THE EFFECT OF FAST TRANSHIPMENT TECHNOLOGY ON THE POTENTIAL FOR INTERMODAL FREIGHT TRANSPORT

Sönke Behrends, Division of Logistics and Transportation, Chalmers University of Technology, Gothenburg, Sweden, E-mail: sonke.behrends@chalmers.se

Jonas Flodén, Logistics and Transport Research Group, Department of Business Administration, School of Business, Economics and Law, University of Gothenburg, Gothenburg, Sweden, E-mail: jonas.floden@handels.gu.se

ABSTRACT

Traditionally, intermodal transport has a medium to high market share for large flows over long distances while the short and medium distances (less than 500km) mainly remain a domain of the road transport sector. In order to allow intermodal transport to compete in the medium distance and high quality market segment, alternative network operations that allow for an intensification of rail services and expansion of geographical coverage are needed. Intermodal liner trains that operate in corridor network designs with intermediate stops between start and end terminals are regularly advocated by intermodal transport researchers as a means to compete with all-road transport on small volumes and short distance markets. Innovative transhipment technologies facilitating fast and efficient transhipments are a necessity for intermodal liner trains since the conventional terminals are not appropriate for intermediate terminals where freight volumes are low and train dwelling times need to be short. The purpose of this paper is to analyse the transhipment unit cost's effect on the modal shift potential of intermodal liner trains based on fast and efficient transhipments. In a theoretical case study the cost and potential modal share for an intermodal liner train on a corridor in Sweden is analysed. The method is based on modelling a competitive situation between traditional road transport and intermodal road-rail transport. The results confirm that *in theory* intermodal liner trains can provide competitive services on short and medium transport distances in case transhipment costs are kept low. Fast and efficient transhipment technologies can open business opportunities for operators and cost savings potential for shippers in a market segment which is dominated by road transport.

Keywords: Intermodal transport, modal shift, modelling, rail transport, transhipment technology

INTRODUCTION

Transport demand is closely linked to economic development and for several decades there was a close correlation between the growth of freight transport and economic growth. In the recent economic slowdown there seems to have been a sudden fall in freight transport demand; however, previous recessions have shown that freight transport is bound to recover more quickly than the rest of the economy (European Commission, 2009). In recent decades, the increase in freight transport demand has mainly been met by road (European Commission, 2006), which imposes significant negative impacts on the society, economy and environment. Despite the introduction of alternative fuels and innovative vehicle technology, the total externalities of the road freight transport sector have increased because the growing road freight transport volumes have over-compensated for the improved emission level per kilometre driven. As a response to the growing unsustainable impacts from road transport, the EU Commission's 2nd White Paper on a European transport policy (European Commission, 2001) emphasises sustainable development and identified the impact on the environment as main challenge. Furthermore, congestion in the economic centres of Europe goes hand in hand with excessive isolation of the outlying regions, where there is a real need to improve links with central markets so as to ensure regional cohesion within the EU. In order to reduce the environmental impacts and existing bottlenecks, the White Paper highlights the need to break the link between transport growth and economic growth and to reduce the imbalance in the development of the different transport modes. A key policy objective is a modal shift from road towards more sustainable modes like rail. However, despite a series of initiatives aimed at revitalizing rail freight, rail's modal share of inland freight transport in EU-25 continues to decline. Though intermodal rail-road transport has grown in absolute figures in countries that have liberalized their rail transport market (Steer Davies Gleave, 2009), this increase has only led to rail being able to maintain its modal share due to the underlying growth in total transport demand.

Traditionally, intermodal transport has a medium to high market share for large flows over long distances, for seaport hinterland flows, for flows between production plants and to depots and for bulk commodities and dangerous goods. Intermodal transport competes in these markets with road transport (Bontekoning and Priemus, 2004). The short and medium distances (less than 500km) mainly remain a domain of the road transport sector because intermodal services cannot compete in terms of price/cost, which for many relations is too high, and the quality of services, which often is too low (Kreutzberger, 2001). The potential for a modal shift in favour of rail can increase drastically if intermodal transport can become competitive in these markets. It is therefore increasingly recognized that the conventional approach to intermodal transport focusing on large flows over long distances may be insufficient to address the persistent problem of a growing modal share of road freight. Incremental innovations within the present rail production paradigm and dominant technology for improving existing operations will not lead to the necessary quality leap (Kreutzberger, 2001).

