have already been determined in step A. These costs are a constant, which do not matter in the minimisation to find the optimal shipment size. In the determination of the P/C matrices it could, in principle, be important to distinguish production costs that might differ between various production regions. These costs then would have to be added to the total transport and logistics costs from the network model and the logistics model.

The total annual logistics costs G of commodity k transported between firm m production zone r and firm n in consumption zone s of shipment size q are (for the moment we are disregarding mode and vehicle type choice; this will be discussed in section 3.4.3):

$$G_{rskmnq} = O_{kq} + T_{rskq} + D_k + Y_{rsk} + I_{kq} + K_{kq} + Z_{rskq} \quad (1)$$

Where:

G: total annual logistics costs

O: order costs

T: transport, consolidation and distribution costs

D: cost of deterioration and damage during transit

Y: capital goods of goods during transit

I: inventory costs (storage costs)

K: capital costs of inventory

Z: stockout costs

In this minimisation, we assume that the subscripts for the specific firms m and n (and also for instance firm size) do not matter. This assumption may be relaxed to accommodate economies of scale in warehousing, ordering and transport. Also, variation of the discount rate for the inventory capital costs and of other preferences between firms could be included. Each of the terms in equation (1) is discussed below.

O is the order cost: the administrative and handling costs of placing, receiving and processing the order. This can be written as the product of shipment frequency and cost per order:

$$O_{kq} = o_k \cdot (Q_k/q_k) \quad (1a)$$

Where:

O: order costs

o : the constant unit cost per order

Q: the annual demand (tonnes per year)

q : the average shipment size.

O should also include packaging costs and handling costs at the production and consumption location.

T is the transport, consolidation and distribution cost, which can be regarded as the expected (shortest path) transport cost outcome for the transport of k between r and s. It includes the costs of consolidation centres, where the shipment might be combined with other shipments to get a more efficient long-haul transport, the costs at distribution centres, where combined shipments are re-allocated to individual shipments, and the costs of transhipment locations, where the same shipment just changes mode (see section 3.4.2).

D_k is costs of deterioration or damage during the trip:

$$D_k = i.j.g.v_k.Q_k \qquad (1b)$$

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 is part of the logistics costs of the shipper.

Y_{rsk} is the capital cost of the goods during the time the transport takes. The implied annual interest rate for this has in some applications been estimated as a coefficient (e.g. Vieira, 1990). These costs also depend on the transport time compared to a full year and on the value of the goods:

$$Y_{rsk} = (i.t_{rs}.v_k.Q_k)/365 \qquad (1c)$$

Where:

t: the average transport time (in days).

I is the inventory (storage or floorspace) cost, excluding the costs of the safety stock. The storage costs per unit w_k depend on the commodity type. 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 (assuming constant shipment rates over time). I_{kq} then becomes:

$$I_{kq} = w_k.(q_k/2) \quad (1d)$$

K are 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). For the moment we use the same interest rate as for Y (but in practical model estimation a distinction will be made, see chapter 4).

$$K_{kq} = i.v_k.(q_k/2) \quad (1e)$$

Z is the stockout cost: 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.

Baumol and Vinod (1970) give a specific formulation for the safety stock costs. They assume a Poisson distribution for demand, and derive the safety stock b as:

$$b_{rsk}= a_k.((u_k+t_{rs}).Q_k)^{1/2} \quad (1f)$$

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 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 :

$$Z_{rskq} = (w_k+i.v_k).b_{krs} = (w_k+i.v_k).a_k((u_k+t_{rs}).Q_k)^{1/2} \qquad (1g)$$

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.

Minimising the above total annual logistics cost with respect to shipment size q gives the optimal shipment size (which can be different for different commodities k and different distances between i and j). A utility maximisation discrete choice model can be formulated for this by treating (–T) as the utility to be maximised and distinguishing an observable part of logistics costs and a random cost component (and assuming a specific statistical distribution function). This model can handle the choice between a discrete number of shipment size alternatives. The influence of who is in control of the supply chain can be incorporated by considering this as a latent categorical variable ('latent class'), with different behaviour for different segments (classes).

The shipper can carry out the transport himself (own account transport) or contract it out to a carrier. This can be represented in the logistics model by distinguishing several costs components that have different values (or different coefficients to express differences in preferences): the transport costs for own account transport might be different from the freight rates of the haulers (whether own account will be cheaper depends to a large extent on the transport volume of the shipper), the amount of control (including issues of timely delivery) is bigger for own account transport.

For the shipment, there is a choice whether to transport it in containers or not. In principle it is even possible to model this choice separately for each leg (so that at a distribution centre the container can be unloaded, and the shipments in it loaded into other containers), together with the mode and vehicle type choice for each leg. In this case, the mode and vehicle type alternatives of sections 3.4.3 and 3.6.2 should be interpreted to include a third dimension, which is containerised or not-containerised. A simpler representation is to use the same loading unit for the entire P/C (or P-W, W-C) flow, say as an extra dimension of the shipment size index q. To make this possible, the transport and logistics costs function should distinguish between containerised and non-containerised transport (for the commodities for which containerised is available):

containerised shipments have less damage to the goods, lower handling and transhipment costs and time and higher transport costs.

In this above logistics model, shipment size (or frequency) will be fully endogenous. This is possible because the factors that influence shipment size are taken into account in the formulation. This includes the stockout costs. Also the influence on the shipment size of changes in customer requirements can be taken into account (to some extent). In recent years, customer requirements have been increasing, which could lead to higher than minimum transport costs. This situation can however still be represented as minimising the total logistics costs as in (1), since the increased customer requirements can be captured by changes in other, non-transport costs items, especially in the stockout costs. These could be a function (a submodel) of explanatory variables, such as the lost revenue from stockout, the probability of losing customers, which in turn depend on factors like the level of competition and the market price. Also, if the retailer is dominant within the supply chain, his cost minimisation could lead to smaller inventories, but then the requirements of the retailer can lead to higher than optimal costs for the manufacturer.

In the EOQ model there is a dominating role for inventories. But some products are 'built to order': produced on demand, with small or no inventories. The EOQ model can still accommodate the determination of shipment size in some of these situations (e.g. products for which the consumer requires very specific and strict delivery schedules for the inputs, as in some process industries. But there can also be goods that are specific instead of generic (Massiani, 2004); goods where stocking cannot be used as a buffer between production and demand, because they are produced tailor-made, on demand. The optimisation problem for the shipper then becomes somewhat different. Now there is a trade-off between a faster and more expensive transport service or anticipating the finalisation of the product. The shipper chooses the arrival time of the inputs to the production process t_a and the departure time of the outputs t_d, as well as the transport time t. The goods will then arrive at the destination at t_d+t and the time available for production is t_d-t_a. For the most likely situations, in which the transport time constraint is not active, the profit maximisation problem for the shipper is as follows:

$$\text{Max}\ \pi\ (t_a,t_d,t) = R(t_d+t) - H(t_d-t_a) - T^i(t_a) - T^o(t) \qquad (2)$$

Where:

π: the profit of the shipper

$R(t_d+t)$: the revenue depending on the arrival time of the goods at the destination

$H(t_d-t_a)$: the production costs depending on the duration available for production

$T^i(t_a)$: the transport cost for the input

$T^o(t)$: the transport cost for the output.

In this problem the value to the shipper of reductions in travel time depend on the sensitivity of the client to the product delivery schedule R't and the sensitivity of the production and logistic process to duration T^{i}' and T^{o}'. Lower frequencies and bigger deliveries will lead to lower revenues (because of a worse match with the client timing requirements), but also lower production costs and -if there are economies of scale in transport- lower transport costs.

For these 'specific' goods, there thus is no optimisation problem that gives the frequency and shipment size. Given that we do not want to go into production scheduling in this project on a logistics model, the shipment size for this kind of goods can be taken as given (exogenous). A number of terms of the logistics cost function that only vary with shipment size (such as order costs) can then be left out the choice problem, and what remains for these goods is the choice of consolidation and distribution centre (whether to use these, and if so, which) and mode choice. If we would know for certain commodity groups that these are specific goods (or what percentage they are), this is how we could approach those.

3.4.3 Consolidation, distribution, transhipment and mode choice.

These choices ideally should be combined with those on shipment size in an overall logistic cost minimisation over alternatives with many dimensions, but could also be handled separately if it is necessary to reduce the dimensionality. We assume that the network model gives the optimal routes and can provide the ensuing transport costs and -for the sake of presentation- that the locations of consolidation centres, distribution centres and transhipment are given[7]. The model described here can be classified as a form of option I for the combination of the logistics model and the network model. For options II and III, the logistics model can be reduced by excluding the mode choice and retaining the choice of consolidation and distribution centre.

The starting point for choices on consolidation and distribution is that of a shipment of goods k of size q that needs to be transported from firm m in zone r to firm n in zone s. Stock keeping is determined from the viewpoint of firm n. The consolidation, distribution, transhipment and mode (h) choices are determined by minimising the sum of pure transport costs (X, which could include monetised transport time), consolidation costs (J) and distribution costs (M), omitting the subscripts m and n for firms, T_{rskqh}:

[7] In the short run, the locations for consolidation, distribution and transhipment can be considered as given. In the longer run, these locations can change. Given that Samgods and NEMO will be used for forecasting for the medium and long term, it must be possible for the forecasting models to change these locations. For publicly owned centres, this can be handled exogenously (just as changes to network links are handled exogenously). But for a model to be used for public policy planning, the long-term behaviour of the private sector should be endogenous. This means that for the (long-term) forecasting mode of the model, the new locations of the consolidation and distribution centres and for transhipments should be added to the choices covered in Step B. In principle, these locations can be determined by the same cost minimisation as already described under Step B, as is also done in some applications of the CAPS Supply Chain Designer, where optimal locations for distribution centres are searched for.

$$T_{rskqh} = X_{rskqh} + J_{kqh} + M_{kqh} \qquad (3)$$

The pure transport costs X_{rskqh} are derived from the network model: these are the costs corresponding to the shortest (cheapest) route (for a direct transport), or combination of routes for each leg between P and C. Transhipment costs are absorbed in J and M. The mode choice (h) is not simply a choice of main mode for the entire flow from P to C (or P to W, W to C), but is a choice of mode for every leg within this flow (e.g. from P to a consolidation centre, then to a distribution centre, then to C). This is worked out below.

To distinguish between shippers that carry out the transport themselves and shippers that contract these out to carriers, eq. (3) could be differentiated according to these options. Especially for less than truckloads, contracting out could be cheaper (even in spite of the profit margin for the carrier), but it would also mean a loss of control and being dependent on others (this could be represented in the model by a dummy variable).

The simplest, but not necessarily cheapest, option would be to transport the shipment directly from P to C without using consolidation or distribution centres or transhipment. In this case the costs of consolidation, distribution and transhipment would not enter T_{ijkq}, but the pure transport costs per tonne are decreasing clearly with increasing shipment size: larger road vehicles and rail and waterway modes usually have lower freight rates per tonne. So, especially for less than full truckload shipments, it is quite likely that the savings from direct transport in terms of J, D and M are smaller than the additional pure transport costs X. Besides the weight of the shipments, one also has to check whether the volume of the combination of shipments will fit on the available vehicles.

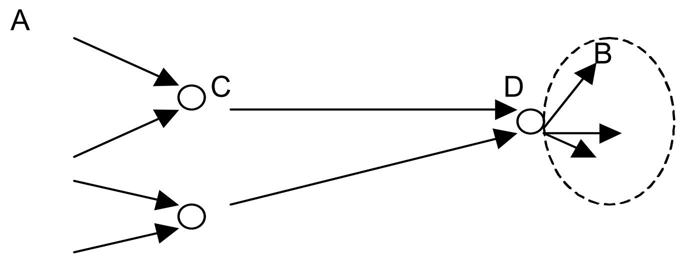

Figure 4 - Consolidation and distribution: the shipment of goods from location A to B is consolidated at C and distributed at D

Another alternative for this transport involves consolidation; using consolidation centres in the neighbourhood of the production location (see **Figure 4**). Here a distinction can be made between consolidation of shipments (for the same or different products) within the same production firm and consolidation of flows of different firms (presumably by a third party, e.g. a wholesaler or carrier). In the latter case, an extra costs term (might be a constant in practice) needs to be added for the transaction costs, loss of control and some profit margin for the third party. To reduce the dimensionality of the minimisation problem only a limited number of alternative consolidation centres (e.g. all within a distance threshold; except for overseas flows, see below) can be considered for each shipment. Such consolidations of different shipments from firms at different but nearby locations require collection rounds by a transport vehicle (usually a road vehicle. This routing problem for a carrier is worked out in section 3.6.3. What the logistics model should do for consolidation is to give probabilities or frequencies for a shipment of a certain size and commodity type (and P and C locations) of being consolidated with possible numbers of other shipments. These probabilities/frequencies can depend on differences in the handling requirements (e.g. refrigerated, palletised): some products can be transported with other products and others cannot. Also, shipments within a firm that is producing other shipments as well have a larger probability of being consolidated. If the shipments are really small, if the P location contains many senders, and if many shipments have the same final destination, consolidation becomes more likely.

At the same time, at distribution centres (see **Figure 4**), combined shipments arrive and are sent out again as smaller transports (but never smaller than the shipment size, that was determined from the C end). The splitting up is necessary because of the shipment size required by the producer or retailer at the final destination (or because of government regulations banning larger vehicles from certain areas). Again, only a limited number of alternative distribution centres (from the destination) need to be evaluated, depending on the distance from the destination (except for overseas flows, where the distribution centres can be further away from the C location). The distribution can be carried out within a firm (either the sender of the receiver) or by a third party (e.g. wholesaler, carrier) for several firms at the origin and destination end. In the latter case (but also if a receiving retailing firm has several stores in the same area) there will be multiple-stop distribution tours serving several locations of producers for further processing or the retailer. These tours will probably only be organised for destinations that are close to each other, products that match and originate from the same distribution centre and fairly small shipments. Again this is a form of the travelling salesmen problem. A simplified model for distribution tours is discussed in section 3.6.3

Consolidation and distribution centres by definition involve a change in the vehicle load size between the incoming and the outgoing flow. This may also involve a change of mode, or a change of vehicle type within the same mode. At a transhipment location, the load size does not change, but there is a change of mode. In practice, most changes of mode imply a change in the transport weight (consolidation or distribution) as well; otherwise there would be no rationale for the change of mode (done predominantly to make use of lower freight rates for bigger loads).

For the same shipment there can be both a consolidation centre and a distribution centre. One of the main aims of the logistics model is to provide the information on the use of such ‘intermediate destinations and origins’. A port and an airport can act as a consolidation centre and/or as a distribution centre. If a transport between P and C is overseas, then it is required that a port or airport is used as a consolidation centre, distribution centre, or transhipment location, with sea transport or air transport on at least one of the legs connected to the (air)port. The (air)port can be at any distance from the P or C. In overseas transports, there can be physical reasons to change mode (e.g. sea to road transport). In practice, the loads of sea and air transport are nearly always considerably larger than those for road transport. In the logistics model we shall treat these transhipment locations as a special case of a consolidation or distribution centre. Transhipment costs will be part of consolidation costs (J) or distribution costs (M).

Several transport 'modes'[8] are available, and a shipment may use one (direct transport), two (use of either a consolidation or a distribution centre) or three modes (use of both a consolidation and a distribution centre). The costs of the shortest route for each mode are determined in the network model (for each of the one, two or three legs). But the mode choice itself is part of the preferred logistics model. We can modify eq. (3) to make the mode choice more specific, as shown below.

Direct transport:

$$T_{rskqh} = X_{rskqh} \tag{4a}$$

Use of consolidation centre only: mode h(1) between P (located in zone r) and consolidation centre c, mode h(2) between consolidation centre c and C (located in zone s):

$$T_{rskqh} = X_{rckqh(1)} + J_{kq} + X_{cskqh(2)} \tag{4b}$$

Use of distribution centre only: mode h(1) between P and distribution centre d, mode h(2) between distribution centre d and C:

$$T_{rskqh} = X_{rdkqh(1)} + M_{kq} + X_{dskqh(2)} \tag{4c}$$

Use of consolidation and distribution centre: mode h(1) between P and consolidation centre c mode h(2) between consolidation c and distribution centre d, mode h(3) between distribution centre d and C:

[8] These need not strictly be modes (truck, train, ship, plane) in the usual sense. In fact, trucks might be used for all three legs: from P to the consolidation centre, from there to the distribution centre, from there to C, but the truck sizes might be different (notably larger for the long haul transports). The definition of 'mode' here encompasses vehicle size (for road transport as well as other modes), and possibly loading unit as well. The key issue is that one, two or three legs are distinguished between P and C, and up to three embedded different OD movements will be passed on to the network model.

$$T_{rskqh} = X_{rckqh(1)} + J_{kq} + X_{cdkqh(2)} + M_{kq} + X_{dskqh(3)} \quad (4d)$$

The costs J and M can also be made dependent on the specific combination of modes used for the shipment to enter and leave the centre. Different vehicle sizes for the same mode (especially for road transport) can be absorbed into the definition of mode h. A random utility discrete choice model can be obtained by using –T as the utility and including random cost components that follow specific statistical distributions. The mode choice model can be of the nested logit type, with a choice between air transport (if available for a commodity group) and other modes on top, and the choice within the non-air modes lower in the tree (also see section 2.1).

3.5 Step C: Aggregation for assignment

This step includes adding up all shipments for the same commodity types to get OD flows (in tonnes for model combination options II and III; in vehicles for option I, see chapter 2) for a limited number of commodity types for assignment. This is simply a matter of straightforward summation over shipments. The current network model (application of STAN) expects inputs in terms of flows in tonnes, but can also handle flows in vehicles.

Given the fact that many distribution centres are close to the population centres and the large size of the transport zones (especially in Sweden where there are fewer than 300 domestic zones), it will regularly happen that the transport from the distribution centre to the C location (e.g. retail store) will be an intra-zonal transport. In the information that is passed from the logistics model to the network model, such transport legs are not relevant for the assignment.

In the model system described above, the network model will give the shortest path (uni-modal) through the network between P, intermediate locations, and C. In some options of the logistics model (options IA and IB, see section 3.8), mode choice will be covered in the logistics model. In the network model, some cost items, that differ only between modes and between inventory options can be dropped. In the present Samgods, value of time is used in the network model cost functions, which also captures some logistics factors that will be included in the logistics model. Inventory cost components (e.g. interest on the inventory in transit) must not enter anymore in the network model, but vehicle and labour-transport related costs are still relevant in comparing routes.

3.6 A worked out example

3.6.1 The inventory versus transport problem

Recollecting terms from section 3.4.2 we get:

$$G_{rskgnqh} = o_k \cdot (Q_k/q_k) + T_{rskqh} + i.j.g.v_k.Q_k + (i.t_{rs}.v_k.Q_k)/365 + w_k.(q_k/2) + i.v_k.(q_k/2) + (w_k+i.v_k).a_k((u_k+t_{rs}).Q)^{1/2} \quad (5)$$

Mode choice per leg will be dealt with in section 3.6.2 and for the moment a general mode index h is used.

The optimal order size for the EOQ model without the safe stock costs, given the above equations, is:

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

If we use the Baumol and Vinod safety stock formulation, the optimal shipment size is the solution in terms of q of the following equation:

$$-(o_k.Q_k)/q^2 + (w_k+i.v_k)/2 + (½).(w_k+i.v_k).a_k(q_k+t_{rs}.Q)^{-1/2} = 0 \quad (6b)$$

In most cases, the EOQ of the model with certain demand is a good approximation to that of the one with uncertain demand (Winston, 1987). Therefore, for practical purposes, equation (6a) can be used.

The transport costs T_{rskq} might be decreasing (per tonne) with increasing shipment size (bigger shipments can be transported using relatively cheaper vehicle sizes and modes). This would add an extra term to the above optimal shipment size:

$$-(o_k.Q_k)/q^2 + (w_k+i.v_k)/2 + (½).(w_k+i.v_k).a_k(q_k+t_{rs}.Q)^{-1/2} + \partial T_{rskq}/\partial k_q = 0 \quad (6c)$$

With economies of scale in transport, the last term will involve q, and (6c) has to be solved for q* numerically. Without economies of scale in transport, the standard EOQ can be used.

3.6.2 The transport logistics problem

In this section we provide an example of how the transport logistics problem can be worked out.

The first choice to be made as part of the transport logistics model is whether to use air, sea, rail-ferry, road-ferry or the Öresund fixed link for the overseas P/C relations.

Ports and airports in overseas relations

If the P or the C location is overseas, then use of one of the above modes of transport is mandatory. For some of the commodity types, air transport can be ruled out (e.g. bulk goods). What needs to be modelled then is:

- The choice of port at the foreign end, the access/egress link to this port and the transport costs involved. Outside Sweden and Norway, the zones used in the national model systems are larger and the network is described in less detail. Nevertheless in the options where mode choice is included in the logistics model, the logistics model will handle mode choice for legs abroad as well. Given the large zone size and lack of network detail, it might be considered to abstract from the use of foreign consolidation and distribution centres (other than through ports and airports) in the modelling of international shipments. No tour modelling for consolidation and distribution abroad will be required. For shipments that are less than full truckload, we can assume that freight rates for consolidated flows for the access/egress to the ports.
- a choice of mode and port to/from Sweden and Norway (including ferry ports and Malmö as the exit/entry point of the Öresund fixed link).
- The land-side transport logistics in Sweden or Norway will be optimised (random utility maximisation) as described below.

For a shipment from an overseas P to a C in Sweden or Norway, the foreign port y and the domestic port p will be chosen on the basis of minimising of the relevant costs from the available foreign ports $y \in Y$ and from $p \in P$ and the available modes.

$$T_{rskqh} = Min_{yph(I)h(II)h(III)}(X_{rykqh(I)} + X_{ypkqh(II)} + X_{pskqh(III)} + J_{ykq} + J_{pkq} + M_{kq}) \quad (7a)$$

These costs consist of the transport cost from the producing firm at location r to foreign port y (by land-based mode h(I)), the transport cost from y to domestic port p (by =sea mode h(II); could be sea ship, rail-ferry, road ferry or fixed link) and the land-based transport cost from port p to the consuming firm at location s (by land-based mode h(III), e.g. road, rail), as well as 'consolidation' (actually transhipment, absorbed for convenience in J) costs at ports y and p, and possibly distribution centre costs for the land-based leg (see below).

For a shipment from Norway or Sweden to an overseas location, this becomes:

$$T_{rskqh} = Min_{yph(I)h(II)h(III)}(X_{rpkqh(I)} + X_{pykqh(II)} + X_{yskqh(III)} + Jp_{kq} + J_{ykq} + M_{kq}) \qquad (7b)$$

For commodities for which air transport is considered to be available (e.g. fresh food products, parcels), the costs from (7a) need to be compared against:

$$T_{rskqh} = Min_{xlh(I)h(II)h(III)}(X_{rxkqh(I)} + X_{xlkqh(II)} + X_{lskqh(III)} + J_{xkq} + J_{lkq} + M_{kq}) \qquad (7c)$$

These are the costs of using the best available chain with foreign airport x and domestic airport l (choice between available airports $l \in L$). The minimum will be chosen. For export shipments, (7b) and (7d) need to be compared and the lowest of these selected.

$$T_{rskqh} = Min_{xlh(I)h(II)h(III)}(X_{rlkqh(I)} + X_{lxkqh(II)} + X_{xskqh(III)} + J_{lkq} + J_{xkq} + M_{kq}) \qquad (7d)$$

However, sea transport, especially for short sea shipping, and air transport, are not only used in overseas transport. They also play a role in domestic transport and intra-Scandinavian flows that in principle could also be served over land, but in their domestic role sea and air transport will be treated the same as the other ‘Scandinavian’ modes (road, rail, see below).

For *transit flows* (both P and C outside Sweden or outside Norway), we recommend that the P/C matrix provides the flows that make use of Swedish/Norwegian ports and airports (including ferries and the fixed link), e.g. on the basis of existing port, ferry and airport statistics. Then eq. (7a) and (7c) could be used to represent the port and airport choice, with not only r but also s abroad, and so could eq. (7b) and (7d), with not only s but also r abroad.

Transport between P and C both in Scandinavia

This is not exactly equal to domestic transport, it also includes (some) flows between Norway, Sweden, Finland (and Russia). It can also be used for the landside part of *transit flows* (e.g. from a Norwegian port through Norway to Sweden or Finland; or from Finland through Sweden to the fixed link). We also recommend that the base matrices include transit flows that use Swedish/Norwegian landside infrastructure, e.g. based on trade statistics, in combination with road, rail and ferry surveys.

First there is the option of direct transport:

$$T^{direct}_{hrskq} = \min_h(X^{direct}_{hrskq}) \quad (8a)$$

Which modes will be available depends on the specific spatial relation studied, as well as on the commodity group k and the shipment size q. The total set of modes h consists of:

- road transport (with say three different vehicle sizes)
- rail (possibly with different train types, such as regular trains, block trains and intermodal rail transport)[9]
- sea (short sea, possibly with different vessel types)
- air transport.

An additional dimension within h could be containerised versus non-containerised.

In practice, use of rail, sea and air transport can better be treated as indirect transport (see below) where the change of mode is handled in consolidation and distribution centres, unless both the P and C firm have their own sidings or quays (only then there can be direct rail and waterway transport). Then (8a) only refers to road transport, with different vehicle sizes.

For indirect transport there is an array of options, of which the minimum cost option (given in (8b)) can be compared against (8a):

$$T^{indirect}_{hrskq} = \min_{h(1)h(2)h(3)cd}(X_{h(1)rckq} + J_{ckq} + X_{h(2)cdkq} + D_{kq} + X_{h(3)dskq}) \quad (8b)$$

The first term within brackets represents the transport cost from the producing firm at r to consolidation centre c, the second term gives the consolidation centre cost of c, the third the transport cost from c to the distribution centre d, the fourth the distribution centre cost at d and the fifth the 'last mile' transport cost to the consuming firm at s. There are three mode choices: h(1), h(2) and h(3). Either the consolidation centre or the distribution centre can be left out, and its costs omitted, but if both are deleted, we have a direct transport again. For overseas flows, the decisions on the use of ports and airports are taken first, using (7a) – (7d), and then the port or airport serves as the r or s in (8a) and (8b).

In principle, the minimisation in (8b) takes place over all available 'land' modes, the available consolidation centres c, and the distribution centres d (mode choice as well as

[9] The current STAN applications also handle several train types and ship types (by using different performance functions). Marshalling yards are handled with delay functions and cost functions, if relevant. Train formation is not handled in STAN.

choice of which consolidation and distribution centre to use). Considerable simplification can be achieved by assuming that:

- h(1) and h(3) are always road transport (vehicle size may still have to be determined);
- The firms at r or s always choose the consolidation centre that is nearest to r (from a set of exogenously given locations), maybe with some non-availability restrictions to represent that some centres cannot handle all commodity groups. This maximises the fraction of long haul with mode h(2) within the total r to s flow, minimising the transport costs for firm r[10].
- The distribution centre closest to s is chosen by the firms at r and s (we could differentiate between shipper-owned centres and those owned by wholesalers and carriers, with different costs, but also a 'transaction cost' for contracting out and becoming dependent upon others).

Under these assumptions, the consolidation centres c and distribution centres d used will vary among P/C pairs (and commodity types), but will not be outcomes of the minimisation. The only choice left within (8b) is mode choice for the long haul (and possibly vehicle size within road transport for the other legs; this can take into account restrictions on vehicle size at the s or r end). The problem of routing different shipments to the consolidation centre and that of distributing multiple shipments from the distribution centre to the receivers is handled separately (see below), and so is empty vehicle running.

