TRAFIKVERKET

REPORT

Representation of the Swedish transport and logistics system in Samgods 1.2.1

2023-04-01

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Dokumenttitel: Representation of the Swedish transport and logistics system in Samgods 1.2.1
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Dokumentdatum: 2023-04-01
Version: 3
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Summary

The national model for freight transportation in Sweden is called Samgods. The purpose of the model is to provide a tool for forecasting and planning of the transport system. Samgods can be used in policy analysis such as studying the effects of a tax change or a change in transport regulation etc. The aim of this report is to give an overview of how the Swedish transport and logistics system is represented in the Samgods model. Samgods consists of several parts, where the logistics module is the core of the model system. This report describes the setup data (2023-04-01) needed to run version 1.2.1 of the Samgods model.

The 16 commodity groups used in the Samgods model are based on the European Standard goods classification for transport statistics, NST 2007. Transport demand is described with commodity specific demand matrices for 588 geographical zones inside and outside Sweden. Demand between sending zones (production, wholesale) and receiving zones (consumption) is described with the help of production-wholesale-consumption (PWC) matrices.

The commodity specific P, C or W zones are split into sub-cells that include firms. The method used to generate the firm to firm flows is to divide the firms at the origin zone and destination zone into three categories according to size. It is therefore a maximum of nine sub-cells per relation. A tenth cell is used for transit flows and single firms' extremely large PC-flows. All small, medium and large firms are assumed to base their logistic decisions on the same optimization principles. Only large firms and singular flows are assumed to be able to have direct access to the rail and/or sea network.

A range of vehicle and vessel types are used to reflect scale advantages in transporting operations, including loading and unloading. The Samgods model uses six vehicle types for road, 11 for rail, 22 for sea and one for air. For the base year 2017, there are 144 pre-defined transport chains used in the model and for the year 2040 there are 213. A distinction is made between container transports and non-container transports.

Infrastructure networks are used to generate the level of service (LOS)-matrix data for each vehicle/vessel type providing transport time and, distance and network related infrastructure charges. The LOS matrices supply information among all administrative PWC-zones and all terminals. There are a total of 171 LOS-matrices, consisting of 160 vehicle specific matrices (40 vehicle types * 4 cost/time matrices) and 11 frequency matrices used to determine wait time in terminals. CUBE-Voyager is used in order to produce the LOS-matrices.

The logistics costs consist of transport costs (vehicle type specific link costs and node costs) and non-transport costs (commodity specific order costs, storage costs and capital costs in inventory as well as capital costs in transit). For each commodity it is assumed that either the overall logistics costs are optimized or the transport costs are minimized. Combining smaller shipments into larger shipments are possible in order to maximize utilization of each transport, this concept is known as consolidation. The current version of the model assumes that consolidation is only possible within a commodity group and can only be performed at terminals. In reality consolidation may also be possible on route in some extent, this is not taken into consideration in the model.

The model generates a huge amount of output at different levels. All the output files generated are described in the last chapter of this report.

1 Introduction

1.1 The Samgods model.

The national model for freight transportation in Sweden is called Samgods. The purpose of the model is to provide a tool for forecasting and planning of the transport system. Samgods can be used in policy analysis such as studying the effects of a tax change or a change in transport regulation etc. The model delivers transport solutions at the national level for import, export and transit flows. Samgods also handles domestic transport among municipalities, and the ambition is to be able to model the regional level in the future. The Samgods model can also be used to perform cost benefit analyses.

The Samgods model system consists of the following set of main software components:

- The logistics model, which is the core of the model system. In the logistics model, different types of commodities are assigned to different types of transport chains based on minimization of the total logistics cost. The logistics model is documented in a method report [1] and a program documentation [2].
- The rail capacity model (RCM), which is a module to manage rail link flow volume constraints. The RCM model is documented in [3].
- Cube Base, where the graphical user interface (GUI) of Samgods is incorporated.
- Cube Voyager, which is a transport modelling software used to implement supply and assignment models.
- Cube GIS, which is the geographical information system where the network of the model is implemented.

In addition, there are several components that have been fully integrated in the model; 'locked solution', 'elasticity module, 'CBA module', 'Compare module' and 'select link'. The component 'locked solution' gives the user a possibility to lock a logistics chain in a specific trade relation. The 'elasticity module' allows the user to calculate effects of slightly changes costs to one or several vehicles in the model. The 'CBA module' allows the user to produce data for a cost benefit analysis for a scenario. The 'Compare module' allows the user to compare the results of two scenarios. The 'select link' component allows the user to trace all logistics chains that passes a selection of links.

A user manual for the Samgods model is provided in [4] and an overview of the file structure in the Samgods GUI is available in [5]. Further, the generation of transport demand matrices used in the model is documented in [6].

1.2 Developments of the Samgods model.

The aspect of logistics is crucial for understanding developments of the freight transport market, the modes of transport and infrastructure requirements. Therefore, it is important that the national freight model explicitly treats logistics choices. Example of such choices are the selection of shipment sizes, consolidation of shipments or the choice of road terminals. The Samgods model should, as realistically as possible, define the likely number of shipments per year, terminal passages, handling technologies used and routes of shipments.

As most freight transport models, the Swedish national freight model system were previously lacking treatment of logistics choices. Therefore, a process to update and improve the existing national freight model system was started. An important part of this was the development of a logistics module. In 2005/2006, a prototype version of the logistics model using Swedish network and cost data, and data on the locations of terminals and distribution centers was developed. The purpose of this version was mainly to show the feasibility of the approach. After having shown that the approach was feasible, a new and extended version of the logistics model has been specified and applied for Sweden within the framework of their national freight transport forecasting system. The basic mechanism in the transport chain choice is minimization of a deterministic total annual logistics cost function. Implementation of a random utility-based logistics model on disaggregate data is foreseen for future versions. Version 1.2.1 of the logistics model is documented in a technical report [2].

The current version of the Samgods model is 1.2.1. Compared to the previous model version 1.2 [7], Samgods 1.2.1 contains a range of updates, for example:

- Updated transport network for vessels.
- Minor cost changes.
- Updated function of vehicle choice.
- An improved possibility to produce data for a cost benefit analyses.
- Changed aggregation level of consolidation rates.
- Possibility to inherit consolidation rates from a reference scenario.

1.3 Purpose and structure of the report

The purpose of this report is to give policy makers, researchers, consultants and users of the Samgods model an overview of how the Swedish transport and logistics system is represented in the Samgods model. The report includes a description of all input data necessary to run the Samgods model version 1.2.1 (setup dated 2023-04-01). The aim is to ensure that the transport system (infrastructure network including costs functions) is described and structured in a way that the clients' requirements can be dealt with and facilitated.

The rest of the report is structured as follows;

- Chapter 2 describes the commodity classification used in the model.
- Chapter 3 describes the division of administrative zones, the PWC-matrices and generation of firm to firm flows, and firms' access to infrastructure.
- Chapter 4 deals with the vehicle classification used in the model (modes, sub-modes and vehicle types) and the generation of transport chains.
- Chapter 5 describes the infrastructure networks and the generation of level of service (LOS) matrices.
- Chapter 6 describes the logistics costs used in the model and the optimization principles applied.

- Chapter 7 provides an overview of the various outputs of the model.

2 Commodity groups

2.1 Considerations regarding the commodity classification.

The commodity classification should reflect the real world. However, it is not possible to model all commodities, some aggregation is needed in order for the model to operate with acceptable run times. Also, the commodity classification needs to be designed in such a way that transport demand can be estimated with an acceptable statistical significance. The basis for aggregation should be homogeneity, i.e. the commodities in a commodity group should be similar with respect to logistic properties such as value and shipment size. Fewer commodity groups will give better run times, but on the other hand goods will be less homogenous. For the purpose of comparison, it is important that the classification is in line with nomenclatures used in official statistics. Also, it is important to note that the optimal number of commodity groups depends on the purpose of the analysis one wants to perform.

2.2 Commodity classification used in the model.

The Samgods model operates with 16 aggregated commodity groups (commodities). The division of commodities is based on the European Standard goods classification for transport statistics, NST 2007. In the NST 2007 classification, commodities are represented by 20 divisions. Divisions 01 to 14 is used in Samgods.[1] For the purpose of the Samgods model, division 01 has been divided into Timber and other Agricultural, foresting and fishing commodities. The last commodity group in Samgods is for goods transported by air freight (Commodity 16). It is created by allocating fractions of certain commodities to group 16. The reason for this approach is that not even small shares of the commodities would go by air solely based on their logistics costs. The reasoning behind the commodity group classification can be found in [8].

All commodities are associated with an aggregate commodity type: dry bulk, liquid bulk or general cargo (which in turn defines e.g. which costs apply, see section 6.4). The value of each commodity, expressed in SEK/tonne in year 2017 prices, were derived in the base matrix project [6], and are listed in Table 9.3. Samgods 1.2.1 uses separate values for domestic transports, transit, import and export. Table 2.1 presents the 16 commodity groups along with the NST 2007 code and aggregate commodity type.

[1] Divisions 15 to 20 consists of Mail, parcels, Equipment and material utilized in the transport of goods, Goods moved in the course of household and office removals etc, Grouped goods, Unidentifiable goods and Other goods.

Table 2.1 Commodity classification and aggregate commodity type.

No	Commodity	NST 2007	Aggregate commodity type
1	Products of agriculture, forestry and fishing	01, excl Timber	Dry bulk
2	Coal and lignite; crude petroleum and natural gas	02	Liquid bulk
3	Metal ores and other mining and quarrying products	03	Dry bulk
4	Food products, beverages and tobacco	04	General cargo
5	Textiles and textile products; leather and leather products	05	General cargo
6	Wood and products of wood; pulp, paper and paper products; printed matter and recorded media	06	General cargo
7	Coke and refined petroleum products	07	Liquid bulk
8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	08	General cargo
9	Other non-metallic mineral products	09	Dry bulk
10	Basic metals; fabricated metal products, except machinery and equipment	10	General cargo
11	Machinery and equipment	11	General cargo
12	Transport equipment	12	General cargo
13	Furniture; other manufactured goods n.e.c.	13	General cargo
14	Secondary raw materials; municipal wastes and other wastes	14	Dry bulk
15	Timber	01, part of	Dry bulk
16	Air freight (fractions of other commodities)	-	General cargo

3 Zones, firms and their access to infrastructure

The purpose of the Samgods model is to provide a tool for planning and forecasting of the transport system. In order to do this, the model needs input data on trade (goods flows) among firms. In Samgods, this is solved by using the following steps. First, transport demand (PWC matrices) are estimated for 588 zones (geographic regions) using data from the Swedish commodity flow survey. See [9] for information on the Swedish commodity flow survey. Second, transport demand are decomposed to the firm to firm level by dividing firms into three categories according to size. The logistic decision is then simulated at the firm to firm level. In this chapter we describe the zoning system, the estimation of transport demand and the decomposition to the firm to firm level, and assumptions regarding the firms' access to infrastructure.

3.1 Administrative zones

There are a total of 588 geographical zones in the Samgods model, of which 290 are domestic municipalities and 298 are foreign zones.

3.1.1 Domestic zones

The 290 domestic zones corresponds to the 290 municipalities of Sweden. The domestic zone numbers are based on the official municipality numbers used by Statistics Sweden. All domestic zone numbers end with 00 and are in the range 711400-958400.[2] Table 3.1 below shows the number of zones per county in Sweden. The zones in Sweden and in the neighbouring countries are visualized in figure 3.1.

Table 3.1 Number of zones per county in Sweden

County	Number of zones
Stockholm	26
Uppsala	8
Södermanland	9
Östergötland	13
Jönköping	13
Kronoberg	8
Kalmar	12
Gotland	1
Blekinge	5
Skåne	33
Halland	6
Västragötaland	49
Värmland	16
Örebro	12
Västmanland	10
Dalarna	15
Gävleborg	10
Västernorrland	7
Jämtland	8
Västerbotten	15
Norrbotten	14
Total	290

[2] The municipality code is derived from the zone numbers as municipality code = (zone number - 700 000)/100.

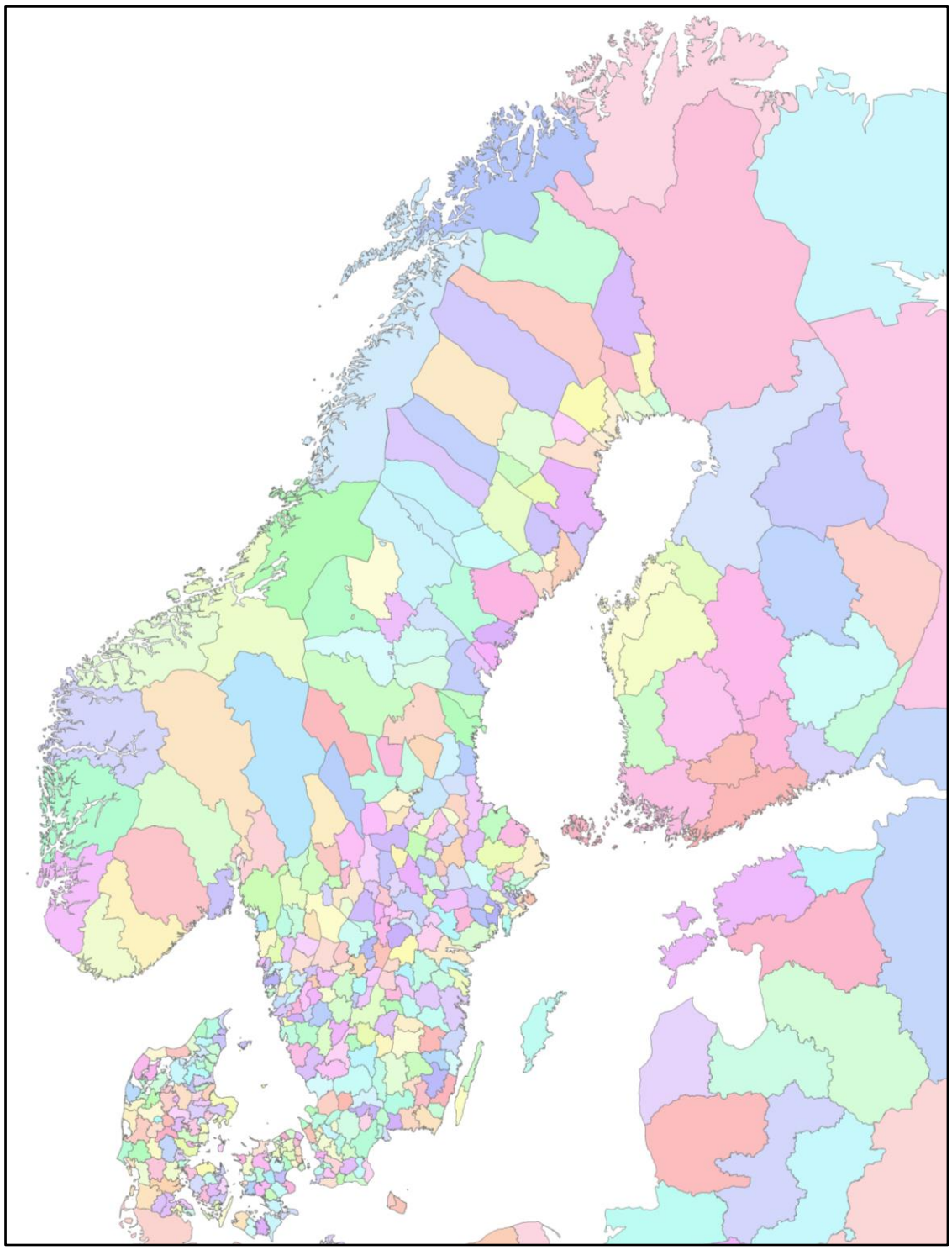

Figure 3.1 Zones in Sweden and in the neighbouring countries

3.1.2 International zones

Inside Europe

There are a total of 298 zones outside Sweden of which 273 are located inside Europe. Of these 273 zones, 192 are located in the neighbouring countries (Norway, Finland, Denmark and Germany). Within Europe, the further away from Sweden, the fewer zones per country. When sorted numerically, the foreign zones come after the domestic zones. The foreign zone numbers inside Europe also end with 00 and are in the range 960100-974900. Exceptions are the newly added zones in Denmark and Norway, which have zone numbers of 977500 and above. The zones within Europe are visualized in figure 3.2.

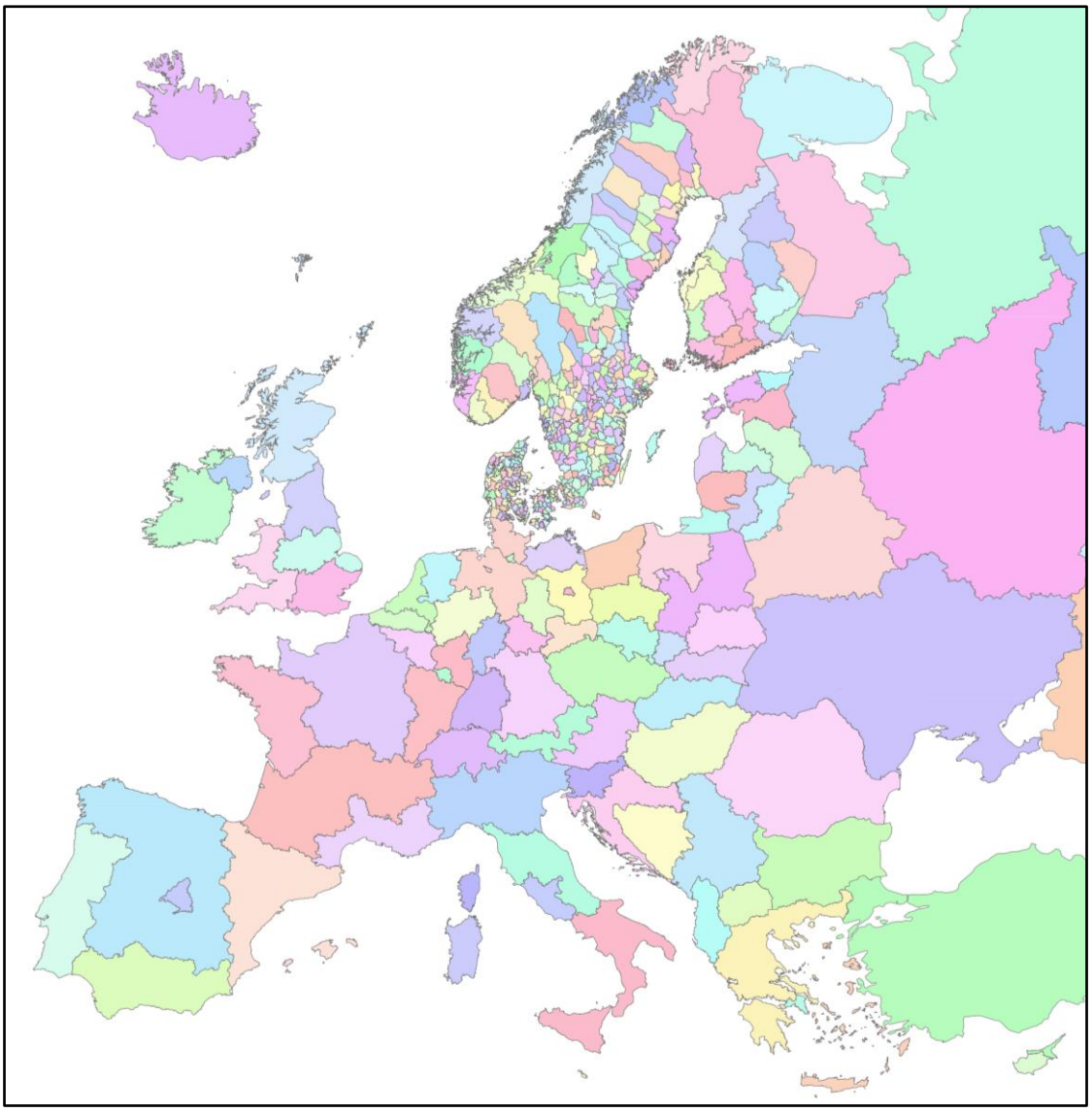

Figure 3.2 Zones in Europe.

Outside Europe

There are a total of 25 zones outside Europe. Countries that are significant trading partners to Sweden are defined as unique zones while other countries with smaller trading flows are aggregated into one joint zone for each continent. Zone numbers between 975000 and 977400 indicate a location outside Europe.

Table 3.2 gives an overview of the geographical break-down of zones outside Sweden.

Table 3.2 Number of zones per country/region outside Sweden.

	Country	Country code	Number of zones
Neighbouring countries	Norway	518	37
	Finland	501	19
	Denmark	519	120
	Germany	520	16
Within Europe	Albania	512	1
	Austria	521	2
	Belgium/Luxemburg	526	2
	Belarus	506	1
	Bosnia	513	1
	Bulgaria	509	1
	Cyprus	550	1
	Estonia	503	3
	France	525	6
	Faroe Islands	530	1
	Greece	511	3
	Greenland	532	1
	Hungary	514	1
	Ireland	529	1
	Iceland	531	1
	Italy	523	5
	Serbia	513	1
	Croatia	513	1
	Lithuania	505	3
	Latvia	504	3
	Macedonia	513	1
	Malta	524	1
	Netherlands	527	2
	Poland	517	8
	Portugal	534	2
	Romania	508	1
	Russia	502	10
	Switzerland	522	1
	Slovakia	515	1
	Slovenia	513	1
	Spain	533	5
	United Kingdom	528	6
	Czech Republic	516	1
	Turkey	510	1
	Ukraine	507	1
Outside Europe	North America	550	2
	Central and South America	550	3
	Near Asia	550	2
	Far Asia	550	12
	Africa	550	3
	Oceania	550	3
	Total		298

3.2 PWC-matrices and disaggregation to firms

Estimation of PWC matrices

In Samgods, the transport demand between sending zones (production) and receiving zones (consumption) is described with the help of production-wholesale-consumption (PWC) matrices. Wholesale (W) is treated separately because of the fact that wholesalers' logistic requirements differ from producers' requirements. The PWC matrices describe the demand for goods transport from one place to another, so that the matrix element (r, s) gives the amount of goods to be transported from zone r to zone s.

The base matrices for the year 2016 derived in the base matrix project are used in Samgods version 1.2.1 [6]. In total, there are 16 commodity specific demand matrices, each with 588 zones. The estimation of PWC matrices is based on data from the Swedish commodity flow survey (CFS) for the year 2016. Since the CFS data are collected using a sample survey, some uncertainty is inevitable. It is important to note that this uncertainty is inherited into the PWC matrices. The information extracted from the CFS are not sufficient to distinguish wholesale (W) and consumption (C) at the receiver side. Thus, special treatment of wholesale (W) is possible only at the sender side. Another problem is that the number of CFS-observations on foreign trade is rather small. Given these data inadequacies, it is important to acknowledge that there might be a gap between the estimated PWC matrices and the true transport demand.[3]

Decomposing transport demand to the firm to firm level

The Samgods model runs at a virtual firm level. Therefore, the commodity specific P, C or W zones are split into sub-cells that include firms. The method used to generate the firm to firm flows is to divide the firms at the origin zone and destination zone into three categories according to size (number of employees). The three categories are:

- small firms (first 33 % of the firm size distribution)
- medium firms (34-66% of the firm size distribution)
- large firms (67-100% of the firm size distribution)

Combining sending and receiving firms, we have 9 possible sub-cells per relation (see table 3.3 below). Further, a tenth sub-cell (No 0) is used for so called singular flows and transit flows. Singular flows are single firms' extremely large PC-flows. Transit flows start and end outside Sweden and are transported ashore on Swedish territory.

