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A SWEDISH INTERMODAL TRANSPORT SERVICE BASED ON LINE-TRAINS SERVING FREIGHT FORWARDERS

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Abstract

This article starts out from the characteristics of *FlexCombi*, a proposed small-scale fine-meshed intermodal transport system based upon transhipment of swap bodies and 20' ISO-containers by standard forklift trucks, at rail sidings and under the overhead contact wire. It has pronounced similarities to the Light-combi system commercially tested in Sweden by Green Cargo. The technical and operational characteristics are matched against the network operation principles and freight flows of Sweden's largest forwarder, Schenker, which currently bases its operations mainly on all-road transport. The study indicates that rail can take a significant share of the long-distance haulage between Schenker's terminals, fulfilling demands regarding transport time.

The study also shows that the transhipment time is crucial for both the productivity and the average speed. The speed of trains, 100-160 km/h, is important for keeping the schedule, for mixing with fast passenger trains during daytime and for covering long distances overnight. An average distance run by the train equipment of 220-300 000 km per year should be achievable, which is about twice as much compared to conventional intermodal systems. Development and investment costs are kept low due to the use of standard equipment.

Keywords: Forwarders' networks; FlexCombi; Intermodal transport; Medium distances; Small-scale
Topic area: B4 Modal Interfaces and Combined Freight Transport

1. Introduction

During the 1990s and early 2000s, the European intermodal transport networks were rationalised, primarily by breaking up the networks into a number of full train shuttles directly between major economic areas. Significant geographical market areas were then abandoned. As a complement, some railways developed small-scale concepts with fine-meshed networks with the common aim of breaking the negative trend towards increasing break-even distances for competitiveness with all-road transport.

One such initiative was taken by the Swedish rail operator Green Cargo (former freight division of Swedish State Railways) when introducing the Light-combi concept based upon fixed train sets making short stops, 15-30 minutes, at sidetrack terminals approximately every 100 km. There, swap bodies were transhipped under the overhead contact wire using a standard forklift truck carried by the train and operated by the rail engine driver. The Light-combi service was introduced as a commercial pilot distributing groceries for the wholesaler DAGAB between 1998 and 2001. The pilot was based upon two line-trains serving seven intermodal terminals connected by lorries to 37 Hemköp stores. Earlier research (Bärthel and Woxenius, 2003 and 2004) has shown that aiming directly for shippers with part loads and full loads was not sufficient in the Swedish market. Failing to target the general cargo segment and actively leaving the forwarders out meant a too small realistic market. Insufficient marketing efforts and lack of financial strength added to that the service did not pass the commercial pilot phase. Nevertheless, the pilot operations showed clearly that the basic technology, using forklift transhipment, worked very well technically and fulfilled the shipper's logistics demands.

This article starts out from the characteristics of *FlexCombi*, a proposed small-scale intermodal transport system very similar to the Light-combi system. Acknowledging that a few forwarders control large parts of the Swedish freight transport market, the characteristics of FlexCombi are matched against the network operation principles and freight flows of Sweden's largest forwarder, Schenker, which currently bases its operations on all-road transport.

The purpose is to analyse how an intermodal transport service designed for intermediate stops along the railway lines can be introduced starting out from a forwarder's freight flows today moved by road between the consolidation terminals or directly between shippers as part loads or full loads. The intention is not to optimise such a service in relation to the forwarder's quantitative and qualitative demand, but to show that it can be done for certain parts of the network.

The analysis is based on real data supplied by Schenker covering their flows between November 2002 and October 2003. The analysis pays special attention to the operative characteristics involving short rail and pre- and post-haulage (PPH) distances, fast transhipment and the utilisation of the rolling stock and terminals. The article also includes a qualitative discussion on barriers for implementing such a service and how this service can be improved by adding flows from competing forwarders and large shippers.

2. The FlexCombi production philosophy

Economies of scale are clearly present in rail transportation and during the last decades European intermodal transport has focused on transport quality, primarily transport time and reliability, and a high load factor for each train. The all-rail and intermodal transport services have been disintegrated and the production philosophy has changed from conventional hierarchical rail networks towards focusing on shuttle trains and block trains between major conurbations and ports. The direct train approach implies that the network structures have been broken down into a number of direct relations abandoning significant geographical market areas with small flows over short distances (SFSD).

In order to compete with road transport on SFSD markets, typically in the 200-500 km range, the aim is to develop and diffuse a fine-meshed network, as a complement to conventional intermodal transport for large flows over long distances. PPH and terminal activities account for a large share of the intermodal costs (see, e.g. Bukold, 1996, Niérat, 1997 and Rutten, 1998) and are major factors in the service quality as perceived by the shipper. Thus the fine-meshed network implies opportunity to get closer to the consignor and the consignee to benefit from the low rail haulage costs.

Traditional production philosophies for high market coverage are characterised by complex systems and low average speed due to marshalling and shunting operations as well as detours, e.g. in hub-and-spoke designs. Here, Bukold (1996) identifies a flexibility gap of traditional production models. Konings and Kreutzberger (2001) as well as Trip and Bontekoning (2002) argue that competitiveness on SFSD markets requires a quality leap, mainly through innovative train operation principles and terminals offering low fixed costs. A certain problem is related to the fact that SFSD services cannot draw on the cost jump of road transport on distances requiring a second driver.

The transport corridor network design, comparable to passenger intercity services, is based on a number of line-trains making frequent stops along a corridor that covers the intermediate markets and facilitates shorter PPH. Such a network serves domestic markets for semi-finished and manufactured goods during the night-leap. During daytime, international goods, less time-sensitive commodities and empty intermodal loading units (ILUs) are moved due to the different transport rhythm.

Along corridors the trains stop at a large number of terminals and if these nodes absorb too much time and costs, the total lead time and price of the service become too unattractive, as elaborated by Bontekoning and Kreutzberger (2001). This requires substantial improvement of the cost-quality ratio at the nodes as well as at the node/link interfaces, which cannot be offered by conventional terminals and related shunting operations.

Thus the network and infrastructure must present the possibility to make short stops (15-30 min) at side track terminals approximately every 100 km, where ILUs can be transhipped under the overhead contact wire. Short-time storage is needed at the terminals since road and rail operations should be detached in time. If not, the time dependency complicates logistics, decreases staff utilisation and, not least, makes the system more sensitive to disturbances.

