Time perspectives on intermodal transport of consolidated cargo

Robert Sommar* and Johan Woxenius**
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96, Göteborg
Sweden
* tel: +46 31 772 1354
fax: +46 31 772 1337
e-mail: robsom@chalmers.se

** tel: +46 31 772 1339
fax: +46 31 772 1337
e-mail: johwox@chalmers.se

EJTIR, **7**, no. 2 (2007), pp. 163-182

Intermodal road-rail freight transport is often argued to have certain cost and time handicaps against all-road transport. Based on theory defining the elements transport time, order time, timing, punctuality and frequency, literature on modal choice is surveyed. With few exceptions, transport time and punctuality is top ranked, while frequency and timing is regarded as less important by respondents. Timing is excluded in some studies and order time is not found. The time elements are also used for comparing the characteristics of intermodal transport and all-road transport. Particular attention is paid to the preconditions for using intermodal transport as part of consolidation networks with subsequent terminal handlings.
Since time aspects in transportation are highly contextual, the analysis is deepened within the framework of a case study focusing Schenker's domestic transport services in Sweden. Schenker's time requirements are matched against the times CargoNet, their main supplier of intermodal terminal-to-terminal services, can offer.
It is concluded that correspondence of the transport time between the consolidation network and the intermodal network are in fact not a strong prerequisite to use intermodal transport, although correspondence of departure and arrival times is significantly higher for the intermodal relations regularly used by the logistics service provider. Regarding timing, adjusting departure and arrival times by one hour will not increase the competitiveness for the consolidated cargo significantly, more profound adjustments are required. The order time of the intermodal freight transport service is not well suited to consolidated cargo due to volume information unavailability. The consolidated cargo schedule is sensitive for rather small deviations in punctuality.

Keywords: Consolidated cargo, intermodal freight transport, logistics service provider, punctuality, time

1. Introduction

Intermodal road-rail freight transport (IFT) is often mentioned among the top priorities for turning the European transport system into a sustainable direction, see, e.g., European Commission (2001). With rising tax levels and fuel prices, increasing problems with congestion and germinating environmental consciousness among shippers, also the road haulage industry has turned an interested eye at IFT. So far, however, IFT development has followed a somewhat disappointing trajectory and scenarios point at steeply rising volumes for all-road transport. Numerous studies on why IFT is not really taking off have been initiated by authorities and research boards at European, national and regional level as well as by the stakeholders within the industry.

A particular wealth of literature relates to shippers' preferences when choosing traffic mode. Examples of studies specifically addressing preferences for IFT are Evers et al. (1996), Golias and Yannis (1997), Harper and Evers (1993), Ljungemyr (1995), Ludvigsen (1999) and Shinghal and Fowkes (2002). Among the parameters making up the transport quality, transport time, punctuality and other time related ones are top ranked in many studies (e.g, Evers et al., 1996; Swedish Rail Authority, 1999; Cullinane and Toy, 2000). The concept of time in relation to transport operations is truly multi-faceted but although it is an integrated part of many studies, it has not attracted abundant attention from researchers (ECMT, 2005). Its perceived importance for development of IFT services motivates further elaboration.

Most studies of modal choice focus shippers. Division of labour in logistics, however, is highly contextual and this certainly includes who really decides which mode to employ. Shipper preferences are obviously vital, but it should be acknowledged that decisions on how to convey the goods are often taken by a logistics service provider (LSP), which is here widely defined as the actor on the supplier side of the market for logistics services. This role is sometimes played by freight forwarders or agents and sometimes by transport operators directly. The LSP has a particularly dominant role for modal choice on markets with a strong intermediary role for mode-independent LSPs. This is realised by Golias and Yannis (1997), who focused forwarders and carriers in an analysis of determinants of IFT market share at routes Greece-Italy-Germany.

Time is critical for LSPs operating consolidation networks utilising rail for long-distance transport. Admittedly, the share of transported tons of consolidated cargo is small compared to the shares of part loads and full loads. Nevertheless, the fact that many transport systems are designed for co-production of part loads and consolidated cargo imply that fulfilling requirements defined by consolidated cargo is very important for IFT success. This is a true challenge since the strong shipper demand for over-night deliveries has to be fulfilled yet activities at both consolidation terminals and intermodal terminals consume considerable time. Risks for propagating delays must also be mitigated. Since consolidation networks are generally designed adhering to the production profile of road transport, it has a prestige value if IFT can compete as a supplier of long-distance conveyance.

The purpose of this article is to elaborate on time aspects in conjunction with intermodal freight transport. Particular attention is paid to possibilities for fulfilling demands set by consolidated cargo within the classic IFT production profile based on night-leap trains between large-scale terminals separated by rather long distances. The geographical scope is set to nations or economic zones where road and rail are relevant options.

The article starts with a theoretical elaboration on elements of time. This is followed by a short review of literature investigating the importance of time for modal choice. A series of figures is then used for elaborating on time aspects particular to intermodal transport and consolidation networks as well as the case when intermodal transport is used for producing the long-distance transport between consolidation terminals. Since many of the issues brought up here are very contextual, analysis depth requires illustration in a well defined framework. Consequently, the article includes a case study. It focuses Schenker's domestic transport services in Sweden and implications when moving consolidated cargo by IFT as an alternative to all-road transport. The analysis is based on real data supplied by Schenker and CargoNet, their supplier of intermodal terminal-to-terminal services, in combination with in-depth interviews with key personnel.

2. Time aspects of transport networks

According to Woxenius (2006), the major time related elements can be distinguished as:

1. Transport time; the scheduled duration of a transport
2. Order time; the required time before departure that a transport has to be ordered to guarantee capacity, a certain price or service level
3. Timing; the scheduled points of time for departure and arrival
4. Punctuality; the ability of keeping the schedule
5. Frequency; the number of departures during a certain time

Among the time elements, transport time and punctuality are clearly the ones most discussed relating to IFT. Yet, speed and precision are not enough if the service has to be ordered long in advance, the departure or arrival time does not fit or if the service is irregular. Some principles for the time elements are shown in figure 1.

In reality, the lines in the figures are rarely straight. Different speeds, as shown by the angle of inclination in the figure, along the route, breaks, waiting times and sorting activities all affect the character of the distance-time curves.

The basis for the *transport time*, shown with the arrow t_a-t_d in figure 1a, is the inherent speeds of the traffic modes, for freight typically ranked air, road, rail and sea. Rail has the best technical and economic preconditions for varying speed, but is hampered by the rigidness of time tables, coordination between trains and propagating delays in the network. An advantage over road, however, is that a centralised train control can prioritise between trains. Nevertheless, in such decisions, at least European freight trains are generally leaving way for passenger trains although there are examples of giving higher priority to freight (European Commission, 2001; SIKA, 2002). The demand for speed is also vaguely connected to the size of consignments. For smaller consignments, however, economic reality most often implies consolidation activities to facilitate economy of scale during long-distance transport. Detours and sorting then consume considerable time.