Table 3.3 summarizes the 10 sub-cells used in the PWC matrices. Further, it gives information about the distribution of transport volume and the number of relations per sub-cell. For example, even though singular flows and transit flows only amounts to 274 out of 8,8 million relations, this sub-cell is responsible for 20 % of the total transport volume.

[3] For further details regarding data and estimation of PWC matrices, see [6].

Table 3.3 Distribution of transport volume and relations per sub cell.

Sub-cell	Explanation	Transport volume (tonnes)	No of relations	Share (tonnes)	Share (relations)
0	Singular flows and transit flows	93 603 125	274	21%	0%
1	Small firm to small firm	44 876 484	2 951 042	10%	33%
2	Small firm to medium firm	39 309 085	824 109	9%	9%
3	Small firm to large firm	33 196 131	491 521	7%	6%
4	Medium firm to small firm	48 061 130	1 510 300	11%	17%
5	Medium firm to medium firm	42 480 635	771 099	9%	9%
6	Medium firm to large firm	33 702 815	366 614	7%	4%
7	Large firm to small firm	43 835 581	1 180 149	10%	13%
8	Large firm to medium firm	37 789 367	490 045	8%	6%
9	Large firm to large firm	38 243 017	241 064	8%	3%
Total		455 097 371	8 826 217	100%	100%

All small, medium and large firms are assumed to base their logistic decisions on the same optimization principle (see 6.4). However, logistic decisions such as the choice of transport chains differ due to the firm's annual transport volume and number of firm to firm relations. Also, the access to infrastructure differ by the size of the firm (more on this in section 3.3.).

3.3 Firms' access to infrastructure

3.3.1 Inside Europe

Road

In the Samgods model, it is assumed that all sending and receiving firms have direct access to the road network and via this network to other modes such as rail, sea and air. This means that goods flows from/to firms located at the centroid (the business centre of a zone) will start/end with a road link.

Rail and sea

In some cases, industrial producers and/or consumers have, via industrial tracks, direct access to the rail network or are located in ports. One example is the iron-ore produced in the mines of Kiruna. Similarly, crude oil is transferred directly from vessels to oil terminals within ports - not first unloaded and then re-loaded for further transport to the business centre. In the Samgods model, direct access to the rail and/or sea network is assumed to be available only when a large firm or singular flow is involved. Thus, direct access is assumed to be available for sub-cells 0, 3,6,7,8, and 9. This assumption is clearly a simplification of reality. For the sea mode for example, there are probably small firms located in ports that use sea transport as first/last link.

However, not all large firms are assumed to have direct access to the rail and/or sea network. If the large firm is assumed to have direct access or not depends on the location of the firm and the commodities produced. For feeder and wagonload trains, direct access is available for all commodities[4] but not all zones. Feeder and wagonload trains are used together in a transport chain, feeder trains act as a "feeder" for the wagonload train i.e. are used as the first or last link.

However, feeder trains are only specified within Sweden. The reason for this simplification is that the primary interest of the model is the Swedish transport system, and it is therefore appropriate to be more detailed at the national level. Further, the knowledge about foreign

[4] Due to calibration matters, there is one exception. Zone N=751 allows direct access for Wagonloads, but only for commodity group 2.

transport systems is limited. Direct access for feeder trains are thus present only in Sweden while direct access for wagonload trains are present only for zones outside Sweden (in Europe).

Direct access to system trains and sea is specified per zone and commodity. The reason for this is that certain locations and/or commodities are more suited for these type of transports, e.g. the iron-ore produced in Kiruna mentioned above. In Sweden, direct access to system trains is available at 64 locations. Other than Narvik (part of the iron ore corridor) and Torneå (connects the Swedish railroad network to Finland and Russia), no direct access for system trains exist outside Sweden. For sea, direct access is available in 42 domestic zones while direct access outside Sweden is limited to the port of Narvik. Again, the reason behind these simplifications is the need to be detailed at the national level and the availability of adequate information.Table 3.4 summarizes the information on direct access to rail and sea in Sweden and the rest of Europe. Figure 3.3 shows the location of the direct access points in Sweden and neighbouring countries.

Table 3.4 Direct access to rail and sea.

	Commodity specific	Number of locations in Sweden	Number of locations in Europe outside Sweden	Total number of locations in Europe
Direct access to feeder trains	No	153	0	153
Direct access to wagonload trains	No	0	35	35
Direct access to system trains	Yes	64	2	66
Direct access to sea	Yes	42	16	58

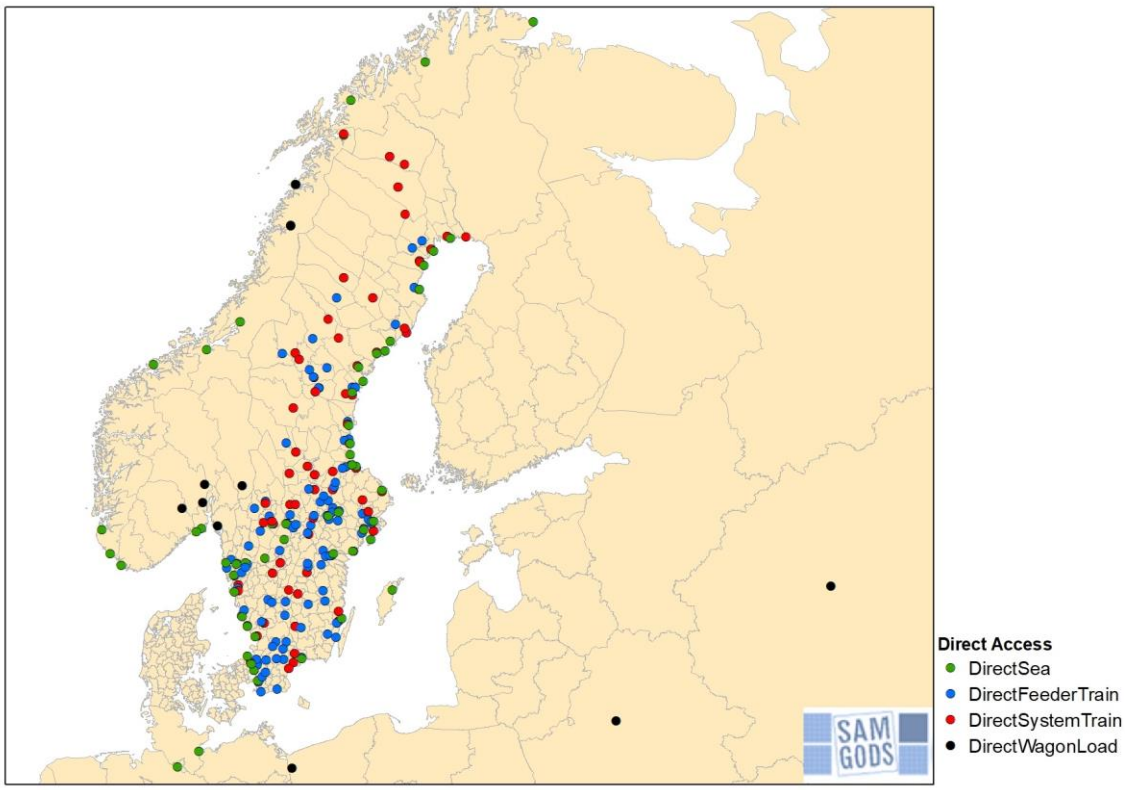

Figure 3.3 Direct access locations in Sweden and neighbouring countries

Air

The Samgods model does not include any direct access for air transport in Europe. This is because airports are not assumed to be the start or end location of any goods flow (at the PWC level). It is necessary to first transport the goods by lorry to and from the airport.

3.3.2 Outside Europe

The Samgods model does not explicitly model land-based networks outside Europe, but it is assumed that all transports start or end in a port or airport that, via a virtual link, is connected to the zone centroid without any distance or cost. Direct access to sea and air is assumed for all zones outside Europe. One difference between sea and air is that direct access to sea has to be specified in the input files while direct access to air is always assumed for airborne flows outside Europe.

These assumptions are clearly a non-realistic simplification of reality, but are necessary to ensure that these zones are connected to Sweden. Again, the model is limited by the information available about foreign transport systems. However, it can be argued that land-based transport cost for shipments that starts or end outside Europe is a relatively small part of the total logistics cost and the results would thus not be affected in any significant way. Further, as stated earlier in this chapter, the primary interest of the Samgods model is to analyse effects in the Swedish transport system. Thus, the conclusion is that the level of details in the model decreases as the distance to Sweden increases.

4 Vehicles/vessels, cargo units and transport chains

In order for the Samgods model to be able to simulate logistic decisions, it is necessary to specify available vehicles and in which combinations (i.e. transport chain) they can be used. In Samgods, this is solved by introducing vehicle types and sub-modes, and by defining pre-set transport chains. This is what will be described in this chapter. Note that throughout the chapter the term "vehicle" will be used to address lorries, trains, vessels, ferries and airplanes. The term "mode" refer to the aggregate transport modes; road, rail, sea and air.

4.1 *V*ehicle classification

4.1.1 Considerations regarding the vehicle classification.

The vehicle classification should reflect the real world. However, it is not possible to model all vehicles, some selection is needed in order for the model to operate efficiently. There are several aspects to consider when it comes to the vehicle classification. It is important to consider economies of scale, the nature of the goods to be transported, wear and tear of infrastructure, laws and regulations and, of course, vehicle classification used in other transport related models. These issues are discussed below.

Economies of scale at the vehicle level

For each mode of transport, several vehicle types are used in the model in order to reflect scale advantages in transporting operations, including loading and unloading. Per provided capacity unit, using larger vehicles results in lower costs. Given a good capacity utilisation for the vehicles employed, there are scale economies in vehicle size for all modes. For rail, economies of scale are possible to model only at the train level. In reality however, scale advantages exist at both the train and the wagon level.

Goods to be transported

Some of the products require special handling equipment for loading and unloading and/or specific vehicles. For example, liquid matters require tanks and pumps. Because of these product related differences, it might seem natural to differentiate vehicle type also by product. A combined classification could thus be vehicle size and type of commodity to be transported. However, such product related additions to the vehicle classification should only be made if the differences have a significant influence on the costs for any given vehicle size, or if the relevant range as well as class of vehicle sizes differ significantly for different products. The commodity based approach chosen in the Samgods model uses few vehicle types and focuses on scale advantages. Following this approach, the best solution is to have as few product related exceptions as possible.

Infrastructure requirements, law and regulations

The state of infrastructure as well as law and regulations put restrictions on the vehicles that can be used in the transport system. They are, of course, closely linked to each other. For example, infrastructure/regulations is a limiting factor for road transport since the highest carrying capacity/maximum permissible weight on roads is currently 74 tonnes.[5] Also, different vehicle

[5] The 74 tonnes lorry is currently only allowed on a small subset of the Swedish road network. For about 95 percent of the road network the maximal allowed weight is 64 tonnes. There are 4 weight classes for roads in Sweden.

types influence wear and tear of infrastructure differently. This implies that the size of the vehicles should be expressed in dimensions that are relevant to the infrastructure holders.

The Samgods vehicle classification in relation to other transport models.

It is important to consider how the vehicle classification compares to other transport related models. First, the vehicle classification should follow the guidelines set out in the ASEK report (Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn), which is a compilation of model parameters recommended to be used in all transport analyses performed by Trafikverket [10]. However, there are some discrepancies between the vehicle types included in the current ASEK 7.0 and the vehicle classification used in Samgods:

- Road: The 74 tonnes lorry (vehicle type 106) defined in Samgods is not present in ASEK. This lorry type is currently only permitted on a small part of the Swedish road network, but the government has plans to increase the usage. This is the reason why it is included in Samgods (see section 4.1.3).

- Rail: The extra-long wagonload train (vehicle type 212) defined in Samgods is not included in ASEK.

- Sea: no differences in classification (however, there are differences in the costs applied, see chapter 6). The barge inland water way (vehicle type 322) is not included in ASEK.

- Air: ASEK does not include any information regarding air transport.

It is also important to consider that the Samgods forecast is used as input in other transport models. The forecast generated in Samgods is used as input in EVA, Sampers/Samkalk, Bansek and TEN-Tec

- EVA is a tool used to analyse and calculate effects for road traffic. The Samgods forecast provides the relevant information needed to generate growth in vehicle kilometres for lorries used as input in EVA. The EVA model does not distinguish between different lorry types.

- Bansek is a tool used to produce CBA output for railroad projects. The Samgods forecast provides the relevant information needed to generate growth in vehicle kilometres used as input in Bansek. The model includes the following train types; long-distance wagonload train, local wagonload train, system train, kombi-train and trains transporting ore.

- Sampers/Samkalk is a national model system used in transport analyses for passenger transport. Sampers/Samkalk does not model goods transport explicitly. However, road and rail congestion is affected not only by passenger transport, but also the number of goods transports in the system. Therefore, the goods flows simulated in Samgods are added to the road and rail networks used in Sampers/Samkalk.

TEN-Tec is the European Commission's Information System used to coordinate and support the Trans-European Transport Network Policy (TEN-T). The Samgods forecast is used to provide information about the goods flows at the 25 Swedish ports included in the TEN-T.

4.1.2 Vehicle types used in the model

Given the considerations above, 40 vehicle types are defined in the Samgods model. The 40 vehicle types cover:

- 6 road vehicles (no 101 – 106),
- 11 train types (no 201 – 212, no 203 is not defined),
- 22 sea vessels (no 301 – 322)
- 1 freight airplane (no 401)

Table 4.1 includes information about the vehicle types and the weight capacity of each vehicle. When it comes to rail, trains are used as vehicle units, not single wagons. The capacities have to be seen as maximum values. It is important to note that for many bulky products, it is the volume that is the limiting factor – not the weight.

Table 4.1 Vehicle classification

Mode	Vehicle number	Vehicle name	Capacity (tonnes per vehicle)
Road	101	Lorry light LGV.< 3.5 ton	2
	102	Lorry medium 3.5-16 ton	9
	103	Lorry medium16-24 ton	15
	104	Lorry HGV 25-40 ton	28
	105	Lorry HGV 25-60 ton	47
	106	Lorry HGV 74 ton	62
Rail	201	Kombi train	610
	202	Feeder/shunt train	488
	204	System train STAX 22.5	959
	205	System train STAX 25	1098
	206	System train STAX 30	6000
	207	Wagon load train (short)	716
	208	Wagon load train (medium)	852
	209	Wagonload train (long)	907
	210	Combi train (XL 750 m 201L)	980
	211	System train STAX 22,5 (XL 750 m 204L)	1400
	212	Wagonload train (XL 750 m)	1480
Sea	301	Container vessel 5.300 dwt (ship)	5300
	302	Container vessel 16.000 dwt (ship)	16000
	303	Container vessel 27.200 dwt(ship)	27200
	304	Container vessel 100.000 dwt (ship)	100000
	305	Other vessel 1.000 dwt (ship)	1000
	306	Other vessel 2.500 dwt (ship)	2500
	307	Other vessel 3.500 dwt (ship)	3500
	308	Other vessel 5.000 dwt (ship)	5000
	309	Other vessel 10.000 dwt (ship)	10000
	310	Other vessel 20.000 dwt (ship)	20000
	311	Other vessel 40.000 dwt (ship)	40000
	312	Other vessel 80.000 dwt (ship)	80000
	313	Other vessel 100.000 dwt (ship)	100000
	314	Other vessel 250.000 dwt (ship)	250000
	315	Ro/ro vessel 3.600 dwt (ship)	3600
	316	Ro/ro vessel 6.300 dwt (ship)	6300
	317	Ro/ro vessel 10.000 dwt (ship)	10000
	318	Road ferry 2.500 dwt	2500
	319	Road ferry 5.000 dwt	3000
	320	Road ferry 7.500 dwt	4500
	321	Rail ferry 5.000 dwt	5000
	322	Barge Inland water way	2000
Air	401	Freight airplane	50

4.1.3 Road

Six typical road vehicles represent lorries (with or without trailer) of various sizes:

- One light lorry under 3.5 tonnes of total weight (total weight includes lorry and goods).
- Two medium sized lorries with 16 tonnes resp. 24 tonnes of total weight.
- Three heavy duty lorries with 40, 60 and 74 tonnes of total weight.

The defined lorry types are chosen based on infrastructure constraints, regulations, lorry types used in other EU-countries and the need to model economies of scale. In Sweden, a ”light lorry” is a lorry with a total weight under 3.5 tonnes that can be driven by anyone with a driver’s license while a ”heavy lorry” is a lorry with a total weight over 3.5 tonnes that requires a special license. The 40 tonnes lorry is standard in most EU-countries whereas the 60 tonnes lorry is common in Sweden and Finland. The 74 tonnes lorry has recently been allowed on a subset of Swedish roads, and in Finland a 76 tonnes lorry is allowed.

4.1.4 Rail

In the Samgods model, a total of eleven train types are defined (but only ten types are used). The use of different vehicle types is driven by the existence of different production systems for rail transport (and the need to model economies of scale):

- Combined trains (combi trains) require unitized cargo units like containers (see section 4.2). These trains combine road and sea with rail. There are two types of combi trains in the model, one regular and one long (750 m).
- There are five wagonload trains defined in the model, but only 4 are used. The first type acts as a feeder or shunt train (type 202) between industrial locations and marshalling yards while the other four types, with differing lengths, act as long-distance trains between marshalling yards. The wagonload system is used for goods with different destinations and fixed frequencies between marshalling yards. Note that vehicle type 209, wagonload train (long), is currently not used in the model. Instead, an extra-long wagonload train (750 m, type 212) has been added.
- There are four types of system trains. These trains are block trains, normally for a single commodity that go with a fixed frequency from one industrial location to another. There are three sizes of system trains depending on the maximum permissible axle weight (STAX). These are ≤ 22.5 tonnes, ≤ 25 tonnes and ≤ 30 tonnes per axle. The system trains with 25 and 30 tonnes maximum axle load are available for a limited part of the rail network and only for certain products. The forth type is a longer version (750m) of the 22.5 STAX train.

Extra-long trains (750 m) can currently be used only at some parts of the Swedish railroad network. The reason is that most parts are not built to handle such long trains. For example, the meeting/passing stations are often not sufficiently long. However, the possibility to use longer trains for goods transport in Sweden is planned to be extended in the future [11].

For rail, economies of scale are possible to model at the train level. Since trains are used as the vehicle unit, it is not possible to model economies of scale at the wagon level in the current

model. This has complications for an analyst who wants model train flows at a more detailed level.

Different types of freight trains display certain speed differences. However, speed differ more according to infrastructure characteristics than to train types and the train speeds are therefore coded universally for all train types per link in the network.

4.1.5 Sea

The 22 vehicle types for the sea mode includes:

- four container vessels, cargo ships used to carry intermodal containers.
- three ro/ro vessels, ”roll on/roll off” ships designed to carry wheeled cargo transported in e.g. cars, trucks and railroad cars.
- ten “other vessels”, including all non-container and non-roro vessels that carry different commodities i.e. dry bulk vessels, dry cargo ships and tankers.
- three road ferries
- one rail ferry
- one inland water way barge used for inland waterway transport.

For vessels, the economies of scale aspect is taken care of by defining the vessel’s capacity in dead-weight (dwt), i.e. the approximate cargo carrying capacity in weight terms in tonnes. Vessels with similar dwt-capacity tend to have similar draught, although there are differences in draught for the same dwt between various vessel categories (tankers, bulk carriers, container vessels etc.) due to different “lines” in the ship design. Sea vessels, as opposed to most land-based vehicles, differ significantly in size and therefore cost. The sea vessels, as defined in the Samgods model, vary from as little as 1 000 tonnes dwt to a maximum of 250 000 tonnes dwt. In the model, a total of 17 different vessels are defined (it is taken into account that certain products/commodities due to their density are transported in vehicles that require more depth than average vessels).

Ferries are in a way part of the road or rail network since they could be replaced by bridges or tunnels. Ferry capacity is normally shared by different firms and commodities. Economies of scale are less relevant for ferries than for vessels; when the size increases the decrease in unit costs is larger for vessels than for ferries. In the model, three road ferries (but only the smallest road ferry is used) and one rail ferry are defined.

Samgods 1.2.1 contains a vehicle type for inland waterway. Sweden had previously chosen not to implement the EU regulations for inland waterway transport. However, since the Swedish shipping industry has shown an increasing interest in this particular type of transport, Sweden has chosen to implement the same regulations as in continental Europe. Thus, since the 16th of

December 2014 it is possible to build or equip ships for inland waterway transport also in Sweden.[6]

There are speed differences between certain types of vessels. Notable examples are between container vessels (20-30 km/h), ro-ro vessels (19-24 km/h) and other vessels (11-22 km/h).

4.1.6 Air

In the Samgods model, one cargo-specific aircraft (freighter) with a maximum capacity of 50 tonnes is defined. This means that freight transports in passenger air planes, so called pax belly transports, are not included.

4.2 Cargo units

Inter modal transports use unitised cargo types and at least two modes of transport. These transports are interesting as they combine the comparative advantages of the different modes. From an analysis perspective it is also important to know the potential for inter modal transports. Conventional freight models use commodity and vehicle classifications but it is much less common to categorize cargo types. There is not much experience when it comes to the modelling of cargo units.[7]

In the Samgods model, the modelling of unitised transports is limited to container transports, in contrast to conventional load on/load off transports. Further, it is assumed that containers can be transported on nearly all vehicle and vessel types. Exceptions are the light and medium sized lorries, system trains and airplanes. On the other hand, combi trains and container vessels are assumed to be used for container transports only. It is also assumed that the container is carried the entire transport chain from the sender to the receiver. Thus, it is not possible to stuff or strip a container along the transport. However, such stuffing and stripping can of course occur in reality, for example in ports.

[6] For further details, see information available at the Swedish Transport Agency's website, https://www.transportstyrelsen.se/sv/Sjofart/Fartyg/Inlandssjofart/

[7] The use of international sea containers has been modelled in the 2005 version of the STAN-model. See SIKA Rapport 2005:2, Modellanalyser av godsflöden i Östra Mellansverige.