Empirically, the Swedish Light-combi concept shows that a maximum train speed of 110 km/h allows for long distances. For instance, 650 km including four intermediate stops can be covered during the night-leap (Bärthel and Woxenius, 2003). Furthermore, the load plan is crucial for decreasing the time spent at terminals.

The intermediate terminals have almost the same characteristics as the intercity passenger terminals, but there are three major exceptions. First, the passengers change trains independently and without centralised planning and control. Second, passenger trains can accommodate a higher load factor with standing passengers during rush hours. Third, passengers pass more or less directly through terminals, while there is a need for detachability and buffering in the freight system since arrival and departure times for lorry and train systems might not match.

At intersections, ILUs can be transhipped directly between line-trains or indirectly using buffers, in order to permit large areas to be covered at relatively low costs. The exchange of ILUs or fixed wagon formations at the intersection terminals requires additional transhipment or shunting and implies complicated operations at the nodes. This underlines the importance of fast train formation, marshalling and handling techniques to facilitate market coverage and a high average speed (see, e.g., Siegmann and Tänzler, 1996).

PPH distance is crucial when the rail haulage distance is decreased. Both Bukold (1996) and Rutten (1998) show that the break-even distance of intermodal transport contra all-road is most sensitive to PPH costs, especially concerning rate of empty hauls and the daily number of hauls performed by the hauliers as specifically shown by Niérat (1997). Transport corridor systems require a much tighter co-operation with hauliers, especially in cases when lorries are part of the transhipment technology or when unmanned terminals are used. In addition, SFSD in general means that the PPHs are fewer and shorter entailing a need for hauliers to engage also in other businesses besides PPH. The maximum local road haulage distance is considered to be 50 km but when the flows fluctuate, lorries can be used for longer haulage in order to avoid stops where only a few ILUs are shifted.

3. Technical characteristics

According to Bukold (1994), achieving competitiveness on SFSD markets requires a change from the approach of *industrialisation* aiming at higher productivity by means of mass production, concentration and economies of scale, to the approach of *flexible capacity management*, supporting low-risk capacity utilisation and less concentrated facilities. Obviously this implies substantial challenges. Furthermore, a cornerstone in the development and diffusion of the concept is to keep the business risk on a low level by using standard equipment flexibly and by developing the concept gradually. The trick seems to be to design cheap, flexible and scalable equipment closely adapted to the needs in the service and network contexts (Bärthel and Woxenius, 2004). This concept makes it possible to start up a small-scale network in SFSD markets with reasonable investments. Since the terminals are of simple design it is possible to establish terminals fast and at low costs. In short, the required characteristics of the proposed system are that it:

- is compatible with conventional large-scale intermodal transport
- is compatible with the currently dominating types of vehicles and vessels
- accommodates 20’ ISO-containers and swap bodies up to 7.82 m long and preferably also 40’ ISO-containers and longer swap bodies of 13.6 m in selected relations
- facilitates low cost terminals, both in terms of investments and operations, for sufficiently many terminals along the lines
- utilises a simple transhipment technology that facilitates quick, flexible, reliable and safe ILU transhipment under the overhead contact wire
- avoids the need for co-ordination of vehicles at terminals
- uses fixed-formation train sets or wagon blocks, no marshalling
- is possible to implement gradually, both technically and commercially

The total time needed for a transhipment operation is a critical parameter for the whole system’s efficiency. Hence, a vital feature of the system is to make stops underway for quick transhipment of ILUs under the overhead contact wire. A longer time needs longer train stops or fixed transhipment staff and equipment, thus decreasing the productivity of the system. The proposed basic element for transhipment is a standard *forklift* having a load capacity of 20-25 tons, already available on the market. The relatively low axle load of such equipment is also an important feature in order to build low-cost terminals without heavy and expensive concrete pavement. The forklift is able to handle a variety of standardised ILUs, mainly 10’ to 20’ containers weighing up to 24 tons and swap bodies up to 7.82 m and 16 tons, under the overhead contact wire.

Between terminals at the ends of the train routes, heavier ILUs such as 40’ containers, 13.6 m swap bodies, European Intermodal Loading Unit (EILU) as proposed by the European Commission (2003) and possibly also semi-trailers, can be handled by reach stackers or gantry cranes. Alternatively, the larger ILUs can be transhipped by technologies for horizontal transhipment such as sideloaders, CCT and Kangaroo Trailer (for an overview, see Woxenius, 1997).

Another important feature is the *independence between train movements and lorry movements*. This feature is facilitated by a simple stand, which provides an intermediate storage between train and lorry. Safety rules prevent handling of support legs when a swap body is lifted by a forklift truck.

The pilot phase of Green Cargo’s Light-combi operations showed that the transhipment time is in the order of two minutes for a forklift with a trained operator (Bärthel and Woxenius, 2003). This is the time needed to position the forklift, lift the ILU off the train and put it safely on a stand, and then drive back to the train. For example, at a large terminal with three operating forklifts in parallel it would be possible to make 15 transhipments in 10 minutes and have an additional spare time of 5 minutes, all within a train stop of 15 minutes. The train engine driver may take part of the transhipment operations. It is assumed that most forklift operators as well as train and lorry drivers can be flexibly used for driving and forklift operations. At the smaller terminals, however, the train engine driver alone will perform the transhipment by use of a single forklift, stationary or carried along by the train.

The basic rolling stock is *standard locomotives*, *flat wagons* and *lorries* suitable for transport of ISO containers and standard swap bodies. The rail wagons should preferably have a load surface of up to 15.8 m length, but it is possible to accommodate one 20' container and a 7.82 m swap body within a total length of slightly more than 14 m at the price of loading flexibility. A four-axle wagon is more suitable for 3-4 short containers (20'or shorter, weighing up to 24 tons each) or three swap bodies of up to 7.82 m each. Longer swap bodies and EILUs can also be carried, but semi-trailers require pocket wagons.