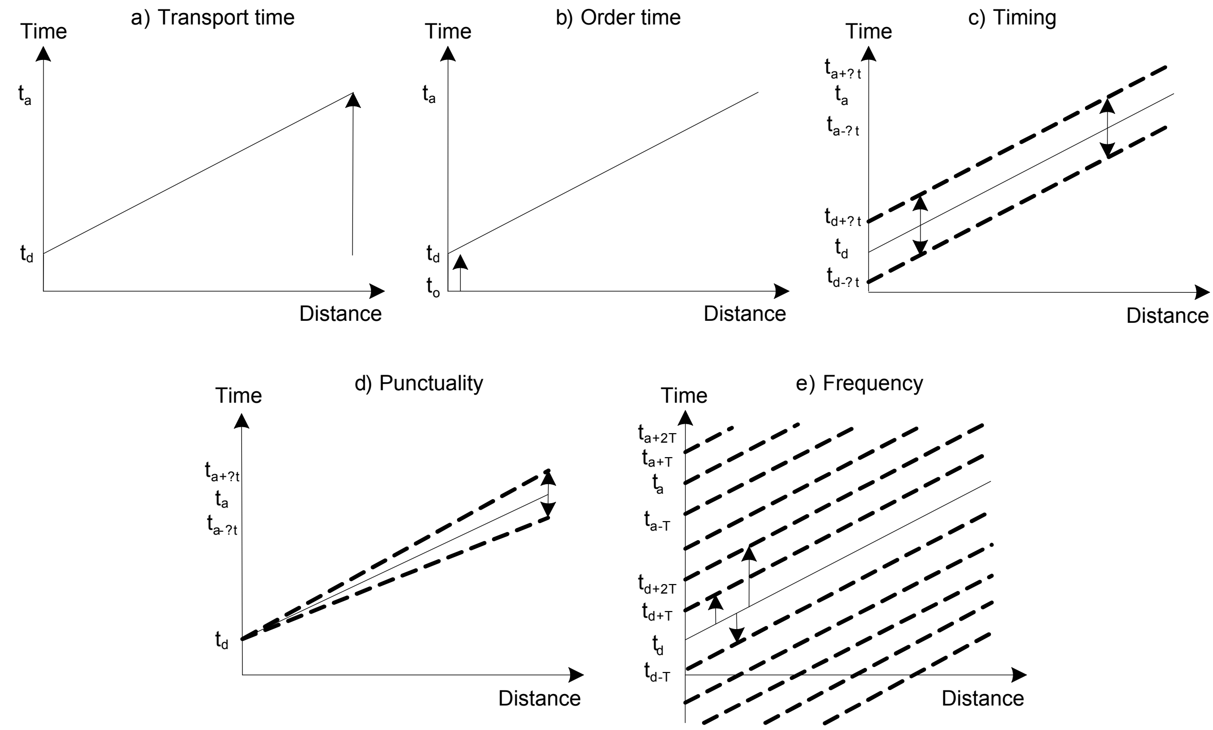

Figure 1. Principles for the time elements. t_o=time of order, t_d=time of departure, t_a=time of arrival are points of time while the elements relate to duration
Source: Woxenius (2006)

The duration of the *order time*, shown with the arrow t_d-t_o in figure 1b, depends more on how the booking information is used for capacity planning or discriminatory pricing than on the traffic mode. In addition to the order time, the shipper obviously has its own planning time before ordering the transport. The majority of consignments in consolidation networks are picked up according to a regular schedule although both quantities and destinations might differ between departures. For consignments following the plan there is often no real order time except for the initial design and contract phase and continuous revisions, but the LSP is sometimes noticed about quantity for capacity planning. For irregular consignments, shippers need to book in advance to be sure to get transport capacity or enjoy certain prices or service levels.

Timing is the positioning of the transport time between specific points of time, in figure 1c shown with arrows as the possibility of moving the transport time vertically. For road, congestion means that both transport time and punctuality might depend on the timing of departure and arrival times and consolidated services always imply a certain degree of compromise. For transport over shorter distances, timing is often more important than speed since the majority of transport assignments are over-night. The preference for pick-up in the late afternoon and delivery in the early morning give clear peaks in delivery truck demand, especially since it coincides with commuting cars.

Punctuality, the unspecified Δt in figure 1d, can be presented as an average deviation from scheduled arrival time. That, however, is a too blunt measure since early arrivals do not make up for late dittos. Even if the absolute value is recorded, one very late arrival among many punctual arrivals might be better than shorter but frequent delays. In other cases, there might be some margin allowing for minor delays while a major delay is disastrous for the shipper.

Consequently, the measure chosen must reveal the character of the delays and it is often given as the frequency of delays in different intervals. Despite significant improvements in later years, rail is still notoriously connected to bad punctuality. Road on the other hand, has a good reputation but is increasingly hampered by congestion. Van Schijndel and Dinwoodie (2000), for instance, estimated that 10% of the operating time of Dutch vehicles is spent in congested conditions.

The *frequency*, i.e., the period between departures (T in figure 1e) inverted, is strongly related to timing and punctuality. In principle, for an equally large goods flow the larger the employed vehicle or vessel, the lower the frequency. Hence, rail offers less frequent departures than road. Frequency does not really apply to individually planned transports of full loads but to all regular transports and of course to time-table based consolidation networks. However, a transport perceived by the shipper as a full truck load might be consolidated with other loads onboard ships or trains at certain links. Frequency then gives more flexibility for the LSP to offer attractive timing. For punctuality, the consequence of a missed departure is obviously lower if there soon is a new departure with available capacity.

2.1 The importance of time for modal choice

Transport time, punctuality and frequency are almost mandatory parts of surveys for shippers' mode preferences. Shinghal and Fowkes (2002), for instance, used these as the only quality attributes when investigating mode choice for freight services in India. In a content analysis of modal choice literature, Cullinane and Toy (2000) identified the major modal attributes. Speed (considered synonymous with transit time and, however less logically, terminal time and transhipment time) and transit time reliability ended up second and third both when counting number of appearances and when trying to estimate relative importance in the surveyed studies. Service (unspecified) was most frequent, while cost was considered most important. Frequency was far lower ranked and timing and order time were excluded in this study.

The Swedish Rail Authority (1999), however, found that Swedish shippers rated timing (formulated as the shipper's ability to affect the departure or arrival time) together with speed as the far highest ranked quality parameter. Also here, cost was top ranked. Nevertheless, another Swedish study (Ljungemyr, 1995), contradictory ranked punctuality (referred to as reliability) as the most important, transport time as the least important and frequency as the second least important out of five quality factors besides costs. One reason for this difference might be that the former study focused conventional wagon load transport and the latter intermodal transport competing for somewhat different categories of goods.

Yet, including costs in the ranking is questionable. Referring to a normal purchasing process it is asserted that such rankings should focus transport quality in a first step in order to generate qualified solutions. Nelldal (2000) divides the process of choosing traffic mode into restrictions, choices and inertias, where restrictions (including elements of time) may eliminate traffic modes. The qualified alternatives are then compared weighing in total costs incurred by each one. Some shippers, however, work with target cost but mainly in renegotiations with an LSP.