In order to allow intermodal transport to compete in the medium distance and high quality market segment, alternative network operations that allow an intensification of rail services and expansion of geographical coverage are needed. Hence, intermodal liner trains operating in corridor network designs with intermediate stops between the start and end terminal are regularly advocated by intermodal transport researchers as a means to compete with all-road transport on small volumes and short distance markets (Rutten, 1995, Rudel, 2002, Bärthel and Woxenius, 2004). Since liner trains provide access to rail, and not only to the region in the vicinity of the start and end terminal but also to the areas along the corridor, more destinations are served and door-to-door transport times can be reduced significantly.

The transport cost and time of an intermodal chain increase markedly at the terminal point (Wiegmans, et al., 1999). Hence, if the node operations are executed by the present conventional terminals which are adapted to the conventional rail operations with morning arrivals and evening departures of trains, they would absorb too much time and money, leading to unattractive integral lead times and costs. A prerequisite for the organizational innovation of intermodal liner trains is therefore fast and efficient transhipment operations at the intermediate nodes, which cannot be achieved by the conventional terminals (Trip and Bontekoning, 2002). Hence, for innovations like intermodal liner trains in rail operations, technological innovations, i.e., innovative transhipment technology, are a necessity if intermodal freight transport is to become competitive in short and medium distance transport and in order to capture significant transport volumes from road transport (Bontekoning and Priemus, 2004). Horizontal automated transhipment technologies fulfil the demand for rapid handling best but the sophisticated nature of innovative concepts often result in high transhipment unit costs (Vrenken, et al., 2005) which is likely to reduce the competitiveness of intermodal transport.

The purpose of this paper is to analyse the transhipment unit cost’s effect on the modal shift potential of intermodal liner trains based on innovative transhipment technologies that allow for fast and cost efficient operations. The paper is based on a case study. The cost and potential modal share for an intermodal liner train on a corridor in Sweden is analysed. The method is based on modelling a competitive situation between traditional road transport and intermodal transport. The case study takes a transport systems perspective and does not focus on the implications for the individual actors in the intermodal transport chain. The case is based on theoretical data constructed by the authors and consequently it does not aim for indentifying what can be achieved in the real world transport system. The aim of the case study is to identify the general modal shift potential of an intermodal liner train based on innovative fast and efficient transhipments.

The structure of this paper is as follows. The following section provides the theoretical background for the case study. Concepts of rail production networks and their implications on transhipment technologies are reviewed, focusing on intermodal liner trains. Then, the case study is presented. First, the case is briefly introduced, followed by a short description of the Heuristics Intermodal Transport (HIT) Model developed by Flodén (Flodén, 2007), which is used for the case study modelling. The section finishes with the presentation of the modelling results. Finally, the implications of the results for transhipment technologies and modal shift policies are discussed and possibilities for further research are outlined.

RAIL PRODUCTION NETWORKS AND TRANSHIPMENT TECHNOLOGIES

Consolidation networks

If freight flows are not large enough to fill larger transport units such as trains, consolidation of freight belonging to different origins and/or destinations during common parts of the route is a necessary operation. The advantages of consolidation are relatively higher service frequencies, higher loading degrees and/or more economies of scale, more destinations from each origin and possibly also the smoothing of handling peaks at terminals. The disadvantages are additional transhipments and detours, which result in increasing chain transit time and costs (Bontekoning, 2000).

If consolidating flows is decided upon, it is generally done systematically, i.e., according to a transport network design. Different options for transport network design are discussed by several intermodal transport researchers (Bontekoning, 2000, Ballis and Golias, 2004, Woxenius, 2007b). Although the research has not arrived at common definitions yet, all researchers distinguish several basic network designs. Woxenius (2007b) defines six significantly different theoretical designs from the perspective of a transport system operator: direct link, corridor, hub-and-spoke, connected hubs, static routes, and dynamic routes (Figure 1).