Standard rail wagons with standard non-expensive tread brakes are suitable for up to 22.5 tons axle load at a speed up to 100 km/h if ordinary Swedish braking distances are applied. The loading capacity of a two-axled wagon is then 32-34 tons and about 65 tons for a four-axled wagon.

Studies have also been made for speeding up the wagons, in the first step to approximately 130 km/h (Jönsson, 2003/a). If ordinary tread brakes are used, such a speed would require longer braking distances, in the order of 2200-2500 m, which is currently allowed on lines where high-speed passenger trains are running at 200 km/h. It would also require some modification to the quite simple suspension of standard rail wagons. A few hydraulic dampers are proposed to be included in the running gear (Stichel, 1999, Jönsson, 2003/b). These modifications are quite simple and incur modest 15-20 % higher costs for the wagon. An alternative to modifications to standard freight wagons is to use modern running gears, either single-axle or bogies, which are available on the market.

An operational maximum speed of 130 km/h would increase the productivity of trains and train staff and would also permit these trains to run more smoothly among faster passenger trains during daytime. Another advantage of the higher speed is to make it possible to run certain trains at longer distances overnight. In cases with few stops it would be possible to run up to 1000-1100 km within 12 hours overnight, for example from southern Sweden (Malmö, Helsingborg) to the east coast north of Stockholm (Gävle, Sundsvall), thus covering the most populated areas in Sweden. Finally, the slightly modified suspension would improve the comfort for the transported goods and minimise damage.

Possibilities to run at a maximum speed of 160 km/h have also been investigated (Jönsson, 2003/b). For such a speed special running gears with disc brakes must be used. This technology is available on the market, both as single-axle running gears and as two-axled bogies. The costs of such wagons are considerably higher, about twice the price of a standard wagon. This more advanced technology may be justified for selected routes and trains, making it possible to run a further distance overnight, up to 1100-1250 km within 12 hours. Such a maximum speed would also be favourable for daytime running on busy passenger routes. Locomotives suitable for these services are available from all major vehicle suppliers.

The more advanced levels can be introduced gradually. It is likely that some parts of the system, e.g. for shorter distances with frequent stops, would never employ the most advanced level. Irrespective of whether newly designed or existing equipment is used it is important that it is compatible with standard rolling stock and can be used for alternative applications.

Trains should normally be run in fixed formations without marshalling operations. The length of trains is not a very critical parameter, although very long or short trains should be avoided. Here, train lengths of 240-360 m, consisting of locomotive plus a number of two-axled and four-axled wagons, are assumed. Such trains are able to accommodate 28-46 ILUs of up to 7.82 m length each.

4. The network operations of the Swedish forwarders

The freight forwarding sector definitely went into a stage of globalisation during the 1990s. Competitiveness on the market required either an international network or a clear niche strategy. This led the Swedish forwarders Bilspedition and ASG, which started as marketing and consolidation organisations for constellations of hauliers, to merge with some Continental European competitors, now operating under the brands Schenker and DHL. Ownership is kept by the German State through Deutsche Bahn and Deutsche Post respectively. For long, the Swedish market for freight forwarding has been characterised by an oligopoly situation with a few dominating freight forwarders as is shown in Figure 1.

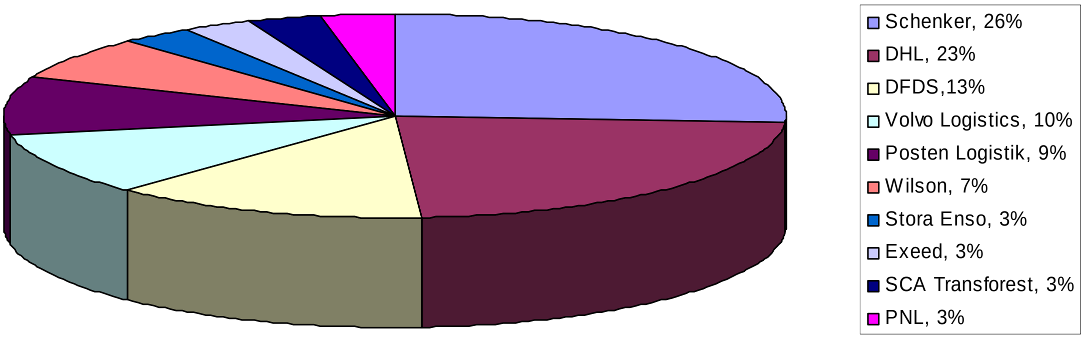


Figure 1. The market shares in tons excluding oil and other bulk transport of Sweden's ten largest freight forwarders. (Source: Dunn and Bradstreet, 2003). Note that Volvo Logistics, Stora Enso and SCA Transforest are forwarders mainly shipping on their own account, i.e., the products of their principals.

It should be noted, though, that these market shares relates to the freight forwarding segment. Shippers can also transport on own account or buy directly from transport operators such as road hauliers, rail operators or shipping lines. In addition, hauliers organised in so called lorry centrals control a significant part of the road transport market.

Unlike in Sweden, the forwarding market is rather scattered in most of Continental Europe. For instance, Schenker has comparable turnovers in Sweden and Germany, implying a German market share of 2% and a Swedish of 26%. Certain countries, mainly in southern Europe, even lack a forwarding level between shippers and hauliers.

Today Schenker has 27 terminals in Sweden, which is similar to the situation for DHL. Besides long experience and worked-up shipper contacts, they benefit from flows large enough for operation of full lorries directly between all terminals. The large size of Swedish lorries, 25.25 m and 60 tons, implies great difficulties for other companies to grow into the Swedish general cargo market, since their flows force them to operate with smaller vehicles or hub-and-spoke networks at higher costs. An example is DFDS, ranked third in size in Figure 1, which operates through three hubs in their domestic network.

Schenker Sweden has a total turnover of about € 1 billion, 4200 employees and moves 18 million tons annually. The 400 associated hauliers employ an additional 7000. The main business is land transport of general cargo (less than one ton domestically, consolidated at terminals), part loads and full loads (from one ton to the capacity of a lorry, directly transported from consignor to consignee) but the service portfolio includes transport and storage of temperature-controlled goods, international forwarding with all modes and customised transport solutions. All services are co-produced in the domestic network for utilising economies of scale and scope.