Direct transport is much more likely for shipment sizes q that allow full truck loads than for less than full truckloads, but the comparison of (8a) and (8b) can be made for both types of shipments (and also for a larger number of shipment size classes, depending on the data). The model will then give the fractions that will be using direct transport and the fractions that will be consolidated and/or distributed. In both cases, consolidation implies that for the long-haul (middle) part of the transport chain, different shipments will be combined. The transport costs for each leg for different vehicle size classes should come from the network model.

[10] In a situation where we would have to determine the optimal location for a consolidation centre, this would not be an appropriate assumption. In this context, the location of the consolidation centre would have to be optimised with respect to all potential flows to be consolidated. Also, in practice there are land-based distribution centres that are not ports or airports and not close to the population centres, but for instance are located in the middle of Sweden (national distribution centres). Such central warehouses are not so much used to reduce transport costs by batching and unbatching goods, but to re-allocate the flows (each for a limited range of products, but large amounts) from different production locations into deliveries (many different products, but small quantities) to big retail stores. The reasons for the choice of location for the central warehouse also have to do with availability and cost of land and labour. To include this in the model, the distribution centre cost should vary among different locations.

3.6.3 Simplified routing problem

Shipments from different P locations that use the same consolidation centre can be transported directly to the consolidation centre (e.g. with relatively small vehicles). Alternatively, tours can be formed on which the same vehicle stops at different P locations to collect the shipments and then transport them to the consolidation centre. These tours are called 'collection tours' and are a form of multi-stop tour formation and scheduling. A similar tour formation problem is present at the other end: the shipments could be transported directly from the distribution centre to the C locations, but can also be organised into multi-stop distribution tours (also called 'milk-round' or 'multi-drop' tours). The current network model STAN does not include the multi-stop routing of less-than-truckload shipments.

In operations research, there is considerable literature on such problems; this particular one is known as the 'travelling salesman problem' (TSP). However, the algorithms used to solve these problems are fairly complex and very computer-intensive. Some of the existing models for this in the commercial sector (e.g. PARAGON) are very sophisticated and also take account of time windows and vehicle size restrictions. These models are used for operational routing and scheduling decisions of larger transport firms. Such an amount of detail, complexity and run time is not needed and is even undesired in a national level model system, which will include many other problems as well. Even at the overall company level, such models are often too detailed. Below, we describe the kinds of models that companies use for more strategic decision-making in transport firms (for instance about the vehicle mix they need to have). This kind of models can be used in a national freight model system as well. The example given here is that of distribution tours, but the concepts apply equally well to collection tours.

The strategic tour models that companies use often start with the total available time of a driver (also taking account of the time required for breaks). Then a distinction is made between the trip between the distribution centre and destination area ('stem distance', 'stem time') and the time to carry out the distribution in the destination area itself, based on an average time and average distance between the drops. Assumptions are made on vehicle size, utilisation rate, etc. (also for future years, if in predictive mode). On the basis of this, the total costs are calculated for various average dropsizes (amount of goods delivered at a location). This can be repeated for different vehicle mixes to select the optimal one.

Below an example (from the UK) is given for a distribution tour with a dropsize of six cages from a depot to a number of delivery points, all located in the same delivery region, and back to the depot. The distance between the depot and the delivery region is the 'stem distance'. The same formulations can be used for other drop sizes and for shipments measured in tonnes, taking volume restrictions of the vehicles into account. This example focuses on the use of road transport. In practice rail, maritime and air transport are used for long-haul trunk transport, not for collection and distribution tours. However, several road vehicle types could be used for these tours.

INPUTS:

Supplier data:

Overnight qualifying time	12	Hours
Break %	1.17	Allowance for rest periods (multiplier on driving time)

Vehicle and driver data:

Vehicle Fixed Cost	74	£ per day
Vehicle Hrs	12.0	£ per day
Vehicle Variable Cost	0.46	£ per mile
Vehicle Capacity	44	Units
Vehicle Utilisation	90.0%	
Driver Cost	141	£ per day
Driver Hrs	12.0	per day
Overnight Allowance	£0.00	per night

Trip data:

Stem miles	53	miles
Stem minutes	86	minutes
Yard Time	15	minutes
Interdrop miles	14	miles
Interdrop minutes	34	minutes
Drop Time Constant	20	minutes per drop
Drop Time Variable	2.0	minutes per unit

CALCULATIONS:

Calculation for a dropsize of 6 cages		Comment on calculation
Total trip distance		miles
2 * stem distance	106,0	Driving distance from source depot to delivery region and back
(number of drops - 1) * interdrop distance	78,4	Driving distance between delivery points
Total trip distance	184,4	miles
Total trip time		minutes
Yard time	15,0	Time to prepare / check vehicle at depot
2 * stem driving time	171,9	Time to drive to and from delivery region, from source depot - based on average vehicle speed
(number of drops - 1) * interdrop driving time	188,2	Time to drive between delivery points (excluding stem) - based on average vehicle speed
number of drops * droptime	211,2	Time to deliver goods (fixed time per drop + variable time per unit delivered) - either can be set to zero if required (i.e. totally fixed or totally variable)
Driving breaks	60,0	Approximate allowance for driver breaks (related to driving time only)
Total trip time	646,3	minutes
Average driver cost per hour	11,77 £/hr	Total driver cost per day (including social costs) divided by average driver hours per day
Average vehicle cost per hour	6,16 £/hr	Total vehicle fixed cost per day divided by average vehicle hours per day (typically purchase / hire costs, insurance, maintenance)
Average vehicle cost per mile	0,46 £/mile	Total vehicle variable cost per mile (typically fuel, tyres, oil)
Trip costs		£
Driver costs	126,81	£
Vehicle standing costs	66,35	£
Vehicle variable costs	85,38	£
Total trip costs	278,53	£

This strategic model for routing does not give a specific order of deliveries to the different clients that are included in a single tour (unlike the travelling salesman problem, TSP). As a result it does permit a calculation of the total costs and tonne and vehicle-kilometrage of the tour, but does not give the inputs for an assignment based on the order of the deliveries (trips from one C to the other). In as far as the different C locations will be in the same zone, this will not be a problem, since these trips do not have to be assigned to the networks. But collection tours that pick up goods from different zones and distribution tours that deliver in several zones do include zone-to-zone trips, which cannot be generated by the model described above. This is especially relevant for consolidation and distribution centres that cover large geographic areas (such as national/regional DC's), but even here the P locations or the C locations of the same tour are often in the same geographical area. The current network model STAN does not include multi-stop routing facilities either. What can be done with the simplified tour model in this context is to produce a trip from the P area to the consolidation centre or from the distribution centre to the C area (the stem distance), and use this in assignment. This simplified tour model will be a kind of regression model with characteristics of the P and C zone (e.g. the number of shipments sent and received) and of the shipment as explanatory variables. For estimation, data are required on various costs items paid by shippers. The added value in terms of assignment of using this strategic routing model is that, instead of many small flows from P locations to the consolidation centre and from the distribution centre, we get a more limited number of combined flows for the stem distances. In case of a consolidation or distribution tour, a less than truckload shipment will lead to only a fraction (e.g. one fifth, with five stops) of a complete vehicle trip between the production location and the consolidation centre or between the distribution centre and the consumption location (and possibly an empty return trip, see below). The pure transport costs will also be lower, since these are shared with other products[11], but the transport time will be longer than for a direct transport.

3.6.4 Modelling empty vehicles

In one of the options (option I) for the combination of the new logistics model with the network model discussed in chapter 2, it was mentioned that a model for empty vehicles needs to be developed as well. Such a model is worked out below. As a matter of fact, it would also be beneficial to use a specific empty vehicle model in the other options as well (however, not as part of the logistics model but in combination with the network model).

In some situations, carriers try to fill (half) empty vehicles using price discrimination and price differentiation. This may for instance mean that shippers pay different prices for a transport from r to s than for the same transport from s to r. The fact that some shippers are prepared to pay a high price for top quality thus creates capacity for cheaper transport of lower quality (in the opposite direction).

A review of procedures and models for representing empty vehicles is give in Holguin-Veras and Thorson (2002). They distinguish the following modelling approaches for empty trips:

- The naïve proportionality approach: the demand model is commodity-based and produces commodity flows in tonnes. Just before the assignment stage, this is translated to flows in vehicle units (loaded plus empty; z_{rs}) by dividing the flows in tonnes between r and s (m_{rs}) by a constant α_0 that represents the average payload factor (in tonnes per trip) for loaded and empty trips that are produced by a single unit of commodity flows:

[11] It would in principle be possible to develop a routing model that, unlike this simplified model, does give the sequence of locations visited, which would not be as complex as TSP algorithms, e.g. based on always choosing to go the closest location that has not yet been visited (starting at the one closest to the centre, or at a randomly chosen production or consumption location from the list that needs to be visited). However, this would also require that we have to determine which shipments will be combined with which shipments. This is an infeasible task; trillions of combinations are possible. This is also the reason why detailed routing models are not used at the strategic decision level for companies (but only for operational planning, usually only for one given day).

$z_{rs} = m_{rs}/\alpha_0$ (9a)

The constant α_0 can be determined empirically using information from traffic counts. This approach implies that the empty trips are directly correlated with the commodity flows, which is a highly questionable, because a commodity flow from zone r to zone s in itself does not lead to empty trips from r to s, but rather to empty trips in the opposite direction.

- This last insight is used in the formulation for empty trips of Noortman and van Es (as reported by Holguin-Veras and Thorson, 2002). Here the number of empty flows between zones r and s is a function of the commodity flow in the opposing direction, from s to r, multiplied by a constant p that is determined empirically. If one also assumes that the average payload from r to s is equal to that from s to r, the Noortman and van Es equation for empty trips becomes:

$$E(z_{rs}) = \frac{m_{rs}}{\alpha_{rs}} + P(E)\frac{m_{sr}}{\alpha_{sr}} = \frac{m_{rs}}{\alpha_{rs}} + P(E)x_{sr} \quad (9b)$$

Where:

P(E): the probability of returning empty

x_{sr}: the loaded trips from s to r

α_{rs} and α_{rs} : parameters to be estimated.

A rather similar formulation was developed by Hautzinger (1984). Both these formulations refer to simplified trip chains (from r to s and back to r again), without intermediate stops.

- Holguin-Veras and Thorson (2002) enhanced the empty trip modelling by considering trips with one additional stop (and showed that this is also a reasonable explanation for trip chains with more than one intermediate stop)

$$E(z_{rs}) = \frac{m_{rs}}{\alpha_{rs}} + P(E)\frac{m_{sr}}{\alpha_{sr}} + \gamma\sum_{t\neq s} x_{tr}\frac{m_{rs}(d_{rs}+d_{tr})^{-\beta}}{\sum_{u} m_{ru}(d_{ru}+d_{tr})^{-\beta}}P(E/s) \quad (9c)$$

Where:

P(E / s): the probability that a vehicle does not get cargo, given that s has been selected as the next destination of the tour.

d_{rs}: distance between r and s (as in a spatial interaction model)

β,γ: parameters to be estimated.

Holguin-Veras and Thorson (2002) tested the naïve proportionality approach, the Noortman and van Es approach and their own first-order chain approach both on a simple two-zone example and on an example with 26 zones. For both cases the naïve models produce considerable directional errors. Their own model performed best, closely followed by the Noortman and van Es approach, both reducing the directional errors by a factor of about 5 compared to naïve approaches. In our new logistics model, the Noortman and Van Es approach can be applied to each OD (each tour leg) separately. For applying the empty vehicle model of Holguin-Veras and Thorson, trip chain information is needed (particularly the zones that are visited and the order of the stops). For consolidation tours and distribution tours, the model described in section 3.6.3 will (unlike TSP) not be able to give this. For the total tour from P to C, the logistics model could give the intermediate stops (the consolidation and distribution centres, ports and airports). At this level, we could apply the formulations of Holguin-Veras and Thorson, but we should be aware that it was originally specified for the urban distribution situation (multi-stop distribution tours). Whether this additional effort is worth the gains compared to the Noortman and van Es approach is an empirical matter. We recommend starting with the specification of Noortman and van Es.

3.7 Differences between commodity groups

Some logistics choices (especially the choice between direct transport and using consolidation and/or distribution centres) and some choice alternatives within the logistic choices (especially. transport modes) may be more relevant for one commodity type than for another. Also the explanatory variables for these choices may differ between commodity groups. Therefore, a number of interviews among firms in Sweden and Norway were carried out by Solving Bohlin & Strömberg to find out what kind of logistics chains they use (direct transport or through consolidation and distribution centres), what modes they use and what the main explanatory variables are for these choices. A related issue is which commodity segmentation should be used in the logistics model and other components of the model system (base matrix model, network model). Table 1 and Table 2 contain the main outcomes of the interviews. More detailed outcomes of these interviews can be found in Annex 2.

Table 1 - Type of logistic chain by commodity group: Sweden

Decision criteria	Sweden Commodity groups										
	Agricultural products	Unprocessed lumber	Processed wood products	Foodstuffs	Crude petroleum	Petroleum products	Iron ore and metal waste	Metal products	Paper and pulp	Earth, stone and building material	Chemicals	Manufactured industrial products
Location of DC/FT	Directly to own DC or external DC.	Transport directly from forest to industry (pulp, paper and saw mills).		Concentration in/near populated areas		Concentration in/near populated areas.		For historical reasons close to the ship building industry	Close to printing and paper retailers	At one of the distribution centres in Sweden	Production plant close to harbour	Close to the bigger population centres
Use of DC/FT		Some reloading centers to change transport mode.	No, direct deliveries	Central distribution centers only.		Deposit sites (40), 4 000 gas stations.	No, direct deliveries from LKAB to either SSAB or Narvik (export)	Central warehouses (4) and 2 regional service centres		Central warehouse and external freight terminals	Direct deliveries	Freight terminals (20-27 ,for the 2 biggest road haulage companies) Direct deliveries for batch goods over 1 Ton
The modes used		85% trucks 15% trains	Trucks	Trucks		Boat and oil trucks	Rail	In rail 100% out trucks 100%	Trucks, Boats	Trucks	Boat (bulk), Trucks (Rail)	Trucks
Vehicle type		Heavy goods vehicles.	Trucks	Combination of heavy goods and light goods vehicles.		Container ships to refineries and 800 oil trucks for distribution.	Rail	Larger and medium sized trucks		Larger and medium sized trucks		Long distance trucks or more medium sized trucks
Frequency			Weekly	Daily deliveries.			Daily deliveries	Daily deliveries	Daily deliveries	Daily deliveries	Weekly/Monthly	Daily deliveries
Consignment size		Full load	Full load	Full load		Full load	Full load	Full loaded cars (80%)	Full load	Per m3	Full load	30kg/ less than 1 ton/ more than 1 ton.
Key influencing factors: -delivery time -delivery accuracy, -total cost,	Delivery accuracy	Delivery accuracy	Delivery time Total costs	Delivery time Total costs		Total costs	Delivery accuracy Total costs	Delivery accuracy	Total costs Delivery time		Total cost (K) Delivery accuracy	Delivery time

Table 2 - Type of logistic chain by commodity group: Norway

Decision criteria	Norway Commodity groups												
	Agricultural products	**Unprocessed lumber**	**Processed wood products**	**Foodstuffs**	**Crude petroleum**	**Petroleum products**	**Iron ore and metal waste**	**Metal products**	**Paper and pulp**	**Earth, stone and building material**	**Chemicals**	**Manufactured industrial products**	**Fish**
Location of DC/FT	Both Regional and Centralised		A local market, dsitribution directly from producers to the local building sites/shops	They use a simulation program which takes into account the location of both the producers and the customers	Oil comes from the North Sea either by boat or pipeline to two coastal refineries (or directly exported)	The main deposits are concentrated in highly populated areas		In the eastern part of Norway within 150km around Oslo, close to both producers and shops/customers (80% of the total Norwegian market)		A local market, dsitribution directly from producers to the local building sites/shops		In the eastern part of Norway within 150km around Oslo, close to both producers and shops/customers (80% of the total Norwegian market	Central warehouses/Fish markets close to the bigger population centres (Oslo,Trondheim, Bergen)
Use of DC/FT	From farmer to 30 production units (slaughter/cutting/processing) to 10 Distribution Centres. From DC either crossdocking with products from the dairy industry or directly to the shops/wholesalers	Transport directly to industry from the forests (Pulp 40%, Paper 20%, Wood 30% and Fuel 10%)	1 Centralised distribution centre	1 central warehouse and 9 regional warehouses mainly due to their market size. Multi pick-up (from several producers) and then reloaded before the transport to the regional warehouses.	There is no crude petroleum transport on the Norwegian mainland	2 refineries, 400 deposit sites (24 main terminals, 50 distribution terminals,Inland heating deposits and coastal terminals). Number of deposite sites has been/will be reduced.		From different producers to 1 central warehouse and from there directly to the different shops				From different producers to 1 central warehouse and from there directly to the different shops	The fish is treated at the harbour, packed and loaded on to trucks an distributed by 3rd party either to different fishmarkets (around 4 in Norway) or to Central warehouses or directly to shops/wholesalers .
The modes and vehicles used	Trucks (and some by train)	90% Trucks 5% Train and 5% Boat		Trucks 95% (trailers for inbound an trucks for outbound). They use DHL and Danzas for the transport (3rd party)	Boat, pipeline	Trucks, boat, train		95 % with trucks. The rest with train (to northern Norway). 3rd party logistics whereof 75% scheduled routes and the rest as single consignment goods or batch goods		Trucks, boat		95 % with trucks the rest with train(to northern Norway). 3rd party logistics whereof 75% scheduled routes and the rest as single consignment goods or batch goods(se DHL and Schenker distr.)	trucks and air (mostly fresh fish), boat and train (mostly frozen fish)
Frequency	2-5 times per week	Daily deliveries to pulp factories	Fixed delivery dates	Daily deliveries				1-2 days a week or daily				1-2 days a week or daily	Daily or every 3rd day(depending on season/weather
Consignment size	Full load/cross docking	Full load is the ambition		Try to get a full load (actual around 70%) They have started mix outbound and return to increase the load.				Full load is the ambition		Full load		Full load is the ambition	
Key influencing factors: -delivery time -delivery accuracy, -total cost,	Delivery time (relative to date of expiry)	Lower inventory levels in all parts of the value chain	Delivery time Total costs	Delivery time Total costs				Most economic is to split it up into smaller consignments and deliver it more frequently than to keep inventories.		Delivery accuracy		Most economic is to split it up into smaller consignments and deliver it more frequently than to keep inventories.	Delivery time

In practice there is considerable variation in logistics not only between commodity groups, but also within commodity groups, when defined at a level of 12-13 groups. Within each group both direct delivery and indirect delivery can be observed. The tables and the conclusions based on these below therefore only give the dominant tendencies within each group.

At this level we come to the following tentative conclusions on direct/indirect transport, mode use and explanatory factors in Sweden and Norway for each of the commodity groups:

- Agricultural products: use distribution centres, mainly trucks, some rail transport, transport time reliability is often a key factor.
- Unprocessed lumber: direct delivery from forest to industry, mainly (large) truck, some rail and ship.
- Processed wood products: direct delivery, mainly trucks, transport time and costs are key factors.
- Foodstuffs: Use distribution centres, mainly trucks, daily deliveries, transport time and costs are key factors.
- Crude petroleum and petroleum products: use distribution centres, rail, trucks and ships, transport cost is key factor.
- Iron ore and metal waste: direct delivery, especially by rail, transport cost is key factor.
- Metal products: use distribution centres, mainly trucks, reliability is key factor.
- Paper and pulp: use distribution centres, trucks and ships, transport time and cost are key factors.
- Earth, stone and building material: direct in Norway, indirect in Sweden, mainly boat and trucks.
- Chemicals: direct deliveries, truck, rail and ship, cost and reliability are key factors.
- Manufactured industrial products: use distribution centres, trucks, transport time is key factor.
- Fish: use distribution centres, all transport modes, transport time is key factor.

An even more general conclusion that emerges from these findings per commodity group is that for bulk products (here also including processed wood products, though these could be classified as general cargo rather than bulk, see below) direct delivery is the dominant chain type. This is of course perfectly plausible: the flows are often of a point-to-point nature, and the volumes are large. Consequently it is unlikely that transport cost savings can be realised by consolidating shipments in consolidation centres and bundling shipments from consolidation to distribution centres. This suggests a simplified version of the logistics model in which for unprocessed lumber, processed wood products, iron ore and metal waste and non-petroleum chemicals only direct transports are allowed (also when applied to for future years). For all other commodities, direct transport needs to be assessed against indirect transport chains. In the full version of the logistics model, the fact that these bulk commodities use direct transport needs to be produced by the logistics model.

The transport modes that are used most by commodity type in Sweden and Norway depend not only on characteristics of the goods, but also on the particulars of the locations of the various sectors in Sweden and Norway, the modes that are available at these locations, and geographic factors (such as the often long distances). We do not see modes that are non-available throughout an entire commodity type, irrespective of location, except maybe that fresh fish needs to be transported by truck given the time pressure of fresh delivery at the C end. But for many P/C and OD combinations, several modes can be unavailable, irrespective of the commodity type to be transported, because the port, airport or railway station is too far away.

Ideally the commodity classification in the logistics model and the network model should be based on the handling characteristics of the goods being transported and also on the related issue that different commodity groups may have different values of time. The categories that are created when using attributes with regards to logistic processes are sometimes called 'logistic families'. In some cases it has proved possible to translate a detailed classic commodity classification (NSTR) into logistic families.

In a previous version of the network model within Samgods (STAN99), six main logistic families were identified. The more recent STAN2002, however, uses commodity groups that are based on aggregating NSTR categories (the CFS uses a commodity classification that is consistent with this).

Within the European SCENES model a conversion has been made at the NSTR two-digit code level. The main element that actually identifies homogeneous freight flows in a practical form is the 'handling category' (e.g. liquid bulk, unitised). Homogeneity in terms of handling category is particularly relevant because different aspects that are represented in the model (e.g. modal choice and intermodal chains, cost functions, load factors, logistic chains) are dependent on the logistics requirements. Besides this, in the SCENES model, the logistics chains are represented by means of an appended module (SLAM) that works with logistics families. The logistics families are built according to the handling requirements of goods. Therefore the flows have been defined on a similar basis to make the interface with the SLAM logistics module easier.

In SCENES, the NSTR two-digit codes were grouped into an alternative NSTR one-digit level coding; small differences in the official NSTR one-digit level coding are needed to make a better match with handling types. In the SCENES-project (SCENES consortium, 2001) the following NSTR2-codes were converted into handling categories (see Table 3).

The flows have been obtained trying to aggregate the NSTR codes with the same handling category. The type of the commodity is also a relevant criterion: agricultural products have not been mixed with solid fuels though both are solid bulk in terms of handling category.

Table 3 - Flows (commodity types) distinguished in SCENES and conversion to handling categories

Freight flow	NST/R group	Handling category
1- Cereals and agricultural products	00 01 04 05 06 09 17 18	General cargo
2- Consumer food	02 11 12 13 16	Unitised
3- Conditioned food	03 14	Unitised
4- Solid fuels and ore	21 22 23 41 45 46	Solid bulk
5- Petroleum products	32 33 34	Liquid bulk
6- Metal products	51 52 53 54 55 56	General cargo
7- Cement and manufact. build. mat.	64 69	Unitised
8- Crude building materials	61 62 63 65	Solid bulk
9- Basic chemicals	81 83	Solid bulk
10- Fertiliser, plastic and other chem.	71 72 82 84 89	General cargo
11- Large machinery	91 92 939	General cargo
12- Small machinery	931	Unitised
13- Misc. manufactured articles	94 95 96 97 99	Unitised

NSTR group 31 is not included in SCENES

Another approach to segmentation of the freight market is to let the segmentation as much as possible follow from the estimation of the logistics model. A logistic family of goods could be defined as a combination of types of goods that have similar parameters in the logistics model. More generally, a market segment could be defined as a combination of commodity, shipper and shipment (transport-related) categories that have similar logistic parameters. This can only be carried out in practice if the *a priori* segmentation on commodity types is rather detailed so that, in estimation, aggregates of the *a priori* segmentation can be formed and it can be tested whether these aggregates have similar estimated logistic parameters.

In the Dutch SMILE model, logistic families of commodities have also been distinguished. The classification was based on seven variables: bulk/general cargo, density, packaging density (units per cubic metre), value/weight ratio, whether or not a distribution centre is used, shipment size and lead time. This resulted in about 50 homogeneous groups, being aggregates of the 542 product groups from the production statistics (Tavasszy, 2000).

For the Norwegian and Swedish national freight model systems, the classification of the existing commodity groups into handling categories can follow that of SCENES (as presented in the table above). This results in the mapping as depicted in Table 4 (which could be further refined in later projects):

Table 4 – Commodity groups in national freight model systems

Sweden	
Commodity group	*SCENES handling type*
Agricultural products	general cargo
Unprocessed lumber	solid bulk
Processed wood products	general cargo
Foodstuffs	unitised
Crude petroleum	liquid bulk
Petroleum products	liquid bulk
Iron ore and metal waste	solid bulk
Metal products	general cargo
Paper and pulp	general cargo
Earth, stone and building material	solid bulk
Chemicals	solid bulk
Manufactured industrial products	unitised

Norway	
Commodity group	*SCENES handling type*
Food	unitised
Fresh fish	unitised
Thermo products	unitised
Vehicles/machinery	unitised
General cargo	general cargo
Timber and wood ware	solid bulk
Minerals and stone products	solid bulk
Chemical products	solid bulk
Metals and ore	solid bulk
Petroleum products, liquid	liquid bulk
Petroleum products, gas	gas bulk
High value commodities	unitised
Frozen fish	unitised

The only commodity group that could not be accommodated in the SCENES handling types is 'petroleum products, gas' in Norway. This requires an additional handling type.

3.8 Explanatory variables

In the Swedish freight value of time study of 1999 (Inregia, 2001), it is hypothesized that the delivery time window and the day of delivery (the same day, the next day, and so on) will be key determining factors of the value of time (and indirectly of the choice among logistic options). The reasoning behind this is as follows:

(a) If after a change in transport time the delivery still fits within the same day and time window, it will cause no changes in production and time will only have a marginal value.

b) If the change in transport time leads to deliveries outside the time windows or to a different delivery day then production is influenced and the value of time will be substantial

Another hypothesis was that non-scheduled transports (including urgent shipments of spare parts and produce to order deliveries) would have a larger value of time than scheduled transports.

In Inregia (2001) six commodity segments were distinguished using a condensed STAN99 classification. The relevant segmentation variables were (some combinations are not relevant):

- Bulk or non-bulk
- Value under or over 25 SEK/kg
- Density in km/m^3 (<0.6; 0.6-1.0; >1.0).

Initial qualitative interviews in the Swedish freight value of time project showed that factors describing the transport suppliers often play a larger role in the choice of transport solution (e.g. mode choice), than characteristics of the infrastructure and the transport modes. Examples of the former are flexibility (how well the supplier can handle unexpected situation during the transport) and capacity (does the supplier have enough resources to carry out the transport when the buyer needs it, or does the buyer have to adjust to the supplier). Factors describing the infrastructure and modes are transport costs, time, risk of delay and risk of damage. The same interviews showed that damage risk was not a major factor for truck transports.

Models estimated on the SP data in Inregia (2001) were used to test a number of hypotheses. This led to the following findings:

- Bulk versus non-bulk goods influences the values of time, delay and damage; so does the value of the goods.
- The values of time differ between modes, and also between product density categories

- Shipments with short time windows and same day delivery have much higher values of time.
- There was no significant difference between scheduled and non-scheduled transports.

