ANALYSIS SAMGODS SYSTEM DESIGN

FOR A HIGH-SPEED RAILROAD SCENARIO

2020-09-04

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for a high-speed railroad scenario

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INTRODUCTION

In a 2040 scenario, higher capacity numbers have been introduced in the railway network in the Samgods model, corresponding to a scenario where a new high-speed rail network for passenger trains has been built in Sweden, leaving more free capacity in the current network for freight trains. The results show a dramatic rise in the number of freight trains in the model results, which has been questioned to be realistic. This report investigates three aspects in the model that affect, and possibly lower, the level of trains that are allocated to the network;

1. Consolidation rates and vehicle sizes: in Samgods, consolidation rates (or filling rates) represent the fraction of a vehicle's capacity that is loaded. The lower the consolidation rates, the more vehicles are needed to transport the same amount of goods. There are several different vehicle types for rail types, and they all have different loading capacities. The smaller the vehicle type that is selected for a transport by the model's algorithms, the more vehicles are needed to transport the same amount of goods.
2. The use of longer (750 meter) trains in parts of the network: New, longer vehicle/train types have been introduced in Samgods and are allowed on certain relations where the infrastructure can accommodate them. Since they could theoretically transport the same amount of goods in fewer shipments than shorter trains, they have the potential to reduce the number of freight trains assigned to the network.
3. Terminal capacity: In Samgods, there are capacity restrictions that are quantified by a maximum number of trains per day (both directions combined) for specific links. However, terminals where goods or train wagons are transhipped between vehicles also have limited capacity in reality, which is currently not reflected by the model. Therefore, the possibility to include these restrictions in the network has been evaluated and tested.

These three aspects are analysed and discussed in three separate chapters below.

The analysis for this report was carried out with Samgods version 1.2 from January 2020.

1 CONSOLIDATION RATES AND VEHICLE SIZES

The scope of the first research question is to identify any relation between rail demand (tons) in OD relations[1] and the filling rates/shipment sizes/vehicle types selected by the Standard Logistics Model, i.e. before applying the capacity restraints in the Railway Capacity Module step. If patterns can be observed, could any connection to specific parameter settings be identified as well?

1.1 METHOD

The scenario *MainSc2040* has been chosen as the data source for the observations, because this is the scenario that is most important for the forecasting work currently done at the STA. The standard logistics module was run for this scenario and the relation between transported volumes and consolidation rate in the model's results are analysed for each vehicle type and, when applicable, for each commodity.

The analysis is made on two principal sources:

1. The CoVo files containing, per aggregate mode (see Table 2), commodity and OD relation:
    a. Goods volumes (in tons)
    b. Consolidation rates

    The CoVo files are found in \CHAINCHOI\Output\CoVo.

2. The rail OD matrices resulting from the standard logistics module step containing numbers per OD relation, aggregated for all commodities, but split per vehicle type, on:
    a. Goods volumes (in tons)
    b. Number of vehicles

The OD matrices contain all goods volumes (alternatively, number of vehicles) between all zones in the network. In the case of *MainSc2040* there are 1377 zones. These include centroids as well as transport terminals. Centroids are the zones where goods flows originate and/or end, whose identifying number end in 00. Transport terminals, on the other hand, are the nodes in which where a vehicle's journey begins and/or ends.

Vehicles in the OD matrices are classified by *vehicle type*, consisting of the numbers 201 to 212 for rail, see Table 1. The following vehicle types for rail are available with the corresponding capacities in *MainSc2040*:

[1] An OD-relation is defined in this report as any pair of nodes, where one is an origin and one is a destination for a transport chain, vehicle, etc.

Table 1: Vehicle specifications in *MainSc2040*.

Number	Description	Capacity (tons)
201	Combi train	610
202	Feeder train	488
204	System train STAX 22.5	959
205	System train STAX 25	1098
206	System train STAX 30	6000
207	Short wagon load train	716
208	Medium wagon load train	852
209	Long wagon load train	907
210	Extra-long combi train	726
211	Extra-long system train STAX 22.5	1142
212	Extra-long wagon load train	1480

In contrast, the data from the CoVo files is given per *aggregate mode*, which is an aggregation of vehicle types, see Table 2. Table 2 also shows the allowed consolidation factors for each aggregate mode, which also could vary between commodities. The initial consolidation factor used for the first iteration in Build chain is 0.75 for all commodities and aggregate modes. In the inputs to the model, the range 0.1[2]-0.95 is specified as a standard for all commodities, however the user-defined, sub mode-specific ranges in Table 2 overwrite the standard ones.

The consolidation rate is calculated in the *BuildChain* and *ChainChoice* procedures in the Samgods model, and these are described in the model documentations. Here we clarify some issues that can be helpful when understanding the role of the consolidation rate in the process of estimating the number of trains in the network.

- The calculated consolidation rates are always between the defined bounds. They are based on a ranking of transport volumes for each sub-mode and commodity. All volumes are ranked from the smallest to the largest. The smallest volume obtains a consolidation factor that equals the lower bound of the interval. The biggest volume obtains a consolidation factor that equals the upper bound of the interval. And volumes in between obtain a consolidation factor in between the lower and upper bound, from a uniform distribution of values between the bounds.3
- The calculations are made per shipment. For example, if the consolidation rate for a rail transport is determined to 0.8, it means that the train is supposed to be filled to 80% of its capacity. A transport with a shipment size of 20% of its capacity is supposed to pay for 20/80=25% of the costs of the train. The number of vehicles for this transport thus equals 0.25. When the network assignment is made (and the total number of trains per link is calculated), this transport will count as 0.25 trains for the links that it uses, say links X, Y and Z. On link X, we also have another transport of 0.7 trains. The resulting number of trains for link X in the network assignment will then be 0.25+0.7=0.95.

[2] Or 0.05, depending on Samgods version
[3] For further descriptions, see the Logistics Model Method Report (Significance, 2019), p. 34-35

Table 2: Aggregate mode specifications in Samgods V1.1.1

Aggregate mode	Vehicle Type	Vehicle number	Lower limit, CONSOL	Upper limit, CONSOL
Containerized modes				
D	Kombi train	201	0.6[4]	0.95[4]
d	Long kombi train	210	0.6[4]	0.95[4]
E	Feeder/shunt train	202	0.6[4]	0.95[4]
F	Short wagonload train	207	0.6[4]	0.95[4]
	Medium wagonload train	208	0.6[4]	0.95[4]
	Long wagonload train	209	0.6[4]	0.95[4]
f	Extra-long wagonload train	212	0.6[4]	0.95[4]
Not containerized modes				
G	Feeder/shunt train	202	0.6[4]	0.95[4]
H	Short wagonload train	207	0.6[4]	0.95[4]
	Medium wagonload train	208	0.6[4]	0.95[4]
h	Extra-long wagonload train	212	0.6[4]	0.95[4]
I	System train STAX 22,5	204	0.66[5]	0.98
T	System train STAX 25	205	0.66[5]	1
U	System train STAX 30	206	0.66[5]	1
i	Long system train	211	0.66[5]	0.98

1.2 RESULTS AND ANALYSIS

1.2.1 Consolidation rates from OD matrices

The analysis of the OD matrices can only give average results, since all commodities are aggregated and the files contain no explicit results for shipment sizes or filling rates. However, these indicators could be calculated on average per vehicle type and relation using the number of tons, the number of vehicles and the vehicle capacities.

As can be seen in Figure 1, the average filling rates are in general high – in most cases over 90 %. Two vehicle types display lower average filling rates: the extra-long combi and system trains. This is probably explained by the low volumes allocated to these vehicle types – only 900 000 and 3000 tons per year, respectively. This gives a first hint that low volumes could result in low filling rates, but the results are far too coarse to give any real insight.

4 Except for commodities 2, 8 and 9, where the limits are 0.63-0.98
5 Except for commodities 2, 8 and 9, where the lower limit is 0.71

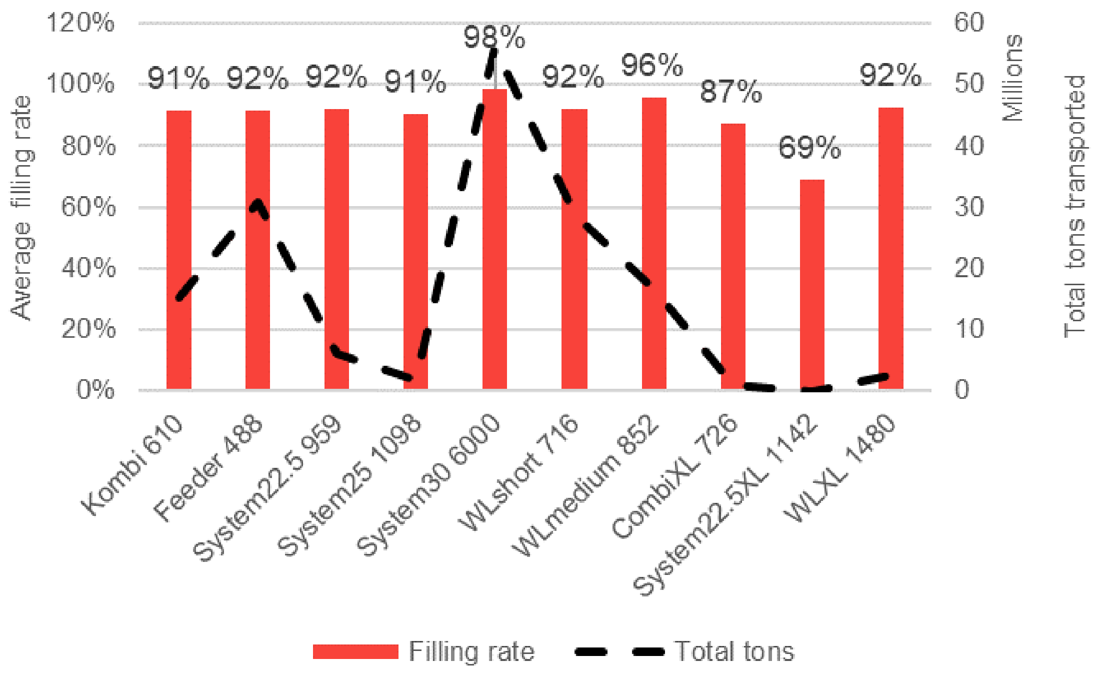


Figure 1: Average results per vehicle type. The vehicle type name is followed by its capacity in tons. Vehicle type "Long wagon load train" has been left out since it has not been allocated any goods in *MainSc2040*.

To further explore any relation between volume (tons) and filling rates, OD relations have been categorised by total volume per vehicle type, see Figure 2. Each dotted line represents a vehicle type, and each data point represents the average filling rate for the vehicle type on all OD relations in the volume range given by the x-axis. Please note that the volume intervals are not of even length – for smaller volumes the ranges are shorter, and vice versa. The thick, black line represents the weighted average for all vehicle types, using the number of vehicles as a weight. There is a clear, but not very steep, relation between the OD volume and the average filling rate.

As highlighted before, these data points are still averages of all vehicles of a specific type on OD relations of a specific volume. The number of relations of which the averages have been formed vary in a large range. More detailed information on filling rates cannot be obtained from the OD matrices. To assess individual filling rates, another data source must be used; the CoVo files, as explained above.

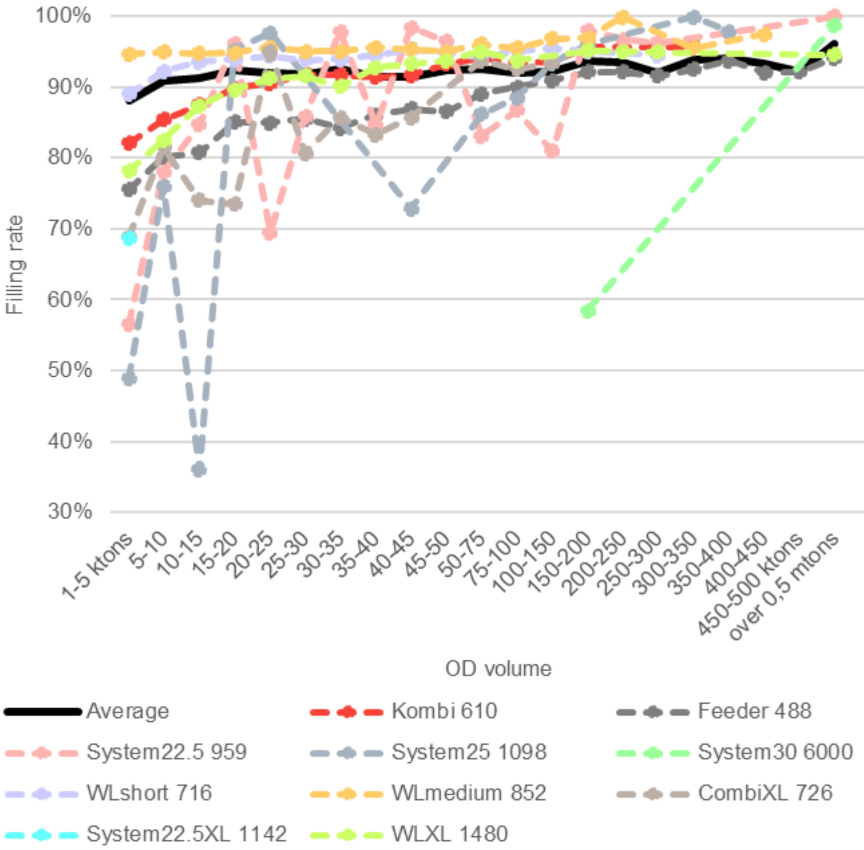


Figure 2: Average filling rate on OD relations after total volume

1.2.2 Consolidation rates from CoVo files

As a comparison, the relation between fill rate and goods volume per OD-relation according to the CoVo files and to the OD matrices can be seen in Figure 3 for vehicle D (combi train), with linear and logarithmic x-axes. Both sources share minimum and maximum values (60% and 98%, respectively) for consolidation rates, which is in line with Table 2.

Moreover, most relations have relatively low goods volumes with some relations having extremely high volumes. In both sources, the fill rate presents a logarithmic increase, as it grows more at lower volumes while the growth slows down at larger volumes. The diagrams with a logarithmic x-axis show that at lower volumes, the fill rate increases following an S-curve according to both sources. Moreover, the clustering of zones made in the CoVo procedure becomes apparent since it clear that several relations of similar size share the same fill rate.

The differences are explained by the fact that the two data sources represent different aggregation levels. The CoVo files contain fill rates for individual shipments and the OD matrices data show the average fill rate for all shipments in all commodities using combi train in the individual OD relations. Therefore, the OD matrices diagrams display fewer data points, but with higher OD volumes.