4.3 Sub-modes and transport chains.

The Samgods model operates with predefined transport chains and each chain can contain a maximum of five legs. If the vehicle classification would be used for this purpose there would be a great number of possible chains and the run time of the model would not be adequate. Therefore, in order to reduce the number of transport chains, sub-modes are created as a link between the mode and the vehicle type. There are a total of 19 sub-modes in the model:

- Three road modes: light lorry, heavy lorry and extra heavy lorry.

- Nine rail modes: one feeder train, two type of wagonload trains (regular and long), two type of combi-trains (regular and long) and four different system trains with maximum axle loads (STAX) of 22,5 ton, 25 ton and 30 ton including one regular and one long for the STAX 22,5 train.

- Six sea modes: direct sea, feeder vessel, long haul vessel, inland waterway barge, road ferry and rail ferry.

The sub-modes are given separately for container transports and non-container transports. The modes, sub-modes and vehicle types assumed in the model are shown in table 4.2.

When it comes to sea transports, a distinction between direct sea and feeder/long haul transports is made. Direct sea transports include only one sea link while feeder and long haul transports build sea-sea links. It is assumed that small feeder vessels “feed” large long haul vessels that go overseas. Thus, feeder ships and long-haul vessels must appear together in a transport chain. Ferry links are handled as sea legs within road or rail chains i.e. they can only appear as an intermediate leg in a transport chain.

As stated above in section 4.1.4, feeder trains act as a “feeder” for the wagonload train. Therefore, feeder and wagonload trains must appear together in a transport chain (feeder train-wagonload train or vice versa). However, since feeder trains are only specified in Sweden (see section 3.3.1), this is not true for transports in the rest of Europe.

In Samgods 1.2.1, there are 155 pre-defined transport chains for the base year 2017 and 224 for the forecast year 2040. The available transport chains can be found in table 9.1 in the appendix. The pre-defined transport chains can be changed via the input files. Note that the number two exists in some of the chains, it enables the same chain to be both the best and the next best solution (for example AJ could be the best solution and A2J could be the next best solution). The number two defines a different transfer point between two submodes compared to the original chain. In the same manner, a possible third and fourth best solutions etc. could also be added.

A sub-program of the logistics model, *Buildchain,* is then used to specify the transfer points per chain using one specified vehicle/vessel type for each leg and commodity. In order to do this, a typical vehicle is defined for each sub-mode and commodity. The typical vehicle is shown in table 9.2 in the appendix. Further, the *BuildChain* program also requires pre-set typical shipment sizes as input parameters. The following step, *Chainchoi, (*another sub-program of the logistics model) optimises by choosing the best vehicle per mode category for each leg. For further details, see the program documentation of the logistics model [2].

Table 4.2 Modes, sub-modes and vehicle types.

Mode	Sub-mode	Sub-ModeNr	VhclNr	Vehicle type	Container transport
Road	Heavy lorry	A	104	Lorry HGV 25-40 ton	Yes
			105	Lorry HGV 25-60 ton	
	Extra heavy lorry	X	106	Lorry HGV 74 ton	
Rail	Kombi train	D	201	Combi train	
	Long kombi train	d	210	Combi train (XL 750 m 201L)	
	Feeder train	E	202	Feeder/shunt train	
	Wagonload train	F	207	Wagon load train (short)	
			208	Wagon load train (medium)	
	Long wagonload train	f	212	Wagon load train (long)	
Sea	Direct sea	J	301	Container vessel 5.300 dwt (ship)	
			302	Container vessel 16.000 dwt (ship)	
			303	Container vessel 27.200 dwt(ship)	
			304	Container vessel 100.000 dwt (ship)	
			305	Other vessel 1.000 dwt (ship)	
			306	Other vessel 2.500 dwt (ship)	
			307	Other vessel 3.500 dwt (ship)	
			308	Other vessel 5.000 dwt (ship)	
			309	Other vessel 10.000 dwt (ship)	
			310	Other vessel 20.000 dwt (ship)	
			311	Other vessel 40.000 dwt (ship)	
			312	Other vessel 80.000 dwt (ship)	
			313	Other vessel 100.000 dwt (ship)	
			314	Other vessel 250.000 dwt (ship)	
			315	Ro/ro vessel 3.600 dwt (ship)	
			316	Ro/ro vessel 6.300 dwt (ship)	
			317	Ro/ro vessel 10.000 dwt (ship)	
	Feeder vessel	K	301	Container vessel 5.300 dwt (ship)	
			315	Ro/ro vessel 3.600 dwt (ship)	
			316	Ro/ro vessel 6.300 dwt (ship)	
	Long-haul vessel	L	303	Container vessel 27.200 dwt(ship)	
			304	Container vessel 100.000 dwt (ship)	
			317	Ro/ro vessel 10.000 dwt (ship)	
	INW	V	322	Barge Inland water way	

Mode	Sub-mode	Sub-odeNr	VhclNr	Vehicle type	Container transport
Road	Light Lorry	B	101	Lorry light LGV.< 3.5 ton	No
			102	Lorry medium 3.5-16 ton	
			103	Lorry medium16-24 ton	
	Heavy lorry	C,S[8]	104	Lorry HGV 25-40 ton	
			105	Lorry HGV 25-60 ton	
	Extra heavy lorry	c	106	Lorry HGV 74 ton	
Rail	Feeder train	G	202	Feeder/shunt train	
	Wagonload train	H	207	Wagon load train (short)	
			208	Wagon load train (medium)	
	Long wagonload train	h	212	Wagon load train (long)	
	System train STAX 22,5	I	204	System train STAX 22.5	
	System train STAX 25	T	205	System train STAX 25	
	System train STAX 30	U	206	System train STAX 30	
	Long system train	i	211	System train STAX 22,5 (XL 750 m)	
Sea	Direct sea	M	305	Other vessel 1.000 dwt (ship)	
			306	Other vessel 2.500 dwt (ship)	
			307	Other vessel 3.500 dwt (ship)	
			308	Other vessel 5.000 dwt (ship)	
			309	Other vessel 10.000 dwt (ship)	
			310	Other vessel 20.000 dwt (ship)	
			311	Other vessel 40.000 dwt (ship)	
			312	Other vessel 80.000 dwt (ship)	
			313	Other vessel 100.000 dwt (ship)	
			314	Other vessel 250.000 dwt (ship)	
			315	Ro/ro vessel 3.600 dwt (ship)	
			316	Ro/ro vessel 6.300 dwt (ship)	
			317	Ro/ro vessel 10.000 dwt (ship)	
	Feeder vessel	N	315	Ro/ro vessel 3.600 dwt (ship)	
			316	Ro/ro vessel 6.300 dwt (ship)	
	Long-haul vessel	O	317	Ro/ro vessel 10.000 dwt (ship)	
	Road ferry	P	318	Road ferry 2.500 dwt	
			319	Road ferry 5.000 dwt	
			320	Road ferry 7.500 dwt	
	Rail ferry	Q	321	Rail ferry 5.000 dwt	
	Inland water way	W	322	Barge Inland water way	
Air	Plane	R	401	Freight airplane	

[8] Consolidated heavy lorry is coded as mode S in the chains file. Consolidation in heavy lorries is only available on an intermediate leg in a chain with at least three legs.

5 Networks and LOS-matrices

The following chapter gives an overview of the level of service-matrices, the links and the nodes for respective transport mode.

5.1 Background

The infrastructure networks are used for several purposes. One is to generate the level of service (LOS)-matrix data for each vehicle type. CUBE-Voyager is used in order to produce the LOS-matrices. The LOS-matrices are providing *the vehicle transport time, distance and network related infrastructure costs* for the route that has the lowest generalized cost (= *Time*(vehicle cost/hour) + Distance*(vehicle cost/km) + road taxes/bridge tolls/rail fees*) per vehicle type for all allowed OD-relations [3]. The LOS matrices supply information between all zones (administrative PWC-zones and terminal zones). In some cases a service frequency per week is used for the OD-relations (for instance 84 trips per week for the ferry Helsingborg-Helsingör). Vehicle type specific LOS-matrices have been extracted:

Total distance matrix (km)	dist
Domestic-only distance matrices (km)	ddist
Pure time matrix (h)	time
Infrastructure charges/fees matrix (kr)	xkr
Frequency matrices	freq

There are a total of 171 LOS-matrices, consisting of 160 vehicle specific matrices (40 vehicle types * 4 cost/time matrices) and 11 frequency matrices. The domestic-only distance matrices are needed for the calculation of tonkm for road rail and sea on Swedish territory, which is presented in official statistics (See section 7.2). Table 5.1 summarizes which infrastructure fees and charges are included and how they are implemented. All costs that are related to the LOS-matrices are presented in section 6 of this report.

Table 5.1 Implementation of infrastructure charges and fees. [9]

Mode		Vehicle type	Distance/time based
Road	Tolls (bridges)	per lorry type	per link (passage)
	Km tax	per lorry type	per link (km)
Rail	Rail infrastructure charges	per train type	per link (km)
	Tolls (bridge)	per train type	per link (passage)
Sea	Fairway dues Sweden)	per vessel type	per node (port)
	Pilot fees (Sweden)	per vessel type	per port and link (km/hour)
	Kiel canal fee	per vessel type	per link (passage)
Air	En route fees	per vehicle type	per (link) km
	Start-/landing fees	per vehicle type	per node (air port)

[9] For further details see table 6.5-6.7 and 6.10.

Another role for the network beside providing LOS-matrices is to describe restrictions that are link-based, such as the restriction that STAX 30 system trains can only use parts of the rail network that have sufficient bearing capacity. All non-link-based or node-based restrictions are dealt with in the input files via very high costs to prevent vehicle use or restrictions in nodes.

As mentioned in section 4.1. there are three long train types (750 m) that are currently used in the Samgods model. The long train types are only used in the year 2040, and within the triangle Hallsberg-Gothenburg-Malmö. Lorries with a weight of 74 tonnes are not allowed in the base scenario for 2017 nor in the main scenario for 2040. However, 74 tonnes lorries are used in a sensitity analysis for 2040.

5.1.1 Inclusion of terminal zones

Both the geographical zones and the possible transfer locations between vehicles need to be defined as zones in order to generate a set of vehicle type-specific LOS matrices. Therefore terminal locations such as ports, airports, lorry terminals, combi terminals, marshalling yards have been defined as additional zones. Including 588 geographical zones (discussed above), the model consists of 1 378 zones for both the base scenario 2017 and the main scenario 2040. This means that there are 790 terminal zones. The base matrices use the same zonal numbering system as the (domestic and international) networks.

The terminals, where it is possible to transfer between different vehicle types, are defined in the network (LOS matrices) as well as in the input file. The terminals are numbered according to the municipality that they are geographically located within, but with the difference that the last two digits are not "00" as with the geographical zones but in the range 01-99. In this way it is possible to see which geographical zone every terminal zone is a part of.

Table 5.2 Terminal zone numbering system by main mode

	Last two digits
Road terminal zone	01-10, 51-59[10]
Rail terminal zone	11-20
Port terminal zone	21-30
Ferry terminal zone	31-40
Airport terminal zone	41-50

[10] Initially numbers 01-10 were allocated to road terminals (maximum of 10 road terminals per geographical zone). A later project by the National Road Administration defined a larger set of road terminals and these were then allocated the range 51-59. In the future it could be possible to re-define e.g. all road terminals to the range 51-69.

The figure Figure 5.1 illustrates the different networks and how they connect.

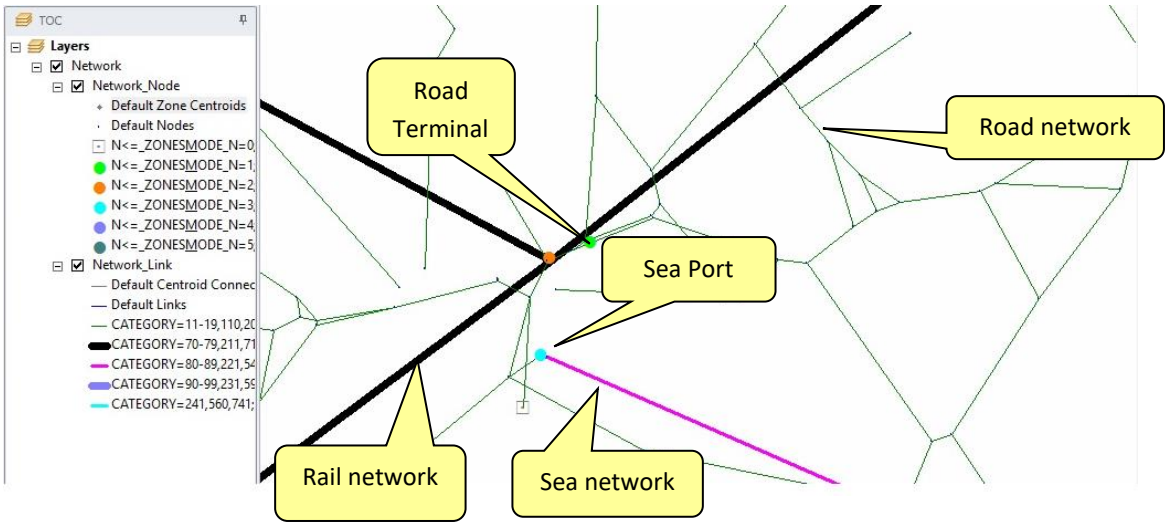

Figure 5.1 Terminals, ports and networks

5.2 Links

For Samgods 1.2.1, the domestic road network has been constructed by using a subset of the Sampers model road network (road numbers 1-499). The domestic rail network is identical to the Sampers model rail network. The international road and rail networks has, for Samgods 1.2.1, been constructed by selecting a subnetwork from the GIS map Euro global map. The exception is Norway, for which the network has been adopted from the Norwegian freight model.

A link in the Samgods model is a path within the transportation network, where transportation is made. A link can for example be a road or a railroad, and can be classified by link category. This means that links can be specified depending on mode (e.g. road, rail, air, sea and ferry). Each link category has specific characteristics such as speed and are numbered according to Table 5.3. This has not direct relevance to the assignment calculation as such, but is used in the LOS-calculation as a way of defining which group of links are to be included. For example to add an extra charge on Swedish rail links but not on rail links outside Sweden.

Table 5.3 List over parameters per link category[11]

Mode	Link category	Speed (km/h)	Number of links
Inside Sweden			
Road links	1-69	10,2-116	54 836
Rail links	70-79	24-122	1 034
Sea links	80-89	12	932
Ferry links	90-99	25	54
Road links – centroid connectors	110	50	584
Road links – terminal connectors	201	50	790
Rail links – terminal connectors	211	40-50	470
Sea links – terminal connectors	221	12	148
Ferry links – terminal connectors	231	25	34
Air links	241	600	10
Total within Sweden			**58 892**
Outside Sweden			
Road links	501-505	0-110	27 158
Sea links – inland waterways	540	5	100
Air links	560	600	302
Rail links	570-579	20-40	4 466
Sea links – Kiel canal	580		2
Sea links	581-599	25-33	4 878
Road links – centroid connectors	610	50-80	666
Rail links – centroid connectors	670, 678-679	17,5–49	22
Sea links – centroid connectors	680		78
Road links – terminal connectors	701	50	654
Rail links – terminal connectors	711	40–50	292
Ferry links – terminal connectors	721	12	208
Sea links – terminal connectors	731	25-40	66
Air links – terminal connectors	741	600	166
Total outside Sweden			**39 058**
Total inside and outside Sweden			**97 950**

The link categories are related to the model, which has a simplified configuration of the transport network. In the model there are zone-centroids, which can be explained as the centre of a zone. A zone-centroid is mainly used as a simplification, where flows to different points in a zone is replaced with flows to one single point in the centre of the zone. Internal zone distance

[11] The classification of whether links are located in Sweden or not are based on Link category. Number of links corresponds to the network for the base year (Base2017) in Samgods v1.2.1.

are in addition used to capture the distance to a physical business within a zone. Distances are added for production and the consumption zones in the LOS-matrices (origin and destination zones of the transport). Distances for each zone is read from the table "Inzone_Distance", the concept is also explained in [1, 2]. Because of this simplification, the zone-centroid not have physical connection to the infrastructure network. Additional links called "centroid connectors" are therefore added to the model to connect the zone-centroid to the transport network. The centroid connector links are defined separately from the other links that constitutes the infrastructure networks.

In the same way there are "terminal connectors", which are links that connect terminals to the transport network via virtual links. Terminal connectors are used in a modelling perspective to enable transports to pass by a location of a terminal without entering it. Without terminal connectors, all transports through a particular node would have been applied costs for loading/unloading even if the transport didn't access the terminal.

Note that the length and speed of terminal and centroid connectors are not included in the LOS-calculations since it is simply a modelling technique and does not represent a part of the physical infrastructural network.

A limitation with the zone-centroids is that it does not allow transport between the points within the zone, which are now replaced with a centroid. Another limitation is that the actual transport distances will be replaced with an average. Both of the previous limitations are accepted since they are, in number and proportion, irrelevant to the other trips.

5.2.1 Road network

Road network in Sweden

The domestic road network has been created from the National Sampers model[12]. The network representation corresponds to the main road network (statligt huvudvägnät) for the year 2016. Road ferry links have been removed from the Sampers application as these are modelled as separate networks. Once the road network was converted the following data characteristics were copied from the Sampers model: link length (km) and speed (km/h). The speeds are originally based on the estimated free flow speed from the speed flow relation at the actual road type [12]. This makes it possible to assign the vehicle specific OD-matrices calculated by the logistics model. The road network in Sweden and neighbouring countries is presented in Figure 5.2.

Road network outside Sweden

The road network outside Sweden, adopted from Euro global map, represents year 2014. It was added to the domestic network and mismatches between the new domestic and foreign networks were corrected. The road network in Europe is the main road network. No official definition exists as these are sometimes motorways, but in other cases, where no motorways exist, major roads are used instead. The network model can be used also for restrictive purposes such as with 60 tonne lorries (vehicle type 105) which are in the default base model allowed only in Sweden and Finland, and not in the rest of Europe according to infrastructure restrictions

[12] Some node numbering issues were resolved by the Road Administration, this was because a small number of node numbers in the Sampers model were not within the "standard" numbering convention and had numbers corresponding to the number classification for Samgods as rail nodes (i.e. 1000-9999).

and regulations[13]. If alternations to this standard restriction are to be tested then this can be done by adjusting the mode selection for a set of specified network links.

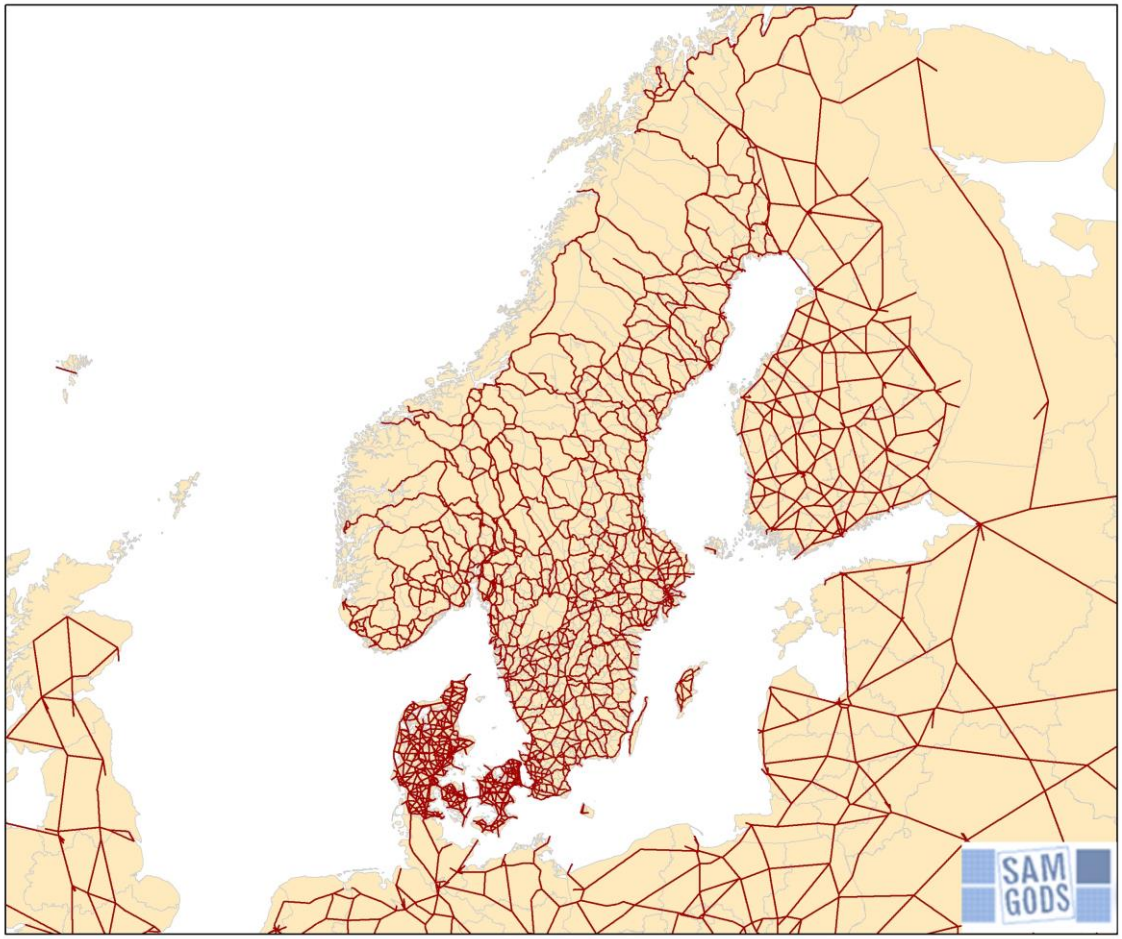

Figure 5.2 Road network (in red) in Sweden and neighbouring countries

Road terminals

111 road terminals are defined in Sweden and 83 outside Sweden (See Table 5.9). These terminals are concentrated to the Southern and Central Sweden. In the Logistics Model no road terminals outside Sweden are defined (which is unfortunate since this may be forcing perhaps longer transport with the incorrect lorry size) [14].

The mode used in the network differs from the submodes used in the logistics model. The network mode is defined per vehicle type, while submode spans over several vehicle types. Also, no distinction is made for shipments by containers and non-containers, since only the type of vehicle is of interest. Lorries up to 3,5 tonnes (vehicle 101), is coded as mode c in the network. Lorries between 3,5 and 40 tonnes (vehicles 102-104), is coded as mode a. Lorries up to 60 tonnes (vehicle 105), is coded as mode b. The extra heavy lorries up to 74 tonnes (vehicle 106), is

[13] This can though be changed in the LOS-files, for example in order to take into account the ongoing trials with longer lorries in Denmark.

[14] The model does only include Swedish goods, and it should be necessary to assume a preload factor to take into account the foreign goods. This approach is used for the large container ports in Europe. See below.

coded as mode B. See Table 5.4 for submode and network link mode per road vehicle. The submode is used in the network chains and link mode is an attribute in the network to set permission for individual vehicles to use a specific link.