Evers et al. (1996), Harper and Evers (1993) and Ludvigsen (1999) all acknowledge that shipper preferences are circumstantial. The latter two studies also detailed the investigation for individual routes used by the respondents, significantly increasing the accuracy of the studies. Also here, time related attributes, particularly reliability, came out highly ranked.

2.2 Time and intermodal transport

Despite abundant research resulting in many good ideas for new network operation principles (see, e.g., Trip and Bontekoning, 2002; Ballis and Golias, 2004; Bärthel and Woxenius, 2004), European IFT is conventionally produced. The production system is characterised by transshipment of unit loads by use of gantry cranes and reach stackers and full train night-leaps directly between terminals. Networks connecting a large number of terminals have yield ground for independently operated rail shuttles (Woxenius and Bärthel, 2006) in order to decrease time, costs and network complexity.

As mentioned, the term full load refers to the capacity of the transport means, thus it is a highly mode dependent measure. Consequently, both a message tied to the foot of a carrier pigeon and 500 000 tons of crude oil in a ULCC tanker are regarded as full loads. In this article focusing consolidated cargo and IFT, the level of full load is chosen as the unit load types ISO container, swap body and semi-trailer. A full unit load is then transported directly between consignor and consignee, although shorter containers and swap bodies can be co-transported with other unit loads in the all-road option, but it is consolidated with other unit loads in an IFT service.

The transhipment between modes implies a certain handicap in time and costs against all-road transport. Figure 2 compares distance and time for all-road transport and IFT of a full unit load directly between a consignor and a consignee. The reason for presenting the axes in this way is that the distance is fixed while the consumed time varies and that this presentation corresponds to common distance-cost charts. There is a strong correlation between time and costs consumed in IFT and the character of a distance-cost curve would be similar.

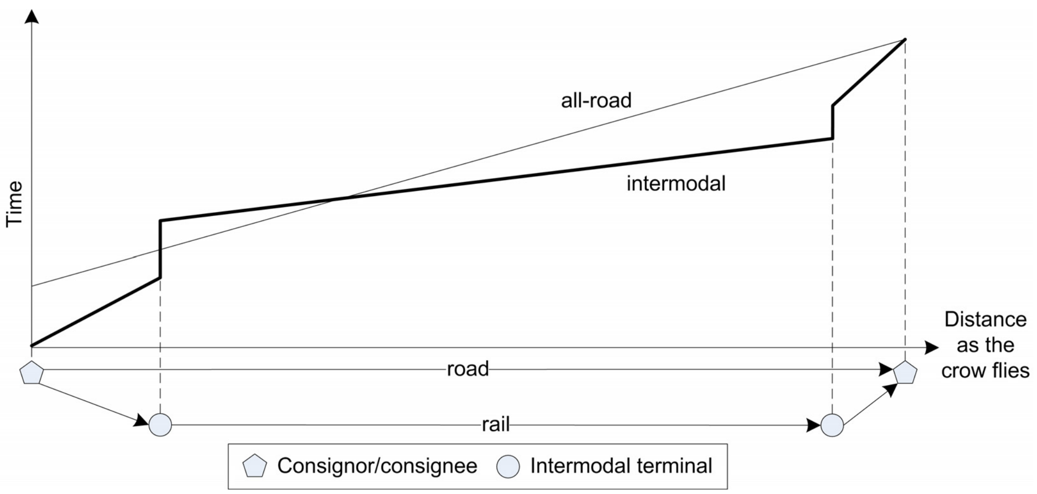

Figure 2. Transport of a full load by all-road and intermodal road-rail transport

The distance in this figure, figure 4 and figure 5 relates to “productive distance”, that is how the crow flies between consignor and consignee. Consequently, the pre and post haulage (PPH) to and from the intermodal terminals that are not positioned on the productive distance line, shown as a simplified map below the graph, is slower than the all-road option that is more direct. Slower speed on urban roads adds to the inclination. At least for domestic services, rail is often faster than road, shown as a steeper curve for road for the long distance. Transhipments at terminals add time but no distance and are thus shown as vertical lines. A particular handicap of IFT is then when PPH is in the “wrong direction” as shown in the example in figure 5.

Strictly time-wise, the handicap is most significant in a distance interval of, say 400 to 700 kms. Over shorter distances, there is enough slack between the pick-up in the late afternoon and the delivery in the early morning to compensate for the PPH and transhipments. Over longer distances, transport time for road is increased by drivers’ rests. For even further distances, all-road often adds another day of transport time giving slack also for IFT.

2.3 Time and consolidation networks

Consignments too small for economically justifying direct transport are either transported as part loads or consolidated cargo. Part loads are picked up and delivered in sequence with other part loads and the consignments stay on the same lorry while transport of consolidated cargo is based on sorting at consolidation terminals. The consolidated cargo service is then produced by a number of sequential activities; pick-up, sorting and consolidation of consignments at a departure terminal, long-distance transport, sorting of consignments at arriving terminal, and, finally, delivery. As the production cycle is based on night-leap transport, the service is offered in number of days from pick-up to delivery. A simplified consolidation network is shown in figure 3.

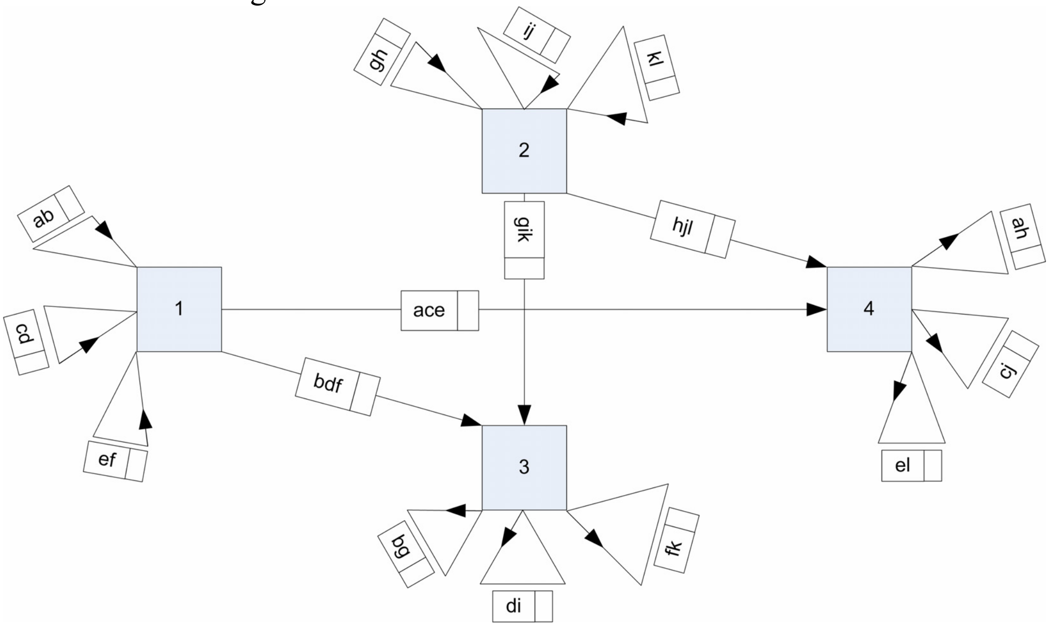

Figure 3. A simplified consolidation network. Consignments a to l are picked up and sorted at the consolidation terminals 1 and 2 and sorted and distributed at 3 and 4

Each of the activities has their timing, together defining a production cycle. In general, pick-up is done during the afternoon, sorting at the departing terminal in the early evening, long-distance transport during the night, sorting at the receiving terminal in the early morning, and delivery during the morning. For distances not possible to cover by transport during one night, an extra day for delivery is added. In figure 4, two consolidation terminals are added and the intermodal service is omitted.