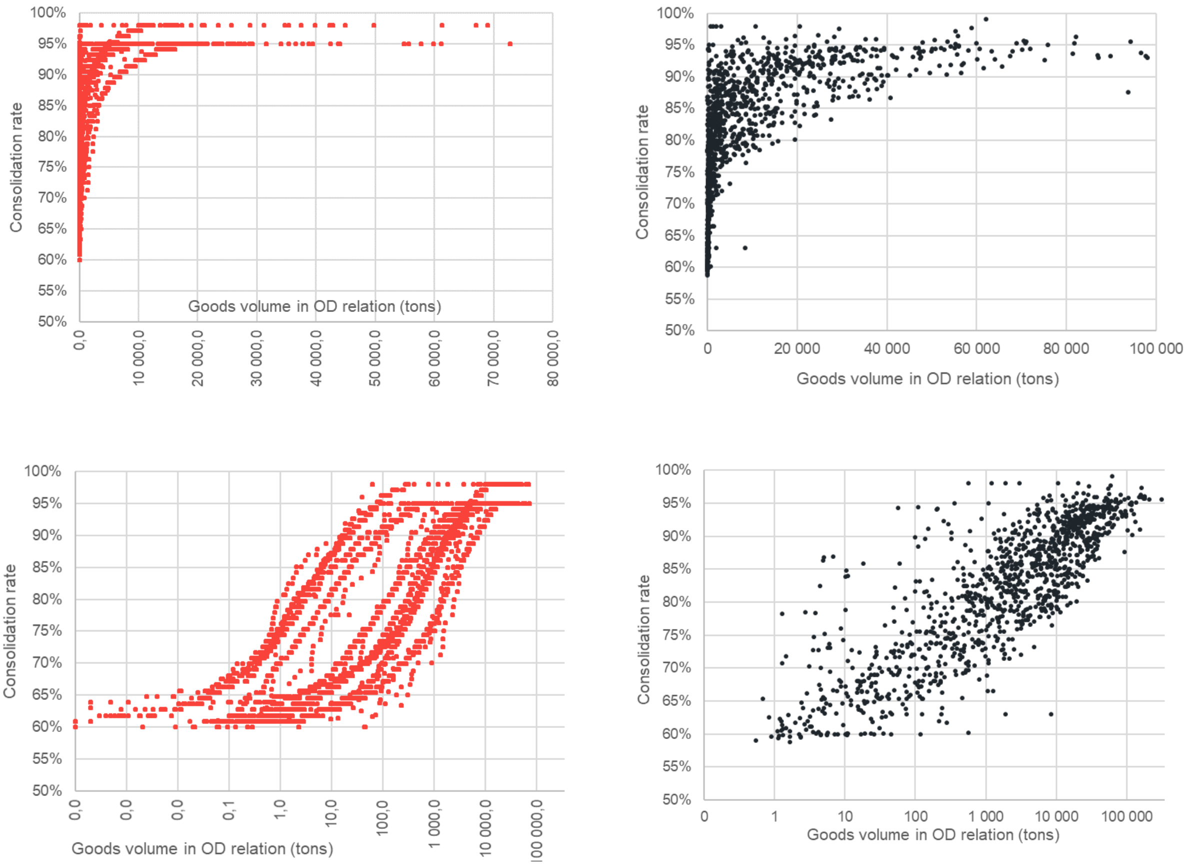


Figure 3: Scatterplots of the consolidation rate versus goods volume per OD relation for vehicle D (combi train, all commodities), according to data from the CoVo files (left) and the OD matrices (right). The lower diagrams display the same data as the upper ones, but with a logarithmic x-axis.

In Figure 5, similar plots are shown for each commodity type and sub-mode separately. The data is taken from the CoVo files. The S-shaped curves are obvious when looking at each commodity and sub-mode in isolation.

The results are explained by the information given in the previous chapter (see page 6). The goods volumes of the individual shipments are typically distributed around an average (typically small) volume. If this distribution is similar to a skew normal distribution (but of course without negative numbers), and the numbers are sorted in an ascending order and then assigned filling rates from a uniform distribution (as in Figure 4 below), the resulting scatter plot will typically look like in these diagrams.

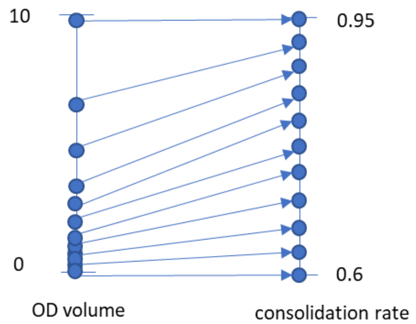


Figure 4: Illustration of the relation between OD volume and consolidation rates for a given vehicle and product group. The drawing shows how the model allocates consolidation rates to OD relations.

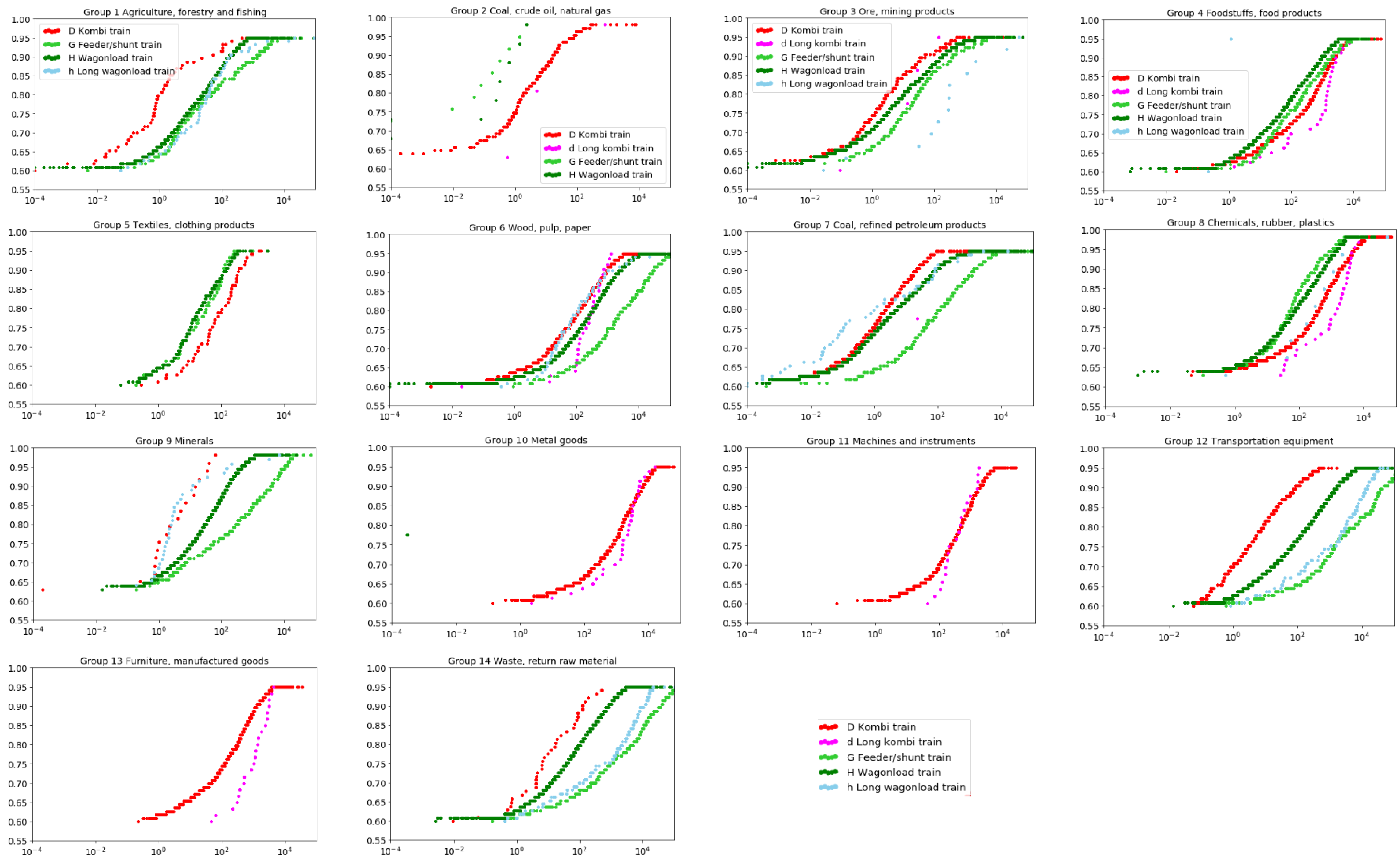
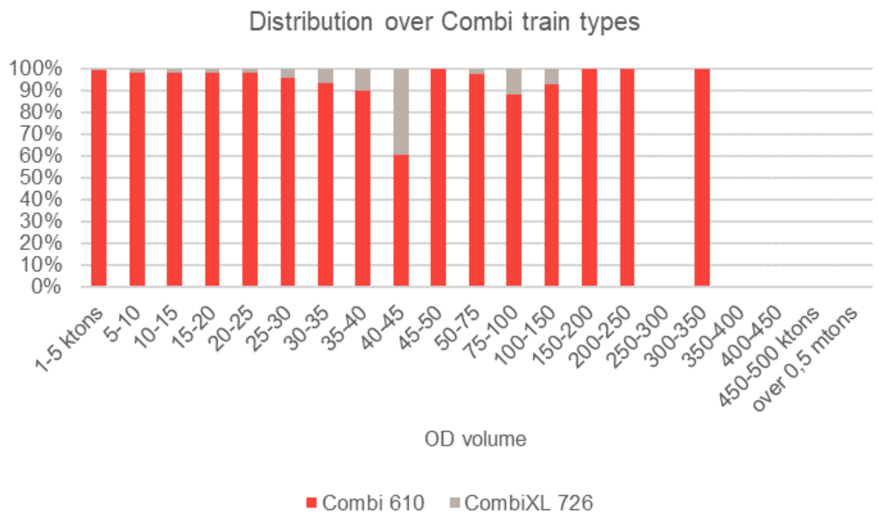


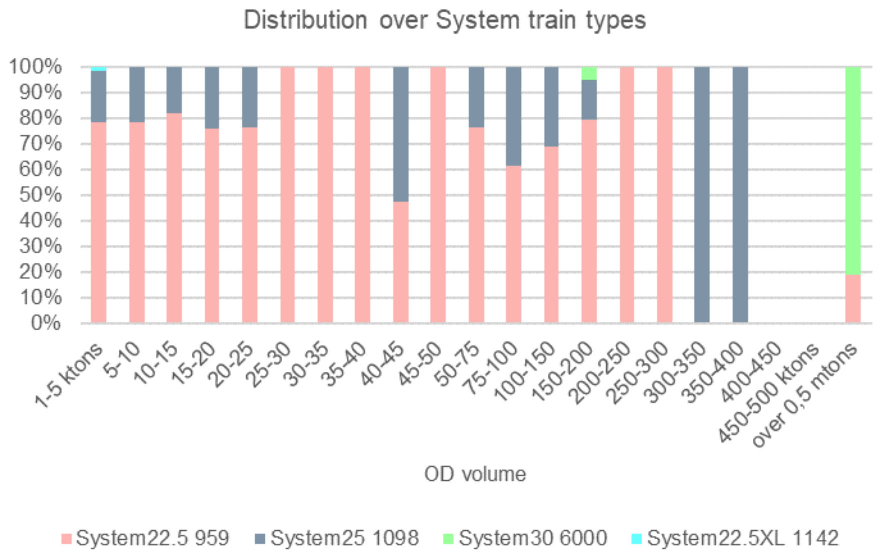
Figure 5: Scatterplots with the consolidation rate (y-axis) and goods volume (x axis, logarithmic) in OD-relations according to CoVo files, per commodity group and aggregate mode.

1.2.3 Vehicle sizes

It is not only the filling rate that determines the number of trains in the network, but also the choice of vehicle type. Like the hypothesis that larger OD volumes should imply higher filling rates, larger OD volumes should also imply larger vehicle types (longer trains). Therefore, the distribution over vehicle types per OD volume interval has been assessed, see Figure 6. Since the different "families" of train types do not compete entirely with each other in the allocation of goods to transport chains, results have been split by family – combi trains, wagon load trains and system trains.

- For combi trains, no clear relation between OD volume and vehicle size can be seen. One explanation could be that the extra-long combi trains are restricted to a (much) smaller network.
- The same goes for system trains, where the extra-long train is only chosen for the smallest OD relations. However, among the standard system train sizes, there is a tendency that the larger trains are used more on the largest OD relations.
- Regarding the wagon load trains, the shortest train is mainly used on smaller OD relations (up to 75 kton per year), while the medium size is used more on the medium relations. For the extra-long train, no clear pattern can be seen. The feeder train dominates on the largest relations.





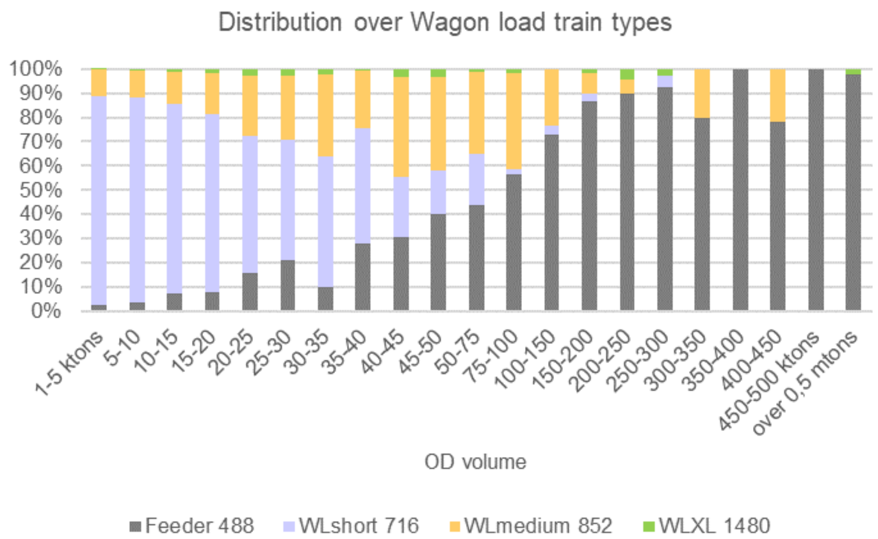


Figure 6: Vehicle size distribution by OD volume. Long wagon load trains (907 tons) have been left out since no goods is allocated to that vehicle type *MainSc2040*.

1.2.4 Shipment sizes

To combine the results on filling rates and on vehicle sizes, the average shipment size could be regarded, see Figure 7 which shows all vehicle types (except the STAX30 System train[6]) and the average, weighted by number of vehicles. The result shows that the shipment size does increase slightly with increased OD volume within each vehicle type, however the average does not reflect that trend. That is explained by the vehicle mix on each volume interval, see Figure 8. The major contributor to this result seems to be the feeder train, which is the smallest train type in terms of capacity, but constitutes a large share of the number of trains on the largest OD relations. It is the train type that carries the second most goods of all in total, after the STAX30 system trains.