Small or medium-sized hauliers are contracted for about 80% of the road haulage between Schenker's terminals while the subsidiary Schenker Åkeri AB supplies the remaining 20%. The domestic network is operated with 4000 lorries of which Schenker Åkeri owns 800. Conventional intermodal transport, supplied by Rail Combi AB, is only used for a few domestic links, mainly for large flows such as Göteborg-Stockholm and very long distances such as Göteborg-Luleå (1250 km). The reasons are attributed to a history of cross-ownership with hauliers and a traditional bias against rail transport, but mainly to the competitive disadvantages of conventional intermodal transport over short and medium distances.

Schenker's network of consolidation terminals is connected with direct relations and the southern terminals are operated by a 24-hour cycle, and the northern is connected to the southern in the same manner but with an extra 24-hour lead time due to the distance. This 24-hour cycle follows a general pattern which starts with collection in the afternoon by small distribution lorries or by larger lorries for the full load and part load segments. The sorting of general cargo is finished during early evening and then the long-haul is performed during the night with a deadline of overnight deliveries in the early morning around 5 am. When the sorting activity at the receiving terminal is finished the distribution starts and the cycle starts over again. In some cases collection and distribution are carried out simultaneously.

5. Design of the transport network

The FlexCombi routes can be arranged in different ways with adherent advantages and disadvantages such as size of the covered market, resource utilisation, possible frequency and possible connections between routes. Viable routes are here identified by matching the production profile of FlexCombi with Schenker's inter-terminal flows and the access to rail infrastructure. The data used regards Schenker's domestic flows in the segments general cargo, part loads and full loads for the one-year period from November 2002 to October 2003. In addition, data on Schenker's requirements for earliest departure and latest arrival for each of its terminals is used.

Some parameters based on the objectives *transport quality* and *cost efficiency* are used to identify which specific terminals to serve and the amount of cargo that can be accommodated in a FlexCombi network. The parameters are:

- Size of flows; in order for a terminal to be considered to be part of the FlexCombi network, sufficient flows are required.
- Distance between the forwarders' consolidation terminals; where the distance is shorter than approximately 150 km, intermodal transport is usually not competitive.
- PPH distance; the tolerable PPH distance is proportional to the long-haul distance by rail and comprises a major cost driver.
- Number of transhipments needed; as this is the other major cost and time driver it is needed to be minimised, resulting in lines along major freight arteries.
- Time restrictions; the possible train timetable imposes limits on the share of flows that can be accommodated when matched against the forwarder's terminal operating cycle.

- Share of goods requiring special attention; some goods might impose demands difficult to fulfil by the FlexCombi system, e.g., over-sized and temperature-controlled goods and such, involving very special time restrictions, requiring at least one lorry departure for each transport relation.

A first assumption is that major flows are present in the triangle between Göteborg, Malmö and Stockholm, which are the major Swedish production and consumption areas and most central distribution warehouses are localised within the triangle. The importance is emphasised by the European Commission (1998) identifying the “Nordic Triangle” as a TEN Priority Project. The counties covered comprise about 70 % of the Swedish population, not saying that the freight flows mirror that pattern. Along the routes constituting the sides of this triangle, many smaller cities and industries are located which have grown in interplay with the provision of rail services. Some industries generating substantial flows, e.g. the forest and steel industries, are mainly based outside the triangle, but on the other hand the size and character of those flows often imply all-rail or sea transport.

Schenker’s data shows that flows are largest towards Stockholm from the west and south parts of Sweden. There are sufficient flows for routes between Göteborg and Stockholm as well as between Malmö/Helsingborg and Stockholm with higher frequency than one train per night-leap. The time restrictions allow for additional extensions further north, at least for an early departure. A route along the west coast between Malmö and Göteborg is not that obvious if only based on Schenker’s flows, but it still has an integrating role for the whole network. Due to short distances, goods related to intermediate terminals often require further extension from Göteborg to be viable.

In order to cover larger geographic markets, the FlexCombi concept implies the use of transhipment between different rail lines and at gateways for connecting to areas not possible to serve by overnight transport, e.g., northern Sweden and the European mainland. A route between Malmö and Borlänge via Skövde and Jönköping can then be identified and goods from Borlänge to the west coast can be transhipped to a connecting route. Malmö is a suitable gateway for connecting the FlexCombi network to services on the European mainland and Stockholm for connections to Finland.

Imbalances occur at all routes but are most distinctive on routes related to Stockholm, which is dominated by service industries and is regarded as a consumption area in freight terms. Furthermore, the demand for transport is varying greatly on different parts of a particular route. A realistic solution is then variable start and end points on the routes and to tranship ILUs between lines.

The system design here involves the definition of a network of lines, the creation of a train timetable and the definition of train size and configuration. The design has to match the requirements and desires from the demand side, expressed in Schenker’s flows in space and time, and at the same time take into account the possibilities and restrictions given by the infrastructure as indicated in Figure 2.

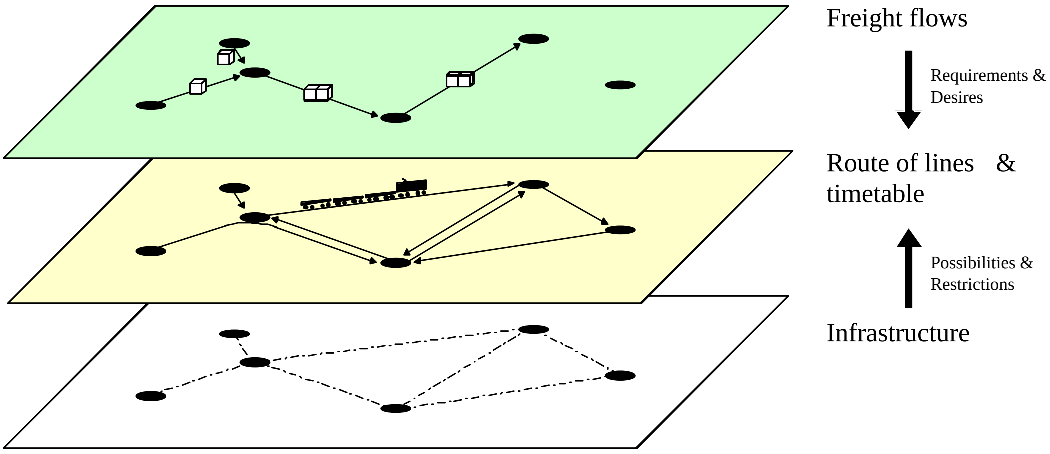


Figure 2. Design of the network matching the production philosophy of FlexCombi with the character of the demand and the accessibility of infrastructure.