On the basis of these outcomes from the Swedish VoT study, the interviews done in this logistics project, stated preference interviews in freight transport done in the past (e.g. De Jong et al, 2004b) and existing freight transport modelling experience (e.g. De Jong et al., 2004a), we conclude that the following factors are important in explaining the size of the shipments, the logistic chains and the modes used:

- Information on inventories kept
- Flexibility and capacity of the transport supplier (carrier)
- Transport, ordering, handling and inventory costs and costs of distribution centres.
- Transport time (specifically with regards to the day of delivery and time window)
- Transport time reliability
- Lead time (if not endogenous)
- Value of the goods shipped
- Volume to weight ratio of the goods shipped.

These variables have to be used (or rather tested) in the logistics models, either as explanatory variables that should get a coefficient (or a distribution of coefficients) to represent their influence on the choices modelled, or as segmentation variables, for which the model coefficients have different values.

3.9 Alternative model structures

In specifying a structure for the logistics model, data availability and computational complexity need to be taken on board. This leads to several possible model structures (with different levels of sophistication), depending on where the compromise between 'ideal' and 'feasible in the short, medium and long run' is found. In distinguishing model structures, we use the same numbering of options (I, II and III) as in chapter 2 for the combinations of the logistics model and the network model.

In Table 5 are four different variants of the proposed model structure for the logistics model for Samgods and NEMO, with a decreasing degree of sophistication. In sections 3.2 – 3.5 in this chapter we described our 'ideal' model. Section 3.6 already contains some simplifications. This 'ideal' model is the option in the second column in Table 5 (option IA: full model). 'Ideal' here means that these are the richest models, but computational complexity and data availability have not yet been taken into account. Therefore, the recommended model might in the end be a different model.

Table 5 - Alternative structures for the logistics model

	Option IA Full model	Option IB Partial Model: reduced complexity	Option II Simplified partial model: mode choice in assignment	Option III Doubly simplified partial model: mode choice in assignment; no shipment size
Lead time and other customer requirements	Endogenous	Exogenous (by commodity type)	Exogenous (by commodity type)	Exogenous (by commodity type)
Who controls the supply chain? Contracting out	Endogenous (e.g. latent class model)	Exogenous (by commodity type)	Exogenous (by commodity type)	Exogenous (by commodity type)
Segmentation (e.g. commodity groups)	Result of model estimation	Exogenous	Exogenous	Exogenous
Locations of consolidation and distribution centres	Endogenous (long term optimal locations)	Exogenous	Exogenous	Exogenous
Model specification	One joint model (with air versus non-air on top of the tree)	Two steps to reduce complexity: -) shipment size -) consolidation, distribution and modes (with air versus non-air on top of the tree)	Two steps to reduce complexity: -) shipment size -) consolidation, distribution	One step removed to further reduce complexity. -) consolidation, distribution; shipment size not studied.
Mode choice (including vehicle size and loading unit)	Endogenous in logistics model	Endogenous in logistics model	Covered in network model (multimodal assignment)	Covered in network model (multimodal assignment)
Empty vehicles; load factors	Endogenous in logistics model	Endogenous in logistics model	Covered in network model (multimodal assignment)	Covered in network model (multimodal assignment)
Required effort	Very large	Large	Medium	Relatively small
Complexity	Very complex	Quite complex	Moderately complex	Relatively straightforward
Output	OD matrices by shipment size and commodity class in vehicle units	OD matrices by shipment size and commodity class in vehicle units	OD matrices by shipment size and commodity class in tonnes	OD matrices and commodity class in tonnes

The other options in Table 5 (columns 3, 4 and 5) have the same models for step A (and therefore also the same disaggregate character and unit of observation as the full model), but the complexity of step B (models for the logistics decisions of firms) becomes successively reduced. Step C is the same for options IA and IB; in these cases the aggregation takes place over vehicle units, by shipment size and commodity class. In options II and III, the aggregation of step C takes place over tonnes transported (by shipment size and commodity class in option II and only by commodity class in option III).

In options IB, II and III the agent that controls the supply chain and the customer requirements, including the lead time, become given values that might differ between commodity types. In option IA, these are choice variables that are explained in the model. The commodity segmentation and locations of consolidation centres and distribution centres become exogenous as well in options IB, II and III.

To reduce the dimensionality of the decision problem, in options IB and II the cost minimisation problem is cut into two pieces: the inventory logistics problem (determining shipment size) and the transport logistics problem (determining transport chains).

All simplifications of option IB are also included in options II and III, but in options II and III mode choice is shifted to the network model and is handled by multi-modal assignment.

The difference between option II and option III is that the former includes a treatment of shipment size and therefore the OD matrices that are fed to the network model contain a distinction by shipment size, with different cost functions and mode/vehicle availabilities per shipment size. Shipment size is not modelled in option III. Model complexity is positively related to the risk of failure and also with run times and maintenance efforts for the resulting model.

Option IB is a special case of option IA. Option II is a special case of IB; and option III is a special case of option II. Option IA is the most general model. All four variants can use the same zoning system.

Options IA and IB both correspond to option I in section 2.3 for combining the new logistics model with the network model. Similarly, options II in Table 5 and section 2.3 correspond; and options III in Table 5 and section 2.3 correspond.

Each of the four options can be subdivided into two options according to the way commodity types will be segmented (see section 3.7):

- Only direct transports available for unprocessed lumber, processed wood products, iron ore and metal waste and non-petroleum chemicals (Sweden) and for timber and wood ware, minerals and stone products, metals and ore and chemical products (Norway).
- Direct and indirect transports available for all modes; the cost minimisation process determines for all commodity groups whether direct or indirect chains are used.

As stated in section 2.3, we have a preference for option I. For the choice within option I (IA or IB), the best choice probably is option IB, given the difficulties that can be expected when trying to make lead time and supply chain dominance endogenous and having the segmentation (partly) result from the mode estimation. Also the cutting of the logistics choices into two parts (shipment size choice and transport chain and mode choice) will make the model more tractable and easier to develop and apply. In addition, for short term applications of the model, there is no need to include the location choice for consolidation and distribution centres. The existing locations can be used to define the choice alternatives for the transport chain selection. However, for long-run applications, it would be of considerable value to have the locations of consolidation and distribution centres in the private sector produced by the model (the locations of ports and airports remain exogenous). This would require an option between IA and IB, with all the features of IB but with additional facility location choice. Therefore, we recommend developing the model as in option IB first, and extending it later to include location choice for consolidation and distribution centres.

This is also related to our recommendation on the treatment of the wholesale sector (see section 2..2). Initial versions of the logistics model can be based on PWC matrices (with location of wholesale given), later versions can try to incorporate the location of logistics activities (by the wholesale and other sectors) in the logistics model itself.

We also recommend a simplification in the model for the bulk products specified above. We suggest making only direct transport available, because this reduces the amount of work in model estimation and implementation and reduces run times considerably without giving up realism in representing existing patterns. The mode used for direct bulk transport will often be road transport, but can be rail or sea if both the P and C locations have rail sidings or quays.

3.10 Output for cost-benefit analysis

The new logistics model could add a number of features to the cost-benefit analysis (CBA) of infrastructure projects[12] and pricing measures that are currently not included in the CBA as implemented in Norway and Sweden. First of all, the logistics model (in all options discussed above) could provide an estimate of one type of newly generated traffic: substitution between direct and indirect transport (and between different forms of indirect transport). Generated traffic is not included in the Samkalk procedure for CBA that is used in Sweden, or in the CBA procedure used by the Norwegian Rail Administration (though this includes substitution between road and rail transport). The options IA and IB could also give the changes in the modal split (in an aggregate way; if requested possibly also in the form of simulated mode changes at the firm and shipment level) that can be used in CBA to give the welfare effects of substitution between modes (but the present network models are also capable of giving aggregate changes in the modal split).

In all of the options for the logistics model described in section 3.8, the combination of the logistics model and the network model will be able to provide the same outputs that are being used now as inputs into the Samkalk CBA: tonne-kilometres, vehicle-kilometres, tonne-hours and generalised costs. The requirement to have outputs in tonne-kilometres necessitates to include in the network model a procedure to calculate the flows in tonnes from those in vehicles (as discussed in section 2.3).

[12] The logistics model can also contribute to the evaluation of other policies (e.g. market (de)regulation), but only if these policies can be simulated as changes in the components of the logistic costs functions (e.g. prices for the services of consolidation and distribution centres).

Many infrastructure projects produce benefits because they bring about a reduction in transport time for one or more modes (there can also be changes in the operating costs when distances are reduced, and delay risk can be reduced and frequency increased). This reduces several components of the generalised costs. In the current Samkalk travel time as such is included in the qualitative costs part (together with delay costs), using standard values of time. The Norwegian CBA for rail transport projects also includes time costs (besides price and delay costs). In the logistics costs formulation as in equation (5), a reduction in travel time will influence the logistics cost of the shipper in two ways: through a reduction in the capital costs of the inventory in transit and through a reduction of the safety stock. In the longer run (with price changes on the transport market), the willingness to pay for time reductions of the carrier (because labour and capital goods can be used more efficiently) needs to be taken into account as well. The proper generalised costs for CBA will be the generalised logistics costs that are fed back to the P/C matrices from the network model and the logistics model.

CHAPTER 4 Design of the model implementation

In this chapter, the data requirements will be formulated (section 4.1) and compared to the data that are available or the additional data that could be collected (section 4.2). For missing data, proposals for new data collection will be worked out (section 4.3). We shall discuss model estimation/calibration (section 4.4) as well as the programming and validation of the model (section 4.5). A time planning and a budget calculation for these tasks were provided separately.

4.1 Data requirements

For the logistics model presented, the following data are needed for step A (disaggregation from flows to firms):

- The number of firms (if possible 'local units', also called 'workplaces'; when the same legal entity has units in different municipalities, we would like to have information at the level of these local units) by commodity type and municipality
- the turnover of these local units
- the number of employees of these firms

This information is required both at the production and the consumption end.

Firms like Dunn and Bradstreet and A.C. Nielsen have this kind of information, but also national statistical offices should have relevant information on this.

Step B (logistic decisions) requires information on the following items (step C requires no extra information):

1. Data on individual shipments: sector of sender and receiver, origin and destination, modes used, shipment size/frequency, use of freight terminals (including intermodal terminals and marshalling yards), consolidation and distribution centres, ports and airports. Preferably this would be transport chain information: which shipments go directly from P to C, which use the above intermediate points.

2. Data on where the freight terminals, consolidation and distribution centres, ports and airports are located.

3. Data on transport and logistics costs: transport costs per km, terminal costs, handling and storage costs (not only for Sweden or Norway, but around the world for international flows).

Most crucial are the data on the shipments of individual firms (item 1 above). More specifically, for estimation of the model of logistics decisions, we need information about the observed outcomes on logistic decisions:

- shipment size (or frequency per year)
- contracting out or not
- use of consolidation and distribution centres, ports and airports on the route between the P and the C locations; this means that we need to know the sender and receiver location as well as all intermediate stops and transfers of the shipment.
- Mode, vehicle size and loading unit used for all legs.
- batching with other goods in consolidation and distribution, characterisation of the consolidation and distribution tours carried out (e.g. number of stops)
- possibly also (for option IA) supply chain control and lead time.

It is possible to estimate the models without observations on some of the endogenous variables. These will then be treated as 'latent variables' (but explanatory variables on these latent variables are required). In the absence of observations on this, the supply chain control variable for instance could be treated as a latent variable (only relevant for model IA; in the other model options this variable is exogenous).

Furthermore for the estimation of the same models we need data on the variables that we think can explain these choices, including:

- Information on inventories kept
- Flexibility and capacity of the transport supplier (carrier)
- Transport, ordering, handling and inventory costs and costs of distribution centres.
- Transport time (specifically with regards to the day of delivery and time window)
- Transport time reliability
- Lead time (if not endogenous)
- Value of the goods shipped

- Volume to weight ratio of the goods shipped.

The spatial detail needs to be that of the municipality (for consistency with the P/C matrices) and the commodity grouping needs to be consistent with the 12/13 categories that will be used in the P/C matrix (and probably in assignment as well), but preferably would be much more detailed.

4.2 Overview of available data in Sweden and Norway

4.2.1 Sweden

The Commodity Flow Survey

In fact, for Sweden, a large part of the required information on the structure of production and consumption in terms of firms and firm size is used as the sampling frame of the Commodity Flow Survey (CFS). The CFS uses as population the outgoing and incoming shipments at particular local units within companies (SIKA, 2003). The sampling frame of these local units was constructed by selecting a subset of local units from the Swedish Business Register (CFAR), and using a stratification by size of the local unit (number of employees), geographic location and the main type of commodity production (based on the sector of the local unit). In the CFS 2001, 12,419 local units were sampled from a population of approximately 38,000.

There are problems, however, to get the CFS sampling frame due to confidentiality. Our consortium can only get the description in the official report, which does not give any details on the distribution of firms at the P and C end. Maybe this step for Sweden should be carried out by Statistics Sweden or SIKA. Alternatively we could go back to the underlying data that formed the basis for the sampling frame of the CFS. Most of the information for the sampling frame of the CFS came from the CFAR of Statistics Sweden (see below).

RAND Europe and Solving Bohlin and Strömberg have received the micro-data (in ACCESS) of the Swedish Commodity Flow Survey (CFS, VFU in Swedish) 2001 (se SIKA, 2003). This consists of two files: one for the outgoing (domestic and international) shipments of firms located in Sweden and one for the incoming (international only) shipments of firms located in Sweden. A stratified (non-random) sample of local units of firms in mining, manufacturing and wholesale registered in Sweden was asked to give information on a systematic sample of up to 150 individual shipments that took place within a specific reporting period of one to three weeks, depending on the number of employees of the local unit (SIKA, 2003).

The CFS 2001 data we received contains information about:

For outgoing shipments:	
–	Postal or zip code from which the shipment is sent; also coded by municipality of origin
–	sector of the local unit
–	size category of the local unit
–	commodity type (in VFU code and UVAV30 code)
–	hazardous goods or not
–	invoice value (with and without imputed values for partial non-response)
–	weight (excluding packaging) of the shipment (with and without imputed values for partial non-response)
–	type of handling (bulk, containers, pallets, …)
–	transport modes inside and outside Sweden (if several modes were used, then the respondent was asked to state these in the order used)
–	postcode and municipality of recipient, if in Sweden
–	location, country and STAN99 region of recipient, if abroad
–	border crossing point, for international shipments
–	access to rail tracks and quay docking site.

For incoming shipments:	
–	Postal or zip code at which the shipment is received; also coded by municipality of destination
–	sector of the local unit
–	size category of the local unit
–	commodity type (in VFU code and UVAV30 code)
–	hazardous goods or not
–	invoice value (with and without imputed values for partial non-response)
–	weight (excluding packaging) of the shipment (with and without imputed values for partial non-response)
–	type of handling (bulk, containers, pallets, …)
–	transport modes inside and outside Sweden (if several modes were used, then the respondent was asked to state these in the order used)
–	location, country and STAN99 region of sender (abroad)
–	border crossing point

The CFS however does not include specific data on the use of distribution centres and freight terminals (unless a respondent should interpret these as the address of the sender or receiver). Also it is difficult and sometimes impossible to identify the whole sequence of modes that is used in a transport chain. The sector of the receiving firms (for outgoing shipments) and the sender (for incoming shipments) is not recorded. The present CFS only has receiving industry codes for incoming international shipments. SCB tested the chain approach in an initial pilot sample, but many respondents did not know the terminal locations.

There are some problems with missing values (partial non-response) for the reported shipments, especially for the type of handling (more than 60% missing) and the access to rail tracks and quay docking sites (more than 70% of the responses missing). Also, there are indications that the domestic legs in international transports (e.g. from the sender to the port or airport) have sometimes been recorded as domestic transports (Andersson, 2004). The outgoing and incoming shipments cannot be linked in a meaningful way (Andersson, 2004).

We have done some initial runs on the CFS2001 files. The file for the outgoing shipments contains 855,269 shipments of which the sector of the local unit at the origin end was coded. 552,505 (almost 65%, unweighted raw sample) of these have as origin a warehouse. Shipments from manufacturers form 33%, and the primary sector (agriculture, mining) only 2% of the shipments. However, the shares in terms of value or weight of the shipments of the primary sector and the manufacturing sector are much larger. The file for incoming shipments includes 60,192 shipments, with sector coded. Here 32,389 (54%) is to local units that are wholesalers. Practically all the rest is to manufacturing, which has a relatively larger share in terms of value and weight.

In Table 6 and Table 7 are the (unexpanded) mode shares in the amount of shipments. Please note that the shares in tonnes or tonne-kilometres will be very different (higher shares for sea and rail). The modes per shipment were defined as follows, based on the mode sequences provided by the CFS:

- If air transport in the chain, then air transport.
- If sea transport in the chain, but not air transport, then sea transport.
- If ferry in the chain, but not air or sea transport, then ferry.
- If rail transport in the chain, but not air, sea or ferry, then rail transport.
- If road transport (car, bus, truck) in the chain, but not air, sea, ferry or rail transport, then road transport.
- Other transport: whatever remains (including unknown; in fact most observations in this category are for missing observations on the transport mode).

Table 6 - Mode split of outgoing CFS shipments (unexpanded)

	International flows Number %		Domestic flows Number %	
Air transport	6306	6	633	0
Sea transport	2518	2	382	0
Ferry	6331	6	1114	0
Rail transport	4060	4	6452	1
Road transport	59550	52	705792	95
Other transport	35104	30	27027	4
Total	113869	100	741400	100

Table 7 - Mode split of incoming CFS shipments (unexpanded)

	International flows Number %		Domestic flows Number %	
Air transport	2735	5	0	0
Sea transport	702	1	65	88
Ferry	3380	6	0	0
Rail transport	2115	3	0	0
Road transport	43331	72	0	0
Other transport	7855	13	9	12
Total	60118	100	74	100

From Table 6 and Table 7 we can conclude that in terms of unexpanded numbers of shipment, transport chains with road transport modes only are highly dominant in the outgoing domestic shipments and dominant in the incoming and outgoing international flows. For the estimation of the logistics model on the CFS, the observations need to be counted as unexpanded shipments.

The CFS 2004/2005 data will be delivered to SIKA on 1 April 2006. The main changes with respect to 2001 are that the question on hazardous goods is omitted and the industry of the receiver of outgoing flows is asked now (but retail and wholesale is one sector).

Register data

The CFAR (Swedish Business Register) includes information on local units, physical locations, number of employees and turnover of firms. Number of firms and number of employees per commodity group (as in STAN) and municipality can be provided from CFAR for local units. The information on turnover however is only collected at the company level (not of the local unit). Researchers may obtain access to classified information after an examination. Turnover for local units was calculated by SCB using proportionality with employment. The turnover at the local unit is classified information, but maybe an agreement to deliver can be made (first step would be a formal request for the data to SCB). Otherwise it will be possible to redo the calculations using the same method as SCB used.

So, at the P end, it seems possible to get the required information on firms for step A. Similar data on firms at the C end are not available in Sweden. SCB once tried to regionalise the foreign trade statistics. Eurostat has classifications that might be of some use. There is also some information on which companies are the big importers. The new CFS 2004/2005 also includes the industry code (10 categories; unfortunately wholesale and retail are one category) for the receiving firm for outgoing shipments. According to Statistics Sweden, for information on the number and size of firms (including retail) in the consumption of goods, several data sources would have to be combined (foreign trade statistics, transport statistics, the CFS itself).

Data on distribution centres and terminals

The Samgods group and the working group for transport analysis in the Norwegian National Transport Plan wrote in 2004 that in Sweden, the publicly available information on freight flows to and from consolidation and distribution centres is limited to ports and airports (from port and maritime statistics and new air transport matrices). No information is available on the use of the other consolidation and distribution centres.

There is some information on the use of distribution centres (e.g. for Schenker), though the CFS does not include these within Sweden. Also there will be a private freight terminal survey by Göteborg University, but this has been delayed. This university also collected data on warehouses in the Stockholm area. The 2004 report "Stockholmsregionens terminalstruktur" of the regional and traffic planning office for Stockholm (http://www.rtk.sll.se/publikationer/index.htm) distinguishes three types of terminals: terminals for goods transported in trailers, containers and similar units, terminals for parcel goods and terminals for food (subgroup of the parcel goods).

Terminal location is covered in the report “Terminals as part of the Swedish transport system – an overview (Woxenius et al. 2003). It contains several listing of different types of terminals (http://www.sou.gov.se/gtd/rapporter.htm). For intermodal transport one source is probably the administrative file that is kept by the Swedish railway inspectorate of private railways linked to the national railway. This file however does not always show the actual workplace situated along the rail track but can probably be used a starting point for further investigation. Similar registers are held at the Swedish Maritime Board, which contains information about quays along the Swedish coastline. Information about access to quay and railway can also be found in the Swedish CFS.

Surveys of transport companies such as warehouses and terminals (turnover and revenue) are also carried out periodically at Statistics Sweden.

On the location of freight terminals, consolidation and distribution centres: the firms register data CFAR contains detailed SNI codes for activities, including a category for goods terminals and a category for goods storage and warehousing (central warehouses). It might be possible to use this business register as a source for the location of logistics centres.

Transport statistics

The lorry surveys are carried out according to EU rules. They give the origin, destination (in Sweden at county level, abroad as countries), commodity group (25 NSTR classes), kilometrage and weight. This is only done for trucks with 3.5 or more tonnes maximum capacity. The data can be made available, but may be classified information at the most detailed level. Similar OD statistics exist for sea transport at SCB. SIKA has the OD data for rail and air. There are also statistics for light trucks for the year 2000.

Production statistics

The IVP are detailed production statistics (again following EU rules), for the national accounts. It gives, for all enterprises, net income and quantity and value of industrial production. It does not include consumption or I/O data. These statistics are available at the municipality level.

Data on transport and logistics costs

On costs, data are needed on transport costs as well as on the costs of ordering, keeping inventories, and of consolidation and distribution centre services and capital carrying costs. The transport costs can be obtained from the network model (for the 12 commodity groups handled), but there are no official statistics for the costs of handling, storage and terminal services (Samgods group and the working group for transport analysis in the Norwegian National Transport Plan, 2004), except for some scattered estimates and public terminal price lists. Therefore most of this information needs to be gathered as part of a new survey.

SCB also gathered some information on transport and logistics costs (SCB, 2004). Also at the end of 2003, SCB has started the production of price indices for transport services (road, sea, air) and forwarding services.

The most desirable information for this project would be information from the firms on their logistics. In Samgods group and the working group for transport analysis in the Norwegian National Transport Plan (2004) it is mentioned that such information is unavailable because of its confidential nature (business secrets). It is clear that recent firm-specific information cannot be obtained, but it might be the case that the sensitivity of firms to sharing this information might decrease as the information gets older.

4.2.2 Norway

One should be aware of differences in data availability between Norway and Sweden (especially the absence in Norway of a commodity flow survey; one should not expect that the additional requirements of a logistics model will warrant organising such an expensive survey in Norway).

Register data

In Norway, information on the revenues and employment by industry type and municipality are available from the Register of Establishments and Enterprises of Statistics Norway (Hovi, 2004). Conversion keys would have to be made between industries and commodity groups.

Data on distribution centres and terminals

Information about the location of terminals, their equipment, usage and costs is currently being collected in Norway by the Institute of Transport Economics (Hovi, 2004), but this refers only to terminals handling general cargo. This project will be completed in December 2004. Information on liquid bulk terminals is probably available from the Norwegian Petroleum Institute (www.np.no).

Transport statistics

A lorry survey is done at the county level (19 counties) per commodity group according to NSTR on a 3-digit level. A sample survey is produced every week and sent out to 190 firms, both transport companies as well as manufacturing companies having their own truck fleet and others e.g. farmers. There is approximately a 95% response rate. There are questions regarding the weight of the goods and the length of the journey. This form is completed for each truck above 3.5 tonnes within those companies for all shipments in the week. OD information exists even on a municipality level but is not published. The information that exists on the municipality level can probably be used by our project in a model as long as we do not publish the collected information. There is no information about distribution centres or freight terminals in these statistics. Furthermore, there are no official statistics that contain information about shipment sizes for domestic transport in Norway. From the above continuous lorry surveys there is information on the load per lorry, but this is defined differently from shipment size. Shipment size is defined in our logistics model as the order quantity and therefore it can exceed the capacity of a lorry (e.g. transported by several lorries). The load per lorry, as used in the statistics, cannot. Also the load from the lorry statistics could contain several small shipments (orders from different firms).

As regards airports. Statistics Norway has statistics regarding the passenger traffic. Statistics about the transport of goods are gathered by the Norwegian Aviation Authority according to EU regulations. Information is available for freight transport in tonnes from airport to airport (also distinguishing different types of aircraft).

Maritime statistics are gathered from the 30 largest ports in Norway. Each port registers information about each shipment weight, commodity (NSTR 2 digits), type of cargo (bulk, etc.), type of vessel, etc. The statistics cover goods to and from ports/airports, not the location of the sender or receiver. No information exists about the type of mode that is used for the hinterland transport. For domestic sea transport in Norway there are counts in terms of shipments, but these are more than ten years old and do not include international maritime transport (Hovi, 2004).

Rail transport. Statistics Norway has no statistics for this sector. The Rail Authority gathers information, in accordance with EU regulations. Information on individual shipments is not available, only aggregated information at the NUTS2 level (six regions in Norway), in tonnes and tonne-kilometres will be available from 2005 onwards. Information per commodity group will only be available at the national level. The Rail Authority will also collect information about intermodal transport (container, trailer, semi-trailer, truck and wagon): tonnes transported, number of units with or without a load, number of TEU (Twenty foot Equivalent Units). Information will also be gathered about train kilometres (not by region). There is no information on terminals.

Production and consumption statistics

The Norwegian production statistics are based on a survey among all 11,000 establishments (producers, excluding the oil industry and agriculture) in Norway. Information is available for local units: sector (NACE, following European guidelines), turnover and employment. Data can be supplied at the municipality level. For number of firms by sector and employment by firm by sector, there are no restrictions. For turnover at the municipality level, there will often be confidentiality problems (only a few firms in the cell): the information needs to be hidden and can only be supplied at a more aggregate level. But it is a good approximation to allocate the more aggregate turnover figures to municipalities proportional to employment. These production statistics only include producers, not wholesalers and retailers. With this exception, it seems possible to get the data needed for step A (disaggregation from zones to firms) of the logistics model at the P end.

Statistics Norway also did a survey into the consumption by production firms (again no wholesalers or retailers). The most recent survey was in 2002 (and, before that, 1997). It contains a sample of 5,000 enterprises from the 11,000 above (focussing on the biggest firms: almost 90% of production covered). These data were not published, but can be used for research. Producers (classified down to 5 digits, similar to NACE) were asked which commodities (6 digit classification, similar to NACE) they consume. This can be given at the municipality level (with the same restrictions as above). By connecting to the production statistics, the number of employees per firm can be given. This implies that the information for the disaggregation step A will also be available for the C end.

For the oil industry, there are similar statistics, but production is off-shore (most firms are based in Stavanger). For agriculture, data are collected by a separate unit of Statistics Norway.

Data on transport and logistics costs

The transport costs can be obtained from the network model (for the 13 commodity groups handled), and also from the lorry surveys described above, but there are no official statistics for the costs of handling, storage and terminal services except for some scattered estimates and public terminal price lists. Therefore, most of this information needs to be gathered as part of a new survey.