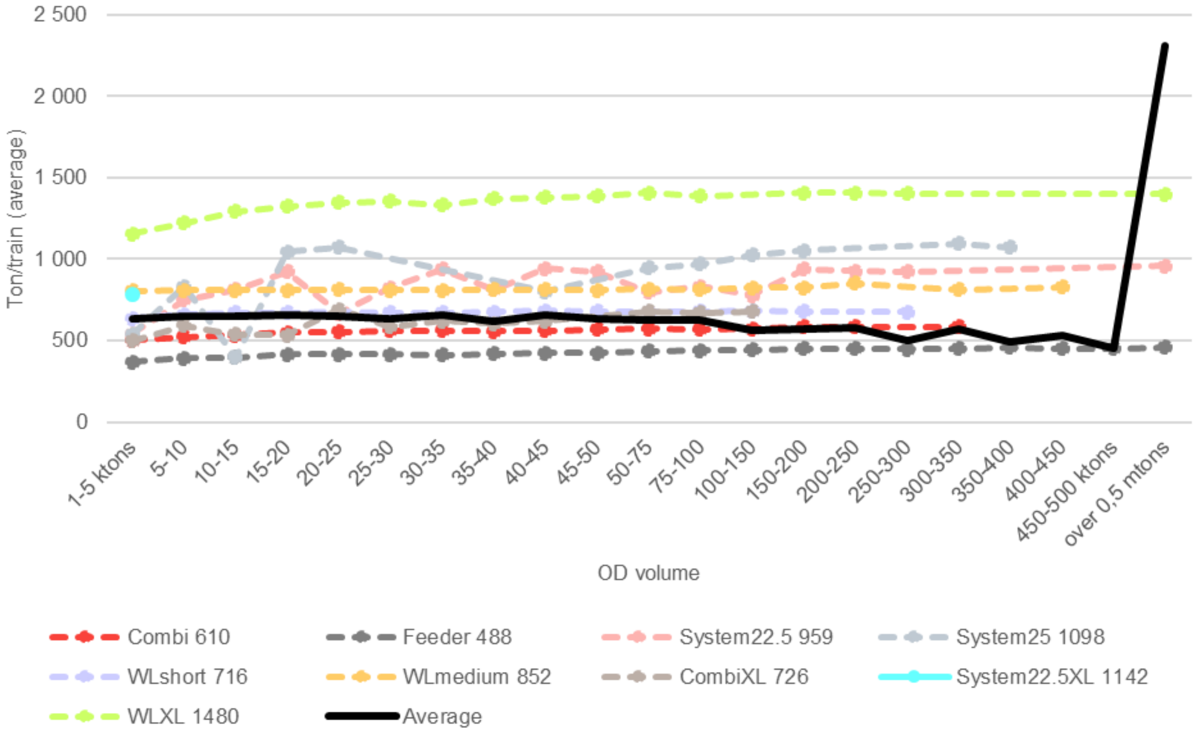


Figure 7: Average shipment sizes (tons per train) per vehicle types, distributed on OD relations by volume

6 For visbility reasons. This vehicle type of capacity 6000 tons is represented by two data points: 3500 tons/train on 150-200 kton OD relations and 5900 tons/train on >0,5 Mton OD relations. These averages are calculated based on a small number of relations

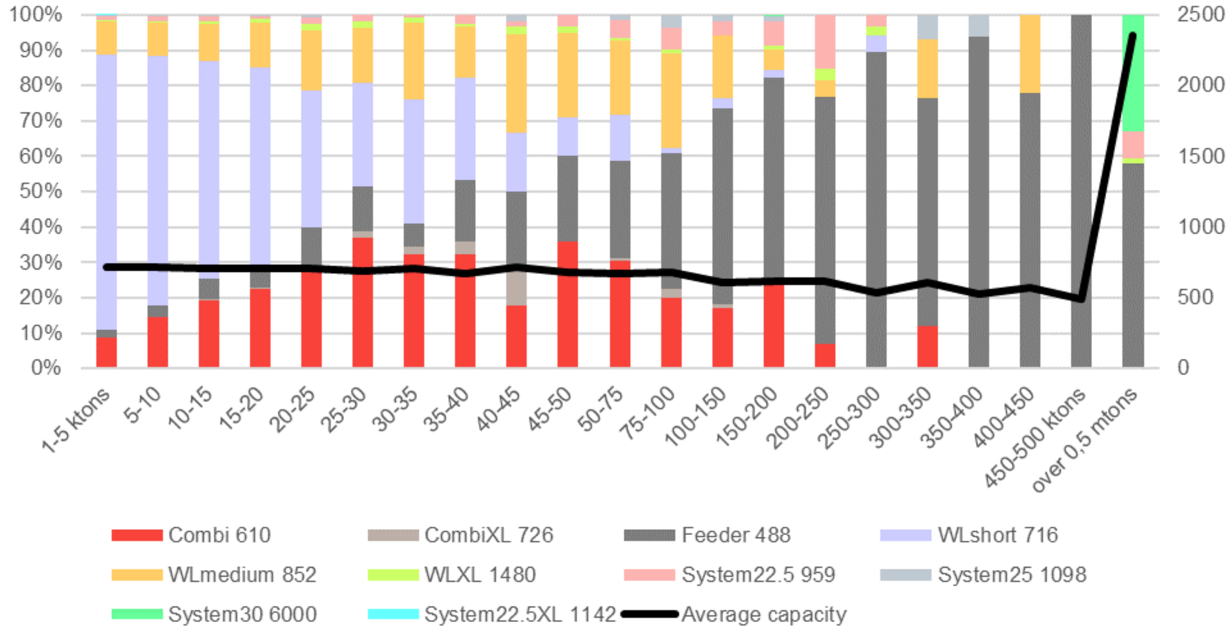


Figure 8: Distribution over all train types on OD relations by volume. The weighted average capacity per volume interval is given by the black line

1.3 CONCLUSIONS

Based on the findings from analysing the OD matrices, the aggregate filling rates (i.e. the transported volumes of goods compared to the combined capacity of non-empty trains in the network) per vehicle type are high. When breaking down the results to individual OD relations, sub-modes and commodities, there seems to be a general relation where higher OD volumes give higher filling rates. However, the *characteristics* of this relation is purely a consequence of assumptions made in the design of the consolidation rate estimation. Though it is a reasonable simplification that consolidated shipments are assigned consolidation rates from a uniform distribution, we have not found any justification that grounds this assumption in theory or empirical results. Therefore, we cannot recommend that relations are derived based on the results of the model, to use for modification of results (e.g. raising filling rates because of higher OD volumes with the purpose to obtain fewer trains).

A more promising path seems to be to analyse the choice of vehicle types more deeply. We have identified two main questions, that have not been possible to answer in this report but seem important to the vehicle levels in the network:

1. The model does not assign shipments to the new, extra-long train types on the OD relations with largest volumes. Actually, these vehicle types are scarcely used in general. What is the reason for that? The network for the XL trains is chosen strategically to capture relations where the demand is high. Why are these vehicle types not selected by the model?
2. Why is the vehicle type *Feeder/shunt train* dominating the large relations? Which are these relations? One would believe that in the real world, these trains are used on relations with less demand to transport goods into a consolidation node, where it is transhipped to larger/longer trains. But the results show that feeder trains dominate in large (volume-wise) relations. Another issue is that feeder trains are only allowed for containerised goods (there are no chain types including sub-mode E – Non-containerised feeder train), which also seems counter-intuitive. It is likely that a general overview of the chain types in combination with a deeper analysis of which vehicle types that are typically used on different links could give more insight to why model results show such high levels of trains in the network.

2 750-METER TRAINS

In *MainSc2040*, three new vehicle types have been introduced in Samgods version 1.2 (vehicle 210, 211 and 212, see Table 1). They represent a 750-meter combi train, wagonload train and system train and reflect the fact that parts of the Swedish rail network are being updated to accommodate longer trains. The new vehicle types are only allowed on certain rail links forming a triangle between Hallsberg, Göteborg and Malmö, see Figure 9.

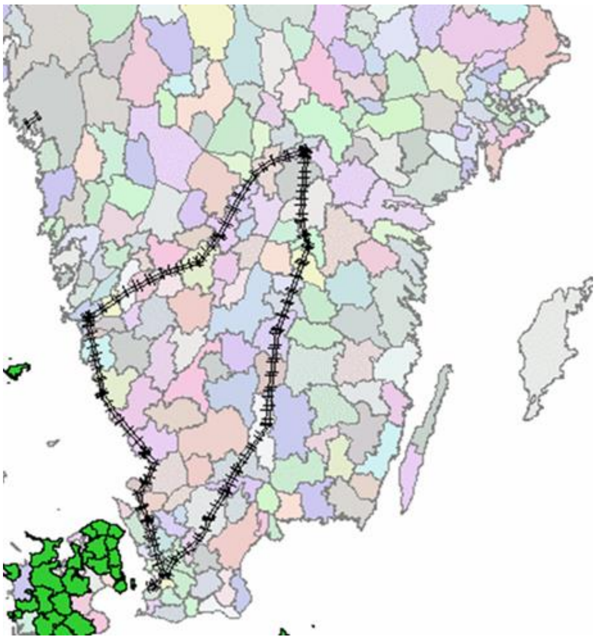


Figure 9: Samgods rail network for 750-meter trains

Before these vehicle types where introduced, the potential effect of longer trains travelling the network in 2040 was modelled by proxy. The capacity numbers (maximum number of trains per day and rail link) in the mentioned triangle was multiplied by the factor 750/630[7] to reflect the increased load capacity when longer trains are available. This approach was used when analysing the effects of the new high-speed rail network for passenger trains on the freight transport market.

The research question in this chapter is how the introduction of new vehicle types has affected the results in terms of vehicle and goods volumes in the network. Would using the new vehicle types instead of the proxy method give other results within the high-speed network analysis?

2.1 METHOD

Since the scenarios for the analysis of the new high-speed network have not been available in this analysis (they are currently only available for an older Samgods version), the relative effects have been assessed using the *MainSc2040* as a base scenario. In an alternative scenario, *Sc2040NoXL*, the new vehicle types were banned from the triangle and instead the capacity was raised by the 750/630 factor on the same links. The comparison between those scenarios is described below.

[7] The maximum length of the old rail vehicle types is 630 meters

2.2 RESULTS AND ANALYSIS

The effects on the overall results in total vehicle kilometres per mode and vehicle type (Samgods report 1[8]) are small. The proxy method gives 0.1 % less vehicle kilometres in total than the main scenario with extra-long trains. It gives 0.8 % more rail vehicle kilometres and 1.5 % more sea kilometres, see Figure 10. When looking at ton-kilometres, the scenario with extra-long trains has 0.8 % more goods on rail than the proxy method.

When breaking the results down to vehicle types, it is the combi trains and the short and medium wagonload trains that present the highest traffic flow (most vehicle-km) with the proxy method, and (except from the XL trains) the feeder/shunt train that travels the least (i.e. least vehicle-km). In *MainSc2040*, the extra-long trains represent around 2.6 % of all train vehicle kilometres, of which it is the extra-long wagonload train that dominates. The extra-long system train only travels 1000 vehicle kilometres in total in this scenario.

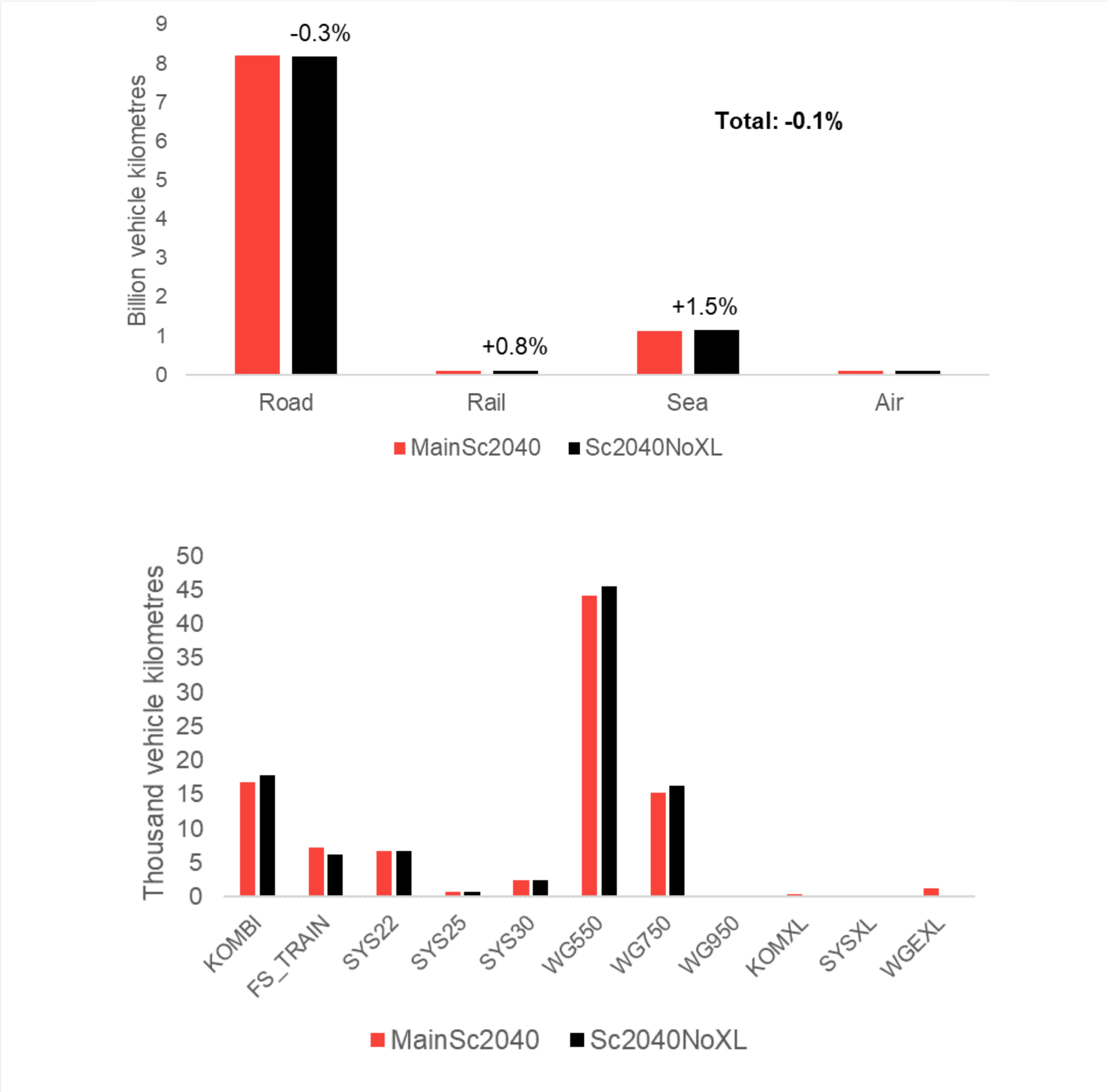


Figure 10: Effects on total vehicle kilometres per mode and train type

When comparing the results per link, only goods volumes (tons) per mode maps are available from the interface. Figure 11 shows tons on rail from the proxy method compared to the scenario with extra-long

[8] All results in this chapter are including the RCM step

trains. Red links have lower flows and green links have higher flows. It seems that on the relations Stockholm-Gothenburg, and Gothenburg-Malmö, the approach with extra-long trains give more railway transports than the proxy method. On the more southern route however, the proxy method gives more goods transported on railway.