The FlexCombi network in terms of routes and timetable is based on Schenker's domestic cargo flows assuming that Schenker will account for the base volumes to be complemented by other shippers and forwarders, who are welcome to buy free capacity. The first step in assigning routes is to translate the O/D-matrix of cargo volumes between Schenker's terminals into number of ILUs, assuming a certain average payload per unit. From these data a network of six lines serving 21 FlexCombi-terminals has been developed as shown in Appendix 1 and Figure 4. Some of the terminals, mainly at the end of lines, are existing conventional terminals, while others still have to be built.

As far as possible FlexCombi terminals have been located close to Schenker's consolidation terminals. Due to the geographical structure of the rail infrastructure and to limit the number of stops, some terminals serve two or three terminals. All lines are operated by *line-trains* and some add the principle *train-coupling and -sharing* to increase the geographical coverage of the system as illustrated in Figure 3.

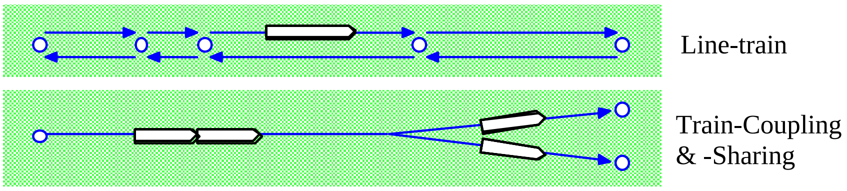
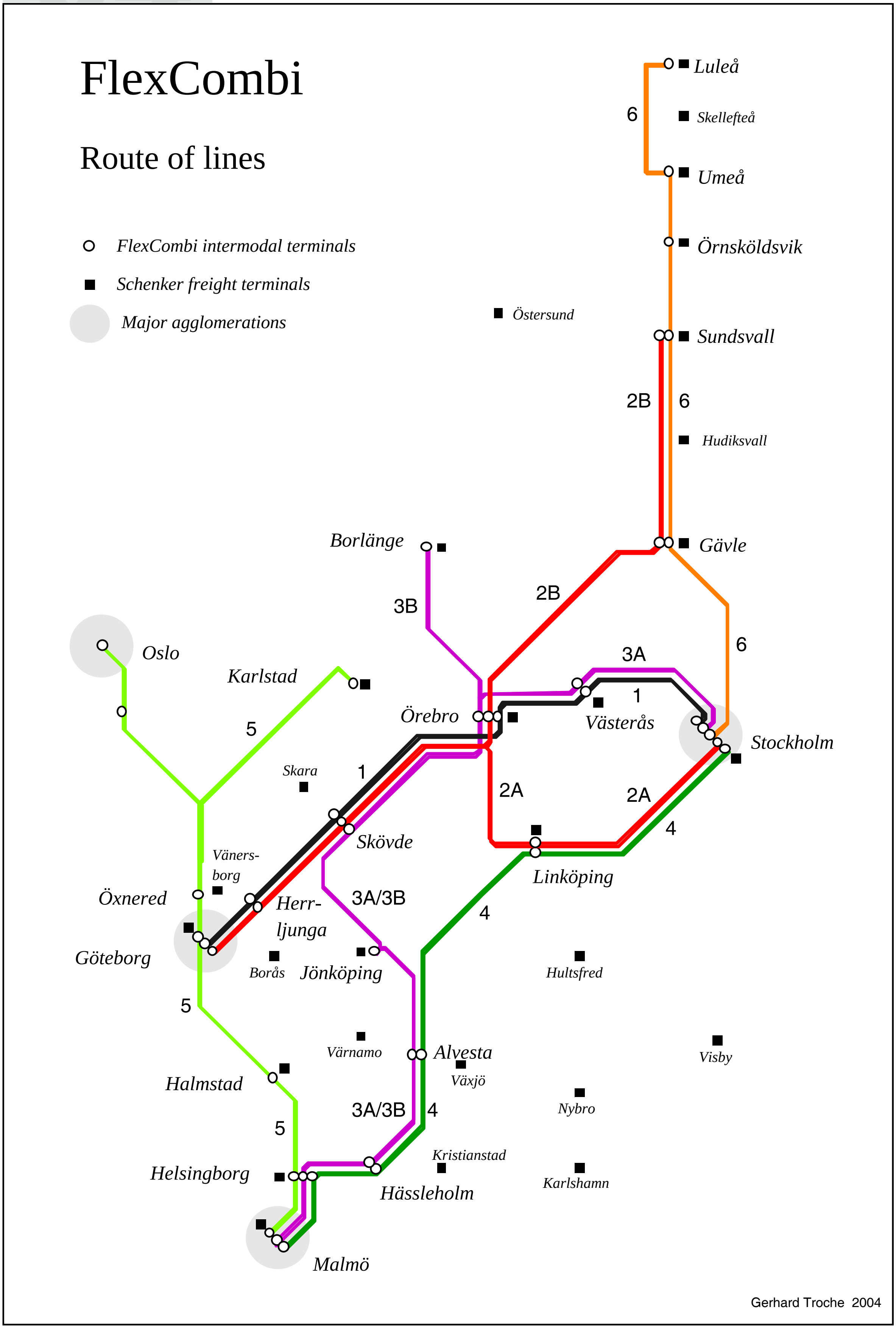


Figure 3. The FlexCombi network is based on line-trains, in some cases combined with the train-coupling and -sharing principle.

The line selection requires that Schenker's volumes justify at least one over-night service per day and direction. On lines justifying more than one daily train, there is a trade-off between offering departures for strict overnight services or introducing day-trains for better utilisation of trains and terminals. In the longer run, it is believed that price incentives can be used for levelling the demand over the day, although the Swedish intermodal operator Rail Combi had to cancel their day-service between Göteborg and Stockholm due to lack of demand.