4.3 Data gaps and proposed new data collection

In section 4.1, the data requirements for the proposed logistics model were listed. In section 4.2 an overview of the available data in Sweden and Norway was provided. In this section we combine the information from the previous two sections to identify data gaps. The section concludes with a proposal for new data collection.

Sweden

The information that is required for step A (the disaggregation to the firm level) at the P end is available for Sweden. For the C end in Sweden, the required information is not readily available. A combination of several data sources (trade statistics, transport statistics and the CFS 2001) could provide approximations, but the CFS 2004/2005 would probably be able to give much better information, since the receiving sector will be included for the outgoing domestic and international flows, not just for the incoming international flows as in the CFS 2001.

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

The fact that the frequency of the shipments by commodity type is not provided in the CFS files makes it hard to use the CFS as a basis for the estimation of the trade-off between inventories and transport (the determination of the economic order quantity).

Information about which party decides on the logistic issues and who pays is not included either. For such data gaps we recommend new surveys (see below).

There might be some indirect information on shipment frequency in the CFS: the local units were asked to give data on some fraction of their shipments (all commodities together). Also, there is an expansion to total tonnes in Sweden. SIKA has asked Statistics Sweden to provide these data.

Because of the absence of data on the receiver (e.g. the sector) and on the use of consolidation and distribution centres, the CFS 2001 can only be used to estimate models explaining mode choice (needed for options IA and IB) and use of port and airport (and even this with some reservations, also see Andersson, 2004). The lorry surveys and other transport statistics might be used to enrich the CFS information, because these surveys also contain information on individual shipments, including by definition the mode used. This would make the estimation database partly an endogenously stratified sample (we shall return to this in the discussion on estimation).

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

There are three ways to solve this problem:

- Use existing data on the locations of distribution centres and consolidation centres and develop cost minimisation models based on the locations of these centres and their costs. This is not a form of model estimation, but a deterministic allocation based on *a priori* fixed parameters (which can be made stochastic, but then with *a priori* fixed distribution parameters). The resulting distribution over logistic/transport chains will not be based on *observed* patterns, but will be a *normative* distribution (the outcome of a particular cost minimisation procedure).
- If the present and planned freight terminal surveys are able to give a representative picture of logistic facility use per commodity group and municipality, this information could be superimposed on the CFS shipments, and the model, including the choice of use of consolidation and distribution centres, estimated on the enriched dataset.
- Collect new data on transport and logistics chains (see below) and use these to estimate the model.

The available data on the explanatory variables is therefore limited to:

- transport costs
- some scattered information on cost of distribution centres

- transport time, and delays
- the value of the goods (the latter is available through the base matrix project, and is required at the level of the value-to-weight transformations used in that project).

Norway

For Norway, the information that is required for the disaggregation to the firm level (step A) seems to be available both for the P and the C end (according to Statistics Norway). There is no commodity flow survey in Norway that could be used in the estimation of a model for the logistics choices (step B). There is some information on individual shipments in the lorry surveys and the maritime surveys, and maybe also for rail and air transport. All this information could be combined to form a sample of shipments for various modes. Of course this would be a selective sample, since it would be based on the actually used mode (endogenously stratified sample), but such information can successfully be used in estimation (see next section). The main problem is that this dataset would not include information on the use of consolidation and distribution centres. It can only be used to estimate a model for mode and port choice. As for Sweden, there are three ways to solve this problem:

- Use data on the locations of distribution centres and consolidation centres from the ongoing project of the Institute of Transport Economics and develop cost minimisation models based on the locations of these centres and their costs.
- Use data from the ongoing project of the Institute of Transport Economics on the use of distribution centres and consolidation centres (available only for general cargo). If this freight terminal survey could give a representative picture of logistic facility use per commodity group (at least for general cargo, where terminal use is most important) and municipality, then this information could be superimposed on the shipment data from the transport statistics, and the model, including the choice of use of consolidation and distribution centres, estimated on the resulting dataset.
- Collect new data on transport and logistics chains (see below) and use these data to estimate the model.

For Norway, the data situation on the explanatory variables is similar to Sweden: available are: transport costs, some scattered information on cost of distribution centres, transport time, delays and the value of the goods (data on the last variable are available through the P/C matrices).

New data collection

We propose that a new survey[13] be carried out both in Sweden and Norway among firms in freight transport and municipalities about:

[13] A pre-study on new data collection in Sweden for the transport industry and the Samgods group is planned for the end of 2004.

- the use and costs of consolidation and distribution centres
- the formation of logistic and transport chains and
- attributes of the shipment, including customer requirements, and handling and storage cost).

The data from such a survey are vital for the estimation of the logistics model (all four model options described in chapter 3). Some of this information is being collected in Norway at the moment as part of the general cargo terminals survey. New stated preference information from shippers and carriers, e.g. with experiments on mode choice, whether or not to use a distribution centre, and on the trade-off between transport and keeping inventories, could be very useful for model estimation, especially because in SP surveys it is possible to avoid strong correlation between explanatory variables.

In the future, it might be possible to use data from Radio Frequency Identification (RFID). These are electronic tags that are increasingly being used to identify the location of specific shipments (tracking and tracing) in certain sectors and that are stored centrally by the respective firms. At the moment, RFID is applied only to a limited fraction of the shipments, and the issues of confidentiality/business secrets and standardisation would have to be sorted out, but in the future this may be able to be used as a source of information for modelling logistics (just as telematics information on vehicle movements can be used for validation of the outcomes of step C, together with non-electronic count data).

4.4 Model estimation

Model estimation is required for step B of the logistics model, the part that deals with the logistics choices. In chapter 3 we gave various cost functions. The full model (option IA) can be estimated from the equation for the total annual logistics costs, such as eq. (1) or eq. (5). A random utility discrete choice model can be obtained by using minus the total annual logistics costs as the observed component of utility and by adding random cost components ε (for omitted variables, measurement errors and such) that follow specific statistical distributions.

$$U_{rskmnqh} = - G_{rskmnqh} + \varepsilon_{rskmnqh} \qquad (10)$$

Where:

$U_{rskmnqh}$: utility derived from logistic and transport choices

$G_{rskmnqh}$: observed component of total transport and logistics costs

$\varepsilon_{rskmnqh}$: random cost component.

In eq (11) below we also introduce an extra subscript z for logistics options (choice of port, airport, consolidation and/or distribution centre). The subscript h could include alternatives in terms of specific transport mode as well as vehicle sizes within a mode.

Using eq. (5) from section 3.6.1 for $G_{rskmnqh}$ we get:

$$U_{rskgnqhz} = \beta_{0qzh} + \beta_{1k} . (Q_k/q_k) + T_{rskqhz} + \beta_2.j.v_k.Q_k + \beta_3.(t_{rs}.v_k.Q_k)/365 + \beta_{4k}.(q_k/2)$$

$$+ \beta_5.v_k.(q_k/2) + (\beta 4_k+\beta 5.v_k).a_k((h_k+t_{rs}).Q)^{1/2} + \varepsilon_{rskgnqhz} \quad (11)$$

Where:

β_{0qzh} = alternative-specific constant

$\beta_{1k} = o_k$

$\beta_2 = i.g$

$\beta_3 = i$ (in transit)

$\beta_{4k}=w_k$

$\beta_5=i$ (warehousing).

What we have done in eq (11) is to include a number of items, such as order costs, storage costs and capital carrying costs, in the coefficients to be estimated. The reason for this is that data on these items will be very difficult to obtain. As a result, the coefficients have specific logistical interpretations. We could distinguish between the implied discount rate (i) of the inventory in transit (β_3) and of the inventory in the warehouse (β_5), because these need not be the same (see Vieira, 1992). The transport costs T_{hrskqz} can be specified as in section 3.6.2. and do not include additional coefficients (though these could include coefficients for transport time and other quality of service attributes within the generalised transport costs).

Cost minimisation thus becomes equivalent to utility maximisation. Including revenues for the shippers and doing profit maximisation instead of cost minimisation is not required here, since the P/C flows (and therefore the sales) are already given.

If we use the extreme value type I distribution (also sometimes called Weibull or Gumbel distribution) for ε, the model becomes multinomial logit (MNL). Nested logit (NL) can be attractive to test, because it seems likely that some alternatives (e.g. road and rail transport) will have a greater degree of substitution than other alternatives (e.g. road and sea transport). This is an empirical question: statistical tests (likelihood ratio tests, using the Chi-square distribution) will tell whether or not the NL gives a significantly better loglikelihood value than MNL.

The mixed MNL model (MMNL) is en extension of the MNL model and provides additional flexibility in the correlation structure and variation between observations, which might be relevant for the logistics model, given the heterogeneity often found in freight transport. The MMNL model can be obtained in two different ways:

- By distinguishing two error components in ε, one following the extreme value type I distribution, and the other following, for instance, a multivariate normal distribution to allow for more complicated correlation structures between alternatives than the NL model allows for.
- By allowing the coefficients in G (the β's) to follow a statistical distribution instead of being a point estimate. This is the random coefficients model or taste variation model. It looks particularly attractive for this application in freight transport, because it is often stated and sometimes observed that preferences in freight transport decision-making are very heterogeneous.

For MNL, many existing software packages can be used. For NL the choice is more limited, and for MMNL only a few model estimation programmes can be used (including Alogit, Biogeme, Nlogit and special-purpose programming in Gauss).

In case the estimation dataset is selective in terms of an endogenous variable (e.g. based on a stratification by mode instead of random sampling), then –provided the model includes a full set of alternative-specific constants- the MNL model can be estimated consistently with standard procedures as if the sample were random or exogenously stratified, with only a correction of the alternative-specific constants after estimation (to reflect the population shares). This property does not hold for more complicated models, but can still be used as an approximation. The alternative is to use substantially more complicated models to correct for the selective sampling (see Hague Consulting Group, 1991).

Instead of estimating a model for all logistics choices simultaneously, it might be more practical to estimate a model for mode choice and use of consolidation and distribution centres first and then estimate a model for shipment size choice. Both models can then be combined by using a measure of minus the expected costs (expected utility) from transport logistics decisions, in the form of the logsum, in the inventory logistics choice. This is one of the features of model options IB and II. In these options, the second step model is estimated first, then the logsum is calculated, and then the first step model is estimated, including the logsum as an explanatory variable.

In Figure 5 the proposed estimation, calibration and validation process for the Swedish and Norwegian national model systems for freight transport are depicted (the estimation data are above the boxes, the validation data are below the boxes). The P/C matrices are partly based on observations and partly synthetic (model-generated). The data used in this process come from the CFS, the regional input-output system rAps (both only for Sweden), economic statistics from national accounts and foreign trade data, and from the questionnaire-based OD surveys (origin, destination, costs, commodity) for truck, rail and sea (in the current Norwegian procedure). The logistics model is estimated on the CFS (Sweden only), information on terminals, available OD information (e.g. on trucks, but also for other modes) and possibly on new survey data, and then transforms the initial P/C matrices into OD matrices.

When no disaggregate estimation data would be available or could be made available in the near future, there are some possibilities to use a normative logistics model, that optimises the logistics choices (see section 4.3) and to make this model more realistic by calibration it to aggregate data (OD information). One could use a normative logistic costs function, assume this works as a logit model with alternative-specific constants and a scale parameter, aggregate the initial results, compare with aggregate data and then adjust the constants and/or scale in an iterative process. This is clearly inferior to estimation on disaggregate data, but could provide a way out if these data would be unavailable.

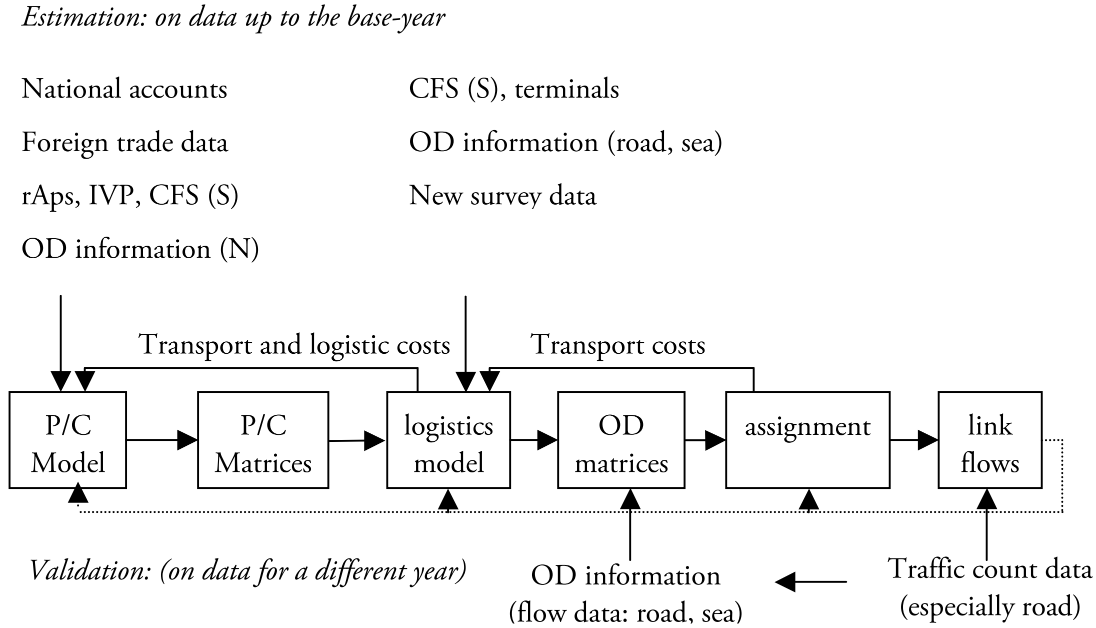

Figure 5 - Estimation and validation of the model systems (S: Sweden; N:Norway)

4.5 Programming and validation

The new logistics model needs to be programmed as part of the Samgods and NEMO systems, especially with interfaces to and from the P/C matrices and network models with definitions, segmentations and formats that match. This also includes the changes that might be needed in the network model and other model components to accommodate the new models.

In application of the logistics model, the P/C or PWC matrices are the starting point. Then for each commodity flow from the P zone to the C zone, one or more firms are generated to be the producer in the P zone and one or more other firms are generated to be the consumer (step A).

After that, in step B, for the total weight of the commodity-specific firm to firm flows, the shipment size is determined first. The logit models provide this in the form of probabilities for the different alternatives with regards to shipment size, which can be summed to give the expected frequencies. But the model application could be simplified by taking a draw from this distribution. This will give a shipment of a certain size of a certain commodity that is transported from firm m to firm n. In model option III, the shipment sizes are not produced by the model, but fixed shipment size distributions (by commodity type) are simply taken from existing data.

The model then assigns probabilities in terms of logistics chains, modes and vehicle sizes to this shipment. In model options II and III, mode choice is not included. These can also be summed or used to draw from. By repeating this procedure a sufficient number of times, we can cover all flows between the firms for the relevant commodities and in this way all flows in the P/C or PWC matrix.

In step C these are aggregated into flows of vehicles (options IA, IB) or tonnes (options II and III) by commodity type between the zones (in all options except III also by shipment size). These are passed on to the network model.

The model application process is iterative (see Figure 5, middle and upper part): after assignment, the new generalised costs matrices need to be used to adjust the P/C or PWC matrices, etc. This gives rise to an **inner loop** (the outer loop is described later in this section):

Inner loop:

1. The base matrix projects (Norway and Sweden) provide initial P/C (or PWC) matrices.
2. The logistics model transforms these into OD matrices, using transport cost provided by the network model.
3. The network model assigns the OD matrices to the networks.
4. The network model and the logistics model provide transport and logistics costs matrices to the base matrix projects.
5. The base matrix project calculates new base matrices on the basis of the new transport and logistics costs and provides these to the logistics model.

   Etc.

This loop continues until equilibrium is reached between (in practice until a pre-set maximum distance from equilibrium is reached. The tasks at both ends consist of running the models as they are (no estimation required within this inner loop): the inner loop is about the adjustment of model variables (inputs and outputs), not model coefficients. What makes this model application loop time consuming is especially the transfer of matrices between the different models.

The validation process is depicted in Figure 5 as well (bottom part of the figure). As part of the validation, the predicted OD flows can be compared to the observed OD flows from OD surveys (by mode: road, sea, maybe rail), preferably for a different year (using the inputs of that year) than used in estimation, to make it an independent validation. To emphasise the independent nature of the model validation, it could be carried out by an independent model validation team: a group of potential model users and other experts. The truck surveys provide information on domestic trucks. Information on foreign trucks can come from the traffic counts. Differences between observed and predicted can be due (apart from measurement errors in the observations) to both the P/C (PWC) model and the logistics model, and separating these is very difficult. Independent observed P/C (PWC) matrices would be needed for a separate validation of the P/C (PWC) matrices.

After the assignment of the OD flows to the networks, the predicted link flows can be compared to observed link flows from traffic counts (especially for road, maybe also for rail). If big discrepancies arise, these need to be analysed. Finally, parameters in all the models can be recalibrated (this requires an iterative procedure). This is the **outer loop** (the inner loop was described earlier in this section), which concerns different equilibrium situations for the inner loop. In the outer loop or model calibration loop, model coefficients in all constituent submodels are adjusted to reach a good match with aggregate data.

The final calibration (to counts and OD surveys) has to be done jointly by both teams. The methodology needs to be worked out, but it can be regarded as one big optimisation problem that needs to be cut into several smaller sub-problems. The objective of the overall optimisation is to minimise a function (e.g. the squared difference) of the distance between the observed and predicted values (traffic counts in particular). One parameter is modified at a time and then the minimisation function tells us which parameter change leads to the biggest reduction in the distance between observed and predicted. The parameters that will be changed first are the ones that have the biggest effect on reducing the distances between the model predictions and the observations, which depends on the first derivatives of the overall objective function with respect to the coefficients (gradient search). The overall optimisation problem is very complex and non-linear. It includes the P/C model, the logistics model, and also the network model (e.g. calibrating a stochastic version of the network model, where the stochastics represent omitted factors and measurement errors). There is no simple recipe for such complex optimisation problems; they cannot be solved analytically, and iterative search procedures are needed. What often works reasonably well is a subdivision into smaller problems. This can for instance be done by extracting from the counts the number of crossings of some screenline (e.g. giving the observed amount of traffic between the North and the South of Sweden or Norway). These observations would not include the effect of route choice, so they can be used to calibrate the other models. Also information from OD surveys (as was described above) can be used to calibrate a problem that does not involve route choice. Observed fractions on specific routes can be used to calibrate the assignment. Observed fractions for the modal split and the use of consolidation and distribution centres can be used to calibrate the logistics model.

CHAPTER 5 Summary and conclusions

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 Solving International, Solving Bohlin & Strömberg and Michael Florian of INRO Canada, has produced a specification of a logistics model 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). This report contains the outcomes of a project to specify how a new logistics module for these model systems could look like. It includes both the scope and structure of a logistics model, as well as an implementation plan.

The scope of the logistics model concerns the boundary lines with other parts of the national freight model systems, notably the base matrices and the network model. We recommend that both for Norway and Sweden the base matrices will initially be PWC matrices, using the current zoning systems and at least the current 12/13 commodity groups. This means that not only flows from P (production) to C (consumption by intermediate producers and retail) are included in the base matrix, but that flows from P to W (wholesale) and from W to C are included as well (treating W just as C and P respectively). The use of consolidation centres and distribution centres between P, W and C by shippers and carriers is covered in the logistics model, which will produce transport flows at the origin-destination (OD) level. The logistics model will initially take the locations of the wholesalers as given. Later on, more complicated logistics models can be developed that explain the location of wholesale (as well as the location of all consolidation and distribution centres), and start from pure P/C matrices.

For the new freight model systems, an 'aggregate-disaggregate-aggregate' model is proposed. The envisaged structure for the national model systems (the boxes indicate model components) is given in **Figure 6**.

The base matrix and the network model need to be specified at an aggregate level (with zones as unit of observation). These two models within the overall freight model system are in the top row of **Figure 6**. The base matrices are the P/C flows (initially PWC flows) and the network model carries out the assignment of the OD flows to the networks. For the logistics model, that is positioned between these two models, we proposed a disaggregate model, at the level of the firm, which is the actual decision unit in freight transport.

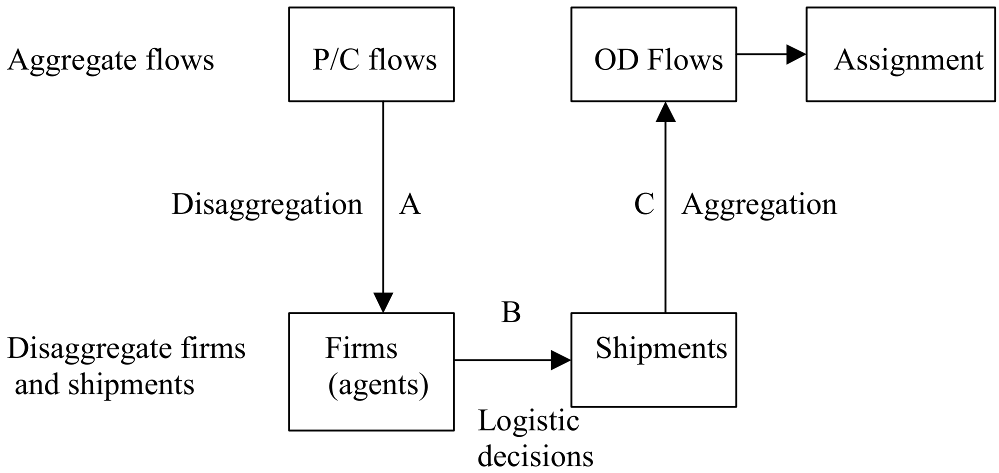

Figure 6 - Envisaged structure of the national model systems

This logistics model consists of three steps:

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

B. models for the logistics decisions by the firms

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

The allocation of flows in tonnes between zones (step A) to individual firms at the P and C end can to some degree be based on observed proportions of firms in local production and consumption and business register data.

The logistics decisions in step B are derived from minimisation of the full logistics and transport costs (modelled as discrete choice models). The different logistics decisions that might be included in step B are:

- Which agent (=a firm) controls the relevant supply chain?

  Choice set: the manufacturer at the P end, the retailer of manufacturer at the C end.

- Lead time.

  The choice set could contain as alternatives: within 24 hours, within 48 hours, within a week, more than a week.

- Frequency/shipment size (so inventory decisions are endogenous).

  The choice set for shipment size could be based on a categorisation in tonnes. Alternatively a functional classification (e.g. less-than-truckload, more-than- truckload) could be used. The latter will probably provide more insight.

- Whether the shipping firm carries out the transport and logistics itself or it contracts out to carriers/logistic service providers (one could go even further and distinguish several types of outsourcing).

  Choice set: do it yourself versus contracting out.

- Choice of loading unit

  Choice set: especially the distinction between containerised versus non-containerised

- Use (and location) of distribution centres, freight terminals, ports and airports and the related consolidation and distribution of shipments and formation of tours (batching shipments at consolidation centres, multi-stop deliveries).

  Choice set: chains of zones, with a specific activity (e.g. origin, consolidation, distribution and destination) at each zone. For the decision of the optimal location of consolidation and distribution centres only a limited number of candidate sites might be available.

- Mode used for each tour leg.

  Choice set: air transport, road transport (possibly several vehicle types), rail transport (possibly with different train types, such as regular trains, block trains and intermodal rail transport), and maritime transport (possibly with different vessel types).

A logistics model which would include all these choices would be very complicated and data-demanding. In Table 8 a number of options for the logistics model are compared, including the full model with all choices, and various simplifications.

The recommended option is option IB. Unlike options II and III, mode choice is handled in the logistics model, where observed and unobserved variation in choices made can be treated within the random utility maximisation framework. Serious difficulties can be expected when trying to make lead time and supply chain dominance endogenous and having the segmentation (partly) result from the mode estimation, as in option IA. Also the cutting of the logistics choices in two parts (shipment size choice and transport chain and mode choice) will make the model more tractable and easier to develop and apply. For short term applications of the model, it is also not needed that the location choice for consolidation and distribution centres is included. The existing locations can be used to define the choice alternatives for the transport chain selection. However, for long-run applications, it would be of considerable value to have the locations of consolidation and distribution centres in the private sector produced by the model (the locations of ports and airports remain exogenous). This would require an option between IA and IB, with all the features of IB but with additional facility location choice. Therefore we recommend developing a model as in option IB first, and extending it later to include location choice for consolidation and distribution centres.

For the majority bulk products, we recommend a simplification to make only direct transport available, because this reduces the amount of work in model estimation and implementation and reduces run times considerably, without giving up realism in representing existing patterns. The mode used for direct bulk transport will often be road transport, but can be rail or sea if both the P and C location have rail sidings or quays.

Table 8 - Alternative structures for the logistics model

	Option IA **Full model**	**Option IB** **Partial Model: reduced complexity**	**Option II** **Simplified partial model: mode choice in assignment**	**Option III** **Doubly simplified partial model: mode choice in assignment; no shipment size**
Lead time and other customer requirements	Endogenous	Exogenous (by commodity type)	Exogenous (by commodity type)	Exogenous (by commodity type)
Who controls the supply chain? Contracting out	Endogenous (e.g. latent class model)	Exogenous (by commodity type)	Exogenous (by commodity type)	Exogenous (by commodity type)
Segmentation (e.g. commodity groups)	Result of model estimation	Exogenous	Exogenous	Exogenous
Locations of consolidation and distribution centres	Endogenous (long term optimal locations)	Exogenous	Exogenous	Exogenous
Model specification	One joint model (with air versus non-air on top of the tree)	Two steps to reduce complexity: -) shipment size -) consolidation, distribution and modes (with air versus non-air on top of the tree)	Two steps to reduce complexity: -) shipment size -) consolidation, distribution	One step removed to further reduce complexity: -) consolidation, distribution shipment size not studied.
Mode choice (including vehicle size and loading unit)	Endogenous in logistics model	Endogenous in logistics model	Covered in network model (multimodal assignment)	Covered in network model (multimodal assignment)
Empty vehicles; load factors	Endogenous in logistics model	Endogenous in logistics model	Covered in network model (multimodal assignment)	Covered in network model (multimodal assignment)
Required effort	Very large	Large	Medium	Relatively small
Complexity	Very complex	Quite complex	Moderately complex	Relatively straightforward
Output	OD matrices by shipment size and commodity class in vehicle units	OD matrices by shipment size and commodity class in vehicle units	OD matrices by shipment size and commodity class in tonnes	OD matrices and commodity class in tonnes

In order to estimate the proposed logistics model, the following data are required:

Step A:

- Data on the size of firms by commodity and zone at the P and C end.

Step B&C:

- Data on shipments
  - shipment size (or frequency per year)
  - sender and receiver locations and all intermediate stops and transfers of the shipment
  - mode, loading unit and vehicle size for all legs
  - batching, number of stops
  - explanatory variables (flexibility, costs, time, reliability, lead time, value, volume/weight).
- Data on locations of consolidation and distribution centres.
- Cost data .

Most of the data for step A seem to be available for Norway and the information at the P end) is available for Sweden. For the distribution of firms at the C end, approximations are necessary.

In Norway, only transport statistics can be used for the data on shipments for steps B and C, but these are not sufficient. There are more data on individual shipments in Sweden (the 2001 Commodity Flow Survey, CFS), but the main CFS data file has no information on receivers. This will be remedied in the CFS 2004/5, but even then there will be no data on the use of consolidation and distribution centres and limited information on frequency.

On the locations of consolidation and distribution centres considerable, but not complete, information is available in both Norway and Sweden.

The available data on transport costs do not substantially encompass the cost data that are already in the network model.