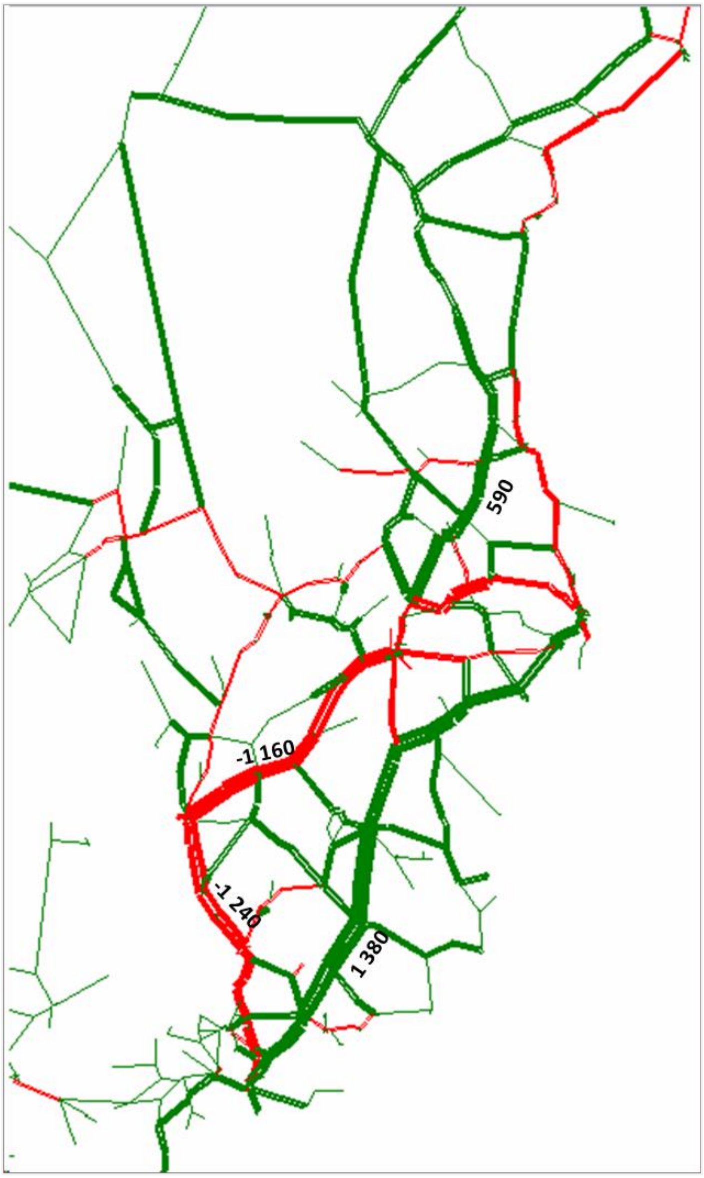


Figure 11: Results from the *Compare* function on the *Sc2040NoXL* scenario, compared to MainSc2040, for total goods volumes (ktons) on rail links.

To further investigate the utilisation of the extra-long trains, Figure 12-Figure 14 shows the number of trains (loaded + empty) in the network, split by extra-long combi trains, system trains and wagonload trains.

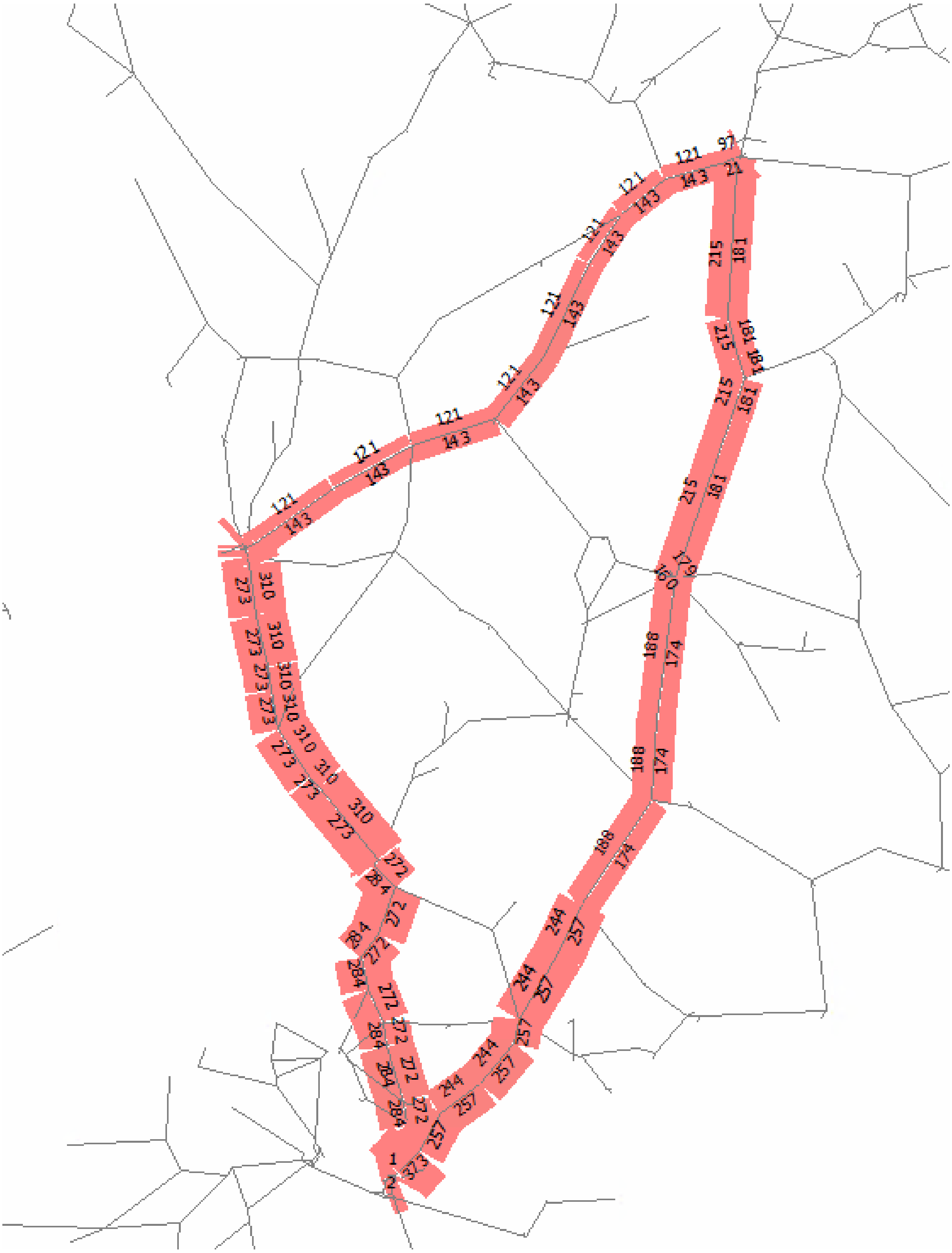


Figure 12: Extra-long combi trains (loaded + empty) per link, in *MainsSc2040*

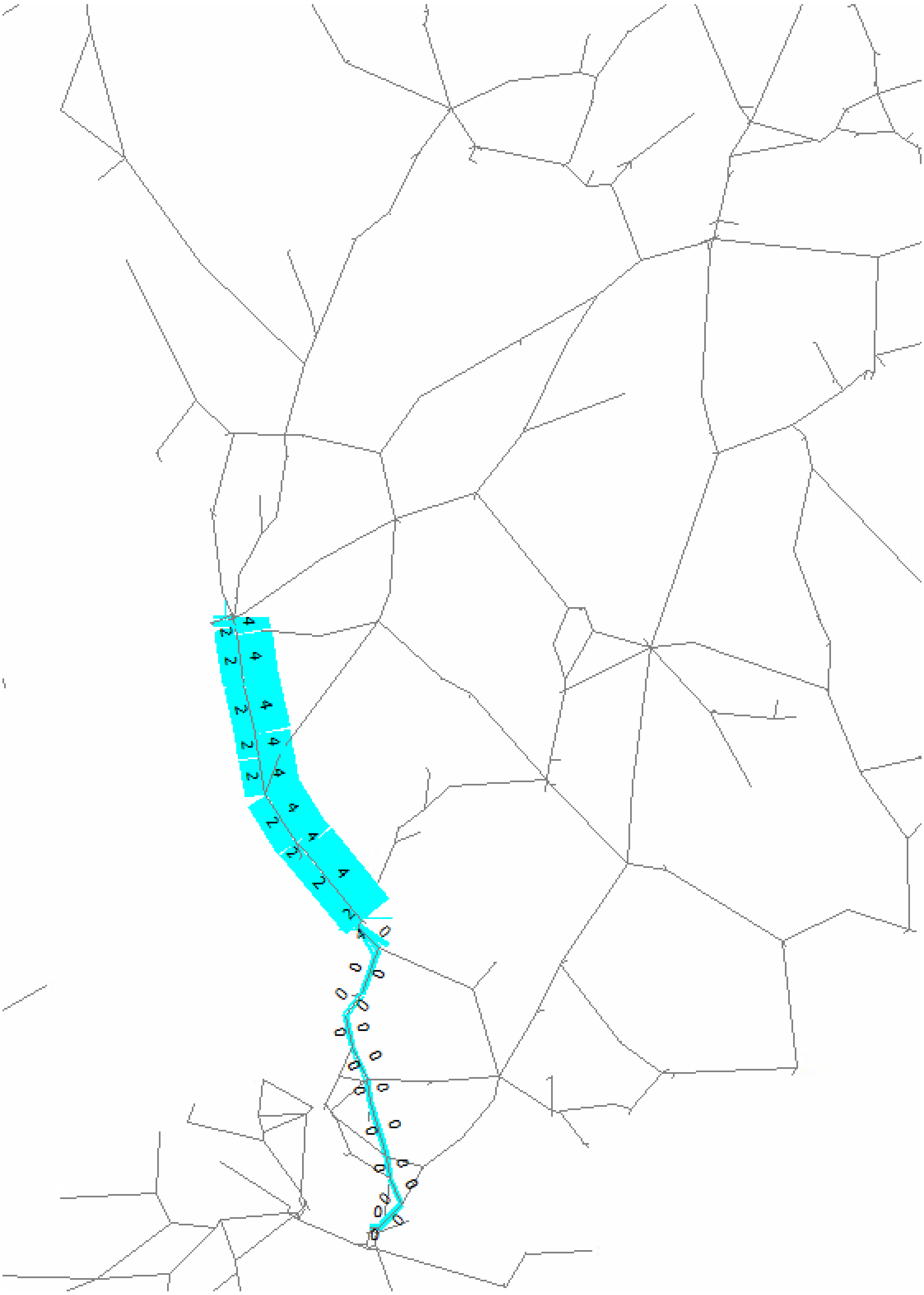


Figure 13: Extra-long system trains (loaded + empty) per link, in *MainsSc2040*

Figure 14: Extra-long wagonload trains (loaded + empty) per link, in *MainsSc2040*

2.3 CONCLUSIONS

To summarise, the results are not straightforward. Though the total number of vehicle kilometres by rail are lower when using extra-long trains instead of the proxy method, and the transport work on the other hand is higher, the difference is small and not necessarily outside the error margin of the model. Figure 11 shows that the transported goods volume by rail increase in some relations and decrease in others. Especially the extra-long system trains are only marginally used. It is hard to judge the potential effect on the high-speed network analysis results based on these results.

3 TERMINAL CAPACITY RESTRAINTS

The current version of the Samgods model does not have limited capacity in terminal handling. However, in the real world, terminals (which here include marshalling yards and loading sidings) do have limited capacity and could constitute bottlenecks in the railway system. This chapter is about how capacity restrictions in the nodes can be suitably represented by capacity restrictions in the Samgods link network. What would be the network effects of introducing these restrictions? Which flows will be affected?

The proposed idea is to introduce connector links to all affected railway terminals and introduce capacity restraints on these, so that flows that do not utilise the terminals are not affected. One challenge is to translate the capacity numbers for the terminals (maximal number of trains that can be handled each day) to capacity numbers for links, because the terminal capacity will probably depend on the type of handling (marshalling of wagons, loading/unloading of goods in system train wagons, lifting of containers on and off wagons, etc.), while the link capacity is given in number of trains regardless of vehicle type.

This solution is tested on 10 railway terminals, including the estimation of the terminals’ maximum capacity in 2040.

3.1 METHOD

Before the proposed method was tested, some initial analyses were carried out to explore the feasibility of the method when expanding it to many/all terminals in the Samgods network:

1. If connector links are to be used, it is helpful to know how terminals are already connected to the main railway network, and thus how many connector links that must be created.
2. To approach the challenge of calculating a combined capacity number for terminals with mixed handling, it is good to know the extent of multi-purpose terminals in the network versus the share of terminals that are specialised in one type of handling.

For question 1, all terminals in MainSc2040 were listed and the number of railway links connected to it was assessed.

For question 2, the terminal list was extended to include which types of goods handling that are allowed in each terminal. The handling types were categorised to marshalling, combi/container handling and other loading/unloading (system and wagonload trains), because these are the main categories of terminal operations. Based on the number of handling categories represented in each terminal, terminals can be divided into specialised (one main type of handling) and multi-purpose (two or more main types of handling) terminals. For specialised terminals, the capacity calculation will be more straight-forward than for multi-purpose terminals. Further, a comparison to real-world terminal facts could possibly result in an adjustment of terminal attributes and reduce the number of multi-purpose terminals, and possibly splitting some Samgods nodes into two or more separate nodes to better represent the real-world operations. Table 3 shows all handling types in Samgods and whether they allow train handling or not.