Gerhard Troche 2004

Figure 4. The FlexCombi network showing rail terminals and Schenker's consolidation terminals.

Table 1 shows an example of a timetable connecting Göteborg and Stockholm and all timetables are shown in Appendix 1.

Table 1. The train timetable for Line 1, Göteborg-Stockholm via Örebro and v.v., operated by 3 train sets.

Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.
0	Göteborg		12:00		18:00		22:00	0	Stockholm		03:00		12:00		22:00
80	Herrljunga	12:40	13:10	18:40	19:10	22:40	23:10	112	Västerås	04:14	04:44	13:14	13:44	23:14	23:44
144	Skövde	13:42	14:12	19:42	20:12	23:42	00:12	210	Örebro	05:33	06:03	14:33	15:03	00:33	01:03
283	Örebro	15:21	15:51	21:21	21:51	01:21	01:51	349	Skövde	07:13	07:43	16:13	16:43	02:13	02:43
381	Västerås	16:40	17:10	22:40	23:10	02:40	03:10	413	Herrljunga	08:15	08:45	17:15	17:45	03:15	03:45
493	Stockholm	18:25		00:25		04:25		493	Göteborg	09:25		18:25		04:25	

It should be noted that several routes are served by more than three departures per day, since they are served by more than one line. For calculation of running times, a maximum speed of 160 km/h has been assumed, resulting in average running speeds of 90-120 km/h. The dwell time for terminal stops has been set to 30 minutes, implying some spare time during the introduction phase. The quite long dwell times may also be substituted by lower train speed. Where applicable, further time has been added for train-coupling and -sharing operations and the change of travelling direction. A time of 2.5 hours has been set as a minimum time between two duties. However, in order to guarantee a high quality of service there should not be two intervals between duties of only 2.5 hours in consecutive order.

Furthermore, train sets have been assigned line by line implying that a train set always operates on the same line. This approach facilitates that disturbances in train set circulation are not spread in the network and that lines can be added or withdrawn without interfering with operations of the others. Following this principle and excluding train sets held in reserve, a total of 23 train sets are required for serving the network. A slight reduction in the required number of train sets can be achieved by more complex inter-line train assignment. Another effect of inter-line assignment may be greater freedom in timetabling, and should be considered when operations prove to be stable and reliable.

Most train sets consist of 20 two-axled flat wagons, accommodating 40 standard 7.15-7.82 m swap bodies or 20’ ISO-containers equalling 40-47 TEU. On lines where train-coupling and -sharing is applied, a train on the joint section consists of a maximum of 30 two-axled flat wagons divided between two train sets.

A phenomenon specific to line-train systems is the occurrence of variations in demand over each route as exemplified by Figure 5 that shows the number of ILUs on Line 1. High resource utilisation requires a flexible capacity management, where the overlapping layers of the FlexCombi routes act as base capacity and lorries would act as complement for variations in time and space. The diagram exemplifies the demand variation over a route typical of line-trains. The lower demand toward the lines’ ends is due to the circumstance, that traffic between the conurbations at the lines’ ends (which are the largest on this line) and the terminals next to it will continue to be transported by lorry due to the short distances.

It should be noted that the transport system proposed here has been designed primarily based on the needs of Schenker as the commercial pilot customer and future key customer. However, the network will be open to other customers as well, primarily to fill free capacity, i.e., to level demand variations in space and time. Depending on other customers’ interests, timetable adjustments and network expansion may be considered. Hence, operating a FlexCombi network will require constant consideration of alternative routings and scheduling.

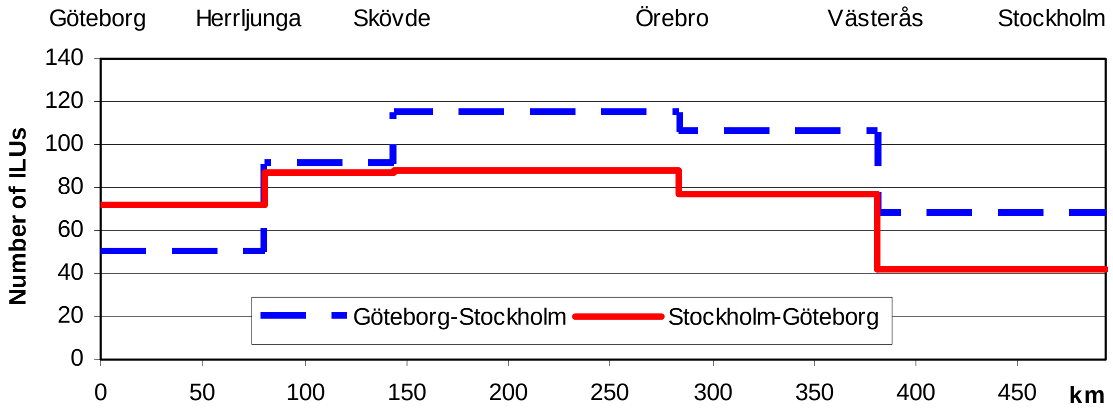


Figure 5. Average daily demand in number of ILUs along Line 1.

6. Implementation and further development

This preliminary study, supported by the experiences from the Swedish Light-combi system as investigated by Bärthel and Woxenius (2003 and 2004), shows that the FlexCombi concept can compete with all-road services on SFSD distances. With the proposed organisation of the system, the PPH distances and the characteristics of the specific flows, FlexCombi should be competitive at distances as short as 200 km. On longer distances, FlexCombi is estimated to offer considerable advantages in costs and environmental impact compared to all-road as well as conventional intermodal transport.

The implementation of the concept can follow a very aggressive trajectory establishing a dense network, possibly leading to that a multitude of shippers will use the service on different links offering a good average resource utilisation. Markets, however, often do not emerge spontaneously; they need to be stimulated or even created. Companies developing SFSD services are thus exposed to significant risks relating to technology, economy and market. Under such circumstances, development via bridging markets (Jacobsson and Bergek, 2003) allows successive increase of capacity and continuous improvement in co-operation between the shippers, the forwarder, the rail operator, the hauliers and the infrastructure provider. The transport service profile is then created by adjusting the character of both supply and demand. This resembles exploring a number of niche markets, which are successively transferred to a mass market by co-ordinating technical components. By linking different network modules, the small flows related to the Scandinavian countries would be co-ordinated in order to benefit from the economies of scale so prevalent in rail transportation.