The biggest gap between required and available data is for the information on individual shipments. We therefore propose that a new survey will be carried out both in Sweden and Norway among firms in freight transport and municipalities about:

- the use and costs of consolidation and distribution centres
- the formation of logistic and transport chains, and
- attributes of the shipment, including customer requirements, and handling and storage costs).

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Annex 1. Modelling Costs in the CAPS Supply Chain Designer (by Phil Gibbs)

1. Introduction

The CAPS Supply Chain Designer is described here to give an example of the logistics modelling approach used in the private sector. It is not proposed here that this software package should be used in the future Samgods or NEMO.

When designing a supply chain with CAPS the user specifies the sites in the supply chain, the quantities of products supplied and demanded, the connections between the sites, applies cost formulae and tables, and then allows the MILP solver (CPLEX) to make open and close decisions within any defined constraints. CAPS SCD models a single time period with a one unit of flow, for example tonnes in a year. Products are used in the system as a way of controlling and costing flow.

2. Site Costs

2.1 Introduction

Sites may be supplying, flow through or demanding. For example, a supply chain may have manufacturing plants as supply points, distribution centres as flow through points and retail outlets or end consumers as demanding points.

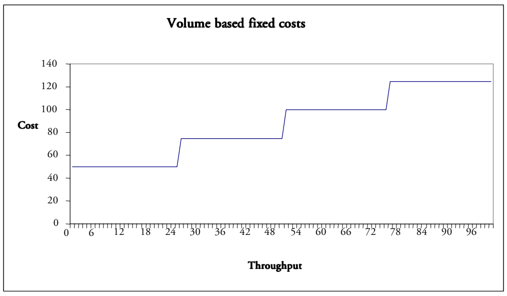
2.2 Fixed costs

A fixed cost is incurred if a site is open. This may be used to model space or management costs, and can be applied to a whole site or to a product at a site. Fixed costs can be specified in ranges of flow, to represent step changes. These may be varied according to the region or country, for example to represent different property valuations. Specific costs could also be applied to known sites, if these were being modelled. A number of fixed cost categories can be used for different types of cost, e.g. a property cost varied according to market rentals, a management cost varied according to employments costs, an IT cost that is standard, etc. This is normally derived from in-company information and public domain surveys.

A typical table for non-volume related fixed costs with regional variations would be:

Geographic code	Property	Management	Systems
A	100,000	100,000	100,000
B	120,000	110,000	100,000
C	140,000	110,000	100,000
D	160,000	115,000	100,000
E	180,000	120,000	100,000

A volume based fixed cost table is below, shown as a graph. This could be used to model extensions to existing facilities or additional levels of management.



If planning over a long time horizon, it may be decided to express some of these fixed costs as variable costs.

2.3 Variable costs

A variable cost is incurred per unit of flow through a site. This can be different for each product at a site, and may also be varied regionally. As with fixed costs, different categories could be used to describe different types of variable costs, e.g. labour and packaging. The cost per unit can be specified in ranges of flow, e.g. if you wish to model economies of scale where the cost per unit reduces as the volume through a site increases.

A cost per unit varied by product type and region for a food retailer could be:

Geographic code	Ambient	Chill	Frozen
A	1.00	1.10	1.20
B	1.10	1.21	1.32
C	1.10	1.21	1.32
D	1.15	1.27	1.38
E	1.20	1.32	1.44

If the product type described the type of movement through a site, the table could be:

Geographic code	Cross Dock	Break Bulk	Stocked
A	1.50	1.25	1.00
B	1.65	1.38	1.10
C	1.65	1.38	1.10
D	1.73	1.44	1.15
E	1.80	1.50	1.20

2.4 Other site costs

Inventory costs are dealt with in Section 4, as these can be modelled on both sites and lanes.

3. Lane costs

3.1 Introduction

Lanes are used to represent all the possible connections in a supply chain. The user may decide not to connect sites, e.g. it may be decided that plants should not go direct to customers as they do not supply all products, or DCs should not serve customers more than x kms or y hours distant for service reasons. The lanes may represent different modes of transport, which would compete against each other in the model. Lane costs are often more complex than site costs. As with site costs, lane costs can be fixed, variable and volume related. There is also a round trip cost model, which is described below.

3.2 Simple cost models

These are not dependent on shipment sizes or vehicle sizes. The simplest model is a cost per tonne per km, but this does not take into account shipment sizes or the fixed costs that are inherent in a delivery using a vehicle. The cost per tonne per km could be varied between lane types, but also it could be varied according to other lane characteristics, e.g. origin ID. Normally a road database is used to calculate the distance on a lane, to avoid the problems inherent with straight-line calculations. The cost per unit on a lane is calculated as the km * cost per tonne per km.

A cost per unit can be used where the distance is not relevant, e.g. for a ferry crossing, as in the table below:

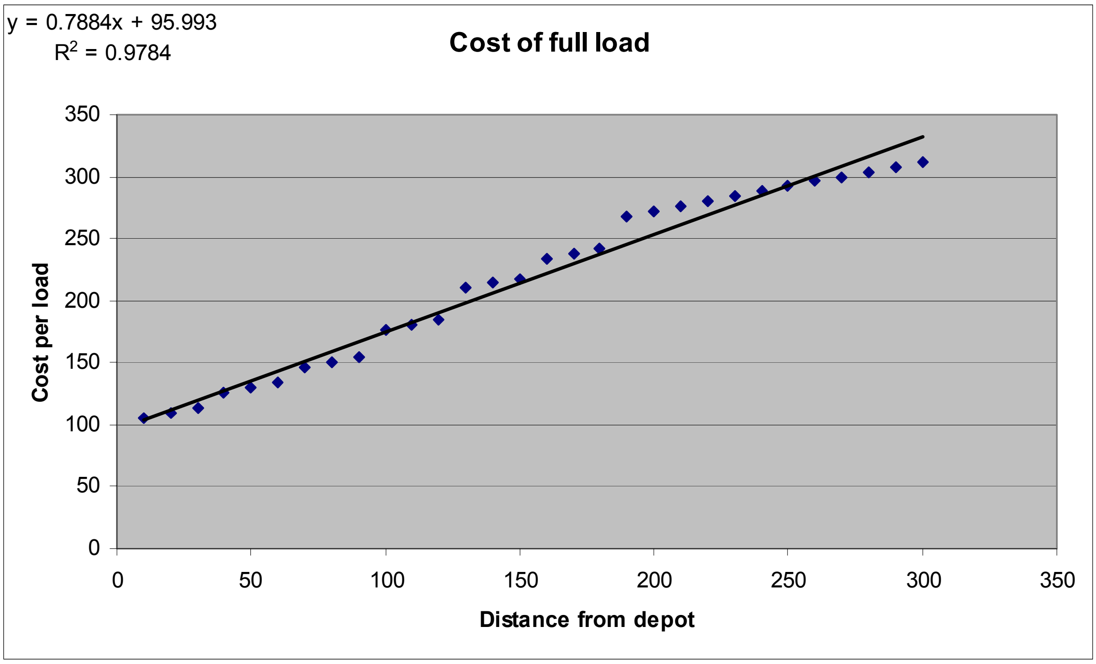
From	To	Cost
Felixstowe	Barcelona	20.21
Dover	Calais	7.87
Calais	Dover	7.87
Barcelona	Felixstowe	18.96

In this case the cost per unit is written directly onto the lane.

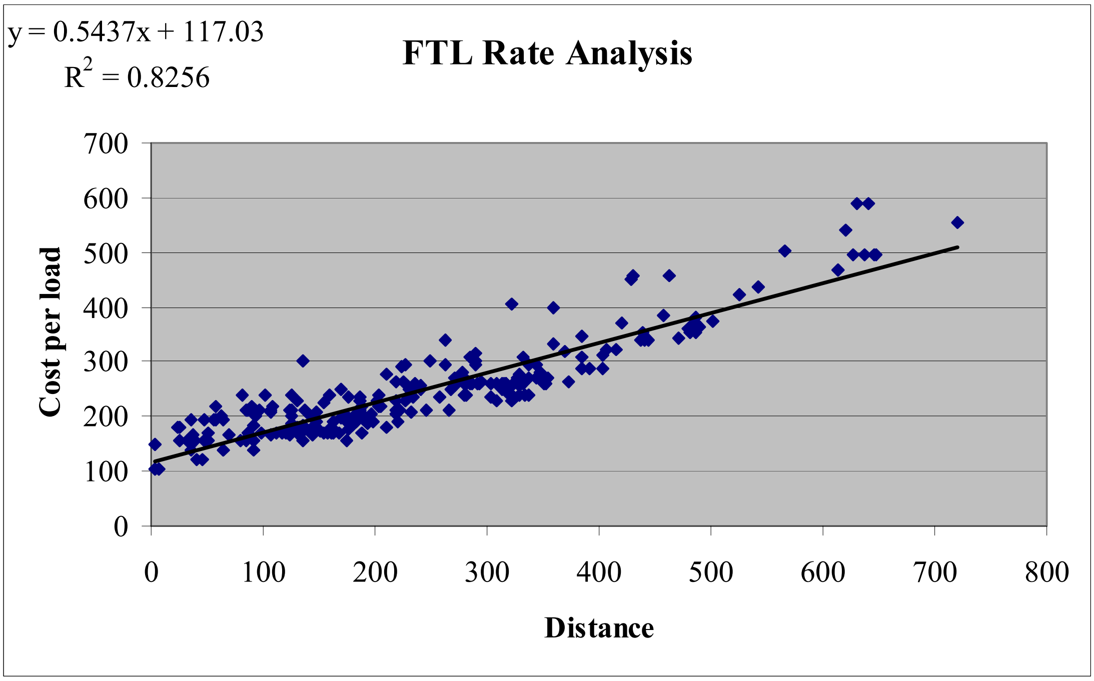
3.3 Full truckload moves

For an FTL movement the user can use a combination of formulae and tables. The load size needs to be specified and could represent a vehicle, train wagon, train, ship, etc, and can be defined on the sending or receiving site or product site, or the lane or product lane. It is possible to factor transport costs according to the country (or region) of origin, to represent that a 100 km journey starting in Germany costs more than a 100 km journey starting in the Czech Republic, due to the different market conditions.

The data for this is normally obtained from a regression analysis of the rates that hauliers charge the client. Sometimes hauliers provide rates in distance bands and these can be simplified using regression, as below:



Sometime we carry out a regression on journeys from a variety of hauliers, as below:



The table below gives the values used in a road based FTL cost model which is varied by country of origin and destination.

From	To	MinCharge	Cost/Load	Cost/KM
BEL	BEL	150.00	50.00	1.50
BEL	CZE	150.00	50.00	1.50
BEL	DEU	150.00	50.00	1.50
CZE	BEL	150.00	25.00	0.90
CZE	CZE	150.00	25.00	0.90
CZE	DEU	150.00	25.00	0.90
DEU	BEL	150.00	45.00	1.20
DEU	CZE	150.00	45.00	1.20
DEU	DEU	150.00	45.00	1.20

The formula in CAPS to calculate the cost per unit for a particular lane is:

$$\text{Cost per tonne} = \frac{\text{Cost per Load} + (\text{Cost per Distance} * \text{Distance}) \text{ or Minimum Charge}}{\text{Load Size}}$$

3.4 Less than truckload moves

For an LTL movement the user may specify values or formulae within a table, where the shipment size is one dimension. This can be used to represent multi-drop vehicle movements for a private fleet or a consolidator. The most common use is a distance banded shipment size table containing a cost per shipment in each cell, as below. As data is normally aggregated for a period of time and/or a geographic area, an average shipment size is typically used. The shipment size can be defined on the sending or receiving site or product site, or the lane or product lane.

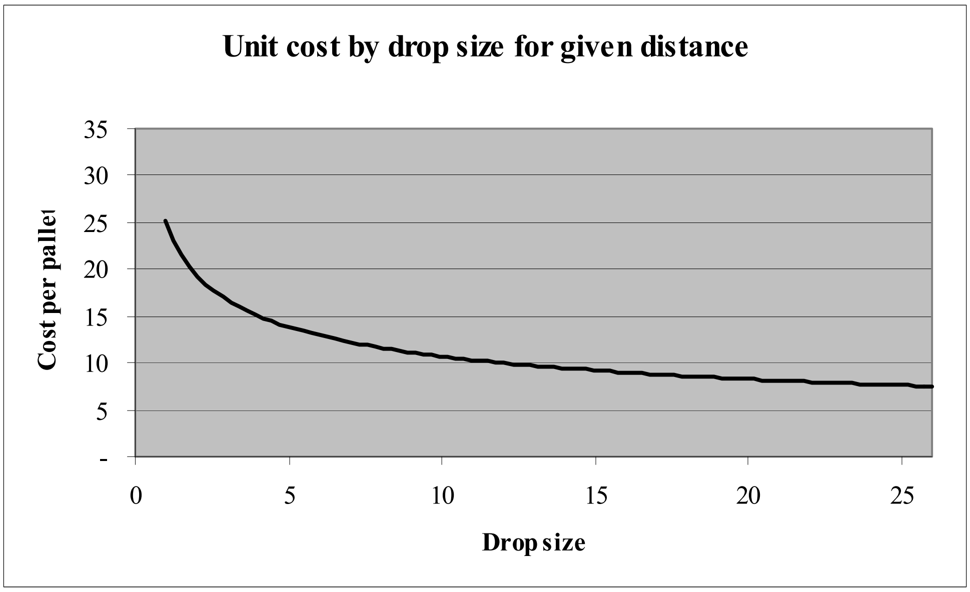
Cost/drop			Drop size			
Distance	1	2	3	4	5	6
25	18.43	26.83	34.94	45.27	55.60	65.92
50	20.00	27.55	39.35	46.72	57.41	68.10
75	21.14	32.22	40.44	52.59	59.23	70.28
100	21.50	34.62	41.53	54.04	66.56	78.40
125	21.86	35.35	49.49	55.50	68.38	81.26
150	22.23	36.07	52.13	67.24	70.20	83.44
175	22.59	36.80	53.22	69.63	86.05	102.46
200	22.95	39.77	54.31	71.09	87.86	104.64

In the table, drop size is used as another word for shipment size, which is measured here in UK-sized pallets. As well as a cost per shipment, it is possible to use a cost per tonne km and a minimum charge as part of the calculation. Instead of distance bands, from and to IDs can be used, e.g. city to city.

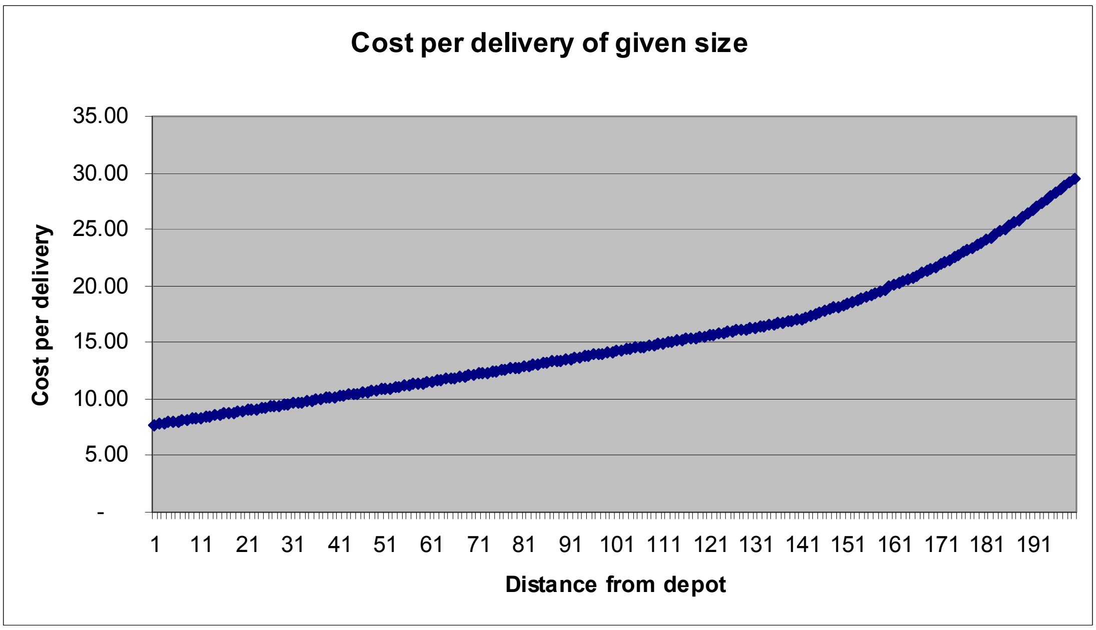
The formula calculates the cost per shipment from the values in the table, and then divides the results by the shipment size to produce the cost per unit on a lane.

In the US, tables based on the CZAR rating system can be purchased, but there is no equivalent in Europe. Again regression analysis from rates tables can be used. If a client operates a private fleet, we have a cost apportionment methodology that can be used to generate LTL tables to use in CAPS.

A typical LTL cost curve represented in table will look like the graph below:



When working with private fleet operators, it is often desirable to reflect how vehicle productivity reduces (in terms of deliveries per vehicle day) the more distant a delivery, if overnight routes are not permitted. At the extreme limit, a vehicle only has time to make a single delivery, which must therefore bear the entire cost of the vehicle and driver. The cost curve in the table could look like the graph below:

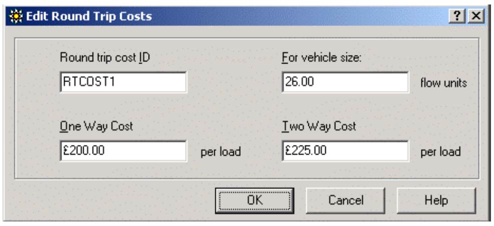


This graph also illustrates the minimum cost applicable to a delivery.

3.5 Round trip costs

It is also possible to model round trip costs, where the cost on a return flow is a different value to the sum of the one-way flows. This would normally only be used for full load movements. This cost model is useful when trying to obtain a balanced network.

For these costs, specific values are applied to lanes for one way and two-way flows.



4. Inventory costs

4.1 Introduction

Inventory costs can be defined in a variety of ways. Some cost components are considered by the optimiser, others calculate inventory costs based on the results of the optimisation. The cost components are:

Component	File	Considered during optimisation
In transit inventory	Lanes	Yes
Cycle inventory	Lanes	Yes
Safety stock (pre solve)	Sites	Yes
Standard (various)	Sites	Yes
Safety stock (post solve)	Sites	No
Aggregate inventory	Sites	No

As costing is generally carried out on the product site or product lane, careful consideration needs to be taken on how products are represented in the system when modelling inventory.

4.2 In transit inventory

This cost component allows the user to model the inventory associated with the transit time between two points. It is calculated as:

Transit time on lane * product value * carrying cost

4.3 Cycle inventory

This cost component represents the amount of inventory on hand between shipments and is assumed to be one half of the shipment size on average. It is calculated as:

Shipment size/2 * product value * carrying cost

4.4 Safety stock (pre-solve)

Pre-solve means that these costs are considered in the optimisation process (on which sites to open and how to flow the goods). If a cost model is post solve, then the optimisation program ignores these costs: they are not considered in determining the optimal solution. After the optimisation routine has finished, the post solve costs are calculated and added to the costs in the system.

This can be a fixed cost on the site or product site or a variable cost. It is calculated as:

Days of demand on hand/model time horizon * product value * carrying cost

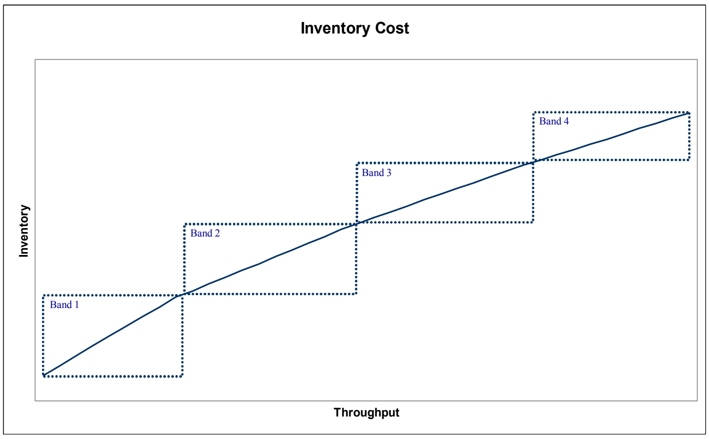
If it is a variable cost, the result of this formula is multiplied by the flow at the product site to give the total variable cost.

Days on hand can be defined as a global value or set in the site or product site file.

4.5 Standard (various)

It may be desirable to use standard site and product site cost components (described above in Section 2) to calculate inventory. These can be fixed costs on the site or fixed or variable costs on the product site. This gives the possibility of allowing volume based costs to be used, so that the costs could be expressed with step changes at different levels of flow (e.g. a reducing inventory cost per unit of flow as the flow through a site increases). The drawback is that the costs would have step changes, rather than being continuous.

The graph below shows how an exponential curve (where inventory units = (flow/24)^0.7) can be approximated by a series of fixed and variable costs with volume breaks:



4.6 Safety stock (post solve)

This cost component considers the following factors: expected lead time, lead time variance, expected demand, demand variance, fill rate, number of turns, carrying costs and product values.

Information	Explanation	Data source
Model horizon	Time duration over which safety stock is estimated	Held in system properties
Expected lead time	Average delay from the time an order is placed to the time the goods are received	Lane or product lane file
Lead time variance	Variation around the mean lead time	Lane or product lane file
Expected demand	Demand during the model horizon	Result of solving scenario
Demand variance	Variation around the mean demand	Site or product site file
Fill rate	Type 1 measures service as the % of periods that experience a stock out. Type 2 measures the % of demand that is satisfied	Site or product site file
Number of turns	Number of times inventory is replenished, usually the number of shipments during the model horizon or the number of production runs	Site or product site file
Carrying cost	Annual percentage of product value	Product file
Product value	Value of product	Product file

In addition to the above data sources, global values can be used.

4.7 Aggregate inventory

This cost component is a way of estimating inventory from throughput using coefficients. It can either be used with a preset formula or can be used to call a custom macro. The following formula is used to calculate the physical inventory, which is then multiplied by the carrying cost and the product value:

Minimum inventory at site

+ coefficient per unit of flow * product flow at site

+ coefficient per exponential unit of flow * (product flow at site ^ flow exponent)

+ coefficient per logarithmic unit of flow * (log product flow at site)

Coefficients can be set as global values or taken from the product, site or product site files.

5. Other Costs

5.1 Production costs

Production costs can be modelled at production line or task level where this is appropriate in a project. Lines and tasks are particular types of site costs. When modelling production, bills of materials need to be defined.

5.2 Duties and drawbacks

Duties and drawbacks can be modelled. Duties are relatively easy to represent: they are simply a cost that applies when moving goods from one trade zone to another. Duty drawbacks, sometimes referred to as duty credits or reliefs, can be claimed when the imported goods have been through a manufacturing process and subsequently exported.

5.3 Tax

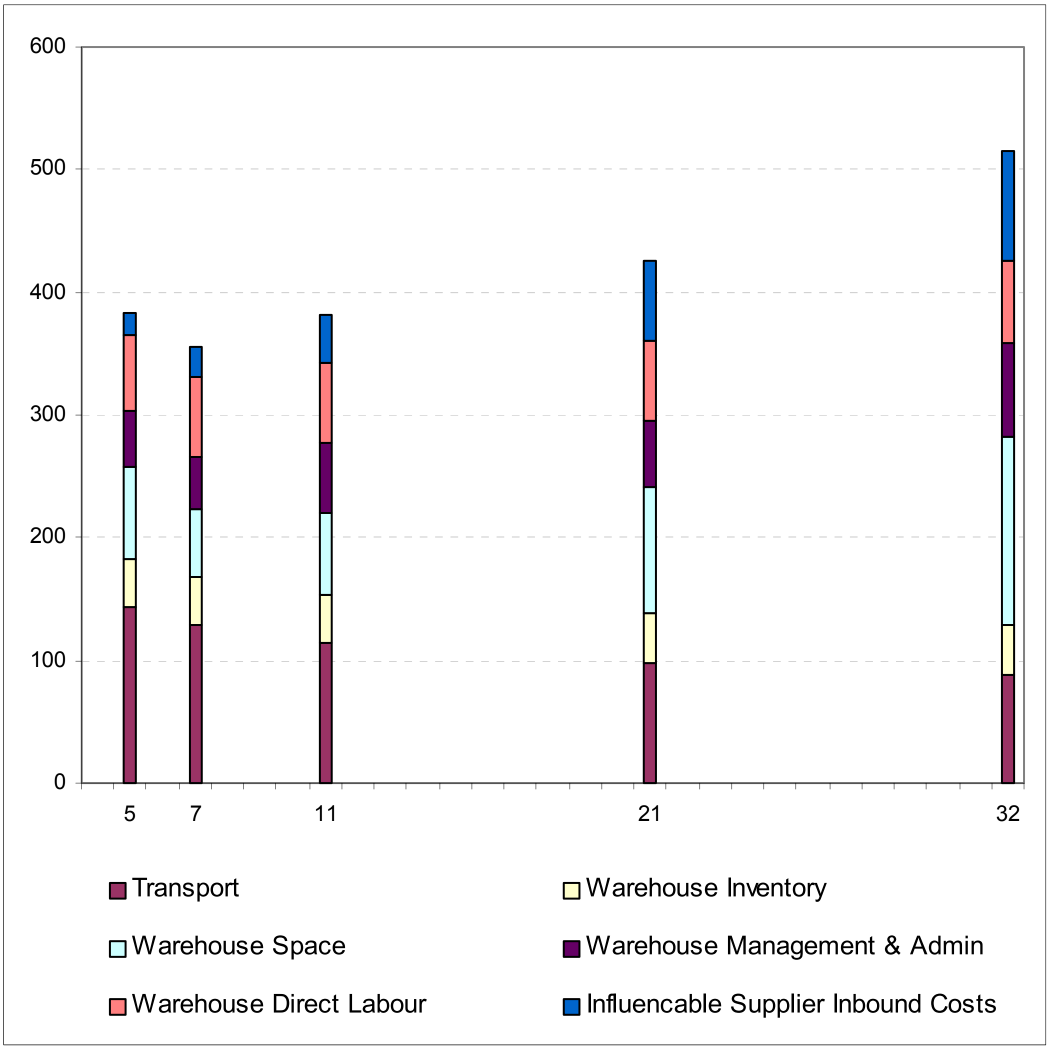
Tax calculations can be included in the cost components that are on sites and lanes, which may be useful when tax rates vary in the supply chain that is being modelled. Transfer prices can also be modelled.

Supply chain strategy: Relativity of costs

Costs in Polish Zloty (date and client confidentia

Source: Martin Baker (Solving)

	Trade-off elements						
Number of Warehouses	Transport	Warehouse Inventory	Warehouse Space	Warehouse Management & Admin	Warehouse Direct Labour	Influencable Supplier Inbound Costs	Total cost
5	143.2	39.5	74.7	45.5	62.8	18.1	383.9
7	128.0	39.7	56.3	42.5	63.9	25.4	355.8
11	113.4	40.0	67.0	56.1	66.6	38.0	381.0
21	97.4	40.4	102.8	53.9	66.3	64.5	425.3
32	87.6	40.9	152.8	77.1	66.3	90.0	514.7


600
500
400
300
200
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0
5
7
11
21
32
Transport
Warehouse Inventory
Warehouse Space
Warehouse Management & Admin
Warehouse Direct Labour
Influencable Supplier Inbound Costs

Annex 2. Outcomes of interviews in Sweden and Norway on the use of distribution centres and freight terminals

SOLVING International
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The Logistics Model

Interviews
The infrastructure in Sweden
regarding Distribution Centres and Freight Terminals

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Paris ● Atlanta ● Barcelona ● Brussels ● Buenos Aires ● Göteborg ● London ● Madrid ● Milan ● Munich ● New York ● Northwich ● Sao Paulo ● Rome ● Shanghai ● Stockholm ● Tokyo

SOLVING International
Bohlin & Strömberg

Commodity Group Food

Placera kundens logotyp här

Food

This industry is undergoing a change in the logistic chain.