Table 5.4 Road vehicle specific values

	Vehicle type	No	Submode	Network link mode
Non-containers	Lorry ≤ 3,5 ton	101	B	c
	Lorry ≤ 16 ton	102	B	a
	Lorry ≤ 24 ton	103	B	a
	Lorry ≤ 40 ton	104	C/S	a
	Lorry ≤ 60 ton	105	C/S	b
	Lorry ≤ 74 ton	106	c	B
Containers	Lorry ≤ 40 ton	104	A	a
	Lorry ≤ 60 ton	105	A	b
	Lorry ≤ 74 ton	106	X	B

5.2.2 Rail network

Rail network in Sweden

The rail networks have been adopted from the Sampers model and “terminal connectors” have been added. Combi trains have access to 162 locations, 43 of which are rail terminals and ports in Sweden and 119 outside Sweden. There are three wagonload sub-networks, one for transports between marshalling yards and another with feeder trains to the yards divided by direction. System trains are modelled as three modes with different network coverage facilitating different maximum axle-weight capacities (STAX), different costs as well as different rail infrastructure fees. STAX 30 covers only the rail track between Kiruna and Luleå. STAX 25 is more widespread and covers the iron-ore rail track in northern Sweden as well as parts of central and western Sweden. STAX 22.5 is available throughout most of Sweden. The rail network in Sweden an neighbouring countries are presented in Figure 5.3.

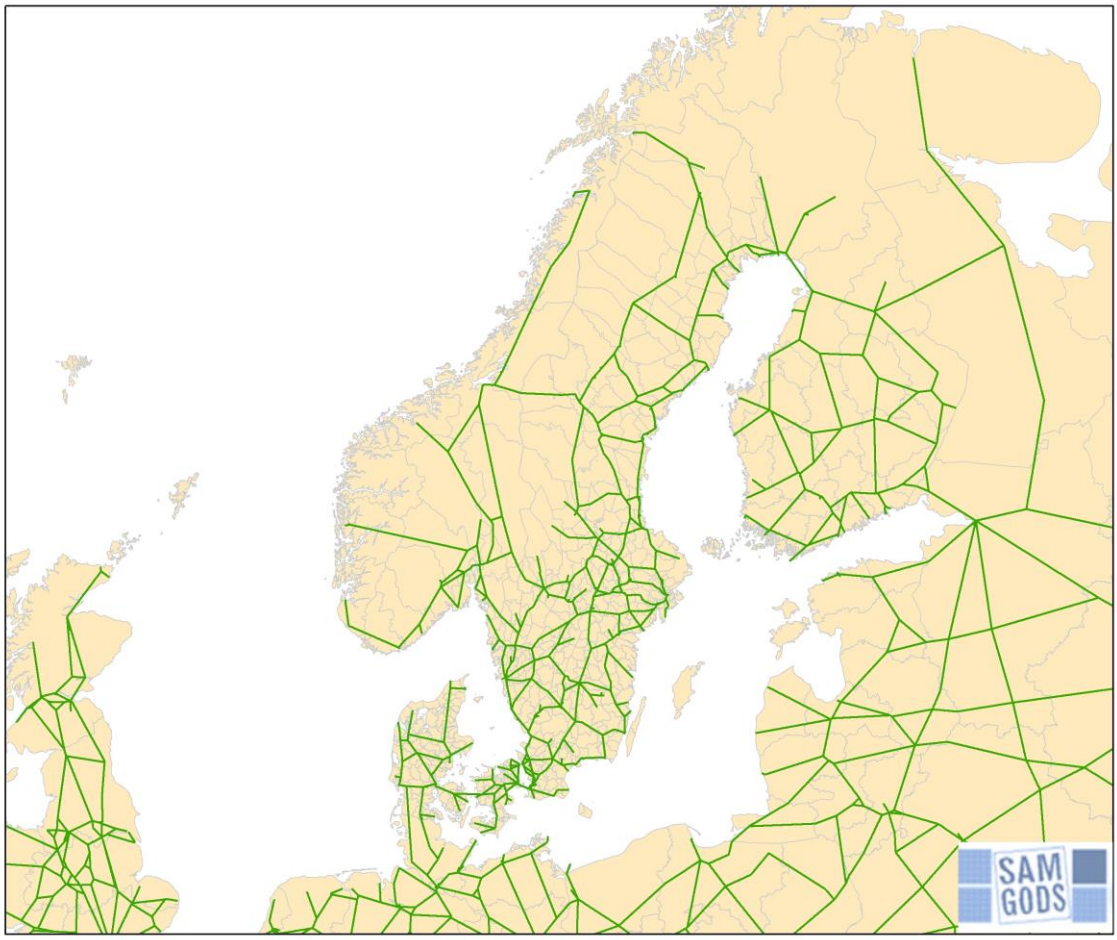

Figure 5.3 Rail network (in green) in Sweden and neighbouring countries

Rail network outside Sweden

Outside Sweden a rail network has been produced for Europe. As for the road network, no rail network is explicitly modelled outside Europe. The rail network within Europe has been adopted from Euro global map. The following assumptions are made:

- Feeder-wagonload trains are not modelled outside Sweden, here wagonload trains are directly connected to the zones.

- Combi rail exists to a limited number of European zones.

- No system trains exist outside Sweden, other than the iron-ore corridor Kiruna-Riksgränsen - Narvik. Additional corridors can be added, if necessary, to the model by adding additional links to the system train network and/or adjusting the list of zones, thus allowing direct access for system trains in more locations.

As mentioned in chapter 4, the use of extra-long trains are currently restricted to limited parts of the Swedish railroad network, but an extended railroad network with possibility to use transportation with longer trains is planned for the future and also included in the main scenario for 2040.

Rail Capacity Management

Limited rail track capacity is an infrastructure restriction included in the model, measured in number of trains per day. To manage the capacity relevant matters, a post processing model called Rail Capacity Management (RCM) has been developed. The RCM uses a linear programming model, which mathematically defines suitable (cost minimizing) combinations among the first best solution and a number of viable alternatives for all firm-to-firm flows using railway in Logistic Model. The linear programming algorithm identifies an optimal solution to the problem, i.e. a cost minimum solution satisfying the capacity constraints. The RCM is described in four steps below [3]:

1. Setting up the first best solution from Logistic Model and suitable second best alternatives that may be used to reduce the railway capacity usage.

2. Selection of transport chain solution combinations, in principle the first solution or any one of the possible alternatives, for all firm-to-firm-relations using railway in Logistic Model. The selection shall minimize the total additional costs (for not always using the first best solutions) while satisfying the capacity constraints.

3. Computation of marginal costs per train on capacitating links. Alternatives may be generated that use alternative transport chains, or use different routes within the current transport chain (by shifting to other transfer points).

4. The process in steps 1-3 is iterated a number of times until the search for new alternatives does not improve the solution enough to make it worthwhile to continue.

Rail terminals

There is a total of 278 rail terminals in the logistics model, whereof 189 in Sweden and 89 outside Sweden.

The network model uses different modal networks depending on the vehicle type and whether the freight is containers and non-containers. For freight with containers, submode “D” and “d” are used for kombi train and long kombi train respectively. These submodes are used for combined rail which connects combined rail terminals, ports where combined rail terminal functions are possible and ports where the transfer between combined rail and sea is possible.

Submode “E” is used for feeder/shunt train with container. For container freight there is one single submode, “F”, for short and medium wagon load trains, while long wagon load trains have submode “f”. When it comes to the non-container freights, submode “G” is used for feeder/shunt train, “I” for system train STAX 22.5, “T” for STAX 25, “U” for STAX 30 and “i” for long system trains. For wagon load trains, submode “H” is used for short and medium trains, and “h” is used for long wagon load trains. All submodes are listed in Table 5.5, which also lists the network link modes. The submode is used in the network chains and link mode is an attribute in the network to set permission for individual vehicles to use a specific link.

Table 5.5 Rail vehicle specific values

	Vehicle type	No	Submode	Network link mode
Containers	Kombi train	201	D	d
	Long kombi train	210	d	D
	Feeder/shunt train	202	E	f/F[15]
	Wagon load train (short)	207	F	h
	Wagon load train (medium)	208	F	h
	Wagon load train (long)	212	f	H
Non-Containers	Feeder/shunt train	202	G	f/F
	System train STAX 22,5	204	I	i
	System train STAX 25	205	T	t
	System train STAX 30	206	U	u
	Long system train	211	i	I
	Wagon load train (short)	207	H	h
	Wagon load train (medium)	208	H	h
	Wagon load train (long)	212	h	H

5.2.3 Sea network

Sea network inside Europe

The sea mode connects both domestic and foreign ports allowing all port-to-port combinations. The Kiel Canal in Northern Germany has infrastructure restrictions that do not allow very large vessels. These restrictions are taken into account during the BuildChain-step, where too large Vessels are not permitted in the Kiel Canal. This means that those vessels that cannot use the Canal are forced to use the longer route over the Northern part of Denmark.

The model version 1.2.1 includes updates of the sea network compared to version 1.2. Network links have been adjusted in order to represent domestic and international traffic in a more distinct way. Link lengths have also been updated and a separate link category (680) representing sea links - centroid connectors has been introduced.

The infrastructure restrictions in the Öresund and/or Baltic Sea are not modelled explicitly in the links of the network, but taken account of at the port level. Assumed infrastructure restrictions per port can be viewed in the input database. The restrictions have been provided by the Maritime Administration. A high value i.e. 9 999 999 assumes unlimited access to a port, a value of 100 000 that only vessels less-than 100 000 tonnes dead-weight (dwt) can access the port. The most significant restrictions, according to the Maritime Administration, are in the

[15] The network link mode differs depending on if the direction is to or from the terminal. F is towards the terminal and f is from the terminal.

Swedish inland lakes (Lake Vänern and Lake Mälaren) where e.g. no vessels over 4 000 tonnes dwt are permitted.

In real world shipping companies adjust their routes to the infrastructure restrictions in by using fairways and call ports with restrictions with partly loaded vessels. This optimizing strategy is not modelled in the actual logistics model neither is taken into account that vessels collect and distribute goods along the route.

Sea network outside Europe

Unlike road and rail, we explicitly model sea links outside Europe. For purposes of convenience we do not show the entire distances in the geographic map but the links between Europe and the destinations outside Europe have real distances and are connected to non-European zones. The Sea network in the model is illustrated in Figure 5.4.

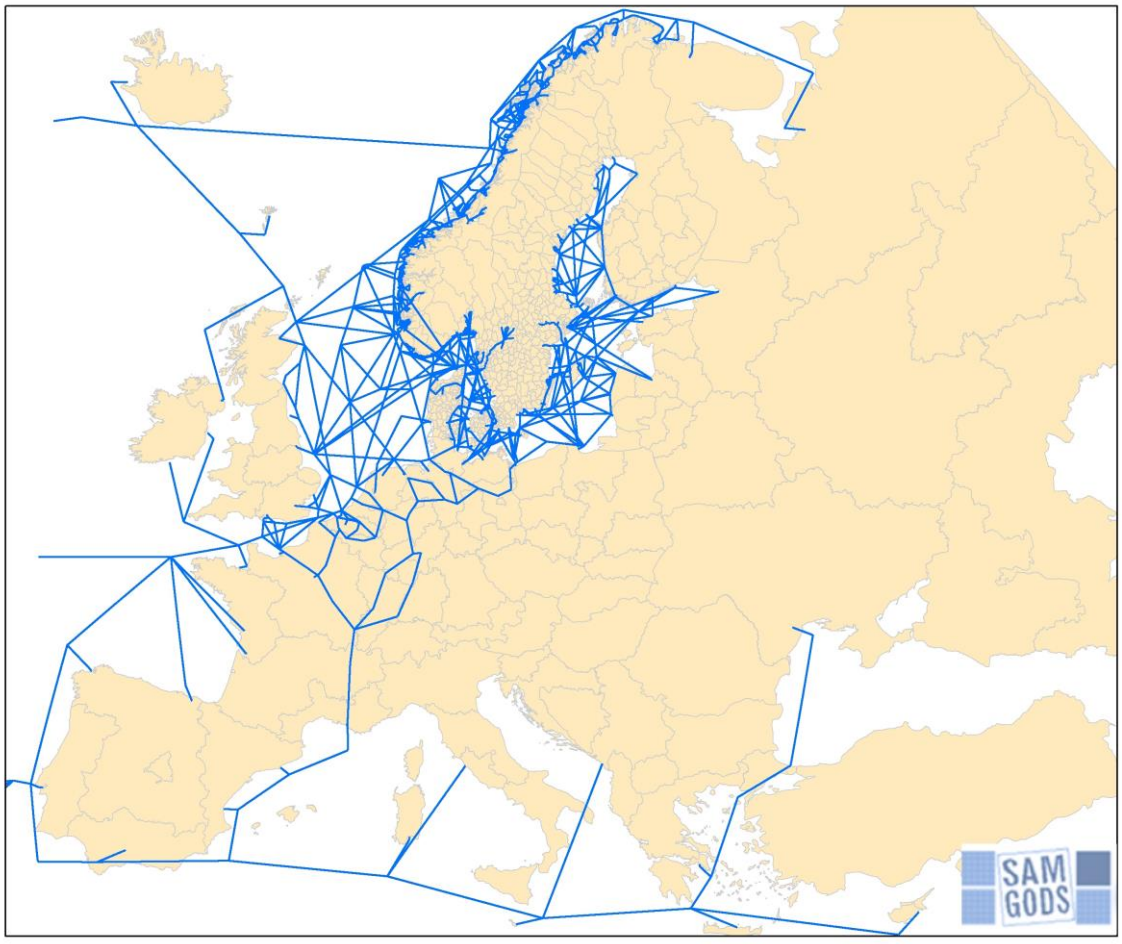

Figure 5.4 Sea and ferry network (in blue) inside and outside Sweden, including ports in Sweden

Ports

There is a total of 197 defined transfer points land/sea, whereof 91 in Sweden. The transfer sea/sea is assumed to be possible only in the large ports in northwester Europe, namely Le Havre, Hamburg, Bremerhaven, Rotterdam and Antwerpen.

There is one sea transport submode “J” for direct sea with containers including vessels with vehicle number 301-317. Feeder vessels with containers use submode “K” and include vehicle number 301, 315 and 316. Long-Haul vessels with containers use submode “L” and include vehicle number 303, 304 and 317. INW-vessels with containers use submode “V”, vehicle number 322. Submode “M” is used for direct sea and non-container vessels, vehicle number 305-317. Submode “N” is used for non-container feeder vessels, vehicle number 315-316. Long-Haul vessels with non-containers use submode “O” and include vehicle number 317. INW-vessels with non-containers use submode “W”, vehicle number 322. Small vessels use network link mode “y”, while large use “z”. INW-vehicles use network link mode “W”. See Table 5.6 for submode and network link mode for each vessel.

For sea there are two different categories of speeds. Those classified as open water use the vessel vehicle specific speed given in input database (table Vehicles_parameters_PartA). Vehicles classified as not open water uses speed given as attributes on individual, these are specific links, e.g. enclosed waterways (e.g. Mälaren, Vänern) or canals such as the Kiel Canal.

Table 5.6 Vessel specific values

Aggregate mode		Vehicle type	No	Submode	Network link mode
Containers	Direct Sea	Container vessel 5 300 dwt	301	J	y
		Container vessel 16 000 dwt	302	J	z
		Container vessel 27 200 dwt	303	J	z
		Container vessel 100 000 dwt	304	J	z
		Other vessel 1 000 dwt	305	J	y
		Other vessel 2 500 dwt	306	J	y
		Other vessel 3 500 dwt	307	J	y
		Other vessel 5 000 dwt	308	J	y
		Other vessel 10 000 dwt	309	J	y
		Other vessel 20 000 dwt	310	J	y
		Other vessel 40 000 dwt	311	J	z
		Other vessel 80 000 dwt	312	J	z
		Other vessel 100 000 dwt	313	J	z
		Other vessel 250 000 dwt	314	J	z
		Ro/ro vessel 3 600 dwt	315	J	y
		Ro/ro vessel 6 300 dwt	316	J	y
		Ro/ro vessel 10 000 dwt	317	J	y
	Feeder vessel	Container vessel 5 300 dwt	301	K	y
		Ro/ro vessel 3 600 dwt	315	K	y
		Ro/ro vessel 6 300 dwt	316	K	y
	Long-Haul vessel	Container vessel 27 200 dwt	303	L	z
		Container vessel 100 000 dwt	304	L	z
		Ro/ro vessel 10 000 dwt	317	L	z
	INW	INW-vessel	322	V	W
Non-Containers	Direct Sea	Other vessel 1 000 dwt	305	M	y
		Other vessel 2 500 dwt	306	M	y
		Other vessel 3 500 dwt	307	M	y
		Other vessel 5 000 dwt	308	M	y
		Other vessel 10 000 dwt	309	M	y
		Other vessel 20 000 dwt	310	M	y
		Other vessel 40 000 dwt	311	M	z

		Other vessel 80 000 dwt	312	M	z
		Other vessel 100 000 dwt	313	M	z
		Other vessel 250 000 dwt	314	M	z
		Ro/ro vessel 3 600 dwt	315	M	y
		Ro/ro vessel 6 300 dwt	316	M	y
		Ro/ro vessel 10 000 dwt	317	M	y
	Feeder vessel	Ro/ro vessel 3 600 dwt	315	N	y
		Ro/ro vessel 6 300 dwt	316	N	y
	Long-Haul vessel	Ro/ro vessel 10 000 dwt	317	O	y
	INW	INW-vessel	322	W	W

There are two submodes for ferry transport: submode “P” for road ferry and submode “Q” for rail ferry. The corresponding network link modes are “p” and “q”. See Table 5.7 for submode and network link mode for each ferry.

Table 5.7 Ferry specific values

Vehicle type	No	Submode	Network link mode
Road ferry 2 500 dwt	318	P	p
Road ferry 5 000 dwt	319	P	p
Road ferry 7 500 dwt	320	P	p
Rail ferry 5 000 dwt	321	Q	q

5.2.4 Air network

There is a single air mode for air freight based on the definition coded in the Samgods-model. There are five Swedish freight airports (Arlanda, Skavsta, Sturup, Landvetter and Örebro). There are no significant amounts of air freight transported within Sweden, therefore no air network or LOS-matrices exist between Swedish airports.

There are also a further 83 airports outside Sweden that are either connected directly to Sweden or via a European hub. Direct services between Swedish and European airports have been included using data collected on air routes by The Civil Aviation. This means that LOS-matrices are calculated for transport between the four Swedish air freight airports and the European air freight hubs, via the hubs in Frankfurt, Copenhagen etc., as well as transport to/from all other air freight destinations in Europe or outside Europe. See figure 5.6. Similarly to sea transport all non-European zones are connected using real distances to the European network.

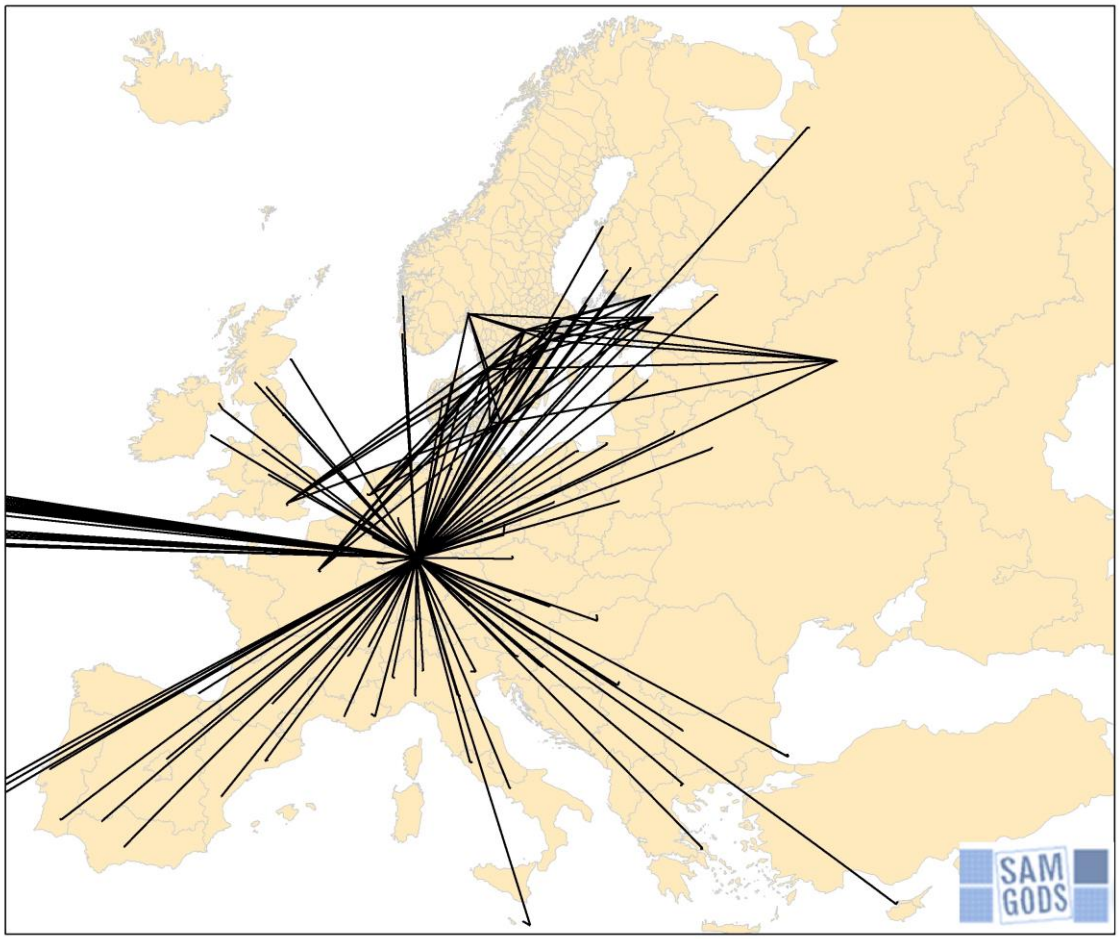

Figure 5.5 Air network (in black) to/from Sweden

The logistics model uses submode “R” for air, while the network link mode is “r”.

Table 5.8 Air plane specific values

Vehicle type	No	Submode	Network link mode
Freight airplane	401	R	r

5.3 Nodes

A node is a hub within the transportation system, where one or several transport modes with different characteristics interlinks and goods/shipments changes cargo carrier or transport mode. The different vehicles, transport modes and cargo carriers have different characteristics, which means that the primary function of a node is bridging the gap of capacity, time, frequency and cost between incoming and outgoing transport mode. A node that interlinks the same transport mode is called an intramodal node, whereas a node that interlinks different transport modes is called multimodal node or intermodal node [13].

5.3.1 Transfer at terminals

Transfers between modes or vehicle types of different size take place in terminals, (transfer zones, see Table 5.9). The terminals' location and their corresponding numbers are defined in the network. Feasible combinations of vehicle types and commodities in any terminal are determined by two independent sets of restrictions on infrastructure (vehicle types) and commodities. The present set up allows the transfer of all commodities at most terminals. There are, however, some terminals that do not handle all commodities. It is also specified which terminals can handle containers.