Table 3: Handling types for terminals. Terminals can have several types specified

Handling type	Rail terminal
Transfer Road Road	No
Transfer Road Train	Yes
Direct Feeder Train	Yes
Direct System Train	Yes
Transfer Road Combi	Yes
Container Handling	No
Transfer Feeder Train Wagonload	Yes
Transfer Road Sea	No
Transfer Combi Sea	Yes
Transfer Wagonload Sea	Yes
Direct Sea	No
Transfer Road Road Ferry	No
Transfer Wagonload Rail Ferry	Yes
Transfer Road Air	No
Transfer System Train Sea	Yes
Direct Wagonload	Yes
Transfer Sea Sea	No

For the test of the method, STA provided a list of 10 railway terminals that should be prioritised. Out of this list, one of the terminals is not included in the Samgods network and two are merged into one node. Therefore, two additional terminals were included. Those were selected from a top-list of railway terminals that handle the most goods according to *MainSc2040.*

The estimation of the terminals' maximum capacity was carried out in a workshop format, preceded by online data collection. Due to the limited time available for the estimation, no interviews or direct contacts with terminal operators has been done, even if this could have aided the estimations. Instead, the estimation relied on terminal and infrastructure data available online and railway experts' knowledge on terminal operations. Information on number of tracks, track lengths and design of yards and terminals has been collected from the BIS[9] system (STA, 2020a).

The estimation followed these steps for each one of the 10 terminals:

1. Find any previous estimation of the terminal's capacity, either by the terminal owner/operator, or by external studies of the node or terminal. If such information exists, the capacity number might be given in other units than the number of trains per day – e.g. the number of handled units yearly. In that case this step also included conversion to the correct unit for Samgods (trains/day). If no previous estimation was found, steps 2-6 below were carried out, before proceeding to step 7.

2. Identify which handling categories are offered in the terminal or node. The considered categories are marshalling, combi/container handling and other loading/unloading. This information was

[9] BIS (Baninformationssystem) is the STA's data system for storing and retrieving information on railway-related facilities and events.

retrieved from the terminals' and STA's webpages, as well as by studying satellite images of the node.

3. Identify which factors that affect the terminal's capacity in the long-term. "Long-term" is considered to imply around 20 years, so that the results can be valid for 2040. This scope excludes factors that area easily changed in the short-to middle term, such as staff and equipment. This is because it is assumed that those are likely to be increased if the terminal would experience an increased demand. A list of the set of factors that can affect handling capacity for each handling category was produced, as shown in Table 4.

Table 4: Identified factors that affect handling capacity for each handling category in the long term

Marshalling	Combi/container handling	Other loading/unloading
Number and length of tracks in the classification yard	Size of storage areas.	Number and length of loading sidings
Number and length of tracks in the arrival yard	Number and length of loading tracks	Number and length of tracks in the handover yard.
Number and length of tracks in the departure yard	Number and length of tracks in the handover yard.	
Whether there is a hump between the arrival and classification yards.[10]	Size of the manoeuvring/driving areas for trucks and/or reach stackers.	
Disposition of the arrival/departure yards in relation to the classification yard.[11]		
Opening hours[12]		
Layout of the connection to the main line[13]		

4. Collect data on these factors for each of the terminals. The factors related to infrastructure are collected by using STA's tool BIS, satellite images, and if available, other material from reports, the terminal's website, etc. On the other hand, opening hours are collected from the terminal's website. If not available, it is assumed terminals are allowed to operate through the night.

5. Identify any common bottlenecks in each of the terminals' infrastructure. This is done by studying the track layout of each node. Common bottlenecks could be e.g. a shared arrival/departure yard with limited capacity, or a switch or track that all arriving and departing trains need to use to go between the terminal and the main line. If such a bottleneck exists, the capacity is given by the maximum number of train movements on it per day.

6. If there is no common bottleneck, the capacity of all terminals in the node is estimated based on the factors that have been identified and collected in step 2 and 3. Please see the Results chapter

[10] This is because in the case when there is a hump, the movement of wagon groups into the classification yard is faster as these only need to be pushed through the hump. On the other hand, a flat yard (i.e. one without a hump) requires a lot of movements back and forth from the shunting locomotive.

[11] The layout of these yards affects the amount of movements that need to be carried out when a train is to be moved between the classification and the arrival/departure yard. For example, if the arrival and classification yards are located parallel to each other, the train needs to be shunted first out of the arrival yard into a dead-end track, and then back again into the classification yard.

[12] Certain intermodal terminals are only allowed to operate during daytime. This is because they are located close to urban/residential areas where noise regulations apply. This is seen as a long-term factor because it is a result of a node's location, which is not easily changed in the short- to medium term.

[13] The nature of the connection to the main line affects the number of movements needed to move a train between the main line and the arrival/departure yards or handover yard.

(chapter 3.2.1) for a complete description of the factors collected for each terminal and their respective sources. When several terminals exist within one node (without a common bottleneck), their respective capacities have been added.

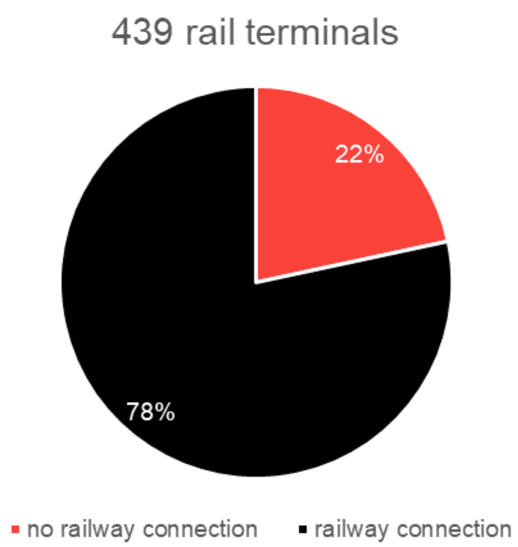
7. For some terminals, adjustment of transfer types in the node and minor adjustments of the connector links have also been suggested to better capture the configuration of the terminal

Finally, these capacity numbers (together with the other suggested adjustments) where implemented in the Samgods model in a copy of *MainSc2040* (Alternative scenario), the mode was run and the results were compared to *MainSc2040.*

3.2 RESULTS AND ANALYSIS

There are 439 terminals in *MainSc2040* that have train handling of at least one kind as specified in Table 3. However, 95 of these are not connected to the railway link network, and can thus not be accessed by trains, see Figure 15 (left). That leaves 344 terminals that have both train handling and are connected to the railway network (in Sweden and abroad). There are also 35 other terminals that *are* connected to the railway network, but do not have any handling of trains – these are not further considered in the analysis.

Of the 344 remaining terminals, 342 have only one railway link connected to them – i.e. nearly all train terminals already have a connector link which could be used for the capacity restraints. The other two terminals are, besides from their respective connector link, connected to each other, which should be easy to adjust in the network, see Figure 15 (right).



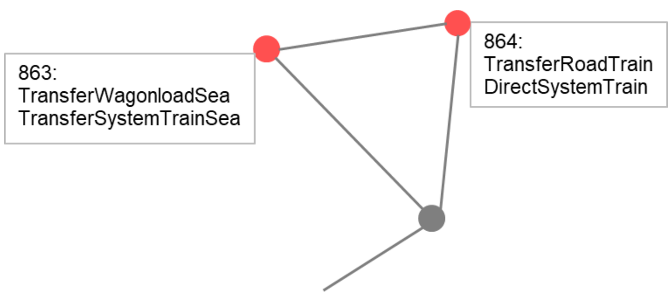


Figure 15: Rail terminals in *MainSc2040* and their connection to the railway network (left) and the only two terminals in the network with more than one railway connection (right)

Breaking the results down to terminal categories, the following assumptions have been made:

- Marshalling includes transfer types “transfer Feeder Train Wagonload” and “Transfer Wagonload Rail Ferry”
- Combi/container handling includes transfer types “Transfer Road Combi” and “Transfer Combi Sea”

– Other loading/unloading includes transfer types “Transfer Road Train”, “Direct Feeder Train”, “Direct System Train”, “Transfer Wagonload Sea”, “Transfer System Train Sea” and “Direct Wagonload”.

Out of the 344 terminals, one third are multi-purpose terminals, i.e. have transfer types in two or three categories. The frequency of the three categories are shown in Figure 16 (where terminals in the “multi-purpose” category are also accounted for in their respective other category (or categories).

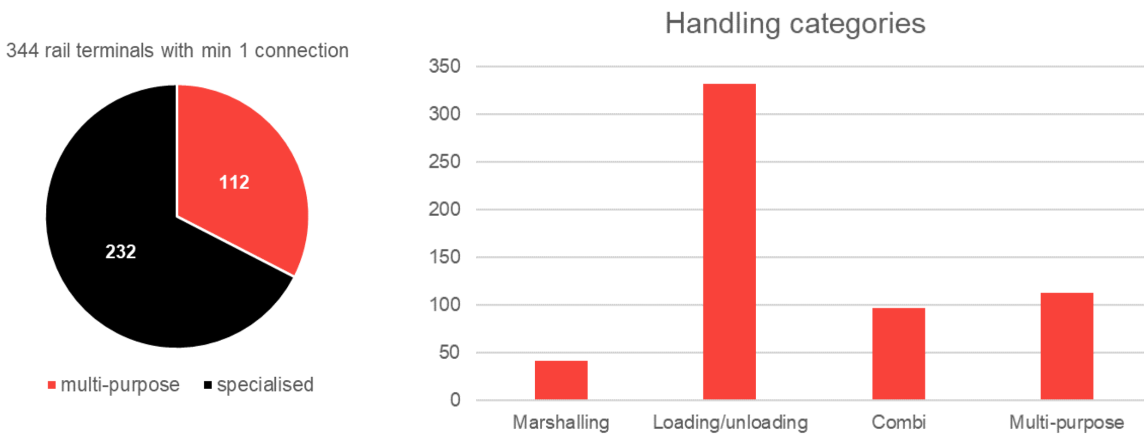


Figure 16: Number of terminals in different categories.

3.2.1 Terminals selected for test implementation

The following list was provided by the STA, to prioritise for capacity estimation:

– Priority 1: Malmö Marshalling Yard (1), Malmö Combi Terminal (2) and Port of Malmö (3). These three terminals are dependent on each other since all trains to and from the port and the combi terminal must pass the marshalling yard and therefore take up capacity there.

– Priority 2: Hallsberg Marshalling Yard (4), which is important to freight train in entire Sweden.

– Priority 3: Port of Gothenburg (5), since it is controlling how much goods that can be transhipped from rail to sea. Sävenäs Marshalling Yard (6), since it sets the level for how much goods that can be distributed by wagonload in the west of Sweden.

– Priority 4: Jordbro (7), since the flows in Samgods through this terminal increase much in previous analyses. Älmhult (8), which has a high demand combined with a high utilisation rate in the switch yard, and it has a combi terminal as well as indoor industry sidings. Falköping (9) which has a combi terminal and timber terminals, which is of interest for the STA, and Katrineholm Combi Terminal (10) which is a pure combi terminal and could be useful as a reference for other combi terminals.

Of these terminals, two had to be removed. Katrineholm Combi Terminal (10) is currently not included in the Samgods network, and Malmö Marshalling Yard and Malmö Combi Terminal are merged into one node in Samgods.

It has been checked which terminals with train handling that display the largest goods flows in *MainSc2040* (before and after the RCM step). The result for the 70 largest terminals is shown in Figure 17. The red labels represent the terminals selected by the STA (where “Malmö” represents the marshalling yard as well as the combi terminal). The black labels have been selected for analysis instead of the two removed nodes in the list. Stockholm-Årsta is a pure combi terminal and the combi terminal with the largest goods flows in *MainSc2040,* and it is proposed to replace Katrineholm in the list. Port of Stockholm has the largest goods flows in the model, after the port of Gothenburg and the two iron ore terminals in Kiruna and Gällivare (which are assumed to not limit the capacity in the long-term), while at the same time it is being moved from *Frihamnen* to the new port in *Norvik*. The capacity is limited, why it would be interesting to evaluate the effects of introducing a capacity restraint.

Below follow sub-chapters where the capacity estimation for each of the selected terminals is described.

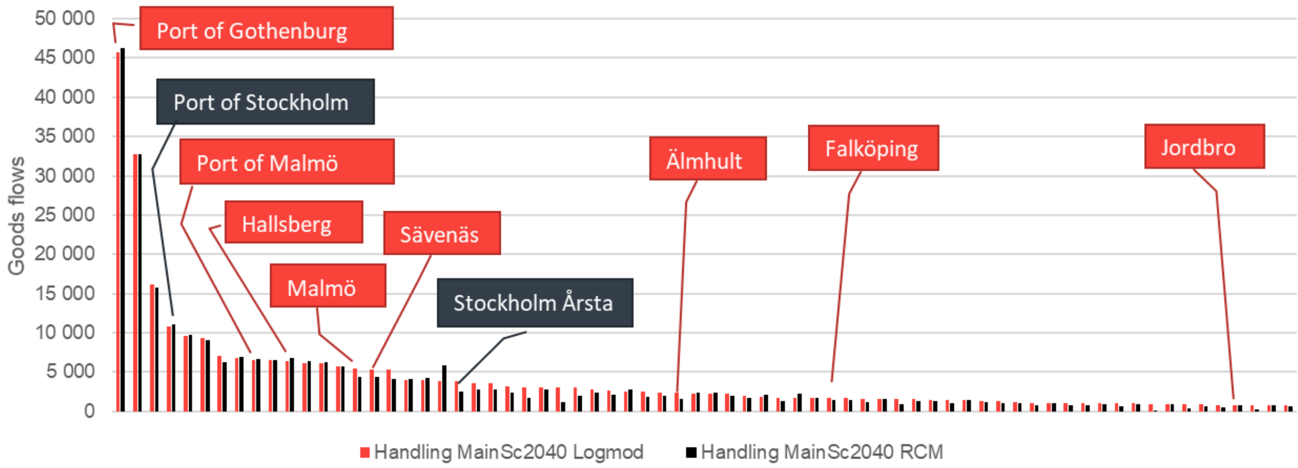


Figure 17: Goods flows per terminal according to *MainSc2040*

3.2.1.1 The Malmö nodes

In the city of Malmö there are three main freight railway nodes: Malmö marshalling yard (which also fills several other functions for freight trains passing through), Malmö combi terminal and the port of Malmö (CMP, Copenhagen Malmö Ports), where the latter two combined have several different types of loading sidings. Those nodes are highly dependent on each other, because trains to and from the port and the combi terminal must pass through the marshalling yard, and thus take up capacity there as well, see Figure 18. This means that the bottleneck is currently the marshalling yard´s arrival yard and is therefore the determinant for the entire node's capacity in terms of trains in and out per day.

However, by 2040 a new track (track 58) will be added to the arrival yard, which will allow many of the trains to access the port and combi terminal directly, and therefore occupy less capacity from the marshalling yard's arrival yard than today. This will free up capacity for marshalling as well as for accessing the two other terminals (STA, 2016a). With this new configuration, (though probably very simplified) it is assumed that the capacity at the marshalling yard is determined by itself, while the capacity of the port and combi terminals are determined by the capacity of track 58.