The logistic chain used to consist of the following steps:

Production- Central Warehouses - Regional Warehouses – Stores

Production → Central Warehouses → Regional Warehouses → Shops

But since sometime the regional warehouses have been omitted

Deliveries to the shops are done between 6 a.m. to 10p.m.

The central Warehouses are located close to the bigger Cities.

Production — Central Warehouses → Shops

SOLVING International Bohlin & Strömberg

Commodity Group Food

Placera kundens logotyp här

Trends

- The production has been heavily centralized
- Number of terminals have been heavily reduced
- The demand for Just In Time deliveries (JIT) have had a major impact on these changes
- The shops are getting less truck deliveries per day than before. This means that the wholesalers are cross docking and deliver full trucks. The producers deliver their goods to the wholesalers.

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SOLVING International Bohlin & Strömberg

Commodity Group Batch and single consignment goods

Placera kundens logotyp här

Batch goods

Goods with a weight over 1 ton are delivered from door to door.

Production → Transport → Customer

Single consignments

Goods with a weight less than 1 ton
Firm A has 20 freight terminals, Firm B 27, located in almost the same places. From these terminals the goods are reloaded onto smaller trucks and then transported to the customer.

Production → Local Transport → Freight-Terminal → Long distance transport → Freight-Terminal → Local Transport → Customer

Tendencies

The ambition is to have more and more goods delivered from door to door. The reason is that it's more costly to run freight terminals.

2004-11-03 4

Commodity Group Batch and single consignment goods

Placera kundens logotyp här

Smaller Packages

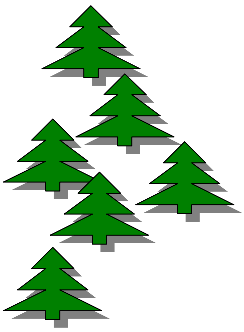
**Both firms interviewed dealing with packages have a separate service for smaller packages with a weight between 2 and 30 kg (and maximum 100kg per delivery).
These are often transported via the same terminals as the single consignment goods but kept in a separate flow.**

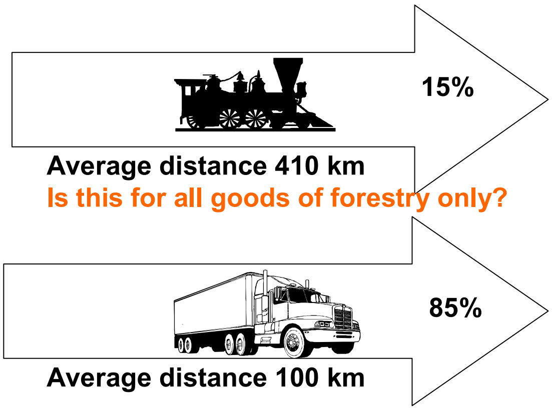
Here the customers are offered the possibility to track the goods as each package is given an own id. Small hand computers are used in the pick up/delivery trucks. Smaller trucks (Volkswagen or similar) are used for short distances.

Commodity Group Forestry products

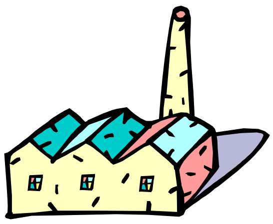
Placera kundens logotyp här

**Transport directly to industry by train or truck.
Total deliveries of 90 million tons.**





Around 30 companies have 60 paper- and/or pulp factories.



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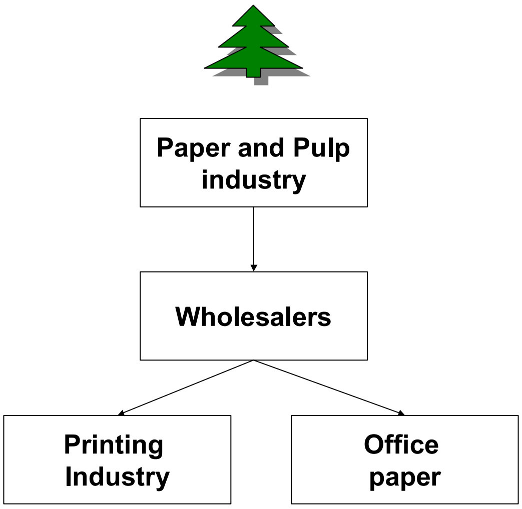
Commodity Group Forestry products

Placera kundens logotyp här



Example from one of the biggest wholesalers in Sweden.

The production cycles are often 3 weeks. In general limited inventory.

The wholesaler keeps inventory for all the different types of paper needed for there printing customers.

Deliveries are made twice a day to the printing industry.

2004-06-02 7

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Forestry products cont.

Placera kundens logotyp här

- **Key criteria:**
  - **Lead times**
  - **Low storage levels (the trees are stored standing up in the forest)**
- **Trends**
  - **Lower storage levels in all parts of the value chain**
  - **Key players change ownership of forest land to reduce transport**
  - **Key focus on how to reduce empty return shipments**
  - **Efficient logistic systems is key to reduce total cost in the industry**

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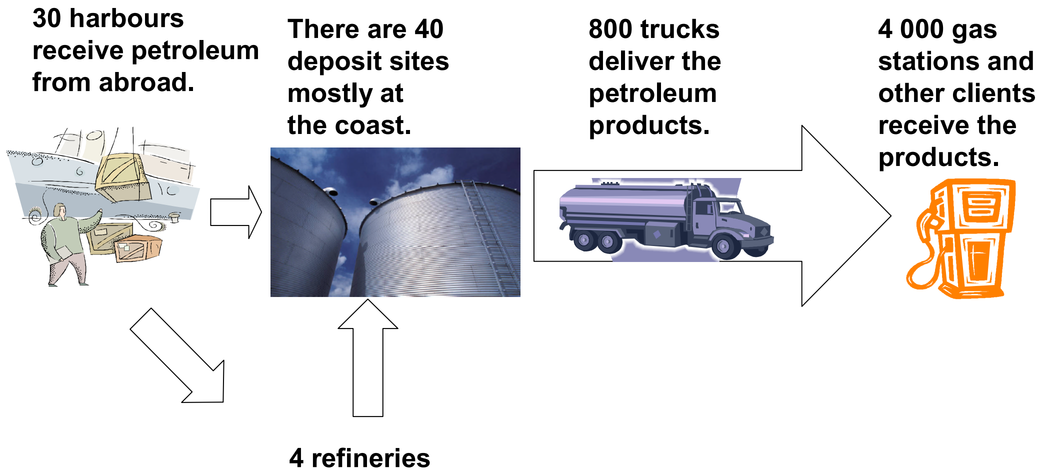
Petroleum products

Placera kundens logotyp här



2004-08-23 9

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Petroleum products cont.

Placera kundens logotyp här

- Key criteria
  - Minimize cost throughout the supply chain
    - Transport of tankers to the country
    - Handle the petroleum in the harbours and deposit sites
    - Transportation to the clients
- Trends
  - Higher usage of resources
    - Number of deposit sites has continued to decrease
    - The amount of petroleum that is stored has reduced both due to lower requirements from the government (less risk of war) and desire to lower the storage space
    - Number of trucks has been reduced
    - The size of the trucks has increased
  - More and more independent contractors handle the transportation

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The Logistics Model

Interviews
The infrastructure in Norway
regarding Distribution Centres and Freight Terminals

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144, avenue des Champs-Elysées 75008 Paris ● Tel. +33 1 53 53 57 00 ● Fax. +33 1 53 53 97 00 ● www.solving-int.com
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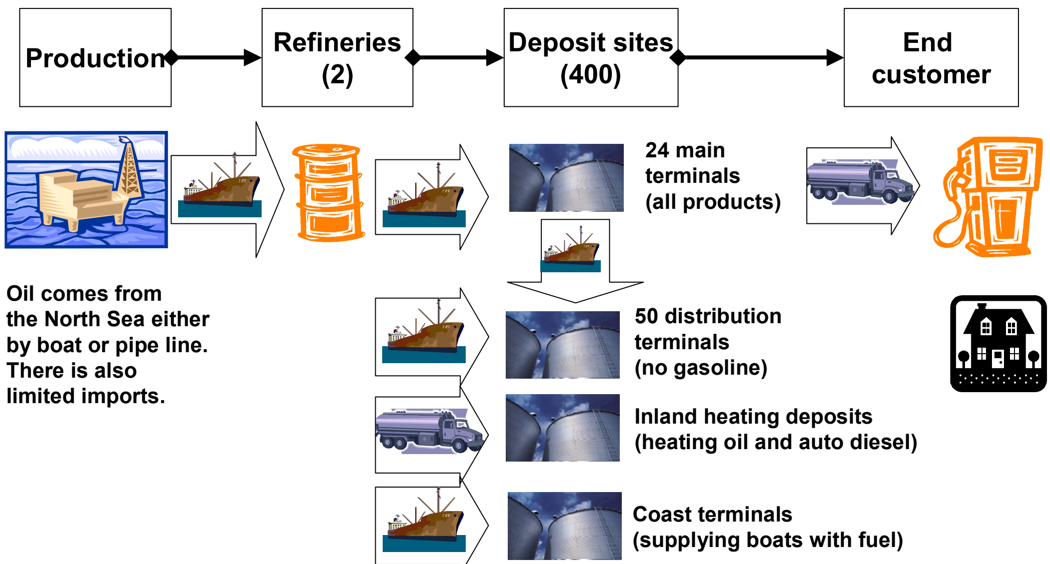
Commodity Group
Petroleum products-Norway



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Commodity Group
Petroleum products - Norway, cont.-

- Comments
  - Several of the petroleum companies have agreements giving them right to use each other's deposit sites to reduce transportation costs
  - The main deposit terminals are concentrated in highly populated areas
  - The higher number of deposits in Norway compared to Sweden is explained by
    - A more complex geography
    - History: they begin to reduce the number of sites when it is evident that they are not profitable
- Trends
  - Fewer gas stations
  - Higher usage of resources
    - Number of deposit sites has continued to reduce
    - Number of trucks has reduced
  - Increased number of petroleum products causes a need for more tanks in each deposit site
  - Centralization of logistics function (eg. Esso has a global logistics function in Birmingham)
  - More and more independent contractors handle the transportation

2004-06-07 3

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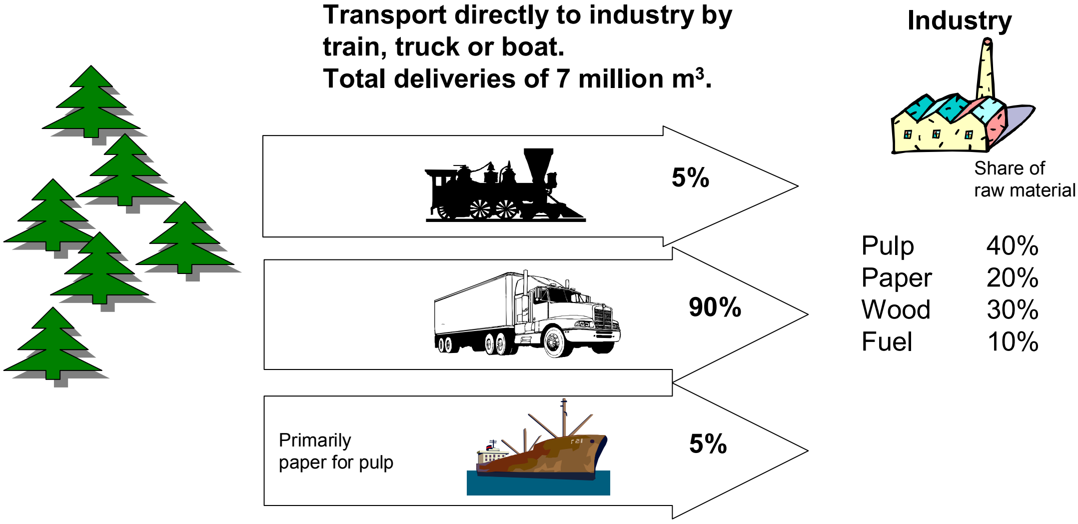
Commodity Group
Forestry products - Norway

Transport directly to industry by train, truck or boat.
Total deliveries of 7 million m^3.



2004-06-07 4

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Commodity Group
Forestry products - Norway, cont.

- **Key criteria**
  - **Frequency (daily deliveries to pulp factories)**
- **Trends**
  - **Lower storage levels in all parts of the value chain**
  - **Developing GPS systems to find demanded type of timber**
  - **Developing new and better ways to measure quality and quantity**
  - **Increased pressure to reduce prices for the raw material**

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Commodity Group Batch and single consignment goods- Norway

Batch goods

Goods with a weight over 1 ton are delivered from door to door.
A separate organisation, within the interviewed firm carries out direct deliveries.

Production → Transport → Customer

Single consignments

Goods with a weight less than 1 ton
A separate organisation, within the firm, called the Network.

This firm has 33 freight terminals. Around 50-60% of the transports are done by rail (for example between the bigger cities Oslo, Bergen, Stavanger and Trondheim), and the rest by truck.
This is due to the quality of the roads and the complex geography.
The freight terminals of the firm are located near the bigger population centres.

Production → Local Transport → Freight-Terminal → Long distance transport → Freight-Terminal → Local Transport → Customer

Commodity Group Batch and single consignment goods- Norway, cont.

Smaller Packages

The interviewed firm has a separate service for smaller packages with a weight between 2 and 30 kg (and maximum 100kg) per delivery

Quick and reliable deliveries: the backbone of the transport system is a high-frequency, timetable-controlled system for maximum predictability.

Less quantities but more frequent deliveries is the trend today.

Commodity Group Batch and single consignment goods- Norway, cont.

Batch goods

Goods with a weight over 2 ton are delivered from door to door.

Production → Transport → Customer

Single consignments

Goods with a weight less than 2 ton

This firm has 12 own freight terminals plus 13 through their agents. Around 23% of the transports are done by rail, and the rest by truck. The freight terminals of this firm are located near the bigger population centres.

Production → Local Transport → Freight-Terminal → Long distance transport → Freight-Terminal → Local Transport → Customer

Commodity Group Batch and single consignment goods- Norway, cont.

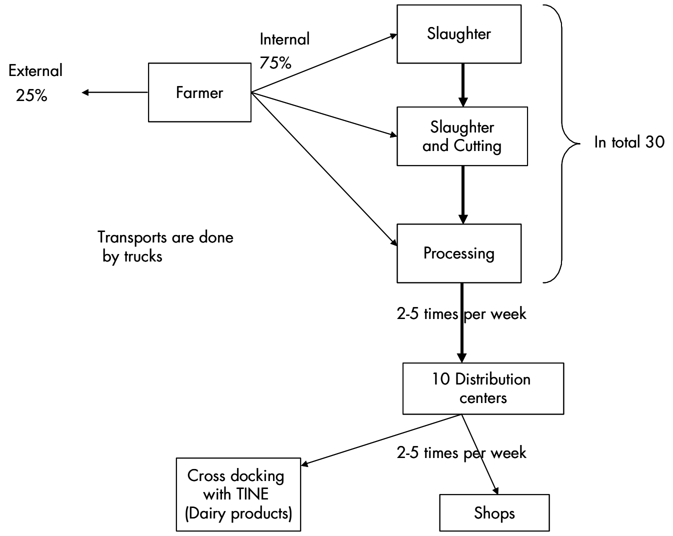
For the customers the most important buying criteria's are :
- trustworthiness
- deliver accuracy

The firm has scheduled transport within Norway. For example goods which arrive from Sweden to Oslo in the night are distributed early next morning within the Oslo area. If the goods should be distributed to outside Oslo then it's reloaded and leaves the terminal in the evening and the goods are delivered the next day. This schedule is the same also for the competitors.

The infrastructure is rather complicated in Norway (for example truck-ferry-truck-ferry and truck is the case up at Vestlandet/Nordvest).

The transport sector in Norway has gone trough changes inrecent years where the bigger companies have bought the smaller ones.

Agricultural products



Annex 3. Minutes of internal project meetings

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 04074)

Minutes of the telephone conference on 23 April 2004

Participants

Moshe Ben-Akiva (RAND Europe, MIT), Mike Florian (INRO-Montreal), Martin Baker (Solving International UK), Ulf Hester (Solving, Bohlin and Strömberg), Sten Bexelius (RAND Europe) and Gerard de Jong (RAND Europe; chair and minutes).

General

Gerard de Jong explained that our group was awarded the contract for the logistics model for Norway and Sweden. The project to develop base P/C matrices for Sweden was awarded to Inregia/VTI/Sintef (in Norway this is part of ongoing projects). The first concertation meeting of both groups and the client groups will take place on 27-4 in Stockholm. Gerard de Jong and Ulf Hester will go there. The meeting will probably be from 10.30 until 14.30 h. This telephone conference is the internal kick-off for this project, with some focus on brainstorming for Phase 1 (scope of the project: boundaries with base matrices and network models).

Subcontracts will be sent to the subcontractors (separate for Solving International and SBS?) as soon as RAND Europe has received the contract from SIKA. The objective of this 6-months project is to specify the structure of a logistics model and to design a plan for implementation in the next 2.5 years. The new logistics model should give information for a base-year as well as for long-term forecasting.

Boundary line with P/C matrix project.

Moshe pointed out that C in P/C not only indicates final consumption (consumers or retailers), but also intermediate consumption by firms for further processing. The main point is that P/C matrices include no transhipment, use of distribution centres or warehousing. Changes in the sectoral structure and location of production will be represented through the P/C matrices and will therefore not be studied in our project. The P/C matrices will probably not include ports and airports (need to check this on the 27th). Therefore this choice needs to be handled in the logistics model as well. Martin argued that distribution centres, ports and airports should be treated separately. Moshe regards this as part of the mode choice that we have to cover. He suggested splitting between mode choice for overseas and for intra-Scandinavian flows.

We also have to check with the clients whether intra-zonal freight transport should be included or only off-diagonal flows. When going from a P/C matrix to an OD matrix, the diagonal will become more important.

The P/C matrices will probably (check with Inregia and SIKA) only give zone to zone flows (in tonnes) by commodity type. The present commodity type classifications in Sweden and Norway are described in the RFP (attached). These have 11-13 types. If we want to use additional information on the shipments and firms we shall have to add it from survey information such as the Swedish commodity flow survey (no such survey in Norway) and a possible new survey on logistics. A possible example is the Oregon freight model, that takes P/C matrices from an aggregate model and then handles the logistics choices (e.g. shipment size) in a disaggregate fashion, mainly by doing Monte Carlo simulation using as much as possible observed data for the mean and variance. As part of our project we could recommend to collect new data (and specify the questionnaire to be used).

Sten has suggested to identify singular flows, e.g. large volumes for a single firm. Moshe reformulated this: we can have models at different levels of complexity for different commodity types, using some preliminary classification.

Mike reacted by saying that in the assignment stage you should not have more than say 15 commodity types (each possibly multiplied by a few shipment size classes, or the distinction between contracting out and carrying out the transport yourself), otherwise it is too hard to keep track. Moshe sees these additional distinctions as choices to be studied in the logistics model (just as mode choice), based on survey data. Mike also remarked that the size of the trucking firms makes a difference in terms of behaviour. Sten said that logistics changes have been most important for commodities that have become more important themselves. This should be kept in mind when deciding on a commodity typology.

Moshe concludes that both the P/C matrices and the assignment are aggregate stages. In between we can opt for more detail or not: two approaches are aggregate-aggregate-aggregate and aggregate-disaggregate-aggregate. Mike warns against going too much in detail in the logistics model: because of the heterogeneity, this might give you a distorted picture. Moshe on the other hand pointed out that aggregates can have big variances. Within disaggregate, Gerard distinguished between modelling at the shipment level and the firm level (since several firms are often involved in the same shipment). The latter is probably too difficult for this project.

Boundary line with network models

Mike asked whether the general idea for the logistics model is to make freight terminals and distribution centres an attractor (centroid) for the network modelling. Gerard confirmed this. The Norwegian and Swedish national freight model systems use STAN for multi-modal assignment. Transfers between modes can take place at coded transfer points, and different modes can be made available for different legs (e.g. depending on the commodity type). This is done by minimising the sum of transport and some logistic costs. Sometimes this gives strange paths, that conflict with the transfer points actually used. Here we should come up with proposals for improvement. Modelling the use of transhipment points elsewhere in the system and inserting these as attractors in the network model is a promising option. The network model can take up to 999 different matrices and produce the paths through the subnetwork for each of the legs of the logistic/transport chains from the logistics model. The mode choice per leg can be handled in the logistics model (or in STAN). For instance for general cargo, the mode is largely determined by the shipment size (e.g. small, then road transport is very likely).

Gerard emphasised that this project should list the pros and cons of several options (with increasing levels of sophistication) on combining the new logistics model and the network model. There will probably be different logistics models for Norway and Sweden, but their structure might be similar.

Martin asked whether the network model could distinguish between time requirements from the clients' perspective. Mike answered that his is not the case. This should be handled in the logistics model. Future versions of STAN will be able to handle unit trains with fixed frequencies. For this project we should focus on the present software, but when the implementation will be completed (3 years from now), the software may have improved.

Action list

Mike will go to New Zealand until early May. He can be reached at mike@inro.ca, but cannot participate in phone conferences from there. Apart from phone conferences the main other mode will be notes, mainly written by Gerard, that will be circulated by e-mail to get everyone's comments and possible additions. Ulf will make a table of which logistics decisions (as listed in the proposal on P. 11) are most important for each commodity type (using the present classification of commodities in NEMO and Samgods, as in the RFP). Gerard will circulate background material, including the Bates/Swahn paper, the RFP, the pre-study on logistics of INRO-TNO/TFK/Tetraplan (with a description of the SMILE model). On 23-4 15.00-17.00 h. there will be a phone conference of RAND Europe and Solving International on what we can learn in this project from logistics models used in the private sector. On 13-5 15.00-17.00 h there will be a phone conference for the entire consortium to start phase 2 (Moshe will then be in Leiden).

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 04074)

Minutes of the telephone conference on 23 April 2004

Participants

Martin Baker and Phil Gibbs (Solving International UK), Ulf Hester and Lars Lingbrant (Solving, Bohlin and Strömberg), Adnan Rahman (RAND Europe) and Gerard de Jong (RAND Europe; chair and minutes).

The topic to be discussed is what we can learn for this project from logistics models developed for private enterprises. What kind of models is used to answer the question how flows of goods from production (P) locations to consumption (C, including intermediate consumption) can best be handled?

Phil explained that these models are usually network models. They search for the lowest cost solution that meets a given service level (in terms of frequency of delivery, lead time and stock availability). If for instance a high frequency or short lead time (as in the pharmaceutical industry) is required at the destination end, the solution will be different (more warehouses, DC's) from the optimum for a lower required frequency and longer lead time (lowest cost usually is with one inventory location). Sometimes a trade-off is modelled between the service requirements and minimisation of logistics cost (including transport cost), but usually the service requirement level is given as a hard constraint (by commodity segment or sector) and within these bounds the logistic costs are minimised.

To find the required service levels we could build on the existing knowledge of Solving, combined with information from new surveys that can be recommended in this project.

The above constrained optimisation problem is formulated as a mixed integer linear programming problem. Solving International has frequently used one such program, called the 'CAPS supply chain designer'. The inputs consist of P and C locations with a matrix of flows from P to C, transport links and costs functions for logistics (including transport) costs. In some studies, the DC's are also part of the given network, other studies start with a 'clean sheet' and start by determining the optimal location(s) for the DC('s). The transport costs can be mode-specific, can depend on FTL or less than FTL and on the service level. After the constraints in terms of service level requirements have been brought in, the cost minimisation is carried out to find the optimal logistic/transport chains.

The costs always include transport costs, DC costs and inventory costs, and sometimes also production cost (usually not, this makes the problem very complex, because production location could vary as well).

Martin: the optimum for a particular company can be suboptimal for the rest of the same supply chain. Adnan: often in a supply chain there is a dominant player, and the balance of power has been changing in the past two decades (e.g. in the food sector, the large retailers have become stronger). This has repercussions on the number and location of the DC's. Most of the models that Solving developed are for one company, sometimes the effect on competitors are investigated as well, or a sector as a whole is studied. Gerard: in this project we don't have to model how supply chains change (is part of P/C matrices), but if a change in the power in the supply chain affects the location of the DC's, we need to have forecasts of this, in order to be able to predict the logistics chains ourselves. Also changes in production location have major consequences on the future's logistic/transport chains. If Ford were to change its production locations, the locations of the DC's in Sweden could be affected, also those of Volvo. The lead time for spare parts for the Volvo retail in Stockholm is less than 1 day. But transport developments (that the models could pick up) are important too: after the opening of the Öresund fixed link, two international car manufacturers closed their warehouses in Sweden and now distribute to Sweden from Copenhagen. We should ask the consultants in the P/C project (and the client), how the P/C locations will change over time and where in the supply chain the power will be (but this other project is just for the base-year). For predicting the future we also need to know how the various costs will change over time.

Phil: a number of manufacturers have succeeded in reducing inventories, by increasing cross-docking and stockholding at LSP's. Ulf: according to the statistics, more than 80% of goods transport in tonnes in Sweden takes place by road, of which 70% for trips less than 100 km.

The data used in the logistic chain analyses for private firms is often made available at the shipment level (or even product level). However, for the analysis, this information is aggregated into a number (often 8-10) commodity groups. Otherwise the problem would be too complicated (millions of possible permutations to choose from). Adnan: we need more data at the stock-keeping unit; at the SKU level. Martin: in distinguishing between commodity classes, one should not go beyond the confidence level of the data, which varies between studies. It might be possible to do the routing and scheduling problem on a sample of data at a detailed level to get formulae that can then in a next step be used for all the data (but at a higher level of aggregation) in the network tool. Adnan: would it be possible to reduce the dimensionality, to make a disaggregate analysis possible? Gerard emphasis that in this project there is already a network model (STAN software) that we can use for route choice (and mode choice) if we want. The question then becomes where we should put our detail. Probably in location and use of DC's and in getting good inventory and DC costs and in classifying goods and taking account of service requirements.

Phil: in some studies for private firms, the first step is on optimal DC location(s), assuming a 'clean sheet' ('blue sky', 'greenfield'). To find this optimum, synthetic DC costs, property costs, employment costs, etc. are used. The optimum can be determined freely by the program (sort of gravity model) or a number of candidate sites can be enumerated and the best one selected by the program (Phil prefers the latter method). The optimum is not necessarily the location with the lowest transport costs; the location costs might be higher there. For the UK such analyses often yield as outcome that the optimum is one DC in the middle of the country ('Magna Park'). Several firms have located their DC's there by now, and since it is becoming more expensive the most recent trend is a move outward.

This optimum can be compared against the existing DC location(s). Reasons why an existing location structure can differ from the optimum are: capacity constraints (the optimum is already full, then locate close to it), history/inertia (moving from the current to the optimal can be very costly). These reasons also explain why different firms are using different logistic/transport chains for the same P/C flows (other reasons are differences in the exact locations of the P and the C and different service levels). Using the same DC and route for all flows for a given P and C is not realistic (even by commodity group).