Table 5.9 Transfers between different vehicle types /modes.

	Terminal/explanation		Number of transfer zones
1	Road terminals	TransferRoadRoad	194
2	Combi terminals or ports	TransferRoadCombi	123
3	Marshalling yards, transfer road /wagonload	TransferRoadTrain	208
4	Ports, transfer road/vessel	TransferRoadSea	217
5	Ferry ports, transfer road/road ferry	TransferRoadRoadFerry	84
6	Air ports, transfer road/air	TransferRoadAir	86
7	Ports, transfer combi trains/vessel	TransferCombiSea	41
8	Marshalling yards, feeder/wagonload in Sweden	TransferFeederTrainWagonload	35
9	Ports, transfer wagonload/vessel	TransferWagonloadSea	97
10	Ferry ports, transfer rail/rail ferry	TransferWagonloadRailFerry	7
11	Ports, transfer system train/vessel	TransferSystemTrainSea	26
12	Ports, transfer between vessels of different size	TransferSeaSea	5
	Total		1123

The cost in terminals are simplified in the Samgods model. The cost and time for loading and unloading are defined by vehicle type and commodity group, whilst the model does not consider which specific terminal that are used. The terminal costs differ between different classes of terminals to include economies of scale and technology differences in terminal operations. Although, it is assumed that terminals which handles more goods uses more advanced technologies, which will affect the terminal costs [1]. This is represented in the model by

applying technology factors (ranging from zero to one) for individual terminals to scale the transfer costs.

The Samgods model uses costs which reflects a standard-terminal or a mean value. Since the different terminals differ a lot in characteristics, the terminal cost and time will from time to time differ relatively much from the mean values set in the model [13].

5.3.2 LOS service frequencies

The service frequency of different vehicle types is used to determine wait time in the different types of terminals. The wait time, calculated as half-headway, has an impact on the capital costs of the goods in transit. In the actual setup the LOS frequency matrices are not unique by vehicle type but by categories of vehicle types.[16] Service frequencies are defined for lorry (vehicle types No 104 and 105), for combi trains (No 201), wagonload trains (No 202, 207-209), system trains (No 204-206), container vessels (No 301-304), other vessels (No 305-314), roro vessels (No 315-317), road ferries (No 318-320), rail ferries (No 321) and airplane (No 401). In the current setup the following frequencies per week are assumed.

Table 5.10 Assumed frequencies per week

		Departures per week	Source
Specified in LOS –matrices			
Lorry	between road terminals	168	Assumption[17]
Combi	between combi terminals and/or ports	5	Assumption, co-ordinated with Gerhard Troche, KTH
Wagon load	between marshalling yards	5	Assumption, co-ordinated with Gerhard Troche, KTH
System train	between enders/receivers and/or ports	5	Assumption, co-ordinated with Gerhard Troche, KTH
Container vessel	between major ports		based on Seglingslista[18]
	between minor ports	0,1	Assumption
RoRo vessel	between major ports		based on Seglingslista
	between minor ports	0,1	Default
Road ferry	between ferry ports		Time tables / Swedish Maritime Administration
Rail ferry	between ferry ports		Time tables/ Swedish Maritime Administration
Inland water way		0.5	
Air	between air ports	5	Assumption
Specified in input files (vehicles)			
To Lorry	transfer to lorry	84	Assumption
Other vessel	tramp traffic (non liner)	0,1	Assumption

Transfers to lorry/road (vehicle type No 101 – 105) from another, non-road mode do not have specific LOS-based service frequency files but default values. 84 departures per week are

[16] Variation by vehicle type is possible but requires more input data.

[17] Differences between lorry terminals should be taken into account. According to information for Southern Sweden frequencies per week in lorry terminals vary between about 25 and 400 lorries per week. See Vägverket Konsult, Göran Forssén, Anders Karlsson, Transportflöden med lastbil via terminaler I Skåne, 2008-09-27.

[18] Svensk Sjöfartstidning, 6 Mars 2007, Seglingslista, Europalinjer.

assumed when transferring between non-road and road vehicles (not including the 74-tonne lorry, which is not modelled by default).

6 Logistics costs

Samgods model version 1.2.1 assumes a rational behaviour when choosing mode of transportation. This assumption holds that the monetary cost of the transportation is the most important aspect when choosing transportation mode. This clarifies the importance of using representative costs within the model in order to make reliable estimates of the reality.

The Samgods model version 1.2.1 includes a wide range of logistic costs mainly related to transportation, but also including warehousing and interest rate. However, the model is an approximation of the logistic system and is unable to capture all details and complexity that exists in reality. For example, costs related to deterioration/damage of goods or stock outs are not included in the model [1].

This chapter contains cost functions and parameters for each vehicle type included in the Samgods model version 1.2.1. In addition, all deviations compared to the recommended cost parameters in Analysmetoder och samhällsekonomiska kalkylvärden (ASEK) [10] is also described in this section.

6.1 Approach

Using the aggregate-disaggregate-aggregate modelling approach (ADA) the logistics model operates at the firm and shipment level.[19] The choice of shipment size and logistic chain is decided on the basis of the firms' total annual logistic costs for each firm to firm flow. Samgods version 1.2.1 is a deterministic cost minimization model. The model has the possibility to generate chains with best and second best transfer terminals. By assuming a normal distribution of the costs around the lowest costs determined in the model, a split of the transport volumes between the best and second best transport options is generated [1]. Therefore, it is essential that the cost elements of feasible logistic alternatives are calculated with sufficient precision i.e. a precision that is reasonably compatible with other data. The logistics costs consist of transport costs and non-transport costs (order costs, storage costs and capital costs in inventory as well as capital costs in transit). The logistics model aims to describe the trade-offs between the different costs components, e.g. transport costs and other non-transport costs.

It is assumed that the firms' transport demand is satisfied by the transport system. The firms optimize their logistics, including transport solutions, based on the prices they meet. In most cases we do not have access to prices for logistics and transport services, therefore we calculate prices based on the carriers and forwarders costs which are easier to get. We say implicitly that the prices the senders and receivers pay in the long run are not too different from these costs.[20] The underlying assumption that operators' costs are the same as shippers' prices does though

[19] while the STAN-model uses zones and tons.

[20] The relative cost is what is determining the optimal solutions. The relationship between cost and price in relevant segments of the transport market needs further thoughts, as well as the question to what extent taxes/dues and charges could be expected to be absorbed by buyers and sellers of the transport markets. There may be hard competition on the carrier market but limited competition on the forwarder market. When it comes to transfer costs in ports, terminals etc. there may exist lower costs than the calculated due to sunk costs. Monopolies may exist.

only hold in the case of perfect competition. In reality there exist imperfections in several market segments. Market conditions between countries are i.e. not harmonized in all aspects.

Total annual logistic costs

Let G denote the total annual logistics costs of commodity k transported between firm m in production zone r and firm n in consumption zone s of shipment size q using logistic chain l: The basic costs, as a function of shipment size q, can be written:

$$G_{rskmnql} = O_{kq} + T_{rskql} + Y_{rskl} + I_{kq} + K_{kq} \quad \textbf{(1)}$$

where:

G : total annual logistics costs

O: order costs (or order setup costs)

T : transport costs

Y: capital costs of goods during transit

I: inventory cost (storage costs representing floor space costs or other holding costs)

K: capital costs of inventory[21]

The transport costs are calculated per shipment and should be multiplied by annual shipment frequency to get the annual total that can be compared with the other logistics costs items. The logistics costs are further described in [1] and [2].

Equation (1) can be further worked out:

$$G_{rskmnql} = O_k\left(\frac{Q_{mnk}}{q_{mnk}}\right) + T_{rskql} + \frac{i * t_{rsl} * v_k * Q_{mnk}}{365 * 24} + \left(w_k + (d * v_k)\right) * \frac{q_{mnk}}{2} \quad \textbf{(2)}$$

where:

o: the unit cost per order

Q: the annual demand (tonnes per year)

q: the average shipment size

i: the interest rate (per year)

v: the value of the goods (in SEK per tonne)

[21] Cost of deterioration and damage during transit (D) and stock out costs (Z) are not used in version 1.2.1 of the Swedish logistics model. These could be implemented in coming versions. In the Norwegian model cost of deterioration and damage during transit is included.

t: the average transport time (in hours).

w: the storage costs (in SEK per tonne per year).

6.2 Non transport costs

6.2.1 Order costs

The order costs O_q^{kmn} are assumed to be a function of frequency only, so that

$$O_{mnk}^{q} = O_k\left(\frac{Q_{mnk}}{q_{mnk}}\right) \quad \textbf{(3)}$$

where:

O: constant cost per order

Q: the annual demand (tonnes per year)

q: the average shipment size.

This assumes that orders are placed regularly, with a frequency f

$$f_{mnk} = \frac{Q_{mnk}}{q_{mnk}} \quad \textbf{(4)}$$

The actual frequency is obtained by solving an optimization problem changing the shipment size, but the relation remains the same according to equation (4).

The key trade off, which underlies the concept of the economic order quantity (EOQ), is that between the cost of placing the orders (which, for a given total demand Q, will increase if a smaller consignment q is ordered), and the costs of holding stock in inventory (which will increase if the consignment size goes up).

The actual order cost is split into a fixed and a proportional cost according to the quantity being ordered [2]. This relation is utilized when estimating the annual demand Q according to:

$$O_{mnk}^{q} = O_k^f + O_k^p * Q_{mnk}{}^{\propto} \quad \textbf{(5)}$$

where:

O: the annual order cost

O^f: the annual fixed order cost

O^p: the annual proportional order cost

Q: the annual demand (tonnes per year)

q: the average shipment size.

$\propto$: parameter used for calculation of the annual demand dependent order cost

The average order costs O(constant cost per order) for each commodity group used in the model, is presented in the appendix, see Table 9.3.

6.2.2 Inventory costs

The inventory (inventory holding) costs I_k^q consist of the storage costs and the capital costs of inventory.

Storage costs

The storage costs w_k depend on the commodity type. The storage costs are expressed per tonnes and commodity though they in practice are not so much dependent on the weight of the goods but on their volume. The total annual storage costs depend on the level of the inventory and therefore on the shipment size q. On average, half the shipment size is stored at any time over the year, assuming constant shipment rates over time. The storage cost can be expressed as:

$$I_{mnk}^q = w_k * \frac{q_{mnk}}{2} \quad \textbf{(6)}$$

Other storage costs are equal to the sum of cost for spaces (depending on cargo's requirements: closed warehouse, open space, tank facilities, bulk storage and the cost per square meter for rental of a given sort of facilities) plus cost for equipment and manpower in the storage site. Also other costs like insurance, energy costs etc. should be included in the calculation of this cost item. Depending on the type of product the inventory holding cost vary considerable. The reason for this is obvious as the resources needed to physically store a product only to a limited extent is depending on the products value, but more on its physical properties.

Capital costs of inventory

The capital costs of inventory K_k^q are defined as the capital costs of the goods during the time the goods are stocked. These are the interest costs on the capital that is tied up in storage, which depend on the average level and value of the inventory (and therefore on shipment size q and commodity type k). According to [1], an interest rate of 10 % is assumed in Samgods model version 1.2.1. The capital cost can be expressed according to equation (7).

$$K_{mnk}^q = i * v_k * \frac{q_{mnk}}{2} \quad \textbf{(7)}$$

The inventory cost is the sum of storage and capital costs of inventory, is presented in the appendix in Table 9.3.

6.2.3 Capital costs of goods during transit

The capital cost of the goods during transit is notated Y_{rsk}. These costs depend on the transport time compared to a full year and on the value of the goods. The capital costs of goods during one single transit may be expressed as:

$$Y_{rskmn} = \frac{i * t_{rs} * q_{mnk} * v_k}{365 * 24} \quad \textbf{(8)}$$

while the capital cost during a whole year is obtained by multiplying with the shipping frequency and may be expressed as[22]:

$$Y_{rskmn} = \frac{i * t_{rs} * q_{mnk} * v_k}{365 * 24} * \frac{Q_{mnk}}{q_{mnk}} \quad \textbf{(9)}$$

The calculations in (9) may also be simplified according to:

$$Y_{rskmn} = \frac{i * t_{rs} * Q_{mnk} * v_k}{365 * 24} \quad \textbf{(10)}$$

The same interest rate of 10 % [1] as for capital costs in inventory is assumed for capital costs in transit. The capital costs of the goods in transit Y are calculated using commodity group specific average monetary values (SEK/tonne/hour) that are multiplied by the total transport time. The total transport time consists of link time, and loading/unloading time at the sender/receiver and transfer time and waiting at the terminal.

6.3 Transport costs

6.3.1 Approach

The cost functions give transport cost for all different vehicle/vessel types. The transport costs include:

- Link costs: vehicle operating costs
- Node costs: costs for loading the goods at the sender and unloading at the receiver and transferring the goods between vehicles (if several vehicles are involved in a transport chain)
- Numerical representation of transport costs is also available in ASEK [10]. Unfortunately, inconsistencies are observed comparing cost elements in ASEK and Samgods. All deviations between ASEK and SAMGODS are extensively explained in this chapter.

The approach to the transports costs is a. o. based on the following assumptions:

Movement of goods

There are economies of scale in the pure movement of goods. Larger volumes will allow larger transport units to be used for which costs do not rise proportionally to volume. However, a prerequisite for reaping scale advantages is that the utilisation rate is reasonably high, which implies that sufficient volumes of goods have to be available. Large ships or lorries are not to be used profitably for short distances since the fixed cost for positioning the respective unit for loading/unloading would be too high in relation to the impact of the lower transport cost for a short distance trip. In reality these “volume restrictions” can be more important than physical infrastructure requirements. The costs presented below are assumed to include return transports for vehicles and containers.

[22] Conversation with Jon Bergström, Trafikverket (2016-05-09)

Loading/unloading

In reality, there are economies of scale in many transferring operations. Such economies of scale of loading/unloading can be exhausted at different levels. Operation at terminals generally includes also other types of activities such as re-grouping of shipments sometimes involving consolidation, intermediate storage services, protecting the goods etc. Up to a limit there are also economies of scale in the terminal operations related to handling and storing of goods.

All these factors mentioned above may not be included individually in the model of technical reasons. Economics of scale in terminals is modelled using an aggregated technology factor which represents the benefit of more effective terminals. Larger terminals are usually more effective since they are able to deal with more cargo per time unit compared with minor terminals.

In transportation, a component of major importance for economies of scale is the network effect or hub effect. By reducing the number of terminals the scope of economies of scale in transport and handling is extended to more relations. Since loading, unloading and repositioning of a larger vehicle/vessel is more costly per time unit as well as often requiring more time such "set up" occasions have to be kept as low as possible. The implication is that the available goods volumes must be loaded and unloaded at a rather limited number of places.

6.3.2 Link costs

Link costs (or vehicle operating costs) are the average company cost per time or distance unit of operating the vehicle/vessel. The costs consist mainly of fuel costs, driver salaries, wear and tear of the vehicle and depreciation. One part of the costs is related to time and another part to distance:

- *distance-based costs* given in the cost functions as cost per kilometer for each vehicle/vessel type. The parameters (cost/vehicle unit km, cost/vehicle unit hour) are multiplied by distance and time values calculated from the networks (LOS-matrices, see section 5.2) to give the vehicle operating costs (pure transport costs).

- *time-based costs* given in the cost functions as cost per hour per vehicle/vessel for all the vehicle/vessel types based on network input for transport time. These are the time costs of the vehicle. Waiting time in the terminals is used for the calculation of capital costs in inventory and transit.

Road

The link costs for road are based on ASEK [10]. The extra heavy lorry HGV 74, vehicle 106, is not represented in ASEK, costs values for this vehicle is instead described in [14].

The distance based link cost for road vehicles are divided into several elements related to abrasion. These are fuel, tyre, deprecation, service and repairing cost. Time based link cost for road vehicles is also divided into several elements related to abrasion. These are capital cost, deprecation, driver, taxes, insurance and other costs. By summarizing the cost elements, the actual link cost for each vehicle in SAMGODS is obtained, these are shown in Table 6.1.

Table 6.1 Distance and time base costs for road vehicles used in Samgods 1.2.1

Vehicle	Vehicle type	Distance cost 2017 [SEK/km]	Distance cost 2040 [SEK/km]	Time cost [SEK/h]
101	Lorry light LGV.< 3.5 ton	2,63	2.38	290,10
102	Lorry medium 3.5-16 ton	4,66	4.41	318,33
103	Lorry medium16-24 ton	6,11	5.39	335,43
104	Lorry HGV 25-40 ton	6,53	6.76	330,61
105	Lorry HGV 25-60 ton	7,56	8.16	345,43
106	Lorry HGV 74 ton	8,08	9.05	349,03

Tax charges per lorry in Sweden and other countries are shown in Table 6.2

Table 6.2 Tax charge per lorry inside and outside Sweden used in Samgods 1.2.1

Country ID	Country name	Vehicle [SEK/veh km]					
		101	102	103	104	105	106
1	Sweden	0	0	0	0	0	0
502	Russia	0	0,31	0,31	0,31	0,31	0,31
513	Bosnia	1,20	1,76	1,76	2,32	2,32	2,32
515	Slovakia	0	0,86	1,82	1,91	1,91	1,91
516	Czech Republic	0,66	1,12	1,62	1,62	1,62	1,62
517	Poland	0	0,47	0,64	0,64	0,64	0,64
520	Germany	1,05	1,40	1,85	1,99	1,99	1,99
521	Austria	0	2,04	2,86	4,21	4,21	4,21
522	Switzerland	0	2,39	4,78	8,36	11,95	14,34
523	Italy	1,23	1,23	1,23	1,23	1,23	1,23
525	France	0	1,31	1,31	1,31	1,31	1,31
526	Belgium	0	0,71	1,19	1,23	1,23	1,23
533	Spain	1,54	1,54	1,54	1,54	1,54	1,54
534	Portugal	0,82	0,82	0,82	0,82	0,82	0,82

There are also some infrastructural charges related to passages at specific bridges (Öresundsbron, Stora Belt and Svinesundsbron[23]). These charges are presented in Table 6.3. Neither the tax charges in Table 6.2 nor passage charges in Table 6.3. are presented in ASEK.

Table 6.3 Toll charge per lorry outside Sweden used in Samgods 1.2.1

BRIDGE NAME	Vehicle [SEK/vehicle km]					
	101	102	103	104	105	106
Öresundsbron	433,00	844,00	844,00	844,00	844,00	---
Svinesundsbron	18,00	90,00	90,00	90,00	90,00	---
Stora Bältbron	312,04	879,59	1 396,27	2 097,48	2 097,48	---

Rail

The logistics model uses maximum capacities per train expressed in tonnes (see Table 4.1). The same approach is chosen for lorries, vessels and air planes. The number of wagons is assumed to be high (about 30 wagons per kombi train, compared to 20 wagons on average, and even more for long haul wagon load trains[24]). Also the maximum number of tonnes per wagons is assumed

[23] For Svinesundsbron, there is only a toll in the base scenario for 2017, not in the main scenario for 2040.
[24] The number wagons per feeder train is demand driven and therefore more spread (in reality).

to be high in the data setup used in Samgods model version 1.2.1. Ideally it would be possible to considerate the effect of bulky goods. The maximum capacity for bulky commodities should be dependent on volume rather than weight. This holds that the maximum number of tonnes per wagon should be lower for bulky commodities [25].

Distance based cost for trains only include electricity costs (no track access charges or abrasion of any kind). The distance and time based costs used in Samgods for 2017 are derived from ASEK [10]. For 2040 it is assumed that the cost of electricity for rail has the same increase as for electric lorries [15]. This implies that the distance based cost increases by 64 % in Samgods, while they are assumed to be constant in ASEK. Note that the distance cost for 2040 differs from the ones in Samgods v1.2, since the electricity price has been changed from private customers to commercial customer price in v1.2.1. The time based cost is assumed to be the same in 2040 as in 2017, in real terms. Costs for both 2017 and 2040 are presented in Table 6.4.

Table 6.4 Distance based cost of electricity for rail vehicles

Vehicle	Vehicle type	Distance cost 2017 [SEK/km]	Distance cost 2040 [SEK/km]	Time cost [SEK/h]
201	Kombi train	12,06	18,74	3 665
202	Feeder/shunt train	8,08	12,55	3 481
204	System train STAX 22.5	16,05	24,94	3 719
205	System train STAX 25	18,66	28,99	3 805
206	System train STAX 30	100,60	156,29	6 472
207	Wagon load train (short)	12,63	19,62	3 772
208	Wagon load train (medium)	14,45	22,45	3 967
209	Wagonload train (long)	15,39	23,91	4 223
210	Combi train (XL 750 m 201L)	13,88	21,56	3 840
211	System train STAX 22,5 (XL 750 m 204L)	19,12	29,71	3 904
212	Wagonload train (XL 750 m)	25,11	39,01	6 891

Infrastructural charges are included in Samgods, concerning all trains in the model. Track fees in Sweden for 2017 and 2040 are derived from [10]. Track fees for each country in Europe is calculated by scaling the Swedish fees with a country specific factor. The track fees used in Samgods for 2017 are presented in Table 6.5.

[25] This is true for all modes and the capacities should be differentiated by commodity group (See Table 2.1) or at least the aggregated commodities dry bulk, liquid bulk and general cargo for all vehicle types.

Table 6.5 Track fees for 2017 for trains used in Samgods 1.2.1 [SEK/km]

ID	Country	Vehicle [SEK/veh km]									
		201	202	204	205	206	207	208	210	211	212
1	Sverige	13	11	17	19	82	14	16	14	16	19
501	Finland	9	8	12	13	57	10	11	10	11	13
503	Estonia	80	70	109	120	521	89	100	90	100	124
504	Latvia	80	70	109	120	521	89	100	90	100	124
505	Lithuania	132	116	179	198	860	147	165	148	165	204
509	Bulgaria	11	9	14	16	69	12	13	12	13	16
511	Greece	11	9	14	16	69	12	13	12	13	16
513	Bosnia	11	9	14	16	69	12	13	12	13	16
514	Hungary	20	18	28	30	132	22	25	23	25	31
515	Slovakia	20	18	28	30	132	22	25	23	25	31
516	Czech Republic	9	8	12	13	57	10	11	10	11	13
517	Poland	42	37	58	64	276	47	53	48	53	66
518	Norway	3	3	4	4	19	3	4	3	4	4
519	Danmark	3	3	4	4	19	3	4	3	4	4
520	Germany	42	37	58	64	276	47	53	48	53	66
521	Austria	20	18	28	30	132	22	25	23	25	31
522	Switzerland	49	43	67	74	320	55	61	55	61	76
523	Italy	29	25	39	43	188	32	36	32	36	45
525	France	77	68	105	116	502	86	96	86	96	119
526	Belgium	67	58	90	100	433	74	83	74	83	103
527	The Netherlands	22	19	30	33	144	25	28	25	28	34
528	United Kingdom	30	26	41	45	195	33	37	33	37	46
533	Spain	47	41	64	71	308	52	59	53	59	73
534	Portugal	20	18	28	30	132	22	25	23	25	31

Additional infrastructure fees in terms of passage cost are included in the Samgods model for some specific locations. Fees are assigned to Öresundsbron and the bridge over Stora Belt, the values used in SAMGODS are presented in Table 6.6. No values for bridge tolls are presented in ASEK.