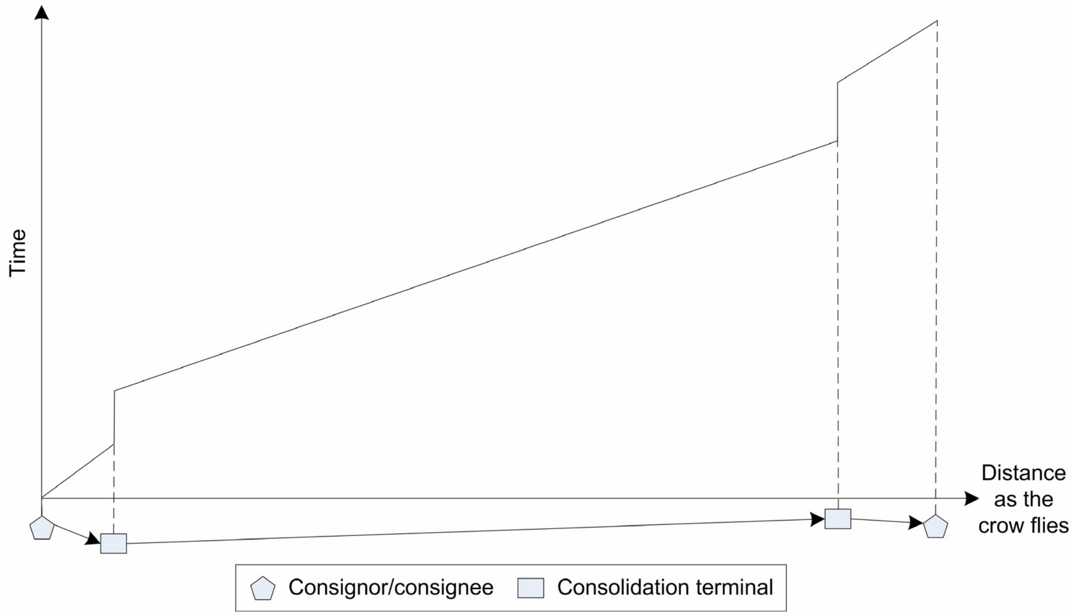

Figure 4. Consolidated cargo transported by road

The character of the curves is similar though. Also here the slower speed on the shorter distances is explained by detours and slower speeds on urban roads. In fact, the average speed during pick-up and delivery is often really slow since these activities are performed in loops with detours and several time-consuming stops.

2.4 Time and intermodal transport supplying consolidation networks

In figure 5, figures 2 and 4 are combined, showing time curves for consolidated cargo. The pick-up and delivery as well as both sorting activities in the consolidation terminals are the same for all-road and for IFT. Between the consolidation terminals, however, the challenge of IFT from two layers of terminal handlings is evident. Moreover, the second intermodal terminal is in this case unfavourably positioned in relation to the consolidation terminal and the consignee. This explains why the curve turns backwards between the intermodal terminal and the consolidation terminal.

Whether time aspects allow conventional IFT to qualify as a supplying system for the consolidated cargo is highly contextual. Some aspects are explained based on figure 5, while others are empirically detailed in the case study in the next section.

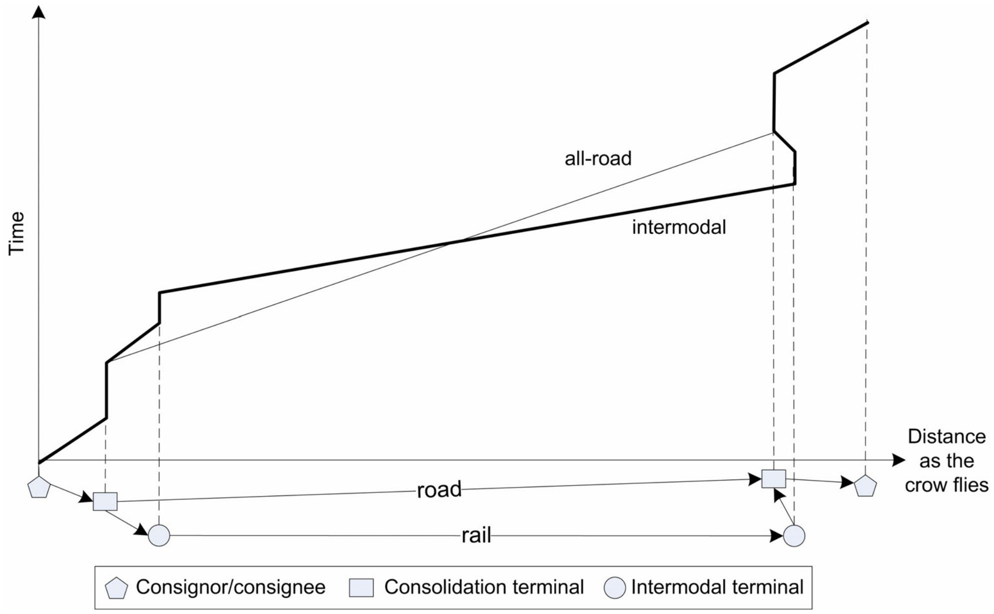

Figure 5. Consolidated cargo by road and intermodal road-rail transport

3. Case study: matching times in a consolidation network and an intermodal transport network

The Swedish market for consolidated cargo, normally characterised by consignments in the range of 30 to 1000 kg, which is sorted and consolidated in terminals, is dominated by the LSPs Schenker and DHL. With approximately 80% of the market they form an oligopoly and they also maintain strong positions in the segments of part loads and full loads. Under their former names Bilspedition and ASG, respectively, they both have a long history of using conventional IFT.

Schenker, which is the larger of the two, particularly regarding consolidated cargo, is chosen for the case study. The purpose of this section is to describe the different time aspects in the case of intermodal transport with the perspective of the demands set by consolidated cargo. This description will illustrate how consolidated cargo demands correspond to the current intermodal transport services. All data is real and retrieved from Schenker and CargoNet.

3.1 Schenker's consolidation network in Sweden

During 2003 Schenker transported approximately 9.6 million tons distributed over 1.9 million consignments of part and full loads in the Swedish domestic network. For consolidated cargo these figures were 1.2 million tons distributed over 5.2 million consignments. Thus, only 11% of the tons but 73% of the consignments related to consolidated cargo.

Schenker operates the consolidation network roughly according to the principles described in section 2.3. The pick-up, delivery and long-distance haulage are subcontracted to hauliers. Between Schenker's terminals, the contracted haulier decides whether to use own lorries or, in turn, subcontract parts of the long-distance transport to intermodal operators. The LSP here act as a "proxy customer" linking a multitude of shippers with the transport operators.