The service levels can be obtained from business contacts, but can partly be modelled (as endogenous variables): which service levels would result from profit maximisation? There is a trade-off between delivery frequency, lead time and shipment size on the one hand and transport costs on the other. The amount of stockholding large depends on the value of the goods. Therefore value to volume ratio's are important in deciding on the commodity segmentation. Martin: the analyses of the logistics operations for private firms typically distinguish 8-10 logistic categories of the goods (based on value to volume ratios and related handling characteristics). This is for one firm. The union of all goods segments from the various one-firm studies would give an unduly large number of goods categories. Adnan: logistic families of goods can also become a trap.

Ulf: the Swedish national road administration has made a classification of the market, based on customer requirements. He will get hold of this and send this to the others (translate if in Swedish). Phil will send documentation about the logistics models used in Solving's studies.

Questions for the client and the P/C project consultants:

1. What will be the detail of the P/C matrices? Just flows at municipality level for some commodity classification (but which)? Or additional information on the producer, consumer and good, such as service requirements at the destination end?
2. Where will the P/C matrices for future years come from? How will changes in production locations be modelled?
3. Can we get information on the dominance of firms in the supply chains and how this might change in the future?

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 04074)

Minutes of the telephone conference on 17 June 2004

Participants

Phil Gibbs (Solving International UK), Moshe Ben-Akiva, Sten Bexelius and Gerard de Jong (RAND Europe).

The topic of the phone conference was to update consortium members on the outcomes of the meeting with the clients groups and the base matrix consortium in Oslo on 15 June 2004, and to get the view of consortium members on items raised by the client groups. In this document, the main outcomes of the Oslo meeting are given in normal characters and the reactions during the phone conference in *italics*. Solving Bohlin and Strömberg was already aware of the outcomes of the Oslo meeting, since Ulf Hester participated in this meeting.

General

The clients were very satisfied with our work so far (both the Swedish and the Norwegian coordinator told me so during a break). They liked the overall structure of the model of chapter 3 of our note. The need for consistency (e.g. on treatment of wholesale, cost used in the P/C project, use of link flows for validation) between our project and the base matrix project was stressed again (I had dinner with 2 persons from this project on the 14th).

Specific comments/questions on our note of the scope and structure of the model:

-) Can STAN do stochastic (multiple route) assignment? This might be preferable here to all-or-nothing assignment.

Moshe: STAN is not just all-or-nothing assignment; even a deterministic assignment with equilibration gives multiple paths. Also the part that will be transferred to the demand model (could be mode choice) becomes stochastic. Gerard will ask this specific question to Mike.

-) We made shipment size/frequency fully endogenous. Might be possible if you include stockout costs and such. But customer requirements have been increasing in recent years and meeting these could lead to higher than optimal logistic costs. Can we accommodate that? Ulf and I answered that to some degree this is in the model of chapter 3: the requirements of the retailer can follow from his cost minimization (e.g. smaller inventories), and (when the retailer is dominant) lead to higher than minimum costs for the manufacturer.

Phil: If you include stockout costs in the logistic costs function, the customer requirements are taken into account. Moshe: then the issue is whether we can predict an increase in the stockout costs; instead of just a parameter, this could be a function, a submodel of stockout costs. Explanatory variables could include the lost revenue, the probability of loosing customers, which depends for instance on the level of competition and the market price. Sten: if the prices between retailer and producer correctly reflect the costs, the optimum will result.

-) Can we take all wholesale (W) activities out of the national accounts and treat them fully in the logistics project? In our model they only perform logistic activities. But in reality they also do marketing, customer services and such. I agreed that we might have taken a too limited view on this sector, but these other activities might not be relevant for transport flows. These also asked whether we could provide ideas for how to go from a Production/wholesale-/consumption matrix (Norway) to a P/C matrix. Anderstig of Inregia said that in the national accounts wholesalers are sometimes registered as sellers or receivers; some production takes place at wholesalers, and wholesale and retail is sometimes mixed. The base matrix project will try to net it out.

Moshe: the marketing activities of the wholesalers may affect the location of the distribution centre. If the P/C matrices would include wholesale, than our job would be easier/smaller. Sten: but the result would be less meaningful. For the flows that start or end at the wholesaler the P/C matrices would not give the transport chain from P to C. Moshe: this issue is related to the issue of whether the locations of the distribution and consolidation centres are taken as given (for short run policy analyses) or optimised (in the long run).

-) The clients would prefer to have complete P/C matrices, including air freight, but agreed on a separate treatment (outside the general mode choice) of air freight shipments in the logistics model.

Moshe: to split air transport from non-air, you also need a model. Gerard: this could be a model at the top of a nested logit model, with the other mode choices lower in the tree. Moshe: this makes sense. The fact that air transport has small volume shares in tonnes, is not so much of a problem for us, because we shall be working with shipments.

-) The definitions (e.g. consolidation centre, consignment, shipment: can be several ships or smaller than a truck) are not always clear. A glossary would be welcome.

-) In the model of chapter 3 we are assuming that inventories are kept at the C end (retailer or further processing). This is because shipments size in logistics is determined through the economic order quantity model (EOQ), which is about a firm ordering from a producer. The inventory decisions might be taken at the P end, but for the inventory at C (vendor managed inventories). They asked whether these inventories are kept by the big retailer or its small franchise shops. I said that the big retailers determine rules for inventory decisions at their local stores. They replied that there are inventories at the P end and between P and

C too. And JIT also implies pushing inventories back to suppliers. I replied that maybe these inventories did not matter for decision-making on shipment size.

Moshe: the inventories at the C end determine the order quantity. Sten: this also depends on the number of clients of a firm. Phil: effects may be passed on up and down the supply chain through prices paid. Gerard: inventories at the P end are determined by production considerations ('production smoothing' inventories). Moshe: this project should not go into production scheduling, that is not a trade-off between inventories and transport but between inventories and production costs; we do not model production here.

-) It should be made clear that the Annex on CAPS is an example of a model used in the private sector, from which we can learn; it's not the idea to use this software in this project.

-) Will the Monte Carlo simulation in step 1 be mathematical or just empirical (in a table)?

Moshe: The idea is to draw from a distribution. This may be a continuous distribution (e.g. normal, uniform, triangular, etc., fitted to the data) or a discrete one (that could be represented by a table, obtained from the data). This is still open.

-) The clients will probably stick with the present 12/13 commodity groups, but can we expand a bit on how to go from NSTR to logistic families based on handling and value of time? The Swedish 12 groups were indeed based on equal volumes (tonnes) per group.

Moshe: this is about market segmentation. A market segment could be defined as having similar parameters in the logistics model. So it could be based on the estimation results for the logistics model, with different a priori commodity types, shipper and shipment attributes (heterogeneity). Phil: a particularly relevant attribute might be the density of the product: besides weight restrictions there are also the volume constraints of vehicle loading space.

-) Presently a value of time is used in the network model cost functions. This introduces some logistics thinking in the model. Which VOT and costs should be in the network model after having included the logistics model? I said that maybe inventory costs (interest on time in transit) need not enter in the network model anymore, only vehicle- and labour-related transport costs. The costs that go to the P/C matrix should include inventory and distribution centre costs, but those of the existing distribution centres or the optimal locations? This depends on the timescale of the analysis: policy analysis or long-term forecasting? These costs are not included in the costs that are transferred from NEMO to the spatial computable general equilibrium model PINGO in Norway.

Moshe: In our ideal model, the network model will give the shortest path (uni-modal) through the network between P, intermediate locations and C. Mode choice will be covered in the logistics model. In the network model, some cost items that only differ between modes and between inventory options can be dropped. The value of time might still be relevant if the network model should include tolls (however this can better be treated by multi-class assignment or even better in the mode choice).

-) The national model systems are also used for project evaluation. Could our model (with economies of scale) give producer surplus, which they cannot calculate at present?

-) Some other (minor) questions and comments will be e-mailed.

New information for Norway and Sweden

Inger Beate Hovi of TØI (Oslo) gave some recent information on NEMO. This now uses 13 commodity groups and includes air transport as a mode, but this is only available for 2 commodity groups. There is information in Norway on the number of firms by P and C in the Register for Establishments and Enterprises. This is by sector, not commodity. There is no shipment size data in Norway, only some on the load per trip. TØI is collecting information on distribution centers, freight terminals, ports and airports (for general cargo only). This will be completed in September. They think they can convert the Norwegian PWC into a P/C matrix, but the calibration of the gravity model on count data may no longer fit well after taking out wholesale. She called transformations to firms and shipments 'scaring', because this requires detailed and reliable data, but even the P/C matrix is an estimate (using for instance value to weight transformations). The disaggregation would increase the uncertainties.

Moshe: one should remember that we also aggregate again after the disaggregation. There the law of large numbers can be invoked and one can get rid of noise. We might also use replications in the Monte Carlo simulation to reduce noise. The reason for the disaggregation is not to predict at the individual level, but to get proper sensitivities.

Inge Vierth of SIKA told me that in Sweden a new data collection effort of the public and private (transport) sector will start soon (will be carried out by a group of Swedish Universities, including Linköping's Dan Andersson). SIKA will give us contact details. Oskar Kleven (Norwegian client coordinator) told me about a survey among firms in Norway about their logistics. A similar survey included 900 firms in Sweden (Chalmers University). Nevertheless they were happy with the fact that we carried out some interviews with firms in our project and with the outcomes of these. Ulf will do a few more in Norway.

The way ahead

The clients will also provide minutes of this meeting. SIKA will collect comments on our note and send these within a week. We do not have to submit a revised note to the clients, but only have to make the changes required in the final report. Only if clarification would be needed, we shall send a separate reply.

The next meeting will be on 2 September in Stockholm. Our next note (working out the model structure in more detail, with one eye, but not two, to the available data; discussions on data gaps and new data collection will not be covered in this note but in the final report) needs to be sent to the clients on 26 August. Inge Vierth will send me the distribution list, so that we can send it directly to all clients.

Gerard will prepare a draft of the new note, that will be discussed at the next phone conference on 20 August, starting at 15.00 h. CET

Gerard de Jong, 17-18 June 2004

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 4074)

Minutes of the telephone conference on 20 August 2004

Participants

Moshe Ben-Akiva (RAND Europe, MIT), Mike Florian (INRO-Montreal), Phil Gibbs and Martin Baker (Solving International UK), Adnan Rahman, Sten Bexelius, Maarten van de Voort and Gerard de Jong (RAND Europe)

Introduction

Gerard said that Ulf and Lars of Bohlin and Strömberg could not make this phone conference, but he had a phone call with them earlier this week and will have another one next Monday. The second deliverable should cover the model structure. A draft of the second deliverable has been distributed and seen by all. It is an extension of the first deliverable, because this one already contained so much information on the structure of the model. Gerard mentions that this phone conference is about answering two questions. The first is whether all revisions and extensions to the deliverable are OK. The second question is whether there are other things we can include in this or the next deliverable (final report, will include a chapter on implementation).

Discussion of comments on the first draft of deliverable two

Sten had a question on P. 10. Does including ports and airports in this project mean that these are linked to the zoning system or that ports and airports become (additional) zones themselves? It is agreed that the second would be better. For transport to/and from the port (P and C) is does not really matter, but ports and airports also have a transhipment function (as choice alternatives). This can be handled with new centroids. But maybe most ports and airports are already a zone itself or close to a zone centroid. This needs to be checked.

P. 11. On the Norwegian PWC matrices and their calibration. The PWC matrices are made by deriving the rows and columns from economic statistics and by predicting the cell values by a gravity model calibrated on traffic counts. The question is what to do if the P/C matrices would be used instead. The present procedure should be seen as a very approximate calibration of the flows (which might get somewhat worse without the W information). It must be using an initial assignment matrix from the networks (in order to use count data). Concentration of counts around the P and around the C would be best. But more generally, the final calibration should wait until the logistics model can provide OD information instead of P/C or PWC. This means starting with a provisionally calibrated P/C matrix, then derive the OD, derive a new assignment matrix, then go back to the calibration of the P/C model, etc: iterative calibration.

P. 12. Adnan pointed out the para on air freight should be rephrased.

P. 15. On option C, Mike remarked that it needs to be worked out what assigning vehicles means for rail transport. You need some logic to build trains (multiple commodities). Also a post-assignment procedure is needed to provide outcomes in tonnes (which is needed, together with vehicles). He shall write a few pages on this issues for this deliverable.

P. 20. Sten asked whether we want to cover seasonal variation, which exists for some products both in the amount of production, consumption and the availability of modes (in winter, the Northern Baltic Sea often freezes). We'll try to find out how important this variation is, but have to leave this open, and discuss this with the client. The Italian National Model for instance has a summer and a winter mode. The idea was that the P/C matrices should be annual amounts, but data as traffic counts might be season-specific. At least one needs to be aware of this issue to remove seasonality from the data.

P. 35. Moshe suggested calling the 3 variants: 'full model', 'partial model' and 'simplified partial model'. It is better not to call some variant the 'preferred' model, if you want to be neutral. Variant II is a special case of I and III a special case of II. I is the most general model. Adnan: Location of ports and airports is not a choice variable (unlike DC's in the long run). This is agreed. The distinction of the 3 variants is judged to be a reasonable one. All three variants could work with the same zoning, but maybe then there would be many consolidation and distribution centres, then variant I could require more zones.

Mike remarked that the costs functions used in STAN in Norway and Sweden are not the same. Those for Sweden are more complicated. In Norway more effort has been spent on the economic models. Getting these on an equal footing would be very useful.

Martin remarked that the table of model variants does not include that variant I requires most efforts and inputs.

P. 41. Moshe said that it is best to use data for different years in calibration and validation, to make the latter an independent test. These are iterative processes.

Martin suggested adding the acronyms used to the glossary, which is rather short (P, C, PWC, OD, …).

Things to add to the deliverables

Mike: STAN can do stochastic assignment now (logit, probit, Burrell). He sent such versions to Hovi and McDaniel.

The seasonality issue can be added: the temporal resolution of the model. Moshe: The present version includes choice variables (e.g. consolidation centres, which shipment sizes), but not an overview of the choice set, how these are generated and which modes are available under which circumstances (e.g. some mode not in winter).

The next phone conference will be to update the team on the outcomes of the meeting with the client on 2 September. It will take place on 9 September 15.30-16.30 CET.

Gerard de Jong, 23 August 2004.

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 04074)

Minutes of the telephone conference on 9 September 2004

Participants

Martin Baker (Solving International UK), Moshe Ben-Akiva, Sten Bexelius, Maarten van de Voort and Gerard de Jong (RAND Europe).

The topic of the phone conference was to update consortium members on the outcomes of the meeting with the clients groups and the base matrix consortium in Stockholm on 2 September 2004, and to get the view of consortium members on items raised by the client groups. In this document, the main outcomes of the Stockholm meeting are given in normal characters and the reactions during the phone conference in *italics*. Solving Bohlin and Strömberg was already aware of the outcomes of the Stockholm meeting, since Ulf Hester participated in this meeting.

1. Presentation and discussion on our second deliverable (Note on the scope and structure of the model, August 2004)

The client were very satisfied with our first deliverable (discussed at the previous meeting), but not satisfied with the progress we have made since then. Bates and Swahn said that the first deliverable gave a very promising sketch of the model structure. Now they like to get the 'full-colour picture'. What we had revised and added was not sufficient. The structure of the model needs to be worked out in more detail and it needs to be shown that the structure is coherent.

Did we reach a conclusion on section 2.3 (variants for the combination with the network model) or did we just park this? We need to say more about the combination of the logistics and network models, and be clearer on our recommendations.

The three steps A, B and C (P. 19) are convincing, but more detail needs to be given on each. It's not true that C is the same for every variant (I, II, III, p. 32) for step B: the aggregation differs between II (vehicles) and III (tonnes).

They also need clear recommendations on the choice of variant I, II or III.

We say that heuristics are needed to generate the transport chains. This is agreed, but these heuristics need to be worked out in more detail.

It might be more efficient –given the project objectives- to focus more on how to model transport chains than to make lead time endogenous (very difficult to really explain this in a model). Maybe other, more feasible variants can be distinguished.

Moshe: how much detail is required in a report on the specification of a model structure is a matter of degree. The expectations of our team and the clients seem to differ somewhat. We should be careful not to waste time on structural issues that cannot be supported by data. So, knowledge of the data might be important before we can go much further on the structure. And it is a matter of available resources. Gerard said that some items on model structure could be worked out in more detail that could be useful in any data situation. Also we are getting more insight into the data situation now and can recommend new data collection. Martin also suggested that we should give the variants a price tag: trade-off between quality and price. Moshe: for the next steps, the clients want us to do not so much further work on the inventory side of the problem (e.g. lead time), but to focus on the structure of the transport problems (including consolidation and distribution centres). Apparently, that is where the gap in the present report is (Martin).

Arild Vold of the Institute of Transport Economics in Oslo said that for some commodities lead time might be modelled and for others (e.g. fish) it would not be negotiable. He also says that our description on P. 9 on the wholesale data is not precise. The I/O data for wholesale are as good as for any other sector. There is uncertainty about the sectors that the wholesale trades with. The 'transport-specific counts' in Hovi (2004) are not traffic counts, but questionnaire-based OD surveys (origin, destination, costs, commodity) for truck, rail and sea (the latter are rather old). American institutes (notably Cambridge Systematics) have published on how to use the US CFS and other data to get OD flows. He'll send references.

Moshe can liaise with freight experts at Cambridge Systematics, if our team or the base matrix team needs it.

Inge Vierth of SIKA remarked that the survey of Swedish private terminals has been delayed. Maybe we shall find the Swedish value of time study of 1999 (Inregia, Fosgerau of COWI) useful: it also contains a section of which agent decides on which, by logistic family (STAN99). This report (in Swedish) is on the SIKA website. Detailed comments on our note will be e-mailed. She also asked how we plan to use the interviews that SBS did. We said that we had already planned to discuss this at our next consortium meeting: indications of endogenous and main exogenous variables per commodity type. In the final deliverable we shall also include the outcomes of the additional interviews carried out in Norway.

Solving Bohlin and Stroemberg have made two tables (one for Norway, one for Sweden) of the main choice and explanatory variables by commodity type. Martin will study these, to see whether the outcomes are plausible (given his experience in other countries) and could be generalised.

Swahn recommended that in the remainder of the project we should not only look at the data issues, but also work out fundamental issues of scope and structure. For instance we want to use the economic order quantity (EOQ) model, with a dominating role for inventories. But some products are 'built to order': produced on demand, with small or no inventories. This is a different optimization (of delivery to demand). Which processes are most prevalent in practice? I responded that it might be possible to extend the EOQ model to accommodate the determination of shipment size in such situations (e.g. products go directly into the store).

Moshe: if the EOQ model is specified properly, the built to order situation is a corner solution. If transport costs become less and less important and the transport system more reliable, a situation without inventories is desirable (assuming no influence of demand fluctuations). We could try to show that in our report. Maarten: this depends on having detailed product descriptions: if someone orders a red car, it is of no use to have a blue car in stock. Moshe: we need to account for heterogeneous inventories. Might use probabilities (of a match with demand) that depend on stock size. Sten: built to order might be for some products only. Moshe: it could also be treated as another choice variable for the shipper. To do it, one needs a particular transport system and manufacturing system. That is traded against low or zero inventory costs. So there are two ways for us to treat this: extra choice or extreme of EOQ model.

Swahn also has concerns about the treatment of the wholesale sector: can it be fully reflected by the consolidation and distribution centres? Wholesale also does some manufacturing, marketing and assembly. This raises both conceptual and data problems (in the economic statistics all roles of wholesale that add value are included; the commodity flow survey (CFS) includes many shipments that involve wholesale, maybe more than would be the case if it only did consolidation and distribution). Maybe the wholesale sector has to be made partly exogenous (or the model extended to include its other roles)? This issue also is of crucial importance for the question how to combine the P/C matrices and the logistics model. May be the production statistics can give insight into the different activities of wholesale (Anderstig). Swahn does not want to challenge the P/C concept: the base matrices for Sweden should be pure P/C, but maybe with some wholesale (non-consolidation and –distribution) activities included as a P and/or C. Bates argued that this depends on the commodity: if the commodity stays the same, it is just consolidation and distribution; if it changes it becomes P and/or C. Swahn: also for manufacturers the output is often in the same commodity group as the input: whether the commodity changes is therefore not a good criterion.

Sten: In some sectors there are complicated series of chains from raw materials to retail. Some steps involve logistics functions (consolidation, distribution), some are production or assemblage. These need to be cut into P/C flows. The criterion can be value added. For instance if more than 15 or 20% value is added, it is production (and consumption), even if in the data it is classified as wholesale. This cut-off point needs to be determined from the data. Would be easy if the distribution is bimodal: many non-producers and many full producers. The base matrix consortium then would make this split.

Moshe: this is also related to the level of detail in the commodity classification that we shall use in step B of the logistics model. Hopefully in step A we can also go to a finer level than 12 or 13 commodities. At the 12/13 level, Swahn's observation (same commodity in and out) will be correct. But if in the disaggregation we can go to many (hundreds) commodities, then input and output will be in different groups and we can also see wholesalers where changes in commodity take place. Then it's a matter of coordination with the P/C project. If a detailed disaggregation *by commodity type could be done, flows to and from wholesale can be included in the initial P/C matrix and some fraction of these will then be taken out after the disaggregation step, to get a 'pure' P/C matrix (including production activities of wholesale). The locations taken out will then serve as information on consolidation and distribution centres. But note that this is all depends on getting a detailed distribution by commodity type.*

Maybe in some cases the Monte Carlo simulation can be done by enumerating the options.

Can we work out the proposed approach for the routing problem for collection tours to consolidation centres and multi-stop distribution tours from DC's? The traveling salesman models are not so easy to incorporate into a big system and computer-intensive.

This is an optimisation problem for carriers, not so much for shippers on which we in the logistics model are focussing. Some of the existing models for this are very sophisticated and also take account of time windows and vehicle size restrictions (Martin). TSP is often very complicated. We don't need this amount of detail and complexity in our national level model system, that will include many other problems as well. Even at the overall company level, such models are often too detailed. The models that companies use start often with the total time of a driver. Then the time between DC and destination area is subtracted. The time left is for the deliveries. Assumptions are made on vehicles size, utilisation rate, etc (also for future years, if in predictive mode). Martin will send one or more worked out examples of such a model. Gerard will ask Mike what is in STAN for the multi-stop routing of less-than-truckload shipments. The options are then to leave it to STAN, or to include a simple carrier routing model (like Martin's examples) just before STAN.

We do not have to treat seasonal variation.

We do not have to think any further about singling out the big flows (P. 18) in our project (might come back in the PC project).

Because of increasing capacity or organisational changes (rail sector), some modes that are not available now, might become available in 20 year from now. Shippers might consider rail as an option if it would be more reliable. Ulf mentioned the Norwegian (rail) freight operator Cargonet that provides network services for rail.

The discussion in our note about new zones and centroids is unclear. Is this proposed for ports and airports or for all consolidation and distribution centres? Does this make the number of zones a function of the logistic outcomes? I responded that this needs to be checked for major transhipment points, attractors and generators: can they be handled properly in the existing zoning system? If not, then this can be solved in a new fixed zoning system. Even that would be a major complication (also for P/C development). We should consider whether this is worth it.

Whether full adjustment of the production factors (e.g. relocation of consolidation and distribution centres) is required for long-run applications actually is a question for the clients: what kind of applications is needed most? The number of and the optimal location of terminals is of some policy interest. Which questions are most relevant and is this functionality worth its price? Therefore we have to let some choices between variants open, and have to give indicative price tags for the variants.

Can we say something about how the model would work in the context of cost-benefit analysis (CBA) as applied in Sweden? What outputs will it give to the CBA? Inge Vierth will send us info on CBA in Sweden, Oskar Kleven on Norway.

Ulf mentioned that he had been in touch with Statistics Norway on data availability. We said that we would have a conference with Statistics Sweden later on 2 September and that we would come back to Statistics Norway after that.

There might be some indirect information on shipment frequency in the CFS: the local units were asked to give data on some fraction of their shipments (all commodities together). Also there is an expansion to total tonnes in Sweden (Christina Kvarström of SIKA knows about this).

2. Presentation and discussion on Inregia's second deliverable

Many items discussed are not relevant for our project.

Given that more than 60% of the (unweighted) CFS is about shipments originating at wholesalers, the Inregia consortium is thinking about methods on how to include these observations to estimate the pure P/C matrix. On estimation/calibration and validation they said both groups should try to get their own models right first. Then, the P/C matrices and the logistics model can be combined to give OD matrices and link flows that can be compared to observations from OD surveys and traffic counts. If big discrepancies arise, these need to be analysed. Finally, parameters in both models can be recalibrated (iterative procedure, joint effort). Bates agreed on then iterative procedure and asked to consider revising the P/C matrix every six months. The new costs are calculated next and six months later, the P/C matrix is redone.

Moshe: The final calibration (to counts and OD surveys) has to be done jointly by both teams. The methodology needs to be worked out (preferably treat is as one big optimisation problem).

The clients also thought that the other consortium had not added material much to its revised first deliverable. The new note was found unclear about the overall methodology, but the presentation at the meeting was much clearer.

3. The way ahead

The next and final meeting was planned for 1 October, but we all need more time. It will now be on 19 October, in Oslo. The draft final report needs to be submitted on 13 October (by e-mail). Inge Vierth will contact us about possible consequences of this for the contract. Bates/Swahn together with one representative from Norway and one from Sweden also want to meet us (and the other consortium) separately, for in-depth discussions. They'll send an agenda. This meeting will take place in Leiden on 20 September (all day). RAND Europe will host this meeting. The meeting with Inregia will be in week 38.

Moshe is available for questions and comments by phone on 20 September 15.00-16.00 CET. The next consortium phone conference is scheduled for 8 October (starting at 15.00 CET) to discus the draft final report. Gerard will call Martin on 15 September 15.30 CET to discuss Solving's inputs.

Gerard de Jong, 10 September 2004

Project 'The specification of logistics in the Norwegian and Swedish national freight model systems' (project 04074)

Minutes of the meeting with the clients on 20 September 2004

Attending: John Bates, Gerard de Jong, Henrik Swahn, Inge Vierth, Oscar Kleven, Maarten van de Voort, Mike Florian (over the phone for part of the meeting).

Issues to discuss:

1. Treatment of the wholesale sector
2. Treatment of ports and airports
3. *S*cope/structure of overall model
4. Relation to network model
5. Alternatives within the logistics model
6. Use of logistic families
7. Economic order quantity
8. Use of logistics model system for CBA
9. Routing problem

Economic order quantity

The model might give some problems for certain commodity types. The Annex by Solving Bohlin and Strömberg gives an overview of the decision-making by sector. This needs to be used to see how the model can be applied for specific sectors.

The economic order quantity model (EOQ) does not seem to be valid for all types of shipments. Shipments that are build to order (BTO) are not stored. Therefore the EOQ model appears not to include these types of shipments. In theory however it does. Goods that are produced BTO are so for specific reasons:

1. Low volumes, low standardisation enable a producer to tailor the product. Since there are few advantages of scale to be gained, production can be done according to the buyer's specific demands. This category also includes some customer tailored products of which the shipment itself is of large volume, although the number of orders usually is not.
2. Consumers can put very stringent demands to the delivery. This can be the case for perishable goods and express cargo. These types of shipments are within the EOQ since the consumer chooses to pay for the additional costs associated with shipping small volumes.