Table 6.6 Toll fees for trains used in Samgods 1.2.1

Vehicle	Vehicle type	Öresundsbron [SEK/passage]	Stora Beltbron [SEK/passage]
201	Kombi train	7 338	10 651
202	Feeder/shunt train	7 338	10 651
204	System train STAX 22.5	7 338	10 651
205	System train STAX 25	7 338	10 651
206	System train STAX 30	7 338	10 651
207	Wagon load train (short)	7 338	10 651
208	Wagon load train (medium)	7 338	10 651
209	Wagonload train (long)	7 338	10 651
210	Combi train (XL 750 m 201L)	7 338	10 651
211	System train STAX 22,5 (XL 750 m 204L)	7 338	10 651
212	Wagonload train (XL 750 m)	7 338	10 651

Sea

The link costs for vessels are derived from ASEK [10], and listed in Table 6.7. For vessels, number 301-317, values listed exclude the sulfur requirement SECA[26]. Additional costs

[26] Sulfur Emission Contol Area (SECA) which is regulating the maximum pollution of sulfur and particles in Baltic sea, North sea and English Channel. See Transportstyrelsen.se for further information.

according to SECA are added per link in the model. For ferries (number 318-321) values listed include SECA since ferries are only modelled within the SECA-zone in the model. The cost for inland waterway barges, number 322, are estimated based on [16] for vessel 1750 DWT. In ASEK, several different barges are listed, with different distance based costs. The value given in Table 6.7 is in line with the values listed in ASEK. Costs for 2040 are 34,6 % higher than for 2017 (an assumed annual cost increase of 1,3 %).

Table 6.7 Distance based cost for vessels/ferries in Samgods 1.2.1

Vessel/ferry	Vessel/ferry type	Cost 2017 [SEK/km]
301	Container vessel 5.300 dwt (ship)	38,68
302	Container vessel 16.000 dwt (ship)	86,45
303	Container vessel 27.200 dwt(ship)	129,12
304	Container vessel 100.000 dwt (ship)	355,39
305	Other vessel 1.000 dwt (ship)	9,18
306	Other vessel 2.500 dwt (ship)	18,19
307	Other vessel 3.500 dwt (ship)	21,85
308	Other vessel 5.000 dwt (ship)	26,86
309	Other vessel 10.000 dwt (ship)	45,14
310	Other vessel 20.000 dwt (ship)	70,38
311	Other vessel 40.000 dwt (ship)	107,87
312	Other vessel 80.000 dwt (ship)	165,67
313	Other vessel 100.000 dwt (ship)	183,43
314	Other vessel 250.000 dwt (ship)	313,57
315	Ro/ro vessel 3.600 dwt (ship)	45,73
316	Ro/ro vessel 6.300 dwt (ship)	66,90
317	Ro/ro vessel 10.000 dwt (ship)	91,12
318	Road ferry 2.500 dwt	73,27
319	Road ferry 5.000 dwt	132,43
320	Road ferry 7.500 dwt	170,43
321	Rail ferry 5.000 dwt	107,10
322	Barge Inland water way	26,00

Time based link cost for vessels consists of capital cost, operative cost, fuel cost for help engines and costs for dry dock. The calculation of each cost element is mainly described in [17] and [18]. No difference between ASEK and Samgods are observed, except for the inland water ways vessel 322, which is not included in ASEK. The cost of vessel 322 in Samgods is estimated based on [16].

Table 6.8 Time based cost for vessels used in Samgods 1.2.1

Vessel/ferry	Vessel/ferry type	Cost [SEK/h]
301	Container vessel 5.300 dwt (ship)	2 595
302	Container vessel 16.000 dwt (ship)	4 802
303	Container vessel 27.200 dwt(ship)	6 628
304	Container vessel 100.000 dwt (ship)	15 620
305	Other vessel 1.000 dwt (ship)	1 287
306	Other vessel 2.500 dwt (ship)	1 805
307	Other vessel 3.500 dwt (ship)	2 062
308	Other vessel 5.000 dwt (ship)	2 391
309	Other vessel 10.000 dwt (ship)	3 240
310	Other vessel 20.000 dwt (ship)	3 999
311	Other vessel 40.000 dwt (ship)	5 212
312	Other vessel 80.000 dwt (ship)	7 462
313	Other vessel 100.000 dwt (ship)	8 042
314	Other vessel 250.000 dwt (ship)	11 507
315	Ro/ro vessel 3.600 dwt (ship)	2 787
316	Ro/ro vessel 6.300 dwt (ship)	3 642
317	Ro/ro vessel 10.000 dwt (ship)	4 618
318	Road ferry 2.500 dwt	5 327
319	Road ferry 5.000 dwt	10 521
320	Road ferry 7.500 dwt	16 559
321	Rail ferry 5.000 dwt	7 534
322	Barge Inland water way	1 184

Vessel is the only vehicle type including positioning costs, related to the initial transfer in relation to the actual position of the vessel. Only non-liner vessels are assumed to have positioning or mobilization costs [1]. The positioning costs used in Samgods are derived from ASEK and are presented in Table 6.9.

Table 6.9 Positioning costs used in Samgods 1.2.1

Vessel/ferry	Vessel/ferry type	Positioning cost [SEK/tempering]
301	Container vessel 5.300 dwt (ship)	0
302	Container vessel 16.000 dwt (ship)	0
303	Container vessel 27.200 dwt(ship)	0
304	Container vessel 100.000 dwt (ship)	0
305	Other vessel 1.000 dwt (ship)	85 743
306	Other vessel 2.500 dwt (ship)	97 721
307	Other vessel 3.500 dwt (ship)	97 728
308	Other vessel 5.000 dwt (ship)	97 577
309	Other vessel 10.000 dwt (ship)	111 051
310	Other vessel 20.000 dwt (ship)	122 137
311	Other vessel 40.000 dwt (ship)	135 027
312	Other vessel 80.000 dwt (ship)	183 795
313	Other vessel 100.000 dwt (ship)	200 788
314	Other vessel 250.000 dwt (ship)	281 606
315	Ro/ro vessel 3.600 dwt (ship)	0
316	Ro/ro vessel 6.300 dwt (ship)	0
317	Ro/ro vessel 10.000 dwt (ship)	0
318	Road ferry 2.500 dwt	0
319	Road ferry 5.000 dwt	0
320	Road ferry 7.500 dwt	0
321	Rail ferry 5.000 dwt	0
322	Barge Inland water way	0

In addition to time and distance based link costs, there are additional fees for vessels and ferries related to fairways and pilots costs. The Swedish pilot fees are specified per port and vessel type, and may be observed in the Samgods model (table "*Node_terminals_Base2017*" in Input_Data.mdb), the file is too big to be include in this report. Information on pilot fees are provided by the National Maritime Administration and the fees in the Samgods model have been calculated based on the Administration's revenues. No pilot fees are included in ASEK.

The Swedish fairway dues are implemented per vessel/ferry type. The fairway dues in Samgods are presented in Table 6.10. No fairway dues are included in ASEK.

Table 6.10 Fairway dues in Samgods 1.2.1

Vessel/ferry	Vessel/ferry type	Vehicle based [SEK/vehicle]	Weight based [SEK/tonnes]
301	Container vessel 5.300 dwt (ship)	3 936	2,35
302	Container vessel 16.000 dwt (ship)	12 036	2,35
303	Container vessel 27.200 dwt(ship)	23 320	2,35
304	Container vessel 100.000 dwt (ship)	71 396	2,35
305	Other vessel 1.000 dwt (ship)	2 220	2,35
306	Other vessel 2.500 dwt (ship)	3 831	2,35
307	Other vessel 3.500 dwt (ship)	4 481	2,35
308	Other vessel 5.000 dwt (ship)	5 917	2,35
309	Other vessel 10.000 dwt (ship)	7 331	2,35
310	Other vessel 20.000 dwt (ship)	14 676	2,35
311	Other vessel 40.000 dwt (ship)	34 288	2,35
312	Other vessel 80.000 dwt (ship)	67 310	2,35
313	Other vessel 100.000 dwt (ship)	110 363	2,35
314	Other vessel 250.000 dwt (ship)	121 174	2,35
315	Ro/ro vessel 3.600 dwt (ship)	2 599	2,35
316	Ro/ro vessel 6.300 dwt (ship)	13 247	2,35
317	Ro/ro vessel 10.000 dwt (ship)	29 992	2,35
318	Road ferry 2.500 dwt	313	2,35
319	Road ferry 5.000 dwt	2 928	2,35
320	Road ferry 7.500 dwt	10 733	2,35
321	Rail ferry 5.000 dwt	6 869	2,35
322	Barge Inland water way	6 445	2,35

Port fees inside and outside Sweden are assumed to be paid as services in the ports and are assumed to be a part of the transfer costs. All vessels crossing the Kiel Canal also has to pay a single tax, this fee is individual for each vessel according to Table 6.11. None of these values are presented in ASEK. No ferries or inland water vessels are assumed to pass the Kiel Canal.

Table 6.11 Passage costs at the Kiel Canal in Samgods 1.2.1

Vessel/ferry	Vessel/ferry type	Passage cost [SEK/passage]
301	Container vessel 5.300 dwt (ship)	53 450
302	Container vessel 16.000 dwt (ship)	88 782
303	Container vessel 27.200 dwt(ship)	118 781
304	Container vessel 100.000 dwt (ship)	174 394
305	Other vessel 1.000 dwt (ship)	24 034
306	Other vessel 2.500 dwt (ship)	32 002
307	Other vessel 3.500 dwt (ship)	35 472
308	Other vessel 5.000 dwt (ship)	41 297
309	Other vessel 10.000 dwt (ship)	58 178
310	Other vessel 20.000 dwt (ship)	78 339
311	Other vessel 40.000 dwt (ship)	111 961
312	Other vessel 80.000 dwt (ship)	167 775
313	Other vessel 100.000 dwt (ship)	174 394
314	Other vessel 250.000 dwt (ship)	174 394
315	Ro/ro vessel 3.600 dwt (ship)	59 768
316	Ro/ro vessel 6.300 dwt (ship)	69 375
317	Ro/ro vessel 10.000 dwt (ship)	116 015

Air

The link costs for the freight airplane are based on the calculations made in 2002 that have subsequently been amended [19]. The largest change from the 2002 calculations came in the distance based costs per km, due to the increase in fuel prices which has taken place. No costs for airplane freight transports are presented in ASEK. The costs used in Samgods are presented in Table 6.12 containing distance, time based link costs

Table 6.12 Link costs for air freight transports in Samgods 1.2.1

Vehicle	Time based cost [SEK/h]	Distance based cost [SEK/km]
401	92 401	78

6.4 Node costs

Each OD leg has a loading cost and loading time at its beginning and an unloading cost and unloading time at its end. The loading and unloading time represent the time costs of vehicles and drivers, which are added to link time. The loading and unloading costs represents the physical loading and unloading process, for instance the cost of using cranes. The base levels for cost and time are the same for loading and unloading, so loading a vehicle is usually as expensive as unloading it. The same loading/unloading costs at sender and receiver are used though different technologies are used in some cases i.e. for timber that is delivered to the paper and pulp industry. There may though be one exception to the assumption of equal loading/unloading costs, this exception is related to the effectiveness of each node known as the technology factor. Effective terminals are assumed to be able to perform loading/unloading faster and cheaper compared to less effective terminals due to the level of technology.

If the goods passes through one or several transfer points there are also transfer costs. The same transfer costs per tonnes is used independent of direction. The transfer costs depend also on the aggregate commodity (dry bulk, liquid bulk and general cargo) and vary with respect to the type/size of vehicles used and the facilities available at the transfer points.

The transfer costs are the sum of the loading/unloading costs for the vehicles that are involved in the transfer. [27] It is also assumed that the time for the first and the second vehicle that are involved in the transfer are added, i.e. there is no overlap between loading and unloading in the transfer. A minimum transfer cost equivalent to the cost for one tonne is assumed. (The transfer

[27] When it comes to the process of loading and unloading of goods onto vessels (also to some extent other vehicles such as lorries, trains, and aircraft) alternative basic technologies are used. Sometimes such technologies require adaptation of the vehicle/vessels as well as the terminal environment. This is the case for ro-ro (which e.g. requires ramps) versus lo-lo which requires lifting equipment. Loading and unloading operation could be a self-contained function carried out by the vehicle/vessel (and its crew) without assistance from external resources e.g. at a terminal or any other specific location. Self-contained loading and unloading has been very important in an historic perspective but its importance has declined somewhat over time. The scale and capacity of the vehicle's own loading and unloading equipment could generally be assumed to be balanced to suit the capacity of the vehicle/vessel as well as the type of service in which the vehicle/vessel is operated. Alternatively, loading and unloading could be an operation that is entirely external to the vehicle or vessel and that is carried out entirely by external resources that are made available at the point of loading or unloading. Support from the crew of the vehicle/vessel could be very small in these cases.

cost of one tonne and ten kg are the same [1]). The costs are also specified for “conventional transports” (non container transports) and container transports.

The above principles for loading and unloading time and cost hold for both containerised non-containerised transports, but the amount of time and cost required varies between containers and non-container transports.

The terminal cost TC of handling for conventional and container transports are calculated as:

$$TC = q_k * c_v * F \quad \textbf{(11)}$$

where:

q_k: Shipment size of commodity k

c_v: Loading/unloading cost for vehicle v (using container or conventional transport)

F: Technology factor for the specific node

6.4.1 Conventional transfers

The node costs used in the Samgods model are derived from ASEK [10]. The exception is vehicle 106 (extra heavy lorry, derived from vehicle 105 and 104) and 322 (barge inland water way) which is based on [16]. Values in ASEK are in turn based on [13]. Table 6.13 presents the node costs for all vehicles in the Samgods model using conventional transfers. Note that vehicles unable to use conventional transfers are not presented in Table 6.13.

Table 6.13 Loading and unloading costs conventional transfer in Samgods 1.2.1

Veh	Cost dry bulk [SEK/tonne]	Cost liquid bulk [SEK/tonne]	Cost generall cargo [SEK/tonne]	Time dry bulk [h/vehicle]	Time liquid bulk [h/vehicle]	Time general cargo [h/vehicle]
101	10.43	---	104.3	0.25	---	2
102	10.43	---	52.15	0.25	---	2
103	10.43	15.65	41.72	0.25	1	2
104	10.43	15.65	20.86	0.42	1.5	1
105	10.43	15.65	20.86	0.58	2	1
106	10.43	15.65	20.86	0.75	2	1
202	9.1	10.24	14.79	5	5	5
204	12.52	17.07	30.73	6	6	6
205	12.52	17.07	30.73	6	6	6
206	12.52	17.07	30.73	6	6	6
207	19.35	17.07	27.31	6	6	6
208	19.35	17.07	27.31	6	6	6
211	12.52	17.07	30.73	6	6	6
212	19.35	17.07	27.31	6	6	6
305	15.93	18.21	132.01	15	21	50
306	14.79	18.21	122.9	15	21	54
307	14.79	18.21	122.9	17	21	54
308	14.79	18.21	121.77	19	21	54
309	14.79	14.79	121.77	21	21	56
310	13.66	13.66	119.49	25	21	65
311	13.66	13.66	113.8	26	21	65
312	13.66	13.66	113.8	27	21	66
313	13.66	13.66	---	27	21	---
314	13.66	13.66	---	31	21	---
315	67.14	67.14	67.14	28	28	28
316	67.14	67.14	67.14	28	28	28
317	67.14	67.14	67.14	28	28	28
318	11.38	11.38	11.38	3	3	3
319	11.38	11.38	11.38	3	3	3
320	11.38	11.38	11.38	3	3	3
321	20.48	20.48	20.48	3	3	3
322	15.93	18.21	132.01	5	6	20
401	1000	1000	1000	1	1	1

As may be observed from Table 6.13, there are no loading/unloading times for general cargo specified for vessel 313 and 314. In reality, general cargo is not transported by such large vessel, which explains the assumption[28].

6.4.2 Container transfers

The logistics model takes into account the trade-off between higher *costs for stuffing and stripping* (putting the goods into the container and taking it out of the container) and lower transfer costs (for transferring the container) in kombi terminals and ports. The use of containers increases the loading and unloading costs at the sender and receiver and reduces the transfer costs (between the modes) in the terminals. Also the transfer time i.e. in ports differs between conventional and container transports. This means that intermodal transports are more attractive than conventional transports for specific commodities, shipment sizes and/or relations.

If the goods are transported in a container the loading/unloading costs are the costs for stuffing/stripping the goods into the container and the costs for lifting the container onto/into

[28] Conversation with Henrik Edwards, SWECO (2016-09-05)

the vehicle. The costs for stuffing at the sender and stripping at the receiver are assumed to be the same. The costs in Samgods related to stuffing/stripping and loading/unloading the container (incl. time estimates) are based on [13]. The stuffing and stripping costs are modelled as link costs and not node costs. The cost of stuffing the container is added to the initial i link according to:

$$T_{kqi} = T_{kqi} + n * c_v^{stuffing} \quad \textbf{(12)}$$

where:

T: Transport cost

n: Number of vehicles

c: Cost of stuffing a container

Observe that the cost of stripping is donated as vehicle specific, but the current version of Samgods uses a general cost of 67 SEK/tonne per tonne independent vehicle type. The cost of stripping the container in Samgods is added to the final link f according to:

$$T_{kqf} = T_{kqf} + n * c_v^{stripping} \quad \textbf{(13)}$$

where:

T: Transport cost

n: Number of vehicles

c: Cost of stripping a container

The current version of Samgods includes 20 and 40 foot containers. The cost and times used for loading/unloading containers in Samgods are presented in Table 6.15, and are derived from ASEK [10]. The exception is vehicle 322 which is based on [16]. Values in ASEK are in turn based om [13]. Table 6.15 presents the loading/unloading costs for the vehicles in Samgods and ASEK which are able to carry containers. Assumed loading weigh of the containers are given in Table 6.14.

Table 6.14 Loading weights for ISO-containers in Samgods 1.2.1

Container	Loading weight [tonnes]
20-foot ISO-container	12,4
40-foot ISO-container	16,9

Table 6.15 Loading/unloading costs for containers in Samgods 1.2.1

Vehicle	Cost [SEK/tonne]	Time [h/vehicle]
104	9.39	0.75
105	9.39	0.75
106	9.39	0.75
201	14.79	3,00
202	15.93	4,00
207	14.79	4,00
208	14.79	4,00
210	14.79	3,00
212	14.79	4,00
301	73.97	19,00
302	73.97	19,00
303	73.97	19,00
304	72.83	19,00
315	67.14	28,00
316	67.14	28,00
317	67.14	28,00
318	11.38	3,00
319	11.38	3,00
320	11.38	3,00
321	20.48	3,00
322	73.97	6,00

Technology factor

The technology factor is used in the model in order to represent the effectiveness of each terminal. The factor is individually defined for each node (ranging from zero to one) and is applied to the transfer costs (vehicle related costs and facility related costs). It is assumed that ports handling more goods also uses more advanced technologies which enables cheaper and faster loadings. For ferry terminals there are fewer opportunities to reduce the loading and unloading costs, therefore the technology factors are not applied for these ports. The technology factor used in the current version of the model is not commodity specific. [1]

Technical development has gradually increased productivity of transport as well as loading and unloading operations and different types of terminal operations. There is probably no reason to assume that this development has come to an end.[29]

6.5 Optimisation principles

6.5.1 Logistics decisions

Within the logistics model different stereotypes of logistic decision making and modelling can be assumed for different commodity groups. For each commodity it is assumed that either the overall logistics costs are optimized or that the transport costs are minimized.[30] In the actual setup, the logistic decisions are derived from minimization of the full logistics costs (including

[29] Sensitivity tests with and without the technology factors in ports should be carried out.

[30] The importance of constraints for i.e. total transport time (e. g for fresh food) or shipment size within the optimizations logics could be included in coming versions.

transport costs) for all commodities. [1] No difference is made between senders that are producers or wholesale firms.[31] [1]

6.5.2 Consolidation

The utilization or filling rate is an important concept in transportation. By grouping smaller shipments together, they become more efficient and cheaper since the filling rate usually increases. This is also known as consolidation.

It is assumed in Samgods version 1.2.1 that goods are only consolidated within a commodity group. This assumption is made for both conventional transports and container transports. In reality nearly all commodities can be transported e.g. in the same container vessel or the same combi train. In the Norwegian model, alternative consolidation routines are tested, a. o. consolidation over specific groups of commodities. In the long run it is desirable also for the Swedish model to relax the assumption that only gods within one commodity can be consolidated. [1]

The current version of the logistics model assumes that goods can only be consolidated in terminals. In reality though, forwarders and carriers make use of the possibility to consolidate along the route. The so called “consolidation along the route” is implemented for road transport in the Norwegian logistics model; it has also been discussed to develop “consolidation along the route” for sea transports. The possibility to include “consolidation along the route” has so far been postponed for the Swedish model [1]. Although, in model version 1.2.1 it is possible to inherit consolidation rates from a reference scenario. This feature enables the comparison between two scenarios to be more consistent, especially when it comes to CBA-analysis.

6.6 Empty transports

The BuildChain step and ChainChoice step give vehicle flows for loaded trips. But for assignment empty vehicles are also required. Empty vehicle flows consist of two components within the logistic model:

- Asymmetric flows will generate empty vehicle flows because overcapacity always has to return empty to the starting point.

- Difficulty of matching incoming and outgoing flows will generate empty vehicle flows, regardless of the flow and reverse flow being balanced or not.

Initially the empty vehicle model was intended for road vehicles only. But the model has been extended to include other modes too in order to allow the user to have detailed control over the model parameters. [1]

[31] We might distinguish between transports between producer and consumers (PC-relations) and warehouses and consumers (WC-relations) in future model versions.

7 Results and output summaries

The users of the logistics model and their clients are interested in different topics, aspects and parts of the results. The model generates a huge amount of output at different levels. There are standard output files at the overall level as well on the commodity level. Tonkm is presented for the Swedish territory as well as for the whole world. Information on frequency/shipment size, distance, costs, time etc. is available at the transport chain level. Information, e.g. on the transfers at a port can be taken for consistency checks etc. In the following we shortly explain the output files that are generated by the program, observe that there are several more output files but the ones listed in this section are considered most useful.