Schenker offers a transport service for consolidated cargo covering the whole of Sweden and consequently operates consolidation terminals spread over the country, currently numbering 29. These consolidation terminals are in turn connected to each other as well as to terminals abroad, either via direct links or via another terminal forming a network of terminals.
Each terminal is responsible for a pre-defined pick-up and delivery area. This area in turn is divided into several sub-areas. A terminal's sub-areas are managed somewhat independently as different hauliers might be employed for each sub-area. Between terminals hauliers are contracted for the long-distance transport and one haulier can be responsible for several of these long-distance relations.

No.	Consolidation terminal location	Intermodal terminal location
1	Luleå	Luleå
2	Umeå	Umeå
3	Sundsvall	Sundsvall
4	Gävle	Gävle
5	Borlänge	Borlänge
6	Stockholm	Stockholm
7	Örebro	Hallsberg
8	Linköping	Norrköping
9	Jönköping	Jönköping
10	Göteborg	Göteborg
11	Kristianstad	Älmhult
12	Helsingborg	Helsingborg
13	Malmö	Malmö

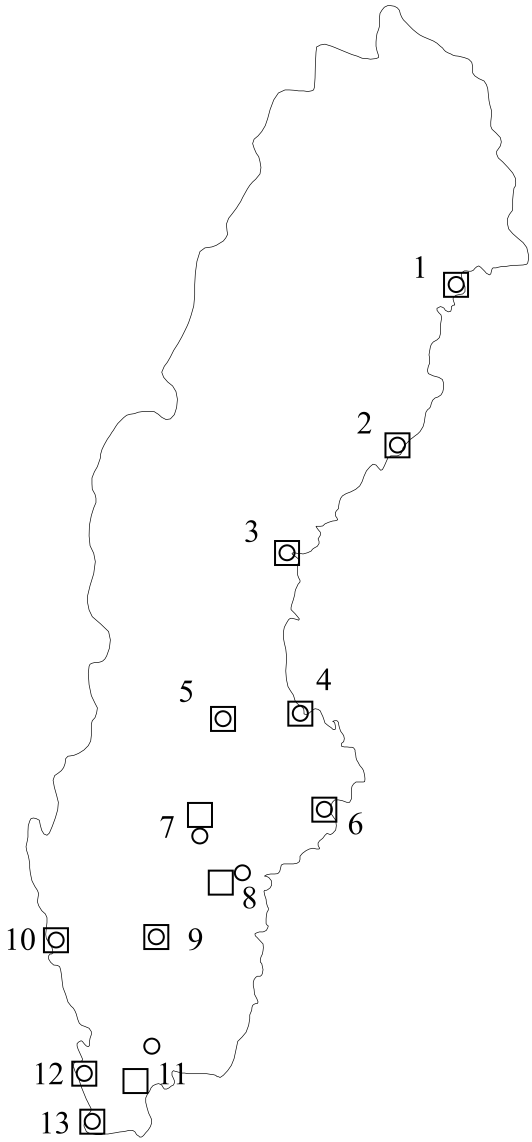

Figure 6. Schenker's consolidation terminals and CargoNet's intermodal terminals in Sweden

On the long-distance other services as part and full loads, parcels and tempered cargo are produced by the same haulier or, except for full truck loads, even by the same truck. The

haulier decides what cargo to go with each vehicle or unit load. More importantly, in the context of the article, the haulier decides whether to use intermodal transport or not.
In table 1 some basic data of the studied terminals and relations is presented. For these terminals there are 156 possible relations (13 terminals that each has relations to all the other 12 terminals) for intermodal transport of which CargoNet offers terminal-to-terminal transport on 123 relations in the timetable of the autumn of 2004, the timetable which the following description and analysis is based on. The consolidation and intermodal terminals are shown in the figure below.
A transport from Kristianstad consolidation terminal via Älmhult intermodal terminal (11 in figure 6) to Linköping consolidation terminal via Norrköping intermodal terminal (8) resembles the example in the figure above.

Table 1. List of the studied terminals and relations

Consolidation terminal	Intermodal terminal	Distance between consolidation terminal and intermodal terminal	Time for PPH [tt:mm]	No. of consolidation terminal relations		Range of distance for consolidation terminal relations		No. of intermodal terminal relations		Range of distance for intermodal relations	
				Dep.	Arr.	Min	Max	Dep.	Arr.	Min	Max
Borlänge	Borlänge	2.9	00:12	26	26	111	851	4	9	443	851
Göteborg	Göteborg	8.0	00:26	28	28	147	1259	11	11	217	1259
Gävle	Gävle	6.4	00:15	26	27	111	745	9	10	174	745
Helsingborg	Helsingborg	5.1	00:14	28	28	65	1425	9	11	217	1425
Örebro	Hallsberg	33.2	00:38	28	27	116	979	9	9	161	979
Jönköping	Jönköping	2.4	00:12	27	28	128	1191	10	5	128	1191
Luleå	Luleå	3.0	00:12	24	25	273	1482	11	12	273	1482
Malmö	Malmö	10.8	00:19	28	28	65	1482	11	11	96	1482
Linköping	Norrköping	42.4	00:46	27	28	116	1067	9	9	198	1067
Sundsvall	Sundsvall	16.8	00:24	25	27	210	946	9	9	315	946
Umeå	Umeå	3.1	00:12	22	26	263	1210	10	10	273	1210
Stockholm	Stockholm	24.6	00:41	28	28	174	913	12	11	174	913
Kristianstad	Älmhult	59.7	01:01	28	26	96	1417	9	6	96	1417
Total/(average)		(15.0)		345	352			123	123		
Not studied consolidation terminal relations:		59-188		389	382	58	1401				

Table 1 further exemplifies that intermodal transport is offered on long distances, but, perhaps somewhat surprisingly, also over shorter distances than regularly considered economic. PPH distances are generally short with an average of 15 km. The relations not studied are clearly located rather far away from the intermodal terminals, but the distance between the consolidation terminals is not necessarily short. In order to compare the consolidated cargo and IFT systems, the consolidation terminal closest to each intermodal terminal is selected and time has been added for transport between the consolidation terminal and the intermodal terminal. This time is specified in table 1 and consists of a distance dependent time, a fix setup time and a time for congestion in Stockholm and Göteborg.
A selection of transport relations is made based on how often the forwarder’s hauliers have used the IFT service. Four IFT usage categories have been distinguished. These are relations where IFT is not used, used only in import/export, used irregularly and used regularly. The IFT usage categories applied is based on data over a three month period during the autumn of

2004. Regular usage is defined as more than 60 TEU transported during the three month period or about 5 TEU per week. The two major usage categories, namely relations were IFT is not used and used regularly, are selected in order to get a large sample to statistically test whether the different time aspects are correlated to the usage of the IFT services. Performing a t-test on the distance of the relations in these both categories confirms that it is a significant difference in this aspect between the two categories (2-tailed significance level at 0.000). These two usage categories include relations to and from the same intermodal terminals. None of the regularly used relations departs and arrives in Älmhult and Hallsberg but a Mann-Whitney test of the representation of departing and arriving intermodal terminals in the relations of two usage categories shows that there is no significant overrepresentation of intermodal terminals in any of the usage categories (Mann-Whitney U (departing terminal of relations not used and used regularly) = 1033.0 ($p = 0.482$) and Mann-Whitney U (arriving terminal of relations not used and used regularly) = 1092.0 ($p = 0.788$)).