Figure 19 shows the current network configuration in Samgods, where node 828011 has the transfer types "Transfer Road Train" and "Transfer Road Combi", which probably represents the combi terminal as well as sidings for loading and unloading wagonload trains. The 828021 node represents the port and has transfer types "Transfer Combi Sea" and "Transfer Wagonload Sea". Note that the Malmö marshalling yard is not currently included in the Samgods network, since the transfer type "Transfer Feeder Train Wagonload" is not set in any of the two nodes.

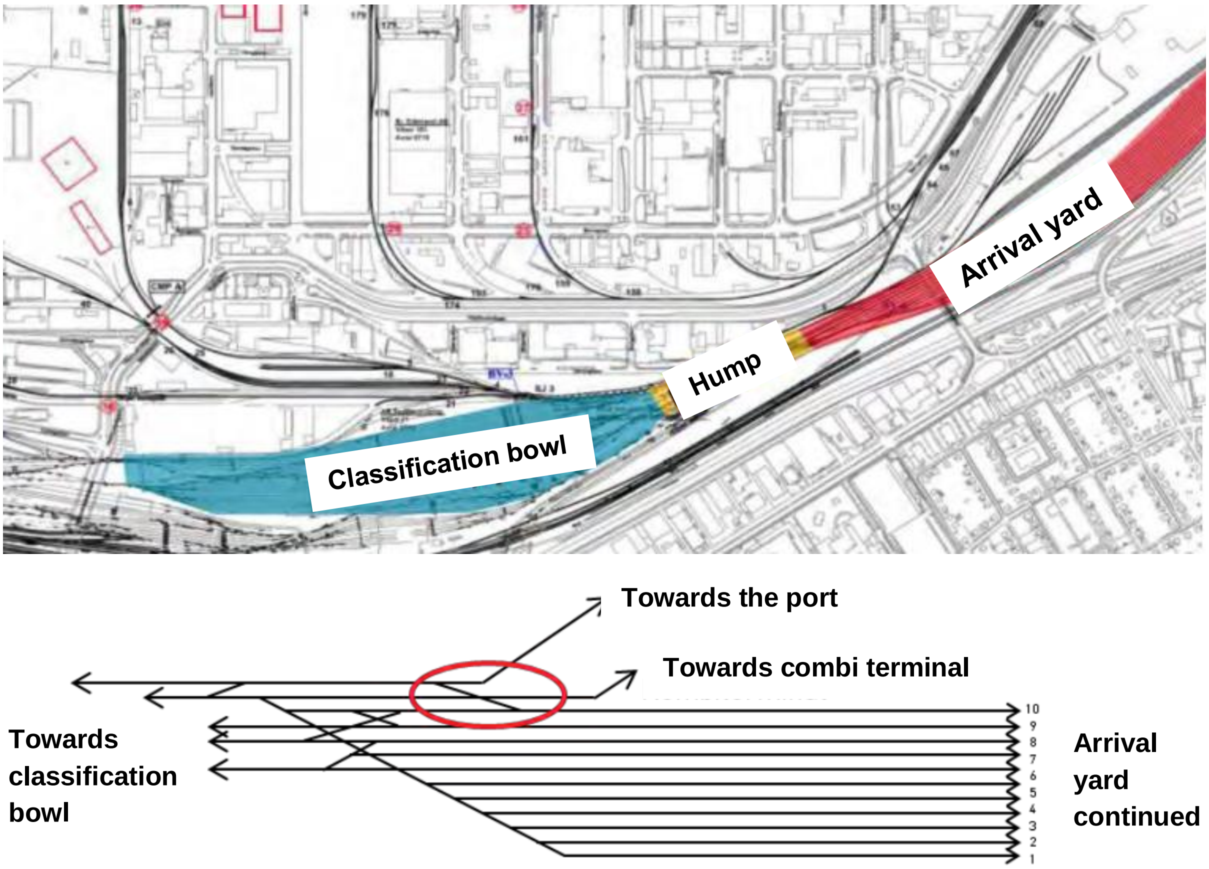


Figure 18: Illustration of the marshalling yard and the connections to the combi terminal and the port. Images adapted from Vectura (2012)

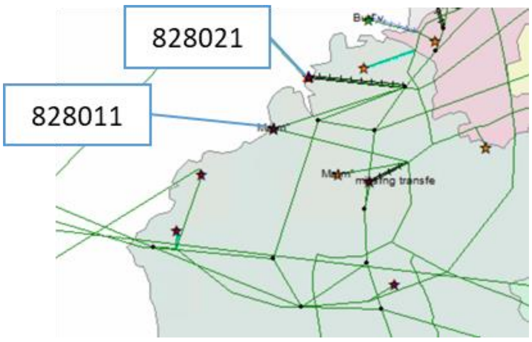
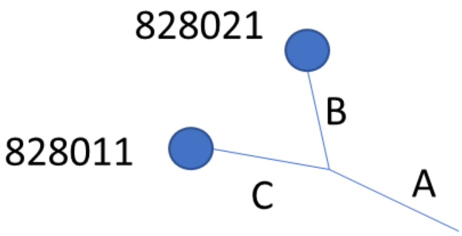


Figure 19: Current implementation in Samgods

To better represent the current situation (without track 58), the following edits are suggested for the base year:

1. Add transfer type "Transfer Feeder Train Wagonload" to node 828011, and remove the other transfer types from this node
2. Add transfer types "Transfer Road Train" and "Transfer Road Combi" to node 828021. Because of the network design, it makes more sense to have the combi terminal and the port in the same node, and the marshalling yard in a separate node

3. Remove the current connector links for the two nodes (i.e. the link that connects each node to the main network)
4. Add new connector links in a similar fashion to this (where A is the link connecting to the main network):



5. Add a capacity restraint to link A, which will be the combined capacity for the actual three nodes, and corresponds to the bottleneck of the arrival yard on the marshalling yard without track 58. This capacity has been estimated to around 30 trains per day (see below), which gives a bi-directional capacity of 60.

For this project however, the focus is the 2040 scenario which includes track 58. Therefore, the capacity of the marshalling yard should be separated from the capacity of the combi terminal and the port. We therefore suggest the following edits for 2040:

1–4. As above, but no network (link) additions are necessary since the two nodes and their connector links are already split in the current implementation.

5. Add a capacity restraint to link C, which corresponds to the capacity of the marshalling yard without the interference of trains accessing the port and combi terminal, which are now using track 58. This capacity has been estimated to around 30 trains per day (see below), which gives a bi-directional capacity of 60 trains per day.

6. Add another capacity restraint to link B, which corresponds to the capacity of track 58 which is now used for all trains accessing the port and the combi terminal. This track is estimated to be the bottleneck, since it is one single track that must handle all train movements to and from the port area, which has a large number of tracks for loading and unloading, as well as the combi terminal. It is estimated to be able to accommodate 2 train movements per hour, one in each direction, which gives a bi-directional capacity of 48 trains per day.

The capacity of the marshalling yard has been estimated based on a mix of sources. According to KTH (2014), 23 trains per day were marshalled here in 2013. Kreera (2019) describes the capacity situation in 2019 as “strained”. However, track 58 will add some capacity, which means the capacity in 2040 will be somewhat higher than today. If the Malmö marshalling yard is compared to the Hallsberg marshalling yard (whose capacity is around 50 trains per day, see separate chapter), Malmö has a smaller classification bowl (24 tracks vs. 32, i.e. 75 %), but also a combined arrival and departure yard which means even lower capacity. Trains coming from and heading to Europe/south must be turned in the yard which takes up more capacity (these are estimated to constitute around 1/3 of all trains in the yard since they are typically longer than trains to/from Sweden/north). The resulting capacity (30 trains per day) is estimated as the middle point between 23 and 37 (which is 75 % of 50), reflecting a higher capacity than 2013, and lower than what it would be if only the size of the classification bowl would limit the capacity. Given that all trains must arrive and depart, the bi-directional capacity of the connector link is set to 60 trains per day.

3.2.1.2 The Hallsberg nodes

Hallsberg has Sweden’s largest marshalling yard. There is also a combi terminal and loading sidings. These terminals are represented by node 886111 in Samgods, see Figure 20, which has transfer types

“Transfer Road Train”, Direct System Train”, “Transfer Road Combi” and “Transfer Feeder Train Wagonload”. STA points out that the marshalling yard and the combi terminal should not share the same capacity, which means that the current node must be split into two.

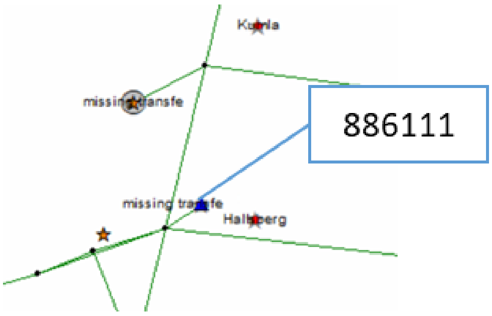


Figure 20: Current implementation in Samgods

In 2015, when Hallsberg had its latest peak in the number of marshalled trains per day, in average 46 trains arrived each day and 48 departed. At this point the maximum capacity is estimated to have been reached. However, around 2028 the arrival yard will be improved and expanded from eight to nine tracks, after which the capacity is expected to increase by 5-10 % (STA; 2020b). Therefore, the capacity in 2040 is estimated to 50 trains per day, which gives a bi-directional capacity restraint on the connector link *to the marshalling yard* of 100 trains per day.

The combi terminal has three full-length (around 720 meters) loading sidings and if operated most of all hours, four trains per day and siding could be handled, which gives a capacity of 12 trains per day. Since the connected railway yard is new, and it should also be possible to use capacity from the marshalling yard’s departure yard if not fully used, the loading sidings are likely to be the bottleneck to the combi terminal’s capacity.

We therefore suggest for 2040 that:

1. A new node is added to represent the marshalling yard. It is given the N=1378 (Voyayer network, 886112 in EMME network). The node does not need to be connected to the road network, only the rail network. The rail connector link is given the same attributes at the connector link to the 886111 node.
2. Transfer type “Transfer Feeder Train Wagonload” is moved from node 886111 to the new node.
3. The connector link for 886111 is given a bi-directional capacity of 24 trains per day.
4. The connector link for the new node is given a bi-directional capacity of 100 trains per day.

3.2.1.3 Port of Gothenburg

In the port of Gothenburg, there are many loading sidings for different types of goods, as well as a new combi terminal. Recently, the old combi terminal near Gothenburg central station was closed and replaced by the new one in the port area. The port of Gothenburg, along with a few other terminals (the refinery and the Volvo area) are accessed by the railway line *Hamnbanan*, which today is partly single-track but until 2040 will have double tracks all the way to the port. In Figure 21, node 848021 represents the port of Gothenburg with transfer types “Transfer Road Combi”, “Transfer Combi Sea” “Transfer Wagonload Sea” and “Transfer System Train Sea”. Node 848011 represents the old combi terminal, which no longer exists (its only transfer type is “Transfer Road Combi”, except “Container Handling”). Figure 22 gives an overview of the railway terminals and sidings in the port of Gothenburg, from the port’s network statement, appendix 1. Lengths of the sidings are also available in another appendix.

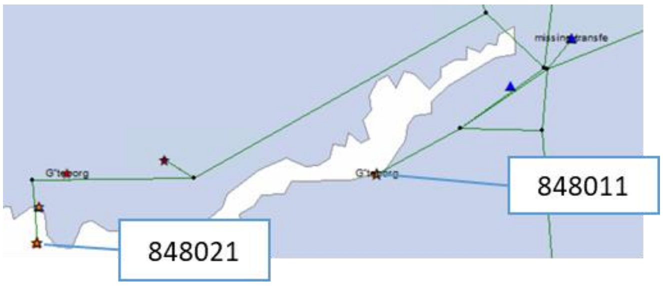


Figure 21: Current implementation in Samgods

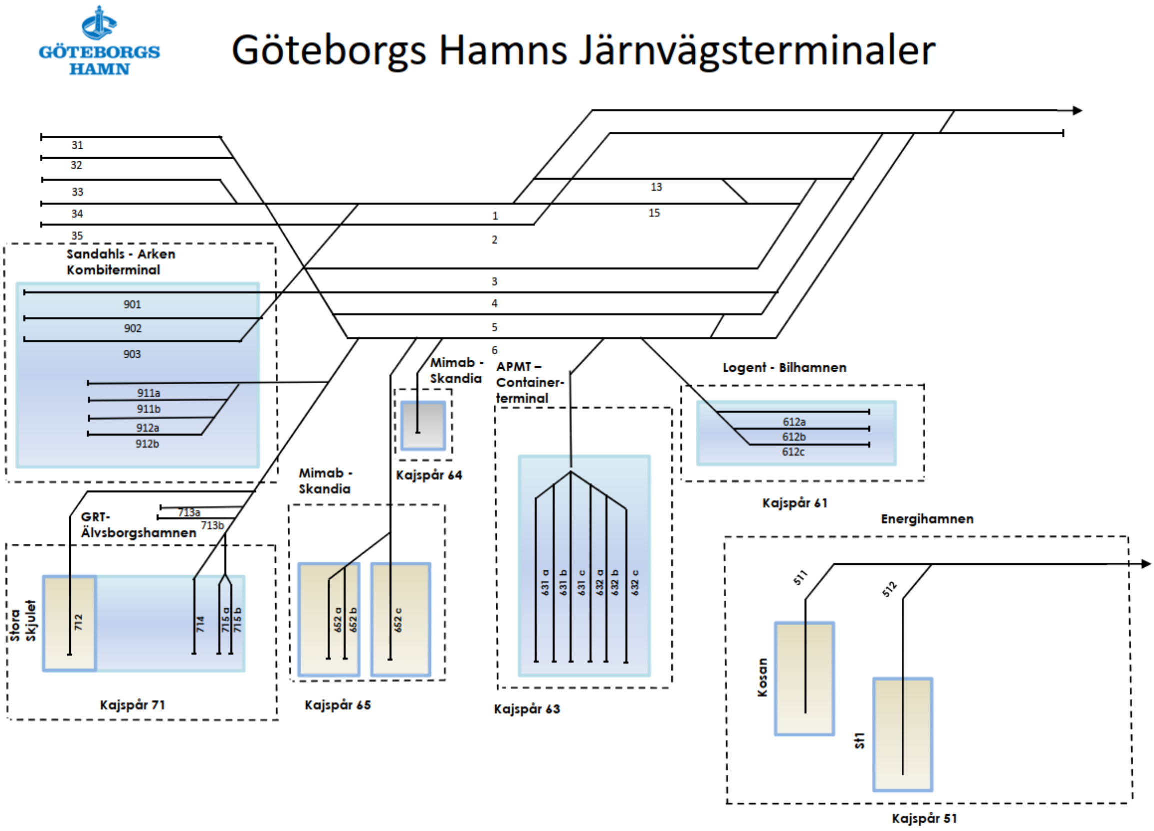


Figure 22: Railway terminals in the port of Gothenburg. From Göteborgs hamn (2019)

The port states on its webpage that, once fully developed, the combi terminal will have the capacity to handle 12 trains per day (Göteborgs hamn, 2020). Except from the combi terminal, the port has another six loading sidings in the APMT container terminal (see Figure 22). In the port's network statement, appendix 2, the operative process for container trains is illustrated, revealing that it takes four hours to handle a train including arrival, unloading/loading and departure. If operations run around the clock, it gives a maximum capacity of 36 trains per day in the port's container terminal. In Figure 22 there are another 14 loading sidings in the port, however many of them are shorter which means trains must be split, which reduces capacity, and furthermore, unloading/loading of other cargo takes longer than lifting containerised units. Therefore, it is assumed that each track can handle in average 1.5 trains per day.