7.1 Overview of output files

Output files are listed in [1] and in Table 7.1. They are grouped into output from the buildchain step, from the chainchoi step, from the aggregation over commodities (merge), in form of tonnes and vehicles at the OD-level (extract) and from data provided by the RCM module. Some of the files are also produced separately by each step in the model (standard logmod, RCM and final), the actual step is then given in the filename. Some files has to be specified in the control files in order to be generated. How to specify the control files is described in [2].

Table 7.1 Overview: Output files

BuildChain	**Description**
Chains<commodity>.dat	available chains per od
ChainChoi	**Description**
chainchoi<commodity>.out	best chain (route, costs) per pwc-cell
VhclRep<commodity>.fac	TotalTonnes, TotalVhcls and LoadFac per origin, destination and vehicle type
ChainChoi<commodity>data06.out	detailed cost log data per commodity and
ChainChoi<commodity>data07.out	detailed cost log data per commodity
VhclRep<commodity>.rep	aggregate costs report per commodity
ChainChoi<commodity>.rep	Domestic and International Shipments, Vehicles, Kms, Tonnes and TonneKms per vehicle type and per chain type
CONSOL_<commodity>_<mode>.314	od-matrix with consolidation factors (output of ranking)
MergeRep	**Description**
ChainChoi.rep	merged Domestic and International Shipments, Vehicles, Kms, Tonnes and TonneKms per vehicle type and chain type
Extract	**Description**
OD_Tonnes<vehicletype>.314	OD-matrix with tonnes
OD_Vhcl<vehicletype>.314	OD-matrix with vehicles (loaded and empty)
OD_Emp<vehicletype>.314	OD-matrix empty vehicle
RCM	**Description**
Commodity.dat	tonnes per commodity group, linked with capacity and capacity utilization

7.2 Buildchain

The Buildchain module builds and selects the best chain type and chain per commodity and for each OD-pair. In the following section, the output files generated by the BuildChain procedure are listed. The OUTPUT folder Buildchain contains the results from buildchain.exe.

a) Chains<commodity>.dat

The Chains<commodity>.dat includes the available chains per OD-pair, which is used as input to the ChainChoice procedure. The content of the file is presented in Table 7.2. One file per commodity group is created e.g. for commodity 2 the file name is Chains02.dat.

Table 7.2 Overview of columns in the file Chains<commodity>.dat

Column	Attribute	Unit	Comment
1	FromZone	NA. Number.	The shipment origin zone
2	ToZone	NA. Number.	The shipment destination zone
3	NrOfChains	NA. Number.	Number of available chains from the origin zone to the destination
4	ChainType	NA. Letter	For each of the available chain the chain type is given
5	FromNode	NA. Number.	Origin of respective leg in the chain
6	ToNode	NA. Number.	Destination of respective leg in the chain
7	FromIndex	NA. Number.	Index of FromNode in nodes file (first node in file has index 0)
8	ToIndex	NA. Number.	Index of ToNode in nodes file (first node in file has index 0)
9	ConsolFac	Dimensionless.	Consolidation Factor used for this leg

There are 2 different versions of the file depending on however it contains capacity restrictions according to RCM, or not:

- ***Chains<commodity>.dat***: logistic chains from standard LogMod
- ***Chains<commodity>_RCM.dat***: logistic chains including capacity restrictions.

7.3 Chainchoi

The ChainChoice procedure simulates the logistic decisions and optimizes the logistic costs. When doing so, the shipment size is determined and a choice is made for a transport chain. The OUTPUT folder **Chainchoi** contains the results from chainchoi.exe.

a) ChanChoi<commodity>.out

The file ChainChoi_<commodity>.out file contains the five best chains (route, costs) per pwc-subcell. The content of the file is presented in Table 7.3. One file per commodity is created and for commodity 4 the file name will be chainchoi4.out.

Table 7.3 Overview of columns in the file ChainChoi<commodity>.out

Column	Attribute	Unit	Comment
1	Key		Solution number/identifier numbered sequentially from 1 per product. One unique number per firm-to-firm solution.
1	NRelations	Number of relations	Number of firm to firm relations within this sub-cell of the
2	AnnualVolume	Tonnes per year	Annual volume per firm to firm relation within this sub-cell
3	Prob		Probablility for the chain, sums to 1 per key
4	ShipmentFreq	Number of shipments	Shipment frequency for a firm to firm relation within this
5	TransportCosts	SEK	
6	AllCosts	SEK	Sum of transport, order and holding costs
7	MargCost	SEK	Marginal cost for rail links included in the transport and total costs respectiveley[32]
8	ChainType		Modes used e.g. CGHC
9	Subcell		
10	Orig		Origin zone
11	Dest		Destination zone
12	VhclType1	Vehicle Type 1	Vehicle used in leg 1 (from Orig to Orig2)
13	NrVhcls1	Number of Vehicles 1	Number of vehicles used in leg 1 (from Orig to Orig2)
14	Orig2		Origin 2
15	VhclType2	Vehicle Type 2	Vehicle used in leg 2 (from Orig2 to Orig3)
16	NrVhcls2	Number of Vehicles 2	Number of vehicles used in leg 2 (from Orig2 to Orig3)
17	Orig3		Origin 3
18	VhclType3	Vehicle Type 3	Vehicle used in leg 3 (from Orig3 to Orig4)
19	NrVhcls3	Number of Vehicles 3	Number of vehicles used in leg 3 (from Orig3 to Orig4)
20	Orig4		Origin 4
21	VhclType4	Vehicle Type 3	Vehicle used in leg 4 (from Orig4 to Orig5)
22	NrVhcls4	Number of Vehicles 3	Number of vehicles used in leg 4 (from Orig4 to Orig5 or
And so on			

This output is provided in several different versions:

- ***ChainChoi<commodity>STD.out*** : solution from standard LogMod
- ***ChainChoi<commodity>LPX.out*** : solution including capacity restrictions[33]
- ***ChainChoi<commodity>RCM.out*** : solution including capacity restrictions
- ***ChainChoi<commodity>XTD.out*** : extended solution where the chains recalculated in RCM replaces the original chains.

[32] This column is only included in the RCM.out file
[33] same as ***RCM.out***

b) VhclRep<commodity>.fac

The file VhclRep<commodity>.fac contains information about total tonnes, total number of vehicles and load factor per origin, destination and vehicle type. The filename for commodity 2 will be chainchoi2.fac and the content of the file is presented in Table 7.4.

Table 7.4 Overview of columns in the file chainchoi<commodity>.fac

Column	Attribute	Unit	Comment
1	Orig		Origin
2	Dest		Destination
3	VhclType		Vehicle Type
4	TotalTonnes	Tonnes	Total Annual Tonnes
5	TotalVhcls		Total annual number of Vehicles
6	LoadFac		Load Factor = TotalVolume / (TotalVhcls*Capacity)

There are 3 different versions of the .fac file:

- ***VhclRep<commodity>STD.fac***: solution from standard LogMod
- ***VhclRep <commodity>RCM.fac***: solution including capacity restrictions (RCM)
- ***VhclRep <commodity>XTD.fac*** : extended solution where the chains recalculated in RCM replaces the original chains.

Each file includes identical column headers, but data is revised according to the actual module used in the process.

c) ChanChoi<commodity>data06.out

The file ***ChainChoi<commodity>data06.out*** contains detailed cost log data per commodity and solution for a selection of relations. The report is more detailed and comprehensive compared to ***chainchoi<commodity>.out***. For example, the filename for commodity 2 and the best solution will be "ChainChoi02data06.out" The data included in the file is presented in Table 7.5.

Table 7.5 Overview of columns in the file ChainChoi<commodity>data06.out

Column	Attribute	Unit	Comment
1	Key		Solution number/identifier numbered sequentially from 1 per product. One unique number per firm-to-firm solution.
2	TotalCost	SEK	Total annual Cost
3	TotalDist	Km	Total Distance
4	TotalTime	Hour	Total vehicle Time (loading and wait time not included)
5	TotalWaitTime	Hour	Total Wait Time
6	TotalLoadingTime	Hour	Vehicle time associated with loading and unloading respectively for all the OD-legs in the transport chain
7	ChainType		Modes used e.g. CGHC
8	Commodity		Commodity
9	Orig		Origin zone
10	Dest		Destination zone
11	SenderType		Sender Type
12	SubCell		Sub Cell
13	Tonnes		Annual volume on a firm to firm relation within this sub cell of
14	NrRelations		Number of firm-to-firm pairs the total demand is split up into.
15	Freq	Per year	Shipment frequency per year
16	ShipmentSize	Tonnes	Shipment Size
17	OrderCost	SEK	Annual order Cost
18	HoldingCost	SEK	Annual holding Cost
19	TransportCost	SEK	Annual Transport Cost
20	NLegs		Number of legs in the solution
21	DirectAcess		Active if value == 1. Means that flows starts and/or ends at terminals instead of at zones. Firms are assumed to have direct access to rail or ports. Thus, there are not any costs associated with transports between zones and terminals, which is the default setting (direct access value == 0).
22	Prob		Probability for the solution

The output file is provided in several different versions:

- ***ChainChoi<commodity>data06STD.out*** : solution from standard LogMod
- ***ChainChoi<commodity>data06RCM.out*** : including capacity restrictions
- ***ChainChoi<commodity>data06XTD.out*** : extended solution where the chains recalculated in RCM replaces the original chains.

d) ChainChoi<commodity>data07.out

The file chainchoi<commodity>data07.out contains detailed cost log data per commodity for a selection of relations. The file structure is similar to chainchoi<commodity>data06.out, but includes different information. One file per commodity group and solution is produced. For example, the filename for commodity 2 will be “ChainChoi02data07.out”. The content of the file is presented in Table 7.6.

Table 7.6 Overview of columns in the file ChainChoi<commodity>_data_07.out

Column	Attribute	Unit	Comment
1	Key		Solution number/identifier numbered sequentially from 1 per product. One unique number per firm-to-firm solution.
2	LegNr		Leg Number
3	Mode		Mode
4	Orig		Origin node
5	Dest		Destination node
6	Dist	Km	Distance
7	Time	Hour	Vehicle time on links
8	VhclType		Vehicle Type
9	NrVhcls		Number of Vehicles
10	ConsolVolume	Tonnes	Volume available for consolidation
11	ConsolFactor		Consol Factor
12	LoadFactor		Load Factor
13	WaitTime	Hour	Wait Time
14	LoadTime	Hour	Load Time
15	TransportTimeCost	SEK	Costs for the transport time, which is given as Time at (7)
16	LoadingTimeCost	SEK	Costs for vehicle time during loading and unloading
17	InterestCost	SEK	Capital costs for the transported goods during. Computed as (interest rate per year) * (product value) * (transport time fraction of a year)
18	DistCost	SEK	Distance Cost
19	InfraCost	SEK	Infrastructure Cost
20	LoadingCost	SEK	Loading Cost
21	PositioningCost	SEK	Positioning Cost
22	FairwayDues	SEK	Fairway Dues
23	PilotFees	SEK	Pilot Fees
24	DomDistShare	SEK	Proportion of the transport distance performed inside Swedish borders (including territorial borders on sea). Value in the interval [0,1].

The output file is provided in several different versions:

- ***ChainChoi<commodity>data07STD.out*** : solution from standard LogMod
- ***ChainChoi<commodity>data07XTD.out*** : extended solution where the chains recalculated in RCM replaces the original chains.

All files include the same number of columns independent of step in the process.

e) VhclRep<commodity>.rep

Contains aggregate costs report per commodity type. One file per commodity group and solution is produced. For example, the filename for commodity 2 will be “VehclRep07.rep”. The content of the file is presented in Table 7.7.

Table 7.7 Overview of columns in the file VhclRep <commodity>.rep

Column	Attribute	Unit	Comment
1	Commodity		Commodity group
2	Vehicle		Vehicle number
3	DomTerri_NodeCosts	SEK	Domestic territory node costs
4	DomTerri_LoadCost	SEK	Domestic territory loading costs
5	DomTerri_LoadTimeCost	SEK	Domestic territory loading time based costs
6	DomTerri_NodeIntCost	SEK	Domestic territory inventory cost in nodes
7	DomTerri_PosCosts	SEK	Domestic territory positioning costs
8	DomTerri_FwayDues	SEK	Domestic territory fairway costs
9	DomTerri_PilotFee	SEK	Domestic territory pilot fees
10	DomTerri_LinkCosts	SEK	Domestic territory link costs
11	DomTerri_TrsTimeCost	SEK	Domestic territory transport time costs
12	DomTerri_LinkIntCost	SEK	Domestic territory inventory cost on links
13	DomTerri_DistCost	SEK	Domestic territory distance costs
14	DomTerri_InfraCost	SEK	Domestic territory infrastructural costs
15	DomTerri_Kms	Km	Domestic territory vehicle kilometres
16	DomTerri_Tonnes	Tonne	Domestic territory tonnes
17	DomTerri_LiftedTonnes	Tonne	Domestic territory tonnes loaded
18	DomTerri_TransfTonnes	Tonne	Domestic territory tonnes transfered
19	DomTerri_TonneKms	TonnesKm	Domestic territory tonnesKm
20	DomTerri_TrpTime	Hour	Domestic territory transport time
21	DomTerri_LoadTime	Hour	Domestic territory loading time
22	IntTerri_NodeCosts	SEK	International territory node costs
23	IntTerri_LoadCost	SEK	International territory loading costs
24	IntTerri_LoadTimeCost	SEK	International territory loading time based costs
25	IntTerri_NodeIntCost	SEK	International territory inventory cost in nodes
26	IntTerri_PosCosts	SEK	International territory positioning costs
27	IntTerri_FwayDues	SEK	International territory fairway costs
28	IntTerri_PilotFee	SEK	International territory pilot fees
29	IntTerri_LinkCosts	SEK	International territory link costs
30	IntTerri_TrsTimeCost	SEK	International territory transport time costs
31	IntTerri_LinkIntCost	SEK	International territory inventory cost on links
32	IntTerri_DistCost	SEK	International territory distance costs
33	IntTerri_InfraCost	SEK	International territory infrastructural costs
34	IntTerri_Kms	Km	International territory vehicle kilometres
35	IntTerri_Tonnes	Tonne	International territory tonnes
36	IntTerri_LiftedTonnes	Tonne	International territory tonnes loaded
37	IntTerri_TransfTonnes	Tonne	International territory tonnes transfered
38	IntTerri_TonneKms	TonnesKm	International territory tonnesKm
39	IntTerri_TrpTime	Hour	International territory transport time
40	IntTerri_LoadTime	Hour	International territory loading time
41	Dom_NodeCosts	SEK	Domestic node costs
42	Dom_LinkCosts	SEK	Domestic link costs
43	Import_NodeCosts	SEK	Imported node costs
44	Import_LinkCosts	SEK	Imported link costs
45	Export_NodeCosts	SEK	Exported node costs
46	Export_LinkCosts	SEK	Exported link costs
47	Int_NodeCosts	SEK	International node costs
48	Int_LinkCosts	SEK	International link costs

The output file is provided in several different versions:

- **VhclRep <*commodity*>*STD.out*** : solution from standard LogMod
- **VhclRep <*commodity*>*RCM.out***: solution where the chains recalculated in RCM replaces the original chains.

- **VhclRep <*commodity*>*XTD.out***: extended solution where the chains recalculated in RCM replaces the original chains.

f) ChanChoi<commodity>.rep

The file ChainChoi<commodity>.rep contains aggregated summary report per commodity including information about domestic and international shipments, vehicles, tonnes and tonnesKms per vehicle type and chain type etc. The filename for commodity 2 will be ChainChoi2.rep. The content of the file is presented in Table 7.8.

Table 7.8 Overview of columns in the file ChainChoi<commodity>.rep

Column	Attribute	Unit	Comment
First part:			
1	OD_coverage		Vehicle Type
2	DNShipments		Number Shipments
3	DNVehicles		Number Vehicles
4	DKm	Km	
5	DTonnes	Tonnes	
6	DTonneKm	Tonne	
7	DAvLoadFac		Average Load Factor =
8	DAvDist (Km)	Km	Average distance
9	DTotalNShipments		Number Shipments
10	DTotalNVehicles		Number Vehicles
11	DTotalKm	Km	
12	DTotalTonnes	Tonnes	
13	DTotalTonneKm	Tonne	
14	DTotalAvLoadFac		Average Load Factor
15	DTotalAvDist (Km)	Km	Averange distance
16	INShipments		Number Shipments
17	INVehicles		Number Vehicles
18	IKm	Km	
19	ITonnes	Tonnes	
20	ITonneKm	Tonne	
21	IAvLoadFac		Average Load Factor
22	IAvDist (Km)	Km	Averange distance
Column	**Attribute**	**Unit**	**Comment**
Second part:			
1	OD_coverageChainType		All available mode chains listed, (from the location and file
2	DNShipments		
3	DCosts (SEK)	SEK	
4	DKm	Km	
5	DTonnes	Tonnes	
6	DTonneKm	Tonne	
7	DTotalNShipments		
8	DTotalCosts (SEK)	SEK	
9	DTotalKm	Km	
10	DTotalTonnes	Tonnes	
11	DTotalTonneKm	Tonne	
12	INShipments		
13	ICosts (SEK)	SEK	
14	IKm	Km	
15	ITonnes	Tonnes	
16	ITonneKm	Tonne	

The output file is provided in several different versions:

- ***ChainChoi<commodity>.rep*** : solution from standard LogMod
- ***ChainChoi<commodity> RCM.rep*** : solution including capacity restrictions (RCM)
- ***ChainChoi<commodity>XTD.rep*** : extended solution where the chains recalculated in RCM replaces the original chains.

All files include the same number of columns independent of step in the process.

g) CONSOL<commodity>_<mode>.314

The file CONSOL_<commodity>_<mode>.314 contains OD-matrices with consolidation factors (output of ranking). The content of the file is presented in Table 7.9. One file per commodity group and mode is created e.g. for commodity 2 and mode C the file name is consol_2_C.314. There is also an aggregated version of this fil for Sea, Rail, Air and Road.

Table 7.9 Overview of columns in the file consol<commodity>_<mode>.314

Column	Attribute	Unit	Comment
1	Origin		Origin Node
2	Destination		Destination Node
3	ConsolFactor		Consolidation factor

7.4 MergeRep

The OUTPUT folder MERGEREP contains the results from MergeRep.exe The MERGEREP program is used to merge the commodity specific output in all .rep files generated by ChainChoi.exe, into a unique .rep file.

a) ChanChoi.rep

This file contains the results from merging all .rep files per commodity into a single file. Contents in the file is equal to the table in section ChainChoi<commodity>.rep.

The output file is provided in several different versions:

- ***ChainChoiSTD.rep*** : solution from standard LogMod
- ***ChainChoiCBA.rep*** : solution used in the cost benefit analysis
- ***ChainChoiXTD.rep*** : extended solution where the chains recalculated in RCM replaces the original chains.

All files include the same number of columns independent of step in the process.

7.5 Extract

The OUTPUT folder **EXTRACT** contains the results from extract.exe (The EXTRACT program used to extract costs output for specific relations and to extract OD matrices). The program generates tonnes and vehicle matrices for each vehicle type. In the control file for the program it is possible to choose if the generated matrices should contain empty vehicles or not.

a) OD_Tonnes<vehicletype>.314

OD-matrix with tonnes for each vehicle type, the content of the file is presented in Table 7.10. The file name for vehicle 104 will be OD_Tonnes104.314

Table 7.10 Overview of columns in the file OD_Tonnes<vehicletype>.314

Column	Attribute	Unit	Comment
1	Origin		Origin Node
2	Destination		Destination Node
3	Weight	Tonnes	

The output file is provided in several different versions:

- ***OD_Tonnes<vehicletype>_STD.314*** : solution from standard LogMod
- ***OD_Tonnes<vehicletype>_FIN.314***: final solution including capacity restrictions (RCM)

All files include the same number of columns independent of step in the process.

b) OD_Vhcl<vehicletype>.314

OD-matrix with vehicles (both loaded and empty) for each vehicle type, the content of the file is presented in Table 7.11. The file name for vehicle 104 will be OD_Vhcl104.314

Table 7.11 Overview of columns in the file OD_Vhcl<vehicletype>.314

Column	Attribute	Unit	Comment
1	Origin		Origin Node
2	Destination		Destination Node
3	Volume	Number of vehicles	

The output file is provided in several different versions:

- ***OD_Vhcl<vehicletype>_STD.314*** : solution from standard LogMod
- ***OD_Vhcl<vehicletype>_FIN.314***: final solution including capacity restrictions (RCM)

All files include the same number of columns independent of step in the process.

c) OD_Emp<vehicletype>.314

OD-matrix with empty vehicles for each vehicle type, the content of the file is presented in Table 7.11. The file name for vehicle 104 will be OD_Emp104.314

Table 7.12 Overview of columns in the file OD_Vhcl<vehicletype>.314

Column	Attribute	Unit	Comment
1	Origin		Origin Node
2	Destination		Destination Node
3	Volume	Number of vehicles	

The output file is provided in several different versions:

- ***OD_Emp<vehicletype>_STD.314*** : solution from standard LogMod
- ***OD_Emp<vehicletype>_FIN.314***: final solution including capacity restrictions (RCM)

All files include the same number of columns independent of step in the process.

7.6 RCM

The OUTPUT folder RCM includes information about costs for empty vehicles and flows of tons used in the cost benefit analysis.

a) Commodity.dat

The file contains a compilation of flows of tonnes per commodity group and link together with capacity utilization and capacity expressed in trains per day. Table 7.13 describes the content of file.