3. Pushing back inventories. Supply chain managers or supply chain dominant actors can due to their dominance in the supply chain push inventories to their suppliers and their customers. This is not actual BTO since the suppliers of a dominant party will need to maintain inventories of these goods as they can be called upon to deliver at very short notice. Examples of these kinds of practices can be found in automotive and electronics / computer supply chains. In these sectors manufacturing of components will, as depicted in Figure 7, be done in large volumes to achieve advantages of scale. The costs of transport within these constructions will typically be with the supplier, leaving the receiver out of the cost optimisation problem on which the EOQ is based.

A recent study by RAND Europe for the Dutch Ministry of Transport (*RAND Europe 2003, Strategic Explorations for DGG*) revealed that BTO does not make up a large proportion of total transport as it typically involves customised products (in the upper left area of Figure 7). For this reason BTO might be considered a corner solution of the EOQ reducing the need for a supplemental model to be designed for the BTO cases that can be identified.

On the other hand, as examples of BTO are proliferate, we might want to go back to the basics of BTO in order to statistically establish a basis for any assumption regarding BTO and its impacts on transport. The question is thus how to determine which products are likely to be built to order. The final report will contain a discussion on EOQ versus BTO.

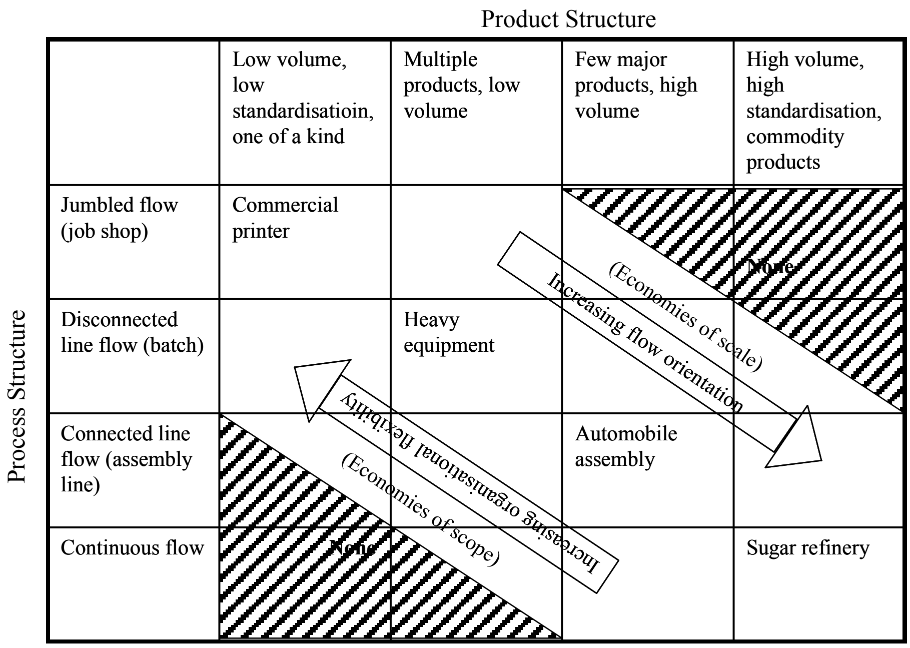


Figure 7 - Process – Product structure

Source: Hayes & Wheelwright 1979

Sweden is characterised by a large proportion of heavy industry and thus by the transport of a lot of bulk goods. This also influences mode choice in which rail has a far larger share than in other European countries.

Wholesale

There are two ‘extreme’ ways of dealing with the wholesale sector in the overall model system:

1. By using a P/C matrix and without any wholesale
2. By using a P/W/C matrix which allows for an additional layer of wholesale activities: all wholesale is included in the trade flows.

In between options would include splitting wholesale activities in a production and a consumption component: part of the wholesale is included in the trade flows, the rest performs logistical functions. The suggestions of Sten and Moshe in our minutes of September 9th relate to such intermediate options.

In order to determine the more suitable of these options for our purposes an assessment needs to be made. Originally the model structure was designed around a P/C matrix, but now several reasons are surfacing that favour the P/W/C:

The wholesale sector is performing far more functions / activities besides storing and reselling goods. In addition manufacturing, assembling and packing are increasingly commonplace in the wholesale sector. This leads to increased value added in this sector and gives reason to adjust the modelling to incorporate these functions. Other sectors (e.g. transport companies, retailers) perform logistics activities as well.

The current CFS data available for Sweden however, only contains information on receivers for international incoming shipments. For domestic shipments it does not contain information on the receiver and does thus not specify whether this is a manufacturer, a wholesaler or a retailer. Since the activities within the wholesale sector are so diverse, it will be difficult to distinguish based on the statistics that are available between wholesales and retailers. The Norwegian data does include the wholesale sector, although it needs to be verified whether the definition used for Sweden would result in assessing other companies in Norway to be wholesalers / perform wholesale activities as well. In order to be able to define wholesalers based on the statistics available, first a definition of wholesalers needs to be sought.

It might be possible to identify manufacturing/assembling at wholesalers by looking at the input/output tables. If the input table contains resources from one commodity and the output table of another, clearly something in addition to keeping inventory has taken place. This however is by no means a full proof way of identifying manufacturing/assembling since the number of commodity groups is fairly limited. Moreover the Swedish I/O tables have no inputs for wholesale. This method can be supplemented by assessing the value added in a wholesaling company. If this is above a certain threshold, activities could be characterised as production.

One clear advantage of using P/W/C is that for the Norwegian case the W data that is available would be used to its full extent instead of being disregarded as would largely happen if a P/C matrix approach would be chosen.

In determining the use of either P/C or P/W/C it should be assessed for different commodity types whether this format is suitable for these commodity types. In choosing between the two types, a discussion with the Inregia consortium would be required. The project consortium will weigh the advantages and disadvantages of using the P/C and P/W/C matrices and choose between them.

If the consortium decides to go with the P/W/C instead of the P/C matrices, the Norwegian, in addition to the Swedish, data also has to be checked for additional wholesalers / wholesale activities. One way to do this is by drawing on characteristics of wholesalers (input/output, percentages value added, commodity type changes, etc) from the Norwegian dataset. Companies whose characteristics are within a certain bandwidth could then be categorised wholesalers.

Ports and airports

Ports will not be modelled as a separate zone since this would require alterations in the zoning. The repercussions of altering the zoning would be such that this is not considered worthwhile.

A possibility that does remain open is to assign several centroids (e.g. commodity specific centroids) per zone. According to Mike Florian it should be possible to use several commodity-specific centroid connector links in the same zone in STAN.

Location choice

The choice of location for a wholesaler would generally be the outcome of an optimisation of transport and logistics costs. In some cases historical, personal and sentimental reasons blur this optimisation and introduce uncertainties. Therefore a stochastic variable should be added to the equation determining wholesalers' locations.

Network model

In STAN transport costs per mode are based on network connections. STAN thus provides distances and costs of transporting along links. It does not incorporate activities at nodes such as consolidation and distribution.

Cargo units such as containers and swap bodies will probably be treated as shipment types. Standard sizes of trains and ships are determined by cost functions. The question remains whether we are retaining these standards per commodity.

Cost functions are defined per link. It might therefore not be possible to expand the number of vehicle types without expanding the number of links, since a cost function for these vehicles would then be missing.

Another option is to run the network model as for different modes. We should also try to avoid duplicating networks, as this would seriously lengthen calculation times. The question on how to expand the number of vehicle types within STAN was posed to Mike Florian. He will answer later by email.

Another question is how STAN deals with and assigns empty vehicles. In practice a percentage of vehicles will receive a return load, while others will return empty. The return loads will be included in the CFS, while the empties will not since they are not carrying anything. In the current Samgods model a load is divided over the outward and return trip (both with a 50% load factor). This obviously leaves room for improvement since it includes some assumptions on the generation of return trips as well. We should preferably seek out those trips having a return load and placing additional vehicles on the network for those trips without a return load. For trains and ships this should not be too difficult since here each of the nodes should maintain in balance in the number of vehicles it holds.

For lorries these empty flows (estimated to make up about 30% of all trips) should be placed on the network in the right direction. The current handling within STAN of empty loads is not an attractive alternative.

Model structure and scope

The discussion of variants of the logistics model and the links with the network model will start with a simple route assignment model (what if then required from logistics model?) and proceed to system with multi-modal assignment.

If the mode choice cannot be included in a stochastic way and is merely done deterministically, we do not encompass the network model. Stochastic mode choice would imply using a random stochastic variable in the logistic cost function.

The different options open in route choices would probably not introduce large differences in costs. Route choice therefore does not have to include stochastic differentiation and can remain deterministic.

Routing

The travelling salesman problem (TSP) is too complex to introduce in a strategic model on a country level. Even for individual companies TSP is only used on an operational level instead of the strategic level due to the complexity brought about by TSP optimisation. Typically a simplified model is used in order to achieve a near optimal solution, since TSP is too heavy in terms of calculation requirements. A simplified model will, be worked out in the final report. We should also be capable of assigning the interzonal consolidation and distribution flows to the network. Henrik Edwards encountered similar problems in Nätra.

Distribution centres

There are different types of distribution centres. The distinction between these is usually dependent on the centre's catchment area. In literature three types of centres can be identified:

- EDC (European distribution centre)
- NDC (National distribution centre)
- RDC (Regional distribution centre)

If for the model only the points of production and consumption are known, the model should ideally determine not only the location of a distribution centre, but also the layout of the distribution network, including the number of distribution centres along which a shipment is typically transported (e.g. using direct distribution from the manufacturer to the consumer, a single distribution centre close to a population centre with city distribution, or multiple distribution centres to which the goods are transported consecutively; e.g. EDC and RDC).

One way of reducing this problem is to a priori determine the most appropriate distribution structure per commodity type / sector (e.g. from the Solving Bohlin and Strömberg interviews).

Another way to incorporate the distribution structure within specific sectors is to collect more data. In Norway in 2001 a study was performed on terminals in the Trondheim region. In addition, TØI is currently working on a terminal study which is due November / December of this year.

The logistics costs should be split and described in more detail. One of the components of logistics costs that needs further specification is packaging. The cost of packaging should only be incorporated insofar it involves bundling packed units (e.g. palletising crates). The cost of assembling and packing individual units is considered to be part of the production costs.

CBA

For cost benefit analysis it needs to be worked out what the new model system can add, especially on logistic costs.

If passenger travel choices are monetised using VOTs, these values are compensated for GDP growth. Perhaps a similar compensation should be applied for freight transport VOTs.

Other remarks

- **1:1 mapping** (page 5 comments) is meant to relate to Chapter 3.4. The remarks in the notes are on the bullets under 3.4
- **Home deliveries**

  Home deliveries are not considered of such a magnitude that they should be included in the model. The model stops at the retailer, not at the consumer (final consumption).

  It is however important to assess which freight transport flows we exclude by excluding home deliveries. For instance in Sweden heating oil is delivered at home. These deliveries are not included in the CFS.

- **Congestion** influences travel and transport costs. If retailers are located outside municipalities this could result in increased congestion and thus in increased costs.

- Is the **building industry** included in the CFS and if so, are building companies characterised as Cs? This will need to be discussed within SIKA and perhaps with the Inregia consortium.
- A general note is that obviously adding detail and including additional features to our model that better incorporate logistical practices will require more resources. It would be helpful if the RAND consortium could give some overview of the **price** pertaining these incorporations and the advances in **quality** that could be made doing so. In assessing these advances, it should be taken into account that the model is to be designed to use datasets that will be available in the future. The variables included in the current datasets should therefore not demarcate current model design efforts.

Documents

- RAND will distribute documents in searchable pdf format
- Inge and Oscar will provide reports on the main commodities produced / transported in Sweden and Norway.
- Oscar will check whether the Norwegian PWC matrices will be available both in weight and in value. For Sweden the trade matrices can be in both dimensions.
- Inge will provide documentation on the locations of (intermodal) distribution centres.
- Inge will send a document providing data on companies' access to rail and ports.

Project "The specification of logistics in the Norwegian and Swedish national freight model systems" (project 04074).

Main outcomes of:

- **the meeting with the clients and the base matrix consortium on 19 October 2004 in Oslo**
- **the internal meeting at RAND Europe (Moshe Ben-Akiva, Maarten van de Voort and Gerard de Jong) in Leiden on 21 October to discuss the outcomes of the Oslo meeting (*in italics)***

John Bates, one of the commissioners on behalf of the clients started by saying that our draft final report was a good report. He'll send detailed comments later. Four issues need to be resolved together with the base matrix consortium:

1) What is our final conclusion on wholesale? We proposed to start with PWC and develop a model on P/C later. Bates supports this. Inregia keeps both options open.
2) Base matrices for both countries can be in weight and value terms. Our report doesn't say much on what can be done with the value matrices. I said that we had originally been counting on weight matrices only, but that we can use the average value-to-weight ratio of a commodity group as an explanatory variable in several logistic and transport choices. We probably don't need value matrices.

   To generate the firm to firm flows from the zone to zone flows in step A of the logistics model, we shall start from the base matrix in tonnes. The registration data can then be used to allocate firms per commodity group (preferably more detailed than the 12/13 groups, say 60 groups) to all P and C zones. The assumption that the firm to firm flows will then be formed on the basis of independence between the P and C allocation could lead to problems. For a certain commodity group there might be 10 producing firms in zone A and 14 consuming firms in zone B. Because of the independence assumption there will then be 140 firm to firm flows between A and B, the sum of which will be equal to the given P/C flow (in tonnes). This is repeated for every zone to zone flow. In reality many of these firm to firm flows are zero: a consumer does not purchase from all suppliers located in each zone that is observed to supply to the zone where the consumer is located. This could be regarded as the maximum number of firm to firm flows. This can lead to unrealistic results when the EOQ model is applied next. An alternative would be a supplier model for the purchasing firm or some form of sampling from the maximum number of flows. The question is whether there are statistics on the number of suppliers (or the number of receivers) that a firm uses (by commodity type). In the absence of official statistics, the logistics experts might be able to give some guidance here. Data is available on the number of shipments by commodity group for Sweden from the CFS, as well as the weight of these. This gives the observed average shipment size per commodity group, which can be used to calibrate the EOQ model together with *the step A model (which fraction of the maximum number of firm to firm flows is realised?).*

The logistics project does not need the matrices in value terms, but would like to receive the value-to-weight ratios used in earlier steps (in the same detail as used there) to do checks and for testing as explanatory variable.

3) Both projects suggest a more detailed treatment of commodities (than 12/13), but don't give specifics. The data seem to be more of a constraint than the software.

4) Treatment of international flows and transit flows in particular (see later).

He also asked some questions about our deliverable:

One was whether it would be possible with good OD data to develop a normative model for the logistics (without proper observations on logistics choices, but doing optimisation) and make it more realistic by calibration to the OD information. I said that there are possibilities for this, but we prefer estimation on choice observations.

This was confirmed in the internal meeting. Bates's suggestion could become relevant if no disaggregate estimation data would be available or could be made available in the near future. Then we could use a normative logistic costs function, assume this works as a logit model with alternative-specific constants and a scale parameter, aggregate the initial results, compare with aggregate data and then adjust the constants and/or scale in an iterative process.

Bates was also convinced that option 1B in our report was the best. He notes that there is some ambiguity in the treatment of mode choice and vehicle type choice in our report.

His main direct comment was about the treatment of international transport (including transit). We need to expand on that. I pointed at pages 38 and 39. We proposed a sort of port and airport competition model, but would leave the hinterland transport at the foreign end to the network model. Inge Vierth made clear that the clients wanted to have this inside the logistics model. The present Samgods model also includes full O to D treatment. They would also like to be able to simulate things as a road toll in Germany. Of course the networks get less dense outside Sweden/Norway, and the zones larger, but for the rest national boundaries should be seen as arbitrary. We have not investigated distribution and consolidation centres outside Sweden and Norway and there may be data problems. The base matrix project had not included anything on transit flows, but the clients wants these in both projects. An issue to be resolved is for which relations Swedish and Norwegian infrastructure will be competitive (Finland-Norway OK, Japan-China not, but what about Japan-USA?).

For the logistics project, the transit flows that use Swedish (or Norwegian) infrastructure need to be given exogenously (this will probably have to be based on judgement, not using a model). The logistics model then can determine which port or airport in Sweden (or Norway) will be used.

It was not clear what we recommended for the routing problem. Bates thought first that we assumed that all consolidation took place at the P zone and all distribution at the C zone. I assured this was not the case. He liked the idea of choosing the nearest available consolidation or distribution centre better. Also he did not object to the maximum of two intermediate points on the landside part of the tour. Some others thought we should allow for more scope for national DC's 'in the middle of the woods', as exist in Sweden, and maybe also for more than three modes/vehicle sizes.

Inge Vierth will send information on how transit traffic is handled at present. SIKA is also looking whether we might use the CFAR (business register) as a source for the location of distribution centres and such.

Henrik Swahn said ours is basically a good report and he supports our choice of PWC to start with and P/C later. He also supports the proposed A-B-C structure (**Figure 3**) and the choice of option 1B (this option provides considerable added value). He also had some questions:

He saw some sentences still saying that the number of zones and centroids would be endogenous. I said we had accepted the number of zones as given.

He was OK with the discussion on specific goods (produced to order) versus the EOQ model.

He added that inventories not only lead to interest cost, but also floorspace costs and such.

We should discuss containers in some detail (e.g. stripping and stuffing). He prefers to treat containers as a loading unit, not a type of good.

The best thing would be to model containerisation explicitly in the logistics model. It could be an extra choice. To make this possible, the transport and logistics costs function should distinguish between containerised and non-containerised transport (for the commodities for which containerised is available): containerised shipments have less damage to the goods, lower handling and transhipment costs and time and higher transport costs, especially for intermodal shipments.

He questions whether the assumption is really required that the stock that determines the shipment size should be located at the C end. This could be over-restrictive. Ulf mentioned examples where the inventories are kept in between the P and C.

There are stocks at production and intermediate locations, but this is due to production scheduling, not transport and logistics.

New data are needed on transport fares, including cheap offers for loads using return capacity.

Can we add something on how to treat intra-zonal flows? Maybe there can be some relation with more detailed (finer zoning) models (under development as well: DISTRA, possibly using components of the passenger model).

Intrazonal flows are not necessarily equivalent to city distribution (interzonal flows are part of this too). For the logistics model it suffices to say that the intrazonal flows will be transported by road as a direct transport and to determine shipment size and vehicle type.

Inge Vierth said that we should not restrict our discussion on vehicle types to road transport, but also mention vessel types and train types (which also involves train formation and marshalling yards), even if most of this is handled in the network model.

Inger Beate Hovi of the Institute of Transport Economics studied our report and had three comments w.r.t. data in Norway:

1) There is a lack of data on shipments in Norway. We propose to use the lorry surveys as one source for this. But these have a different definition of shipment size: the load is reported, which could consist of several small shipments that are consolidated.
2) The terminal structure in Norway has historic reasons. It could differ significantly from an optimal structure. The trend is towards fewer terminals.
3) There is a skewness in flows in and out of the Oslo area: more loads are going out. As a result there is empty capacity going into the Oslo area. This is sometimes offered for very low prices, leading to some illogical transport patterns.

As part of the discussion on the Inregia base matrix report, validation/calibaration was discussed. We can distinguish the transfer of variables between the two projects (e.g. base matrices, cost matrices) and the joint revision of model coefficients to better represent observed data. This could work with two loops (one inside the other). It needs to be worked out by both consortia.

Way ahead: The plan was to deliver the final report on 1 November. This is shifted to 5 November. We'll receive detailed comments from the commissioners and minutes of the meeting no later than 28 October. The clients also want to organise a seminar on these two projects to finalise Phase I on 30 November in Stockholm, where Bates and Swahn will present their conclusions. The consultants will present as well. It is not certain yet who else will be invited (e.g. other consultants), but they want to get some second opinions. We'll be paid to attend (not part of the present contract). They expect a new call for tender by the end of 2004. Our final report will be placed on the SIKA and NTP websites.

Annex 4. Minutes of discussions with Statistics Sweden and Statistics Norway

Outcomes of phone conference from SBS with Statistics Sweden SCB (Lars Werke and two colleagues) on 2 September 2004

Gerard explained the structure of our proposed model and the data we need. Then we discussed various statistics.

Lars confirms that the sampling frame used for the CFS is confidential information. The underlying data (register data mainly) needs to be requested from SCB. For step A (disaggregation) of our logistics model we need data on the number of firms and their size by commodity group and municipality at the P and C ends. For production this should be possible. Number of firms and number of employees per commodity group (as in STAN) and municipality can be provided for local units. Turnover is only collected at the firm level (however for some firms it is known at the local unit) and calculated for local units using proportionality with employment. The turnover at the local unit is classified information, but maybe an agreement to deliver can be made (first step would be a formal request for the data by our group). Otherwise we can calculate it ourselves using the same method as SCB used.

Similar data on firms at the C end is not available. SCB once tried to regionalize the foreign trade statistics. Eurostat has classifications that might be of some use. There is also some information on which companies are the big importers. The new CFS 2004/2005 also includes the industry code (10 categories, wholesale and retail unfortunately are 1 category) for the receiving firm for outgoing shipments. The present CFS only has receiving industry codes for incoming international shipments. They tested the chain approach in an initial pilot sample, but many respondents did not know the terminal locations.

The CFS 2004/2005 data will be delivered to SIKA on 1 April 2006. The main changes w.r.t. 2001 are that the question on hazardous goods is omitted and that the industry of the receiver of outgoing flows is asked now (but retail and wholesale is one sector).

The fact that we and Inregia found that more than 60% of the outgoing shipments in the raw CFS data has wholesale as sender should not lead to the conclusion that wholesale is dominant. The expanded results are very different. Andersson from Linköping also started with the unweighted CFS, but reached other conclusions when using the expansion factors. Some companies fill in all shipments during a week, others a small fraction. To use the CFS we should make sure we have the expansion factors and the formula to apply these. He'll answer the questions that Maarten van de Voort asked SIKA on the CFS.

There is some info on the use of distribution centres (e.g. for Schenker), though the CFS does not include these within Sweden. He'll send this. Also there will be a freight terminal survey by Göteborg University. This university also collected data on warehouses in the Stockholm area.

The lorry surveys are carried out according to EU rules. They give the origin, destination (in Sweden at county level, abroad as countries , commodity group (25 NSTR classes), kilometrage and weight. This is only done for trucks with 3.5 or more tonnes maximum capacity. The data can be made available, but may be classified information at the most detailed level. Similar OD statistics exists for sea transport at SCB. SIKA had the OD data for rail and air.

The IVP are detailed production statistics (again following EU rules), for the national accounts. It gives for all enterprises net income and quantity and value of industrial production. It does not include consumption or I/O data.

On the location of freight terminals, DC's and such: some are in the firms register data (which contains codes for some of these activities). Lars will send information about it.

Information on transport and logistics costs: SCB did some work for Inge Vierth on such costs. They'll send us information about it.

Ulf noticed that in the SNI classification, the same sector (e.g. automotive) includes both manufacturing and retail.

A similar session needs to be held with Statistics Norway. The data we are looking for includes:

- The number of firms (if possible local units) by commodity type and municipality, the turnover and employment of these firms, at the production and the consumption end.

- Data on individual shipments: sector of sender and receiver, origin and destination, modes used, shipment size/frequency, use of freight terminals, consolidation and distribution centres, ports and airports. Preferably transport chain information. Which shipments go directly from P to C, which use the above intermediate points?

- Data on where the freight terminals, consolidation and distribution centres, ports and airports are located.

- Data on transport and logistics costs (transport costs per km, terminal costs, handling and storage costs).

Outcomes of phone conference with Kristin Odegard and Oystein Linnestad of Statistics Norway (Ulf Hester and Gerard de Jong) on 29 September 2004

Ulf has been in touch with statistics Norway for this project before. He e-mailed our specific questions. Gerard explained the nature of the current project: we are trying to find out which data is available; the actual data transfer is not needed for this project, but may come later.

Kristin Odegard works on lorry statistics and Oystein Linnestad works on Maritime statistics at Statistics Norway.

A lorry survey is done at the county level (19 counties) per commodity group according to NSTR on a 3 digit level. A sample survey is done every week and sent out to 190 firms, both transport companies as well as manufacturing companies having their on truck fleet and others e.g. farmers. Approximately 95% responds. There are questions regarding the weight of the goods and the length of the journey. For each truck above 3.5 tonnes (it is not clear how this is defined: loading capacity, weight of the lorries? Kristin promised to come back with more detailed information), within those companies, this form is completed for all shipments in the week. OD information exists even on a municipality level but is not published. The information that exists on the municipality level can probably be used by our project in a model as long as we do not publish the collected information. There is no information about distribution centres (DCs) or freight terminals (FTs).

As regards airports. Statistics Norway has statistics regarding the passenger traffic. Statistics about the transport of goods is gathered by the Norwegian Aviation Authority and not by Statistics Norway. Oystein will be so kind to get in touch with them on behalf of our project and then mail us information.

Maritime statistics. Such statistics are gathered from the 30 largest ports in Norway. Each port registers information about each shipment weight, commodity (NSTR 2 digits), type of cargo (bulk etc.), type of vessel etc. The statistics cover goods to and from ports/airports, not the location of the sender or receiver. No information exists about the type of mode that is used for the hinterland transport.

Rail transport. Statistics Norway has no statistics for this sector but will be so kind to contact with the Rail Authority and mail us after that a.

Transport costs. No such statistics are gathered by Statistics Norway.

The additional information mentioned above could be sent to us both by e-mail Ulf Hester ulf.hester@bs.se and Gerard de Jong jong@rand.org

Gerard and Ulf thanked Kristin and Oystein for having taken their time and thanked them in advance for the additional information that will be sent. Our report will be sent to (among others): Norskt Vegvesen, Transport Okonomisk Institut, Vägverket and SIKA by the 13^{th} of October so we would appreciate if the additional information could be sent to us, if possible, well in advance of that date.

Outcomes of phone conference with Nils Petter Skirstad of Statistics Norway (Ulf Hester and Gerard de Jong) on 15 September 2004

Ulf has been in touch with statistics Norway for this project before. He e-mailed our specific questions. Gerard explained the nature of the current project: we are trying to find out which data is available, the actual data transfer is not needed for this project, but may come later.

Nils Petter Skirstad works on industry statistics (excluding oil and agriculture) at Statistics Norway.

The Norwegian production statistics are based on a survey among all 11,000 establishments (local units?). Information is available for local units: sector (NACE, following European guidelines), turnover and employment. Data can be supplied at the municipality level. For number of firms by sector and employment by firm by sector, there are no restrictions. For turnover at the municipality level, there will often be confidentiality problems (only a few firms in the cell): the information needs to be hidden and can only be supplied at a more aggregate level. But it is a good approximation to allocate the more aggregate turnover figures to municipalities proportional to employment. These production statistics only include producers, not wholesalers and retailers.

Statistics Norway also did a survey into the consumption by production firms (again no wholesalers or retailers). The most recent one was in 2002 (and before that 1997). It contains a sample of 5,000 enterprises from the 11,000 above (focussing on the biggest firms: almost 90% of production covered). This data was not published, but can be used for research. Producers (classified down to 5 digits, similar to NACE) were asked which commodities (6 digit classification, similar to NACE) they consume. This can be given at the municipality level (with the same restrictions as above). By connecting to the production statistics, the number of employees per firm can be given.

For the oil industry, there are similar statistics, but production is off-shore (most firms are based in Stavanger). For agriculture, data are collected by another unit at another location. Nils Petter will contact them for us, ask the same questions and report to us by e-mail (ulf.hester@bs.se). Gerard de Jong will send the 13 category commodity classification of the Norwegian freight transport model, so that the correspondence with the production and consumption statistics can be checked.