In total, the above gives a maximum of 69 trains per day, which would occupy a capacity of 138 trains on the connector link. According to the current scenarios in Samgods, Hamnbanan today has a capacity of 108 trains, but with double tracks along its full length it will have capacity for 150 trains which is more than 138 trains. It is therefore suggested that in the 2040 scenario:

1. Node 848011 is removed[14]
2. The connector link to node 848021 is given the bi-directional capacity of 138 trains per day[15]
3. Hamnbanan (that also connects to other terminals) keeps its capacity of 150 trains per day

3.2.1.4 Sävenäs marshalling yard

Sävenäs is the main marshalling yard in the west of Sweden. Except the marshalling facilities, there are also loading sidings. The current implementation in Samgods includes node 848013, which has transfer types “Transfer Road train” and “Direct System Train”, but not “Transfer Feeder Train Wagonload”, which should be added to reflect that marshalling is taking place here.

Figure 23: Sävenäs marshalling yard in Samgods

Currently, the marshalling yard has capacity problems, but it is planned to be rebuilt before 2040 which will increase its capacity somewhat. According to an investigation by STA (2016b), the re-design of Sävenäs includes e.g. longer but fewer tracks in the arrival yard, fewer tracks in the classification bowl but of more homogenous lengths. Sävenäs does not have a separate departure yard. Trains departing to the east must pass the arrival yard to access the main line, and trains departing to the west must also be further handled in this area, which takes up extra capacity.

According to the timetable for 2019 (T19), 27 trains per day have the marshalling yard as their destination. However, that is not equivalent to all of them being marshalled there. According to KTH (2014), 21 trains per day were marshalled there in 2013.

It is estimated that after the renovation, Sävenäs will have about the same capacity for marshalling as Malmö. This is because they will have a similar set of tracks in the different yards, and different but equally severe constraints to the capacity which originate from the overall design of the respective yards. Thus, the capacity in 2040 is estimated to 30 trains per day, which gives a bi-directional capacity of 60 trains per day on the connector link in Samgods. Suggested edits:

1. Add transfer type “Transfer Feeder Train Wagonload” to node 848013
2. The connector link to node 848013 is given the bi-directional capacity of 60 trains per day.

3.2.1.5 Jordbro

Jordbro, south of Stockholm, is a node with a few loading sidings, both public ones provided by the STA and the municipality of Haninge, as well as industry sidings belonging to companies present in the node. In Samgods it is represented by node 713611, which has transfer types “Transfer Road Train”, “Direct Feeder Train” and “Direct System Train”.

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[14] In the model it was not possible to remove the node from the network as it resulted in errors during the run. Instead, the vehicle allowances for the rail link connecting to the terminal were set to 0, so that no rail vehicles can access the node

[15] In the voyager network this corresponds to link 386 – 74897 (where node 386 is equivalent to node 84821). The connector was not present in the capacity table before, so it is added and given the ID_LINK = 524

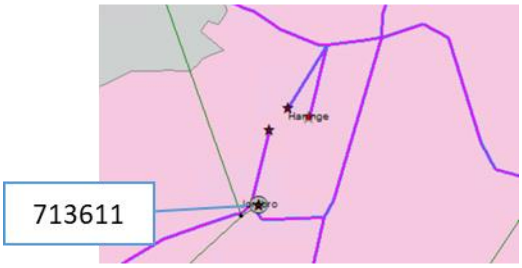


Figure 24: The Jordbro node in Samgods

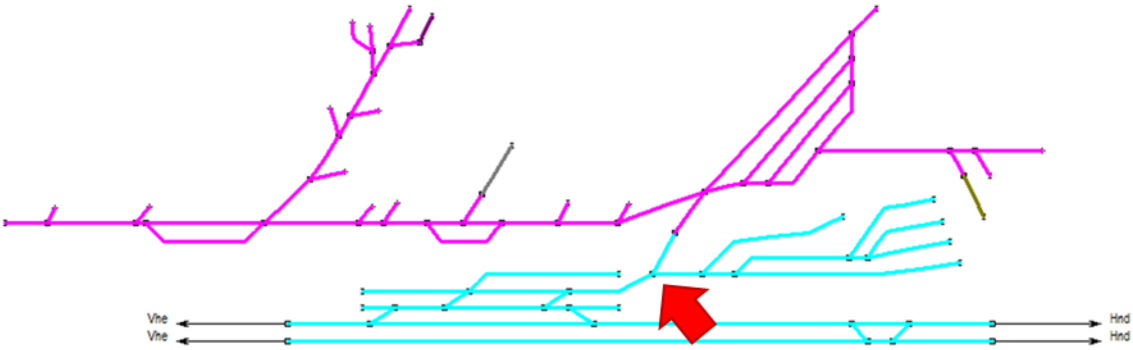


Figure 25: Sidings in the Jordbro node. The red arrow represents the switch that is currently a bottleneck for incoming and outgoing trains. Map from BIS (STA, 2020a)

According to the map of sidings provided by BIS (Figure 25), all access to the loading sidings must use the switch marked by the red arrow. Since there are a few loading sidings, the switch seems to be the bottleneck or the limiting factor to the node's capacity. Since the sidings are short, trains typically need to be split which means every arriving and departing train requires several shunt movements over the switch. Adding to this is the fact that wagonload wagons probably are spread between different sidings. The access of one full length train to the loading sidings (arrival and departure) will probably occupy the switch seven to eight hours, which means maximum three trains per day. Therefore, the bi-directional capacity on the connector link should be set to six trains per day. Suggested edits:

1. The connector link to node 713611 is given the bi-directional capacity of six trains per day.

3.2.1.6 Älmhult

In the Älmhult node, there is a combi terminal as well as loading sidings in connection to IKEA's warehouses, and there is a yard for shunting wagonload trains. In Samgods, the node 776511 has transfer types "Direct Feeder Train", "Transfer Road Combi" and "Transfer Feeder Train Wagonload". The STA states that the yard is busy today but there is also a demand to use it for more traffic.

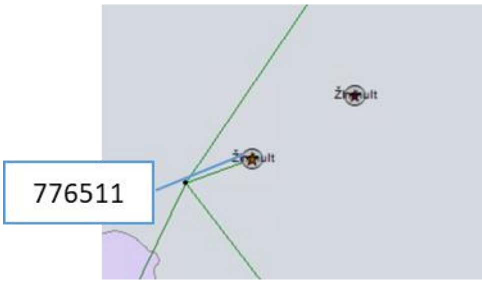


Figure 26: The Älmhult node in Samgods

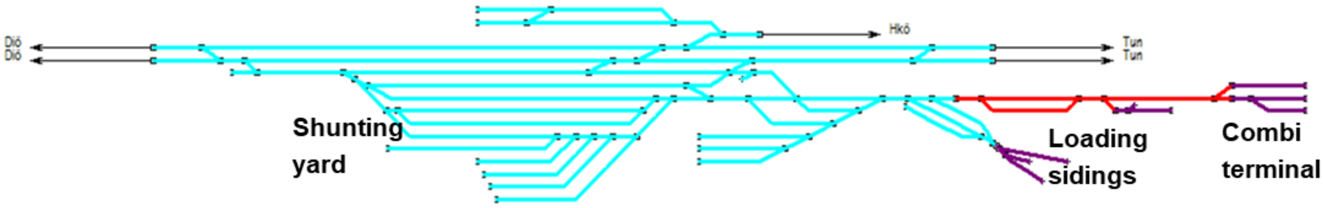


Figure 27: Map of tracks in the Älmhult node, from BIS (STA, 2020a)

Starting with the combi terminal, the loading sidings there are only little more than 400 meters long, which means the combi trains are probably split before pushed to the terminal along the long parallel siding, which will take up time, especially if wagonload trains are also accessing the IKEA sidings along the same track. There are three loading sidings in the combi terminal and if it is assumed that unloading and loading on one of the track takes half a day, the maximal capacity of the combi terminal will be three full-length trains per day.

IKEA's loading sidings include two full-length tracks and one shorter. The same time consumption for unloading and loading along a track is assumed as for the combi terminal – two trains per day and track. That implies four trains per day in total for the full-length tracks, and two halves of one train per day for the short track – in total five trains per day.

Third, the capacity for shunting in the shunting yard must be added to the total node capacity. However, the capacity in the yard is also consumed by the trains that are accessing (and in some cases, being split for) the combi terminal and industry sidings. The combi trains are estimated to consume six hours in total each day (three trains that are using the yard for both arrival, split and departure). The wagonload trains that are accessing the IKEA industry sidings are assumed to use 20 minutes each for arrival and 10 minutes each for departure – this applies to the four long trains that do not need to be split. The short train is assumed to use 1.5 hours in total. This means that in total 10 hours, of around 20 available hours in a day, is taken up by the already mentioned trains. That leaves another 10 hours for shunting additional trains, which should suffice for around three trains per day, given the available tracks. This assumes that they are not full-length trains (750 meters).

The combined node capacity is thus estimated to 11 trains per day, or a bi-directional capacity of 22 trains. Suggested edits:

1. The connector link to node 776511 is given the bi-directional capacity of 22 trains per day.

3.2.1.7 Falköping

In Falköping there is a combi terminal as well as terminals for timber. In Samgods the node is represented by 849911, with transfer types "Transfer Road Train", "Direct Feeder Train" and "Direct System Train", which means combi handling should be added.

Figure 28: The Falköping node in Samgods

In the combi terminal, there are two sidings of length 595-645 meters – i.e. not full-length (750 meters) but long enough to assume trains are not split – it is thus assumed that combi trains that use this terminal are little longer than 600 meters maximum. If unloading and loading of one train takes six hours, the terminal should be able to handle in total six trains per day, assuming it is not open the full 24 hours of the day.

There are two timber terminals, one for company A (green) and one for B (purple in Figure 29). The one belonging to B is longer and assumed to take one full-length train, while the shorter A sidings are assumed to take two halves of one full-length train.

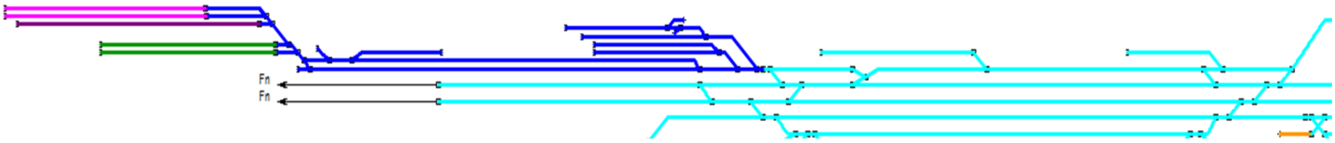


Figure 29: Map of the sidings in the Falköping node (the area of the other side of the main tracks (Västra Stambanan) have not been included since they are not used for terminal operation). Map from BIS (STA, 2020a)

The full-length train at the B siding is assumed to need around four hours for loading, which gives a capacity of four trains per day. For the shorter A sidings, the procedure takes more time since it must be split and turned (they are assumed to arrive from/depart to the north, as opposed to the B trains that are assumed to go south). Therefore, these sidings are only given the capacity of three full trains per day.

In total, that gives a node capacity of 13 trains per day, or a bi-directional link capacity of 26. This assumes that arrivals and departures are spread out over the day. The yard's capacity is very limited, which makes the operations vulnerable if many trains had to use the yard simultaneously.

There are also a few shorter loading/industry sidings (dark blue in Figure 29). However, since the already mentioned 13 trains are estimated to use the yard for around 12 hours, it would probably be difficult to use those sidings while the already mentioned terminals are used to the maximum as well. Suggested edits:

1. Add transfer type “Transfer Road Combi” to node 849911
2. The connector link to node 849911 is given the bi-directional capacity of 26 trains per day.

3.2.1.8 Stockholm-Årsta combi terminal

In Årsta, there is a combi terminal which has no other types of operations. This is also reflected by the implementation in Samgods, where node 718012 has the single transfer type “Transfer Road Combi”.

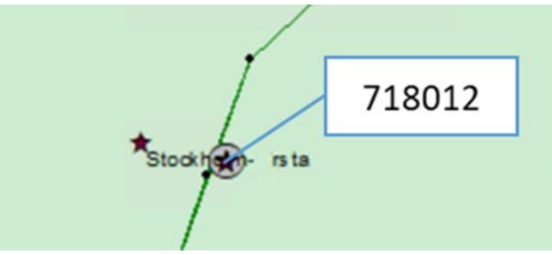


Figure 30: The Årsta combi terminal in Samgods

In its commercial materials (see Jernhusen), the terminals capacity is stated as 120 000 units per year. The following averages are assumed:

- 1.8 TEU/unit (which implies most handled units are 40ft containers and trailers)
- 75 TEUs per train (which implies train lengths at around 560 meters – the length of the loading sidings at the combi terminal are roughly of that length – with longer trains they must be split in halves which is not assumed here)
- Operations 250 days per year, since the terminal is in an area with a high degree of housing

This would translate the capacity to around seven trains per day, or a bi-directional connector link capacity of 14 trains per day. Suggested edits:

1. The connector link to node 718012 is given the bi-directional capacity of 14 trains per day.

3.2.1.9 Port of Stockholm

The old container port in Stockholm is represented by node 718021 in Samgods, see Figure 31. However, since the Port of Stockholm opened its new container port in Norvik south of Stockholm, the old port has been closed. Therefore, it is suggested that node 718021 is removed in the 2040 scenario, and replaced by a new node in Norvik. The capacity constraint derived below applies to the Norvik node.