Table 7.13 Overview of columns in the file Stan.dat

Column	Attribute	Unit	Comment
1	EMMEFR		Starting Emme node
2	EMMETO		Ending Emme node
3	A		Starting Voyger node
4	B		Ending Voyager node
5	KTon	Kilo tonns	Total amount goods transported between specific nodes
6	NLoadVhc	NrOf Trains/day	Number of loaded trains
7	NEmptyVhc	NrOf Trains/day	Number of empty trains
8	P01_kTon	Kilo tonns	Bidirectional transports of commodity group 1
9	P02_kTon	Kilo tonns	Bidirectional transports of commodity group 2
10	P03_kTon	Kilo tonns	Bidirectional transports of commodity group 3
11	P04_kTon	Kilo tonns	Bidirectional transports of commodity group 4
12	P05_kTon	Kilo tonns	Bidirectional transports of commodity group 5
13	P06_kTon	Kilo tonns	Bidirectional transports of commodity group 6
14	P07_kTon	Kilo tonns	Bidirectional transports of commodity group 7
15	P08_kTon	Kilo tonns	Bidirectional transports of commodity group 8
16	P09_kTon	Kilo tonns	Bidirectional transports of commodity group 9
17	P10_kTon	Kilo tonns	Bidirectional transports of commodity group 10
18	P11_kTon	Kilo tonns	Bidirectional transports of commodity group 11
19	P12_kTon	Kilo tonns	Bidirectional transports of commodity group 12
20	P13_kTon	Kilo tonns	Bidirectional transports of commodity group 13
21	P14_kTon	Kilo tonns	Bidirectional transports of commodity group 14
22	P15_kTon	Kilo tonns	Bidirectional transports of commodity group 15
23	P16_kTon	Kilo tonns	Bidirectional transports of commodity group 16
24	P01_Vday	NrOf Trains/day	Number of loaded trains for commodity group 1
25	P02_Vday	NrOf Trains/day	Number of loaded trains for commodity group 2
26	P03_Vday	NrOf Trains/day	Number of loaded trains for commodity group 3
27	P04_Vday	NrOf Trains/day	Number of loaded trains for commodity group 4
28	P05_Vday	NrOf Trains/day	Number of loaded trains for commodity group 5
29	P06_Vday	NrOf Trains/day	Number of loaded trains for commodity group 6
30	P07_Vday	NrOf Trains/day	Number of loaded trains for commodity group 7
31	P08_Vday	NrOf Trains/day	Number of loaded trains for commodity group 8
32	P09_Vday	NrOf Trains/day	Number of loaded trains for commodity group 9
33	P10_Vday	NrOf Trains/day	Number of loaded trains for commodity group 10
34	P11_Vday	NrOf Trains/day	Number of loaded trains for commodity group 11
35	P12_Vday	NrOf Trains/day	Number of loaded trains for commodity group 12
36	P13_Vday	NrOf Trains/day	Number of loaded trains for commodity group 13
37	P14_Vday	NrOf Trains/day	Number of loaded trains for commodity group 14
38	P15_Vday	NrOf Trains/day	Number of loaded trains for commodity group 15
39	P16_Vday	NrOf Trains/day	Number of loaded trains for commodity group 16
40	CapUtil	%	Capacity utalization rate
41	CapTrains/day	NrOf Trains/day	Daily capacity on rail links[34]

[34] Includes both empty and loaded trains

The output file is provided in several different versions:

- ***Commodity_STD.dat*** : solution from standard LogMod
- ***Commodity_CBA.dat*** : solution used in the cost benefit analysis
- ***Commodity_XTD.dat*** : extended solution where the chains recalculated in RCM replaces the original chains.

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9 Appendix

Table 9.1 Predefined transport chains

Number	Potential chain	Explanation	Included in model year 2017	2040
1	A	Direct transport by heavy lorry	yes	yes
2	ADA	Heavy lorry-kombi train-heavy lorry	yes	yes
3	AdA	Heavy lorry-long kombi train-heavy lorry	no	yes
4	ADJA	Heavy lorry-kombi train-direct sea-heavy lorry	yes	yes
5	ADJDA	Heavy lorry-kombi train-direct sea-kombi train-heavy lorry	yes	yes
6	ADKL	Heavy lorry-kombi train-feeder vessel-long haul vessel	yes	yes
7	AJ	Heavy lorry-direct sea	yes	yes
8	AJA	Heavy lorry-direct sea-heavy lorry	yes	yes
9	AJDA	Heavy lorry-direct sea-kombi train-heavy lorry	yes	yes
10	AKL	Heavy lorry-feeder vessel-long haul vessel	yes	yes
11	APA	Heavy lorry-road ferry-heavy lorry	yes	yes
12	AV	Heavy lorry-INW	yes	yes
13	AVA	Heavy lorry-INW-heavy lorry	yes	yes
14	B	Direct transport by light lorry	yes	yes
15	BR	Light lorry-plane	yes	yes
16	BRB	Light lorry-plane-light lorry	yes	yes
17	BS	Light lorry-heavy lorry	yes	yes
18	BSB	Light lorry-heavy lorry-light lorry	yes	yes
19	C	Direct transport by heavy lorry	yes	yes
20	c	Direct transport by extra heavy lorry	yes	yes
21	CGH	Heavy lorry-feeder train-wagonload train	yes	yes
22	CGHC	Heavy lorry-feeder train-wagonload train-heavy lorry	yes	yes
23	CGHM	Heavy lorry-feeder train-wagonload train-direct sea	yes	yes
24	CH	Heavy lorry-wagonload train	yes	yes
25	Ch	Heavy lorry-long wagonload train	no	yes
26	ch	Extra heavy lorry-long wagonload train	no	yes
27	CHG	Heavy lorry-wagonload train-feeder train	yes	yes
28	CHGC	Heavy lorry-wagonload train-feeder train-heavy lorry	yes	yes
29	CM	Heavy lorry-direct sea	yes	yes
30	CMC	Heavy lorry-direct sea-heavy lorry	yes	yes
31	CMI	Heavy lorry-direct sea-system train STAX 22,5	yes	yes
32	CMT	Heavy lorry-direct sea-system train STAX 25	yes	yes
33	CMU	Heavy lorry-direct sea-system train STAX 30	yes	yes
34	CPC	Heavy lorry-road ferry-heavy lorry	yes	yes
35	CUM	Heavy lorry-system train STAX 30-direct sea	yes	yes
36	CWC	Heavy lorry-INW-heavy lorry	yes	yes
37	cWc	Extra heavy lorry-INW-extra heavy lorry	yes	yes
38	GH	Feeder train-wagonload train	yes	yes
39	Gh	Feeder train-long wagonload train	no	yes
40	GHC	Feeder train-wagonload train-heavy lorry	yes	yes
41	GHG	Feeder train-wagonload train-feeder train	yes	yes
42	GHM	Feeder train-wagonload train-direct sea	yes	yes
43	GHMI	Feeder train-wagonload train-direct sea-system train STAX 22,5	yes	yes
44	GHMT	Feeder train-wagonload train-direct sea-system train STAX 25	yes	yes
45	GHMU	Feeder train-wagonload train-direct sea-system train STAX 30	yes	yes
46	GHQH	Feeder train-wagonload train-rail ferry-wagonload train	yes	yes
47	HC	Wagonload train-heavy lorry	yes	yes

48	hC	Long wagonload train-heavy lorry	no	yes
49	HG	Wagonload train-feeder train	yes	yes
50	hG	Long wagonload train-feeder train	no	yes
51	HGC	Wagonload train-feeder train-heavy lorry	yes	yes
52	I	Direct transport by system train STAX 22,5	yes	yes
53	i	Direct transport by long system train	no	yes
54	IM	System train STAX 22,5-direct sea	yes	yes
55	iM	Long system train-direct sea	no	yes
56	IMC	System train STAX 22,5-direct sea-heavy lorry	yes	yes
57	IMHG	System train STAX 22,5-direct sea-wagonload train-feeder train	yes	yes
58	J	Direct transport by sea	yes	yes
59	JA	Direct sea-heavy lorry	yes	yes
60	KL	Feeder vessel-long haul vessel	yes	yes
61	LK	Long haul vessel-feeder vessel	yes	yes
62	LKA	Long haul vessel-feeder vessel-heavy lorry	yes	yes
63	LKDA	Long haul vessel-feeder vessel-kombi train-heavy lorry	yes	yes
64	M	Direct transport by sea	yes	yes
65	MC	Direct sea-heavy lorry	yes	yes
66	MHG	Direct sea-wagonload train-feeder train	yes	yes
67	MHGC	Direct sea-wagonload train-feeder train-heavy lorry	yes	yes
68	MI	Direct sea-system train STAX 22,5	yes	yes
69	MT	Direct sea-system train STAX 25	yes	yes
70	MU	Direct sea-system train STAX 30	yes	yes
71	RB	Plane-light lorry	yes	yes
72	SB	Heavy lorry-light lorry	yes	yes
73	T	Direct transport by system train STAX 25	yes	yes
74	TM	System train STAX 25-direct sea	yes	yes
75	TMC	System train STAX 25-direct sea-heavy lorry	yes	yes
76	TMGH	System train STAX 25-direct sea-feeder train-wagonload train	yes	yes
77	U	Direct transport by system train STAX 30	yes	yes
78	UM	System train STAX 30-direct sea	yes	yes
79	UMC	System train STAX 30-direct sea-heavy lorry	yes	yes
80	UMGH	System train STAX 30-direct sea-feeder train-wagonload train	yes	yes
81	VA	INW-heavy lorry	yes	yes
82	XdX	Extra heavy lorry-long kombi train-extra heavy lorry	no	yes
83	XdJA	Extra heavy lorry-long kombi train-direct sea-heavy lorry	no	yes
84	AJdX	Heavy lorry-direct sea-long kombi train-extra heavy lorry	no	yes
85	cB	Extra heavy lorry-light lorry	yes	yes
86	cS	Extra heavy lorry-heavy lorry	yes	yes
87	cC	Extra heavy lorry-heavy lorry	yes	yes
88	cH	Extra heavy lorry-wagonload train	yes	yes
89	Bc	Light lorry-extra heavy lorry	yes	yes
90	XA	Extra heavy lorry-heavy lorry	yes	yes
91	AX	Heavy lorry-extra heavy lorry	yes	yes
92	WB	INW-light lorry	yes	yes
93	HQH	Wagonload train-rail ferry-wagonload train	yes	yes
94	CHM	Heavy lorry-wagonload train-direct sea	yes	yes
95	HM	Direct sea-wagonload train	yes	yes
96	MH	Wagonload train-Direct sea	yes	yes
97	AdJA	Heavy lorry-long kombi train-direct sea-heavy lorry	no	yes
98	AdJdA	Heavy lorry-long kombi train-direct sea-long kombi train-heavy lorry	no	yes
99	AdKL	Heavy lorry-long kombi train-feeder vessel-long haul vessel	no	yes
100	AJdA	Heavy lorry-direct sea-long kombi train-heavy lorry	no	yes

101	LKdA	Long haul vessel-feeder vessel-long kombi train-heavy lorry	no	yes
102	CGh	Heavy lorry-feeder train-long wagonload train	no	yes
103	CGhC	Heavy lorry-feeder train-long wagonload train-heavy lorry	no	yes
104	CGhM	Heavy lorry-feeder train-long wagonload train-direct sea	no	yes
105	ChG	Heavy lorry-long wagonload train-feeder train	no	yes
106	ChGC	Heavy lorry-long wagonload train-feeder train-heavy lorry	no	yes
107	GhC	Feeder train-long wagonload train-heavy lorry	no	yes
108	GhG	Feeder train-long wagonload train-feeder train	no	yes
109	GhM	Feeder train-long wagonload train-direct sea	no	yes
110	GhMI	Feeder train-long wagonload train-direct sea-system train STAX 22,5	no	yes
111	GhMT	Feeder train-long wagonload train-direct sea-system train STAX 25	no	yes
112	GhMU	Feeder train-long wagonload train-direct sea-system train STAX 30	no	yes
113	GhQh	Feeder train-long wagonload train-rail ferry-long wagonload train	no	yes
114	hGC	Long wagonload train-feeder train-heavy lorry	no	yes
115	IMhG	System train STAX 22,5-direct sea-long wagonload train-feeder train	no	yes
116	MhG	Direct sea-long wagonload train-feeder train	no	yes
117	MhGC	Direct sea-long wagonload train-feeder train-heavy lorry	no	yes
118	UMGh	System train STAX 30-direct sea-feeder train-long wagonload train	no	yes
119	hQh	Long wagonload train-rail ferry-long wagonload train	no	yes
120	ChM	Heavy lorry-long wagonload train-direct sea	no	yes
121	hM	Direct sea-long long wagonload train	no	yes
122	Mh	Direct sea-long wagonload train	no	yes
123	CMi	Heavy lorry-direct sea-Long system train	no	yes
124	GHMi	Feeder train-wagonload train-direct sea-Long system train	no	yes
125	iMC	Long system train-direct sea-heavy lorry	no	yes
126	iMHG	Long system train-direct sea-wagonload train-feeder train	no	yes
127	Mi	Direct sea-Long system train	no	yes
128	cGH	Extra heavy lorry-feeder train-wagonload train	yes	yes
129	cGHc	Extra heavy lorry-feeder train-wagonload train-extra heavy lorry	yes	yes
130	cGHM	Extra heavy lorry-feeder train-wagonload train-direct sea	yes	yes
131	cHG	Extra heavy lorry-wagonload train-feeder train	yes	yes
132	cHGc	Extra heavy lorry-wagonload train-feeder train-extra heavy lorry	yes	yes
133	cM	Extra heavy lorry-direct sea	yes	yes
134	cMc	Extra heavy lorry-direct sea-extra heavy lorry	yes	yes
135	cMI	Extra heavy lorry-direct sea-system train STAX 22,5	yes	yes
136	cMT	Extra heavy lorry-direct sea-system train STAX 25	yes	yes
137	cMU	Extra heavy lorry-direct sea-system train STAX 30	yes	yes
138	cPc	Extra heavy lorry-road ferry-extra heavy lorry	yes	yes
139	cUM	Extra heavy lorry-system train STAX 30-direct sea	yes	yes
140	GHc	Feeder train-wagonload train-extra heavy lorry	yes	yes
141	Hc	Wagonload train-extra heavy lorry	yes	yes
142	hc	Long wagonload train-extra heavy lorry	no	yes
143	HGc	Wagonload train-feeder train-extra heavy lorry	yes	yes
144	IMc	System train STAX 22,5-direct sea-extra heavy lorry	yes	yes
145	Mc	Direct sea-extra heavy lorry	yes	yes
146	MHGc	Direct sea-wagonload train-feeder train-extra heavy lorry	yes	yes
147	TMc	System train STAX 25-direct sea-extra heavy lorry	yes	yes
148	UMc	System train STAX 30-direct sea-extra heavy lorry	yes	yes
149	cHM	Extra heavy lorry-wagonload train-direct sea	yes	yes
150	cGh	Extra heavy lorry-feeder train-long wagonload train	no	yes
151	cGhc	Extra heavy lorry-feeder train-long wagonload train-extra heavy lorry	no	yes
152	cGhM	Extra heavy lorry-feeder train-long wagonload train-direct sea	no	yes

153	chG	Extra heavy lorry-long wagonload train-feeder train	no	yes
154	chGc	Extra heavy lorry-long wagonload train-feeder train-extra heavy lorry	no	yes
155	Ghc	Feeder train-long wagonload train-extra heavy lorry	no	yes
156	hGc	Long wagonload train-feeder train-extra heavy lorry	no	yes
157	MhGc	Direct sea-long wagonload train-feeder train-extra heavy lorry	no	yes
158	chM	Extra heavy lorry-long wagonload train-direct sea	no	yes
159	cMi	Extra heavy lorry-direct sea-Long system train	no	yes
160	iMc	Long system train-direct sea-extra heavy lorry	no	yes
161	cGHC	Extra heavy lorry-feeder train-wagonload train-extra heavy lorry	yes	yes
162	cHGC	Extra heavy lorry-wagonload train-feeder train-extra heavy lorry	yes	yes
163	cMC	Extra heavy lorry-direct sea-extra heavy lorry	yes	yes
164	cWC	Extra heavy lorry-INW-extra heavy lorry	yes	yes
165	cGhC	Extra heavy lorry-feeder train-long wagonload train-extra heavy lorry	no	yes
166	chGC	Extra heavy lorry-long wagonload train-feeder train-extra heavy lorry	no	yes
167	CGHc	Extra heavy lorry-feeder train-wagonload train-extra heavy lorry	yes	yes
168	CHGc	Extra heavy lorry-wagonload train-feeder train-extra heavy lorry	yes	yes
169	CMc	Extra heavy lorry-direct sea-extra heavy lorry	yes	yes
170	CWc	Extra heavy lorry-INW-extra heavy lorry	yes	yes
171	CGhc	Extra heavy lorry-feeder train-long wagonload train-extra heavy lorry	no	yes
172	ChGc	Extra heavy lorry-long wagonload train-feeder train-extra heavy lorry	no	yes
173	X	Direct transport by Extra heavy lorry	yes	yes
174	XDX	Extra heavy lorry-kombi train-extra heavy lorry	yes	yes
175	XDJX	Extra heavy lorry-kombi train-direct sea-extra heavy lorry	yes	yes
176	XDJDX	Extra heavy lorry-kombi train-direct sea-kombi train-extra heavy lorry	yes	yes
177	XDKL	Extra heavy lorry-kombi train-feeder vessel-long haul vessel	yes	yes
178	XJ	Extra heavy lorry-direct sea	yes	yes
179	XJX	Extra heavy lorry-direct sea-extra heavy lorry	yes	yes
180	XJDX	Extra heavy lorry-direct sea-kombi train-extra heavy lorry	yes	yes
181	XKL	Extra heavy lorry-feeder vessel-long haul vessel	yes	yes
182	XPX	Extra heavy lorry-road ferry-extra heavy lorry	yes	yes
183	XV	Extra heavy lorry-INW	yes	yes
184	XVX	Extra heavy lorry-INW-extra heavy lorry	yes	yes
185	JX	Direct sea-extra heavy lorry	yes	yes
186	LKX	Long haul vessel-feeder vessel-extra heavy lorry	yes	yes
187	LKDX	Long haul vessel-feeder vessel-kombi train-extra heavy lorry	yes	yes
188	VX	INW-extra heavy lorry	yes	yes
189	XdJX	Extra heavy lorry-long kombi train-direct sea-extra heavy lorry	no	yes
190	XdJdX	Extra heavy lorry-long kombi train-direct sea-long kombi train-extra heavy lorry	no	yes
191	XdKL	Extra heavy lorry-long kombi train-feeder vessel-long haul vessel	no	yes
192	XJdX	Extra heavy lorry-direct sea-long kombi train-extra heavy lorry	no	yes
193	LKdX	Long haul vessel-feeder vessel-long kombi train-extra heavy lorry	no	yes
194	XDA	Extra heavy lorry-kombi train-heavy lorry	yes	yes
195	XdA	Extra heavy lorry-long kombi train-heavy lorry	no	yes
196	XDJA	Extra heavy lorry-kombi train-direct sea-heavy lorry	yes	yes
197	XDJDA	Extra heavy lorry-kombi train-direct sea-kombi train-heavy lorry	yes	yes
198	XJA	Extra heavy lorry-direct sea-heavy lorry	yes	yes
199	XJDA	Extra heavy lorry-direct sea-kombi train-heavy lorry	yes	yes
200	XPA	Extra heavy lorry-road ferry-heavy lorry	yes	yes
201	XVA	Extra heavy lorry-INW-heavy lorry	yes	yes

202	XdJdA	Extra heavy lorry-long kombi train-direct sea-long kombi train-heavy lorry	no	yes
203	XJdA	Extra heavy lorry-direct sea-long kombi train-heavy lorry	no	yes
204	ADX	Heavy lorry-kombi train-extra heavy lorry	yes	yes
205	AdX	Heavy lorry-long kombi train-extra heavy lorry	no	yes
206	ADJX	Heavy lorry-kombi train-direct sea-extra heavy lorry	yes	yes
207	ADJDX	Heavy lorry-kombi train-direct sea-kombi train-extra heavy lorry	yes	yes
208	AJX	Heavy lorry-direct sea-extra heavy lorry	yes	yes
209	AJDX	Heavy lorry-direct sea-kombi train-extra heavy lorry	yes	yes
210	APX	Heavy lorry-road ferry-extra heavy lorry	yes	yes
211	AVX	Heavy lorry-INW-extra heavy lorry	yes	yes
212	AdJX	Heavy lorry-long kombi train-direct sea-extra heavy lorry	no	yes
213	AdJdX	Heavy lorry-long kombi train-direct sea-long kombi train-extra heavy lorry	no	yes
214	A2J	Heavy lorry-(different loading point compared to AJ)-direct sea	yes	yes
215	A2JA	Heavy lorry-(different loading point compared to AJA)-direct sea-Heavy lorry	yes	yes
216	AJ2A	Heavy lorry-direct sea-(different loading point compared to AJA)-Heavy lorry	yes	yes
217	C2M	Extra heavy lorry-(different loading point compared to CM)-direct sea	yes	yes
218	C2MC	Extra heavy lorry-(different loading point compared to CMC)-direct sea-Extra heavy lorry	yes	yes
219	CM2C	Extra heavy lorry-direct sea-(different loading point compared to CMC)-Extra heavy lorry	yes	yes
220	CMM	Extra heavy lorry-direct sea-direct sea	yes	yes
221	CMMC	Extra heavy lorry-direct sea-direct sea-Extra heavy lorry	yes	yes
222	J2A	direct sea-(different loading point compared to JA)-Heavy lorry	yes	yes
223	M2C	direct sea-(different loading point compared to MC)-Extra heavy lorry	yes	yes
224	MMC	direct sea-direct sea-Extra heavy lorry	yes	yes

Table 9.2 Vehicle type in BuildChain for each sub-mode by commodity type
(See Table 2.1 for commodity group numbers and Table 4.2 for vehicle numbers and mode)

Commodity	A	D	d	E	F	f	J	K	L	V	X	B	C	c	G	H	h	I	i	M	N	O	P	Q	R	T	U	W
1	104	201	210	202	208	212				322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
2	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
3	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
4	104	201	210	202	208	212	303	301	303	322	106	101	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
5	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
6	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
7	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
8	104	201	210	202	208	212	303	301	303	322	106	101	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
9	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
10	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
11	104	201	210	202	208	212				322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
12	104	201	210	202	208	212				322	106	101	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
13	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
14	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	309	315	317	319	321	401	205	206	322
15	104	201	210	202	208	212	303	301	303	322	106	102	104	106	202	208	212	204	211	310	315	317	319	321	401	205	206	322
16												102	104										318		401			

Table 9.3 Commodity values, inventory costs and order costs

No	Commodity	Value Domestic [SEK/ton]	Value Import [SEK/ton]	Value Export [SEK/ton]	Value Average [SEK/ton	Inventory costs (capital costs + storage costs) [SEK/(year,tonne)]	OrderCosts [SEK per shipment]
1	Products of agriculture, forestry and fishing	2 130	9 950	2 130	2 747	824	624
2	Coal and lignite; crude petroleum and natural gas	2 440	2 440	4 610	2 440	732	624
3	Metal ores and other mining and quarrying products	720	1 460	720	779	234	624
4	Food products, beverages and tobacco	18 070	18 070	19 820	18 358	5 507	624
5	Textiles and textile products; leather and leather products	143 780	156 210	143 780	153 435	46 030	624
6	Wood and products of wood; pulp, paper and paper products; printed matter and recorded media	5 840	5 620	5 840	5 810	1 743	624
7	Coke and refined petroleum products	4 020	4 020	3 470	3 740	1 122	624
8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	33 360	15 010	33 360	22 137	6 641	624
9	Other non-metallic mineral products	4 030	5 870	4 030	4 453	1 336	624
10	Basic metals; fabricated metal products, except machinery and equipment	16 160	16 160	22 290	18 415	5 525	624
11	Machinery and equipment	164 500	164 500	224 890	187 043	56 113	624
12	Transport equipment	89 880	89 880	91 590	90 554	27 166	624
13	Furniture; other manufactured goods n.e.c.	38 050	38 050	32 320	35 642	10 692	936
14	Secondary raw materials; municipal wastes and other wastes	2 620	2 620	3 110	2 743	823	936
15	Timber	520	520	880	524	157	936
16	Air freight (fractions of other commodities)				1 339 679	401 904	936

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