Table 2. IFT usage categories

	Not used	Used only in import/export	Used irregularly	Used regularly
Number of IFT relations	61	12	13	37
Average distance	471	485	684	864
Distance standard deviation	292	234	455	314

3.2 Transport time

Scheduled transport times in relation to road distance for the studied consolidated cargo terminal relations as well as the corresponding transport time for IFT are presented in figure 7. Note that transport time for consolidated cargo is more linearly correlated to distance than for IFT. Interestingly, the shortest transport time for IFT is about 8 hours over a distance about 450 km while relations of shorter distances have longer transport times. The clustering of times around 12, 36 and 60 hours emphasises the night-leap production cycle.

Table 3 presents the transport time of the consolidated cargo and IFT for different arrival days of consolidated cargo. The number of relations where the transport time of IFT is less or equal to the demands set by consolidated cargo is also presented. At half, or 19, of the regularly used relations, the IFT service offered fit the consolidated cargo requirements compared to only two of 61 relations where IFT is not used. Comparing the transport time for the different usage frequencies reveals that where the intermodal service is regularly used, the transport time is considerably lower than for the other relations suggesting that the forwarder have strong preferences for relatively short transport time. An explanation to the relatively short transport times might be that these relations in-all have large volumes, thus facilitating for CargoNet to operate by direct trains.

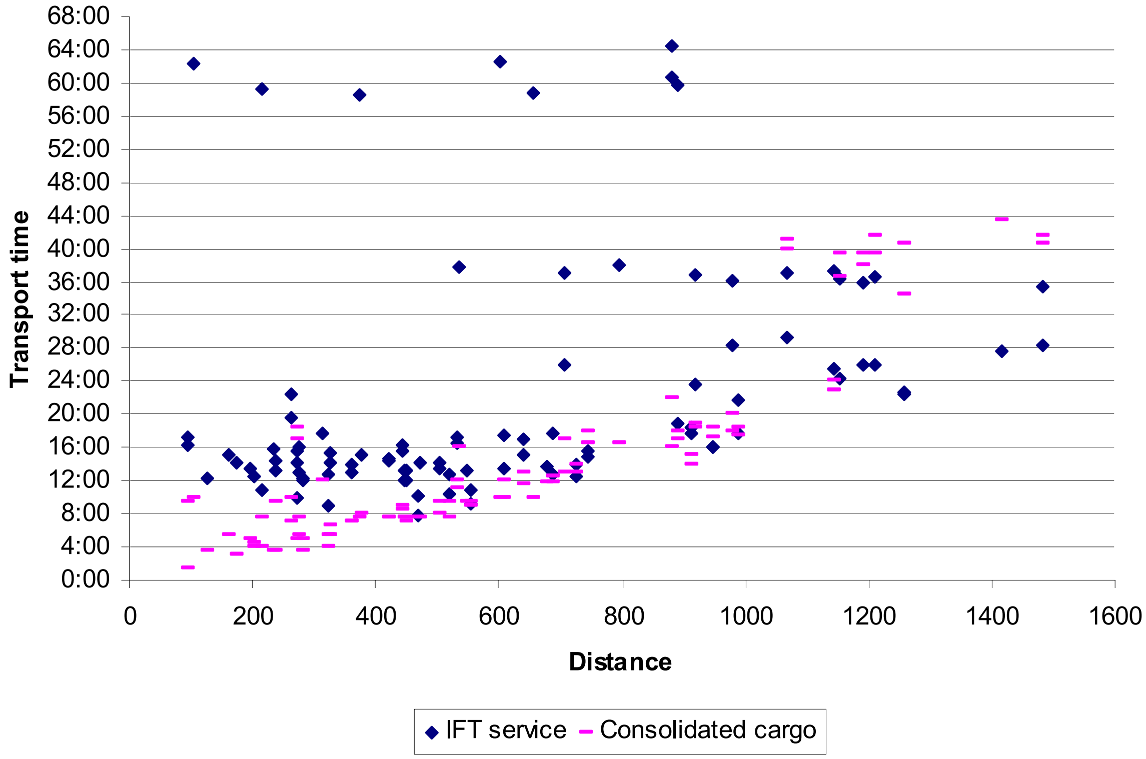

Figure 7. Schenker's consolidated cargo terminal-to-terminal domestic transport times related to travelled road distance and the corresponding transport times of the IFT service

Table 3. Average transport time of the IFT services and of consolidated cargo terminal-to-terminal transport

	IFT usage frequency					
	Not used			Regularly used		
Consolidated cargo arrival day	**Number of relations**	**Average transport time for consoli-dated cargo**	**Average transport time for IFT**	**Number of relations**	**Average transport time for consolidated cargo**	**Average transport time for IFT**
0	7	3:21	20:41			
1	53	10:31	23:27	25	13:07	15:35
2	1	43:30	27:43	12	39:22	30:00
Total/ (average)	61	(10:14)	(23:13)	37	(21:38)	(20:15)

To test whether transport time is a significant aspect in relation to the usage of IFT in the consolidation network a comparison of the transport time demand by consolidated cargo with the transport time with IFT have been conducted. The t-test 2-tailed significance was 0.000 which result in the conclusion that transport time is a significant aspect.

3.3 Order time

Some hauliers associated with Schenker have pre-booked capacity in CargoNet's trains. If the haulier will not use all of this capacity, notification is required by CargoNet at noon the departing day. This is also the deadline for booking extra capacity. At this time information of the amount of consolidated cargo is not available to the haulier, indicating a mismatch between the order times in the general cargo and the IFT services.

3.4 Timing

The large number of departing and arriving relations per consolidation terminal illustrates the challenge of timing departures and arrivals for efficient operation of the network. Table 4 and table 5 illustrates the production cycle for consolidated cargo and IFT respectively. Arrival day zero, one, two and three means for how many days after departure the arrival is scheduled, e.g., arrival day two for IFT means departure on Monday and arrival on Wednesday. When a relation has one timetable for weekdays and a different timetable for weekends, the timetable for weekdays is displayed. Further, table 5 displays the times at the intermodal terminal for last handing in at departure and first handing out at arrival.

Studying table 4 and table 5 reveals that departures from the consolidation terminals are scheduled from early afternoon until late evening and that IFT departures are also scheduled in the afternoon and evening but not in the late evening. Looking at arrival day one, arrivals generally seem to be scheduled earlier in the morning for consolidation terminals than for the intermodal terminals. However, both for consolidated cargo and IFT, the production cycles seem to be adjusted at some terminals, i.e. the same service times are not applied to all terminals. To exemplify, Luleå has the earliest arrival at eight and Umeå at six. This obviously affects the earliest delivery of consolidated cargo to the consignees as well as the arrival time requirements on the IFT service. It can also reflect that the volume of consolidated cargo is limited which enables later arrival times due to expedient handling.