The concept might either be designed for a restricted range of customers or ILUs or as an open system for all shippers or all ILUs. Large bundling networks, like the FlexCombi system, are characterised by complex operations and the need for controllability in order to fulfil the performance requirements from the forwarder that are derived from the shippers. Booking procedures/systems, prognoses, rules of thumb, internal planning and control systems are required in an open market-oriented system, renouncing the ability of more detailed planning in commercially or technically closed systems (Sjöstedt *et al.*, 1994). Levelling flexibility and specialisation is a critical choice, but offers opportunities in the development and diffusion of large socio-technical systems. The limited technical openness of FlexCombi decreases the control problems to a few types of technical interfaces.

Individual actors' adoption rate of new concepts is affected by the system's compatibility (Rogers, 1962), i.e. the correspondence with existing values and experiences, which is related to Jensen's (1990) communicability. This is closely connected to the legitimacy that the new concept entails for each actor. Thus, if the operational characteristics and timetables correspond with existing principles for Schenker's road systems the adoption rate will increase in the short term. During the implementation phase, lorries would be used for building up flows and for backup in case of train breakdowns.

Further, all business is local and the far-reaching technical standardisation of the rail industry does not imply that rail system design and sales efforts can be centralised and detached from PPH operators' and shippers' locally specific needs (Brehmer, 1999 and Enarsson, 2001). According to Nelldal and Andersson (1992) this is the main reason why rail operators often fail to enter more peripheral market segments, especially those regarding small customers with small consignments. Thus the image is affected by inter-organisational informal contacts and networks (Rogers, 1962 and Webster, 1969). Through the creation of inter-organisational networks, the image of a transport concept might change over time with significant inertia.

Development and diffusion of SFSD systems is significantly affected by technical, economical and market uncertainties. To decrease the uncertainty regarding economy and market the system designer should strive towards creating customer loyalty. Important commercial design factors are the *availability*, i.e. a customer's opportunity to use a transport system without long-time agreements; *time discrimination*, i.e. restrictions to choose time of departure or last call related to a specific shipment; and *price discrimination*, i.e. the transport price related to long-time contracted users (Sjöstedt *et al.*, 1994). Success is generally explained by the competence to find flows ready to abandon the dominating demand for road transport characteristics or the dominating night-leap transport schedules. This demands implementation of new SFSD services in close co-operation with selected customers as early adopters. In this case the full system is designed to fit Schenker, while other potential users are supposed to level the flows and facilitate a higher resource utilisation. Pricing is here a delicate task, since Schenker can assert that they should enjoy low prices due to the large and stable flows while other users can assert that they reserve spare capacity and have to adhere to a system developed and adapted for Schenker and thus argue for budget or even marginal cost pricing. A particular problem with one dominating customer is that other users fear that their ILUs will be kicked out in case of shortages of slots in the trains.

Introducing line-trains involves considerable risks. The business risks of exploiting the FlexCombi concept merely relate to filling the trains but also half-full trains can be motivated by related gains in other parts of the network and low marginal costs. The resources in the FlexCombi in terms of terminals and the rolling stock are either shared with other services or have a clear second-hand market in case of abortion of the service. Resources must also be flexible enough to be moved around the network until the demand is stable. Furthermore, the exploitation involves rather short time frames since the technology is known and often available directly or on a leasing market.

The FlexCombi system may be developed further when the service is extended and more shippers or forwarders are included. A continuous quality management combined with a successive marketing towards new customers would create a stepwise path towards an open transport system. New technological innovations, primarily regarding transhipment techniques, would offer more technical openness and thus extension towards technical and corporate interoperability within Europe (Mulley and Nelson, 1999). Perspectives for further development regarding the operation of trains are; (1) increased train frequency, (2) replacing lines with train-coupling and -sharing with independent lines,

(3) prolongation of lines, (4) new lines, (5) opening of new terminals and diffusion of the system to new markets and (6) adapting train speeds to the specific demand at each departure and to ensure smooth and efficient circulation of trains.

7. Conclusions

The study supports and strengthens the earlier results saying that forwarders, controlling significant parts of the Swedish freight transport market, cannot be neglected when introducing a fine-meshed intermodal service in a less densely populated area. Forwarders' flows are often also a better base for such SFSD systems than the traditional flows controlled by railways.

The study suggests a system allowing quick and reliable transhipment of standardised ILUs during short stops at sidetrack terminals along the route. The time needed for transhipment along the route is crucial for the overall productivity, the average speed and the possibilities to cover long distances overnight.

The study also confirms the importance of quick transhipment operations avoiding the need for co-ordination of trains and road vehicles at terminals. The simple forklift technique used at sidetrack underway terminals fulfils this demand.

It is also of importance that trains and their engine drivers have a high productivity. This is enhanced by the high average speed of the trains, as well as the proposed utilisation of trains for both night and day operations. An average distance run by the train equipment of 220-300 000 km per year should be achievable depending on the number of stops and the chosen maximum speed (100-160 km/h).

The use of standard ILUs, wagons, locomotives and forklifts, is preferred to bring down development cost and for the possibility to implement the system gradually with existing components. The system can then be improved gradually as long as the equipment is compatible within and outside the intermodal system to ensure low-cost standard equipment with a second-hand market.

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Appendix 1: Timetables for the six proposed FlexCombi lines

Line 1, Göteborg-Stockholm via Örebro and v.v., 3 train sets.

Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.
0	Göteborg		12:00		18:00		22:00	0	Stockholm		03:00		12:00		22:00
80	Herrljunga	12:40	13:10	18:40	19:10	22:40	23:10	112	Västerås	04:14	04:44	13:14	13:44	23:14	23:44
144	Skövde	13:42	14:12	19:42	20:12	23:42	00:12	210	Örebro	05:33	06:03	14:33	15:03	00:33	01:03
283	Örebro	15:21	15:51	21:21	21:51	01:21	01:51	349	Skövde	07:13	07:43	16:13	16:43	02:13	02:43
381	Västerås	16:40	17:10	22:40	23:10	02:40	03:10	413	Herrljunga	08:15	08:45	17:15	17:45	03:15	03:45
493	Stockholm	18:25		00:25		04:25		493	Göteborg	09:25		18:25		04:25	

Line 2 A, Göteborg-Stockholm via Linköping and v.v., 2 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.
0	Göteborg		11:30		21:30	0	Stockholm		21:17		11:17
80	Herrljunga	12:10	12:40	22:10	22:40	221	Linköping	23:07	23:37	13:07	13:37
144	Skövde	13:12	13:42	23:12	23:42	463	Skövde	02:23	02:53	16:23	16:53
386	Linköping	16:18	16:48	02:18	02:48	527	Herrljunga	03:25	03:55	17:25	17:55
607	Stockholm	18:38		04:38		607	Göteborg	04:35		18:35	

Line 2 B, Göteborg-Umeå and v.v., 4 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.
0	Göteborg		11:30		21:30	0	Umeå		16:18		06:18
80	Herrljunga	12:10	12:40	22:10	22:40	115	Örnsköldsvik	17:15	17:45	07:15	07:45
144	Skövde	13:12	13:42	23:12	23:42	323	Sundsvall	19:29	19:59	09:29	09:59
283	Örebro	15:11	15:41	01:11	01:41	543	Gävle	21:49	22:19	11:49	12:19
511	Gävle	17:35	18:05	03:35	04:05	771	Örebro	00:13	00:43	14:13	14:43
731	Sundsvall	19:55	20:25	05:55	06:25	910	Skövde	02:23	02:53	16:23	16:53
939	Örnsköldsvik	22:09	22:39	08:09	08:39	974	Herrljunga	03:25	03:55	17:25	17:55
1054	Umeå	23:37		09:37		1054	Göteborg	04:35		18:35	

Line 3 A, Malmö-Stockholm via Jönköping and v.v., 4 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.
0	Malmö		17:00		22:00	0	Stockholm		17:00		22:00
69	Helsingborg	17:34	18:04	22:34	23:04	112	Västerås	18:14	18:44	23:14	23:44
146	Hässleholm	18:50	19:20	23:50	00:20	210	Örebro	19:33	20:33	00:33	01:33
244	Alvesta	20:09	20:39	01:09	01:39	349	Skövde	21:43	22:13	02:43	03:13
374	Jönköping	22:07	22:37	03:07	03:37	449	Jönköping	23:23	23:53	04:23	04:53
474	Skövde	23:47	00:17	04:47	05:17	579	Alvesta	01:21	01:51	06:21	06:51
613	Örebro	01:27	01:57	06:27	06:57	677	Hässleholm	02:40	03:10	07:40	08:10
711	Västerås	02:46	03:16	07:46	08:16	754	Helsingborg	03:56	04:26	08:56	09:26
823	Stockholm	04:30		09:30		823	Malmö	05:00		10:00	

Line 3 B, Malmö-Borlänge and v.v., 2 train sets

Km	City	Arr.	Dep.	Km	City	Arr.	Dep.
0	Malmö		22:00	0	Borlänge		17:50
69	Helsingborg	22:34	23:04	172	Örebro	19:33	20:33
146	Hässleholm	23:50	00:20	311	Skövde	21:42	22:12
244	Alvesta	01:09	01:39	411	Jönköping	23:22	23:52
374	Jönköping	03:07	03:37	541	Alvesta	01:20	01:50
474	Skövde	04:47	05:17	639	Hässleholm	02:39	03:09
613	Örebro	06:27	06:57	716	Helsingborg	03:55	04:25
785	Borlänge	08:40		785	Malmö	05:00	

Line 4, Malmö-Stockholm via Linköping and v.v., 3 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.	Arr.	Dep.
0	Malmö		20:30		00:00		10:00	0	Stockholm		10:00		13:30		23:30
69	Helsingbg.	21:04	21:34	00:34	01:04	10:34	11:04	221	Linköping	11:50	12:20	15:20	15:50	01:20	01:50
146	Hässleh.	22:20	22:50	01:50	02:20	11:50	12:20	428	Alvesta	14:04	14:34	17:34	18:04	03:34	04:04
244	Alvesta	23:39	00:09	03:09	03:39	13:09	13:39	526	Hässleh.	15:23	15:53	18:53	19:23	04:53	05:23
451	Linköping	01:53	02:23	05:23	05:53	15:23	15:53	603	Helsingbg.	16:39	17:09	20:09	20:39	06:09	06:39
672	Stockholm	04:13		07:43		17:43		672	Malmö	17:43		21:13		07:13	

Line 5, Malmö-Karlstad and v.v., 2 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.
0	Malmö		21:45		12:00	0	Karlstad		12:00		21:45
69	Helsingborg	22:19	22:49	12:34	13:04	169	Öxnered	13:24	13:54	23:09	23:39
156	Halmstad	23:33	00:03	13:48	14:18	251	Göteborg	14:35	15:20	00:20	01:05
306	Göteborg	01:18	02:03	15:33	16:18	401	Halmstad	16:35	17:05	02:20	02:50
388	Öxnered	02:44	03:14	16:59	17:29	488	Helsingborg	17:49	18:19	03:34	04:04
557	Karlstad	04:38		18:53		557	Malmö	18:53		04:38	

Line 6, Stockholm-Umeå/-Luleå and v.v., 3 train sets

Km	City	Arr.	Dep.	Arr.	Dep.	Km	City	Arr.	Dep.	Arr.	Dep.
0	Stockholm		16:00		21:00	0	Luleå		18:00		
182	Gävle	17:39	18:09	22:39	23:09	354	Umeå	21:56	22:26		10:30
402	Sundsvall	19:59	20:29	00:59	01:29	469	Örnsköldsvik	23:23	23:53	11:27	11:57
610	Örnsköldsvik	22:13	22:43	03:13	03:43	677	Sundsvall	01:37	02:07	13:41	14:11
725	Umeå	23:40	00:10	04:40		897	Gävle	03:57	04:27	16:01	16:31
1079	Luleå	04:06				1079	Stockholm	06:06		18:10	