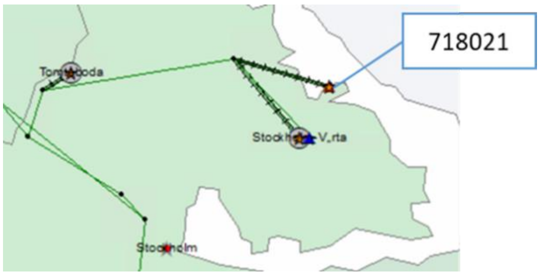


Figure 31: Current implementation in Samgods

However, during the analysis, it was found that the main part of the goods handled in Port of Stockholm (Frihamnen) in Samgods *MainSc2040* was not transported by rail. Further, the connector link to node 718021 is only open to a few train types, not including combi. The new Norvik node should be connected to the railway between Jordbro and Nynäshamn. However, this railway is not open to any vehicle types in *MainSc2040.* Further, the link connecting Jordbro to Älvsjö is also only open to a few train types, not including combi. This means that moving the node requires many network edits, that have the potential to affect the Samgods results in ways that are not intended by this analysis. Since the rail flows through the old node turned out to be very limited (possibly due to the restricted use of the connector link), it was decided to not include the edits as part of this analysis. It is still recommended that the STA makes the edits in the model, but they should be carried out with knowledge of why the current link restrictions are configured as they currently are. The capacity estimation of the Norvik node is still included below.

The Norvik port is connected to the railway system by a 4400-meter industry siding, which includes a yard with three 750-meter tracks and two 360-meter loading sidings in the container terminal (Stockholms hamnar, 2020).

Since the loading sidings are short, the train needs to be split. During the unloading/loading, the next train could wait at the yard. Compared to the container terminal in the port of Gothenburg, loading/unloading is assumed to take longer in Norvik since there are no portal cranes and reach stackers must be used instead – it is therefore assumed a train takes five hours instead of four. Since the port is located in a remote area, operations should be able to continue around the clock which gives a maximum capacity at around five trains per day (this assumes only containers are handled), or a bi-directional capacity of 10 trains per day on the connector link. It is possible that the infrastructure and facilities around the port will be expanded in the next 20 years, since the port just recently opened. But since there is no official information on the dimensions and characteristics of such an expansion, it has not been included in this analysis.

3.2.1.10 Summary

Figure 32 summarises the estimated capacities in this report. The marshalling yards (Malmö, Hallsberg and Sävenäs) and the large ports with substantial railway infrastructure (Gothenburg and Malmö) stand out in terms of capacity. Other nodes (combi terminals and industry/loading sidings) have lower capacity, measured in trains per day. Please note that the Hallsberg combi terminal is represented by separate bar from the marshalling yard, corresponding to the suggested split of the current Hallsberg node into two.

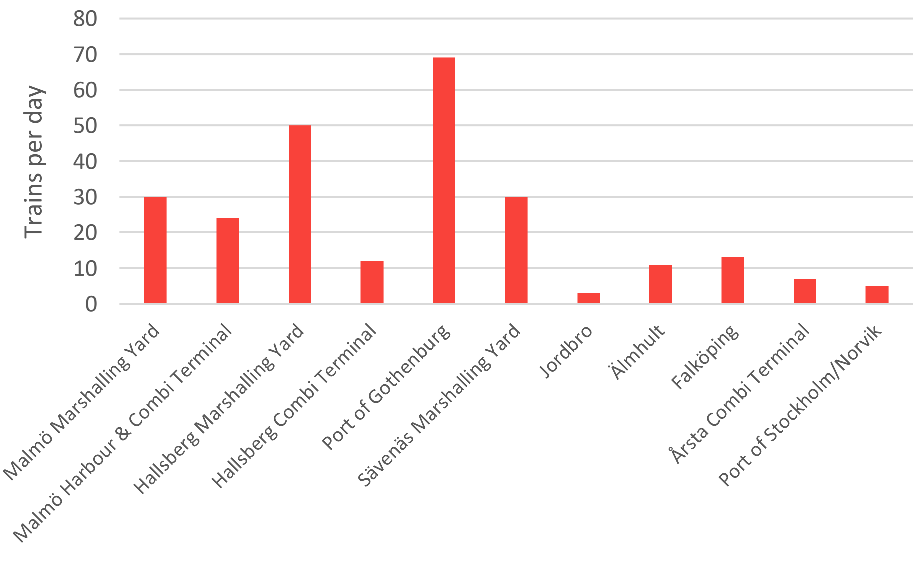


Figure 32: Summary of estimated terminal capacities. The number refers to the number of trains handled in the terminal. If counting arriving and departing trains separately (as will be done on the connector links), the numbers must be multiplied by two.

3.2.2 Samgods run result

The scenario with terminal capacity (Sc2040TerminalKap) presents a decrease in domestic total vehicle-kilometers for rail of almost one million vehicle kilometres, or -2.2%. At the same time, there is a slight increase in vehicle kilometres for road and sea transports, as shown in Table 5. This corresponds to the result that was expected, i.e. that a limit on node capacities would decrease the amount of trains in the network.

Table 5: Thousand vehicle kilometers per mode in base scenario and in the alternative scenario with restricted node capacities.

VEH_CLASS	Main scenario	Sc2040 TerminalKap	Alternative - Main	Alternative vs Main
TotLorry	4 008 386	4 023 559	15 173	0.4%
TotRail	56 698	55 434	-1 265	-2.2%
TotSea	118 902	119 651	749	0.6%

Figure 33 shows the comparison map for the goods volumes[16] transported per link between the alternative scenario (Sc2040TerminalKap) and the main scenario. The effect from the changes in terminal capacity in goods volumes can be seen throughout the network. The largest decrease is observed in the Southern Main Line (Södra Stambanan). At the same time, there is a slight increase in goods volumes in some parts of the network, most visible around the Gothenburg area.

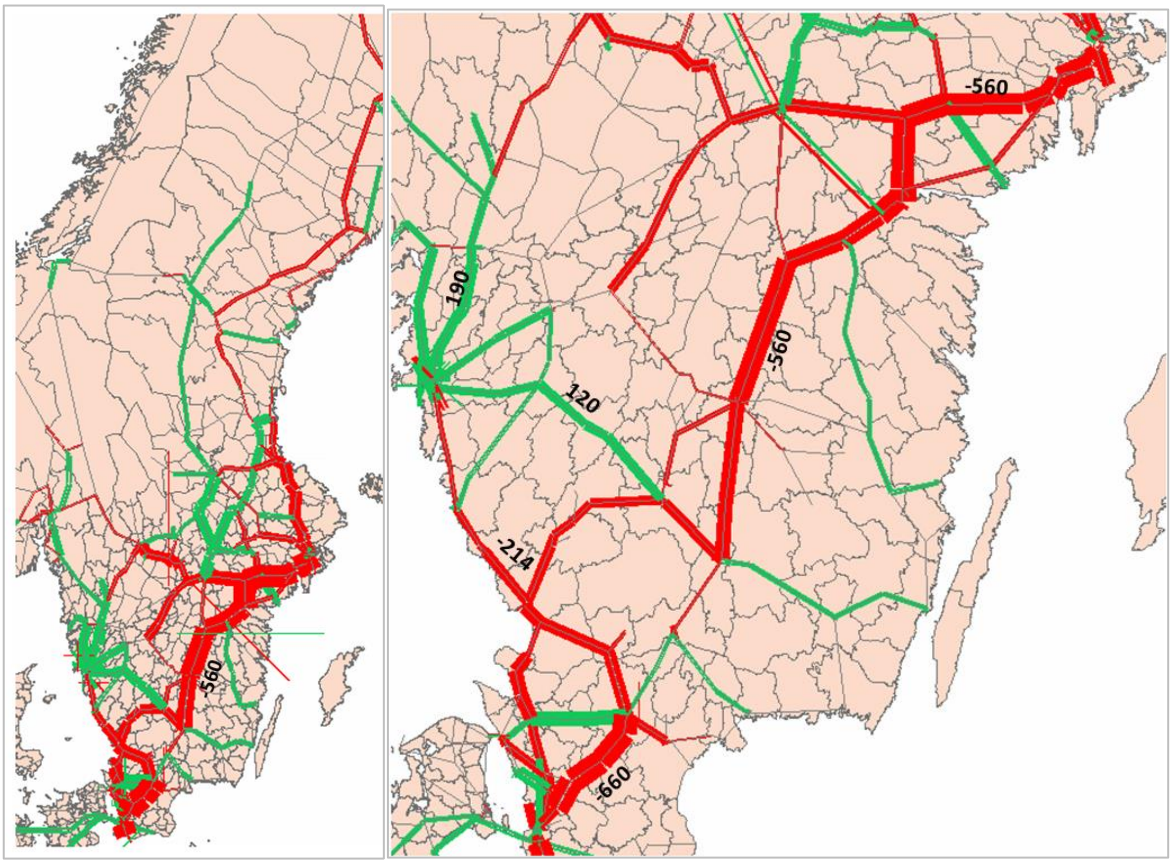


Figure 33: Comparison map for goods volumes (kton per year) in scenario Sc2040TerminalKap vs MainSc2040.

[16] Samgods does not produce results in map form for the comparison of the number of vehicles in different scenarios, it only produces comparison maps for goods volumes.

In the alternative scenario, the number of trains increases in the port of Gothenburg, the Malmö and Hallsberg nodes as well as the Gothenburg combi terminal (when comparing to both the old and new terminals in MainSc2040). On the other hand, the number of trains in Jordbro, Älmhult, Falköping and Stockholm Årsta decrease, although at a comparatively lower degree.

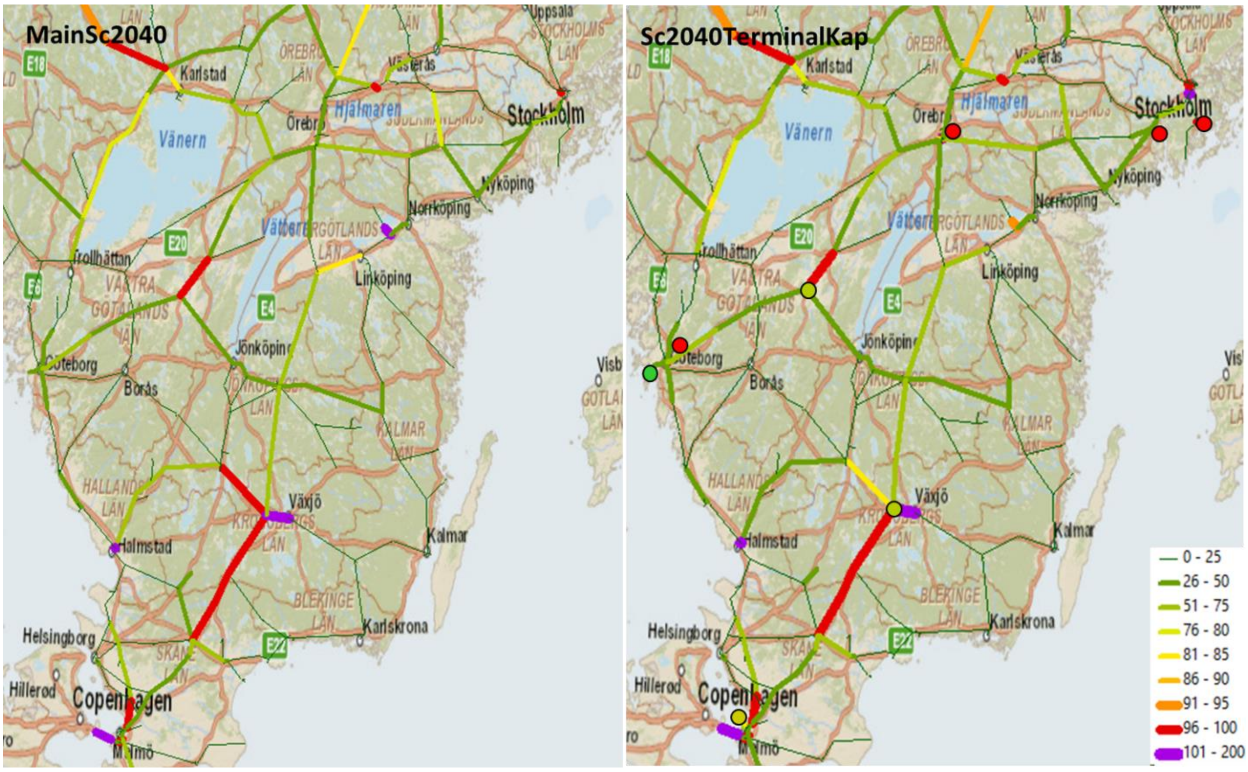
Table 6: Capacity and number of trains per day (bidirectional) in the connector links to the selected terminals, MainSc2040 and SSc2040TerminalKap

Node	Capacity Restriction		Nr of trains per day		
	MainSc2040	Alternative (SSc2040TerminalKap)	MainSc2040	Alternative (SSc2040TerminalKap)	Alternative - Main
Port of Gothenburg	-	138	38	49	10
Gothenburg, old combi terminal	-	-	15	-	(-15)
Göteborg Sävenäs combi	-	60	34	60	26
Malmö nodes	-	118	44	72	29
Hallsberg nodes	-	124	110	120	10
Jordbro	-	6	11	6	-5
Älmhult	-	22	16	13	-3
Falköping	-	26	19.0	18.6	-0.4
Stockholm Årsta Combi	-	14	21.4	14.0	-7.4

The rail capacity utilization in MainSc2040 and the alternative scenario Sc2040TerminalKap is shown in Figure 34. For the alternative scenario, the utilization of terminals is shown in the circles with black border. It is not shown for the base scenario as this scenario does not have a specified capacity for terminal connectors.

The utilization of the lines in the network is similar in both scenarios, with a slight decrease in the alternative scenario which reflects the decrease in the number of trains. The nodes of Gothenburg combi terminal, Hallsberg, Stockholm Årsta and Jordbro have a very high utilization in the alternative scenario (between 97% and 100%). Except for the Gothenburg, it the nodes with high utilization rates are situated by lines with low utilization in the alternative scenario. This might indicate that the terminal capacity is lower than the surrounding lines and thus acts as a bottleneck. On the other hand, the Malmö nodes, Älmhult and Falköping are located in connection to lines that already are already full, and therefore not enough trains are able to circulate and use the remaining capacity in the terminals.

Figure 34: Rail capacity utilization Sc2040TerminalKap vs MainSc2040. The circles in the capacity utilization map of Sc2040TerminalKap



3.3 CONCLUSIONS

To summarise, the results reflect the expected effect, i.e. the introduction of terminal capacity limits resulted in a general decrease in the amount of trains. However, the number of trains did increase slightly in some parts of the network, which could be partly explained by the other changes made in the model apart from capacity limits (for example changes in transfer types). When applied to a scenario with high-speed trains, where the capacity of the lines is relatively large, it can be expected that the terminals will act as bottlenecks and thus reduce the number of trains in the network.

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