Table 4. Departure and arrival times for consolidation terminals

Terminal	Departure		Arrival times per arrival day								
			0			1			2		
	Min	Max	Min	Max	Count	Min	Max	Count	Min	Max	Count
Borlänge	19:00	19:00				03:00	06:00	6			
Göteborg	18:00	20:30				00:30	12:00	6	09:00	09:00	1
Gävle	18:00	19:00				01:00	08:30	8			
Helsingborg	17:00	19:30	23:00	23:00	1	02:30	07:00	8	06:00	06:00	1
Örebro	15:00	00:00	22:00	23:30	2	00:30	11:00	7			
Jönköping	17:00	19:30				00:30	12:00	3	08:00	08:00	1
Luleå	15:00	17:00				08:00	12:00	4	06:00	08:30	5
Malmö	15:00	18:30	23:30	23:30	1	00:30	09:00	4	09:00	09:00	2
Linköping	16:30	19:30	23:00	23:00	1	01:00	10:00	6	10:00	10:00	1
Sundsvall	12:00	18:00				04:00	11:00	8			
Umeå	13:00	17:30				06:00	13:00	6	08:30	08:30	2
Stockholm	17:00	20:30	22:00	23:00	2	00:30	07:00	7			
Kristianstad	13:00	22:00				02:30	13:00	5			
Total	12:00	00:00	22:00	23:30	7	00:30	13:00	78	06:00	10:00	13

Table 5. Departure and arrival times to/from intermodal terminals

	Departure		Arrival times per arrival days 1			2			3		
Terminal	**Min**	**Max**	**Min**	**Max**	**Count**	**Min**	**Max**	**Count**	**Min**	**Max**	**Count**
Borlänge	18:00	18:00	08:00	08:00	4				06:00	08:00	2
Göteborg	14:45	20:45	05:00	15:00	7						
Gävle	17:50	19:15	05:30	07:45	8						
Helsingborg	19:00	19:00	06:00	11:00	8	06:00	06:00	1	06:00	06:00	1
Hallsberg	17:45	17:45	06:15	06:15	6	06:15	06:15	2	06:15	06:15	1
Jönköping	15:45	19:45	06:30	06:30	2	06:30	06:30	2			
Luleå	17:15	19:00	09:15	21:15	9						
Malmö	17:00	18:00	06:00	09:00	5	06:00	06:00	2			
Norrköping	17:00	17:00	07:00	07:00	6	07:00	07:00	2			
Sundsvall	15:00	17:30	07:25	08:15	4	08:15	08:15	1	06:00	06:00	3
Umeå	18:00	18:00	07:00	19:00	8						
Stockholm	16:45	20:00	03:15	10:00	9						
Älmhult	09:00	18:45	06:00	09:00	3	06:00	06:00	1	06:00	06:00	1
Total	09:00	20:45	03:15	21:15	79	06:00	08:15	11	06:00	08:00	8

To level the workload at the consolidation terminal the departure and arrival times for different relations are scheduled within a certain time span. This is facilitated by that trucks in road transport at the outset can be scheduled independently from each other. Not all relations offer this flexibility though, since the distance travelled only allows early departure and late arrival to be within the time available for the overnight production cycle. Another circumstance limiting the possibility to freely schedule departure and arrival times is that the distance is in the range that a round trip can be performed during the night-leap illustrating the sometimes contradictory objectives of the subsequent activities. Thus, road transport in consolidated cargo has restrictions on how it can be scheduled which affects the timing demands on IFT.

Table 6. Timing of IFT compared to consolidated cargo time demands and the effect on timing of adjusted departure and arrival times

	IFT usage frequency		
Number of relations where:	**Not used**	**Regularly used**	**Total**
Departure of IFT incl PPH match consolidated cargo	23	22	45
Arrival of IFT incl PPH match consolidated cargo	2	20	22
Both departure and arrival times match	2	15	17
Adjusted departure times match	33	33	66
Adjusted arrival times match	2	23	25
Both adjusted departure and arrival times match	2	21	23

On all relations but two where the transport time of the IFT service corresponds with the transportation time available for consolidated cargo, the timing of departure and arrival (presented in table 6) also corresponds. This fact suggests that the intermodal operator have timed their departure and arrival correctly to the demand of the forwarder on these relations or, the opposite, that the forwarder has adjusted its departure and arrival times to enable IFT on these relations. However, only on 17 of the 98 relations the IFT can fulfil the departure and arrival timing demands from consolidated cargo. This fact shows the limited possibility to use the available intermodal transport service for consolidated cargo. A statistical test (Mann-

Whitney U = 532.5 (p = 0.000)) of timing fulfilment between the two IFT usage categories shows that timing is a relevant time aspect for IFT usage in the consolidation network.
A question of importance in the timing aspect is whether having one more hour available at departure and/or arrival would result in a better match, i.e. whether rather small improvements will have any effect. The effect of adjusting departure times is larger than adjusting arrival times as Table 6 illustrates. In total, adjusting IFT departure with one hour and arrival with one hour would make the timing match on six more relations and make the transport time two hours shorter.
Further, the mean distance of the regular relations are highest of all usage categories implying that IFT is preferred for longer distances (see table 2). Specifying this mean distance for relations where both departure and arrival times correspond with the IFT service and where they do not correspond results in 1018 km and 536 km respectively. This fact shows that the IFT service is better timed for consolidated cargo over longer distances.

3.5 Punctuality

Table 7 reveals a rather negative image of the performance of the IFT service. This data is for all arrivals to each individual terminal counted on relation basis for October 2004. To some of the terminals, units from several relations arrive in the same train, i.e. co-production of several relations in the same train. One of the terminals, Älmhult, is excluded because there was no data available. There seem to be a vast difference of the punctuality performance at the different terminals, both in terms of the share of late arrivals and mean minutes of delay when delayed.

Table 7. CargoNet's punctuality during October 2004

	No. of arrivals	**No. of late arrivals**	**Percentage of late arrivals (%)**	**Mean minutes of delay when delayed [hh:mm]**
Borlänge	147	63	43	00:47
Göteborg	209	16	8	00:29
Gävle	163	35	21	00:48
Helsingborg	175	134	77	00:36
Hallsberg	168	104	62	01:11
Jönköping	90	0	0	00:00
Luleå	163	6	4	00:11
Malmö	123	38	31	00:51
Norrköping	189	108	57	00:45
Sundsvall	98	51	52	01:22
Umeå	158	8	5	00:28
Stockholm	171	43	25	00:47
Total	1854	606	33	00:40

The data of the punctuality of the IFT services presented in table 8 is perhaps of greater interest to the forwarder. This image is considerably more positive for the relations actually used in terms of the frequency of late arrivals. Relations that are regularly used have better performance than the IFT relations not used. A t-test (2-tailed significance = 0.024) of the share of late arrivals between the IFT usage categories gives that punctuality is a significant time aspect for IFT usage.

Table 8. Punctuality per studied usage category of intermodal transport by Schenker

	IFT usage frequency		
	Not used	**Regularly used**	**Total**
Total arrivals	877	603	1885
Late arrivals	367	149	612
Share of late arrivals	42%	25%	32%
Total minutes late [hh:mm]	368:58	138:05	597:29
Minutes per late arrival [hh:mm]	01:00	00:55	00:58

The impact of poor punctuality on the consolidated cargo schedule has not been investigated in more detail here. In interviews, however, Schenker staff indicated that punctuality has been significantly improved and does not constitute a major problem in the domestic Swedish IFT.

3.6 Frequency

The studied IFT relations have a service frequency from one departure up to 10 departures per week. For consolidated cargo all but one of the 98 relations has at least one daily departure on weekdays. One relation can have more than one daily departure depending on the volume to be transported. Service frequency for the IFT relations for the two usage categories is presented in table 9. A Mann-Whitney test comparing the importance of IFT service frequency between the usage categories gives that service frequency is an important time aspect for usage of IFT (Mann-Whitney $U = 865.0$ ($p = 0.008$)).

Table 9. Number of relations per weekly IFT service frequency and IFT usage frequency

IFT service frequency	**IFT usage frequency**	
[Number of departures per week]	**Not used**	**Regularly used**
1	9	
4	2	1
5	46	30
6	4	2
9		3
10		1
Total	61	37

4. Conclusions

This article elaborates on the time elements transport time, order time, timing, punctuality and frequency. In particular, the coordination between an LSP's consolidation network and a subcontracted IFT network is studied. In the case study, both networks clearly follow the night-leap production cycle with departure time in the early evening as common dimensioning time, i.e. departure times are more uniform than arrival times. Transport services offered by both the consolidation and the intermodal network are therefore adjusted to the geographical position of each terminal, thus contextual and the service hours offered are not the same for all terminals in the network.

For consolidated cargo, the LSP uses intermodal transport primarily over longer distances, which is in line with the common view of the competitive strength of intermodal transport.

Correspondence of the *transport time* between the consolidation network and the intermodal network are not a prerequisite to use intermodal transport. This means that the time requirements consolidated cargo puts on the intermodal transport service is not instrumental to whether the hauliers will employ intermodal transport. But, undoubtedly, fulfilling the time requirements of consolidated cargo will make the intermodal transport service more competitive and increase the willingness for using intermodal transport. Correspondence of departure and arrival times is significantly higher for the intermodal relations regularly used by the LSP. This fact shows that the IFT service is better suited for consolidated cargo over longer distances.

Regarding *timing*, adjusting departure and arrival times by one hour will not make the intermodal service considerably better fitted to the consolidated cargo production. This fact entails that if the intermodal transport service and the consolidated cargo should correspond better, more profound adjustments like shortening the terminal times are required. During the *order time* of the IFT service, relevant volume information is not available to the haulier which results in that the haulier must act on an assessment of the volume if the consolidated cargo should go by IFT.

For *punctuality*, the effect of the delays shows that the current schedule of the network for consolidated cargo is sensitive even for the relatively short delays occurring in the studied IFT services. However, relations that are attractive to the hauliers contracted by the LSP show better performance than the average IFT relations studied.

Due to the strong night-leap production cycle, the *frequency* is of less importance in the case study. Although some relations in the consolidation network are served with several departures by lorries and very few of the intermodal relations by two daily trains, the period between departures is short. Hence, the current demand for trains in daytime is considered as very low regarding consolidated cargo.

Acknowledgements

The research is co-financed by the Swedish Agency for Innovation Systems (Vinnova) and the Swedish Rail and Road Administrations.

References

Ballis, A. and Golias, J. (2004). Towards the improvement of a combined transport chain performance. *European Journal of Operational Research*, vol. 152, no. 2, pp. 420-436.

Bärthel, F. and Woxenius, J. (2004). Developing intermodal transport for small flows over short distances. *Journal of Transportation Planning and Technology*, vol. 27, no. 5, pp. 403-424.

Cullinane, K. and Toy, N. (2000). Identifying influential attributes in freight route/mode choice decisions: A content analysis. *Transportation Research Part E: Logistics and Transportation Review*, vol. 36, no. 1, pp. 41-53.

ECMT (2005). *Time and transport*. Round table 127, European Conference of Ministers of Transport, Paris.

European Commission (2001). *European Transport Policy for 2010: time to decide*. White paper, Office for official publications of the European Communities, Luxemburg.

Evers, P.T., Harper, D.V. and Needham, P.M. (1996). The Determinants of Shipper Perceptions of Modes. *Transportation Journal*, vol. 36, no. 2, pp. 13-25.

Golias, J. and Yannis, G. (1997). Determinants of combined transport market share. *Transport Logistics*, vol. 1, no. 4, pp. 251-264.

Harper, D.V. and Evers, P.T. (1993). Competitive Issues in Intermodal Railroad-Truck Service. *Transportation Journal*, vol. 32, no. 3, pp. 31-45.

Ljungemyr, H. (1995). *Vilka transportfaktorer har betydelse för kombitrafikens andel av godstransporterna? (Which factors influence the market share of intermodal transport?)*. VTI-meddelande Nr 773, Linköping (in Swedish).

Ludvigsen, J. (1999). Freight Transport Supply and Demand Conditions in the Nordic Countries: Recent Evidence. *Transportation Journal*, vol. 39, no. 2, pp. 31-54.

Nelldal, B.-L. (2000). *Competition and co-operation between railways and trucking in long distance freight transport - an economic analysis*. Royal Institute of Technology, Stockholm.

Shinghal, N. and Fowkes, T. (2002). Freight mode choice and adaptive stated preferences. *Transportation Research Part E: Logistics and Transportation Review*, vol. 38, no. 5, pp. 367-378.

SIKA (2002). *Tid och kvalitet i godstransporter (Time and quality in freight transport)*, SIKA, Stockholm (in Swedish).

Swedish Rail Authority (1999). *Profilering av järnväg - en uppföljande marknadsundersökning (profiling rail - a follow-up marketing analysis)*, KAN Kommunikationsanalys, Stockholm (in Swedish).

Trip, J.J. and Bontekoning, Y. (2002). Integration of small freight flows in the intermodal transport system. *Journal of Transport Geography*, vol. 10, no. 3, pp. 221-229.

Van Schijndel, W.-J. and Dinwoodie, J. (2000). Congestion and multimodal transport: a survey of cargo transport operators in the Netherlands. *Transport Policy*, vol. 7, no. 4, pp. 231-241.

Woxenius, J. (2006). Temporal elements in the spatial extension of production networks. *Growth & Change: A Journal of Urban and Regional Policy*[1], vol. 37, no. 4, pp. 526-549.

Woxenius, J. and Bärthel, F. (2006). Intermodal Road-Rail Transport in the European Union, Forthcoming in Konings, R., Priemus, H. and Nijkamp, P. (eds.) *The Future of Intermodal Freight Transport, Concepts, Design and Implementation*. Cheltenham, Edward Elgar Publishing, UK.

[1] ISI Journal Citation Reports® Ranking 2005: 16/38 (SSE: Planning & Development), Impact Factor: 0.644.