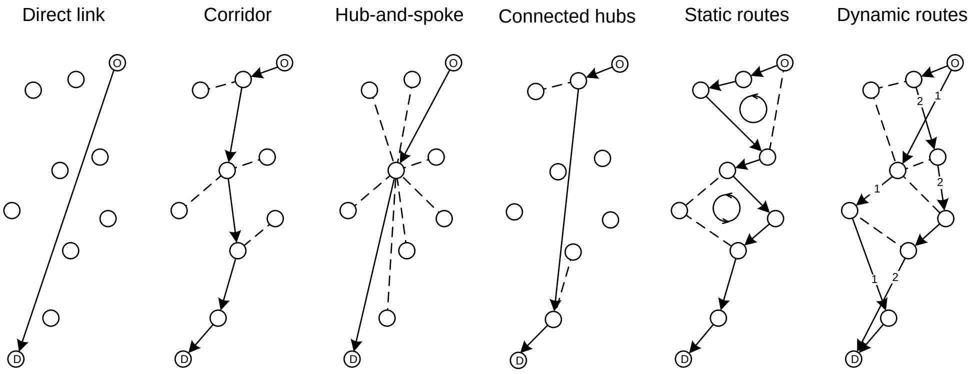

Figure 1 – Six options for transport network design. Source: Woxenius (2007b)

In a *Direct link,* trains run directly between an origin and a destination terminal without handling on the way. Direct trains are the most economic and rapid operating rail mode. Trains operated in a *Corridor* pass several terminals on their route between start and end terminal. They offer regular service and higher frequencies and allow for the integration of terminals with smaller demands in a network of intermodal transport. Distances between the terminals are comparably small and train waiting times at the terminal are rather short. In a *Hub-and-spoke network* one node is the hub and all unit loads call this node for transfer. In this design it is possible to offer connections between a large number of origins and destinations with medium and small terminals. However, this design implies long train formation and bundling times in the hub and detours even for transports between adjacent spoke terminals. In *Connected hubs networks,* short feeder trains connect several terminals of a region to a hub where the loads are consolidated for the long-distance transport between the hubs. It can thus be described as a direct link with regional consolidation. In a *Static routes design* a number of links are used on a regular basis and several nodes are used as transfer points along the route. Transfer is not needed at every node. *Dynamic routes* provide maximum flexibility by designating links depending on actual demand.

Rationalising of the railway sector, competition from the road transport and the high purchase and exploitation costs of terminal equipment have encouraged a strategy aimed at increasing the economies of scale and minimising the costs of intermediate transhipment or shunting (Trip and Bontekoning, 2002). As a consequence, the dominating production principle of rail transport today is direct links and their use increases at the expense of consolidation networks (Bärthel and Woxenius, 2004). The emphasis is on direct terminal-to-terminal shuttle services and a highly concentrated intermodal network with a relatively small number of nodes and a strong focus on a limited number of high volume, mainly maritime, corridors between economic core regions and seaports. While in this setting rail transport is easy to operate and provides good transport quality and economy for large flows over long distances, i.e., 500 km and more (Flodén, 2007), the short and medium distance transports remain a domain of the road transport sector.

One reason for the development toward terminal concentration is that profit margins in terminal operation are low and often cause the need for subsidies (Unseld and Kotzab, 2008). The necessity of higher productivity has been achieved by virtue of larger and more automated equipment, which involves high fixed costs. As a consequence, these large and centralized terminal installations require high volumes of load units in order to distribute the high fixed costs of the terminal to a large number of transhipments.

Terminals and transhipment technologies

The transhipment function performed in terminals is an indispensible element in consolidation networks. The terminal functions and performance requirements of the terminals depend on freight flow characteristics, the type of consolidation network and its location in the network. Generally, intermodal transport researchers distinguish between four terminal types which differ in their function in the intermodal network (Wiegmans, et al., 1999, Bontekoning, 2000, Woxenius, 2007a). These are start and end terminals, intermediate terminals, hub terminals and spoke terminals. Woxenius (2007a) provides a detailed assessment of the crucial performance characteristics of terminals and an overview of the implication on the transhipment technologies. *Intermediate terminals in corridors* served by intermodal liner trains handle a limited number of unit loads which are transhipped at intermediate nodes for distribution in the terminal region. At these terminals only a few load units on each train are handled. Therefore, it is of paramount importance that the transhipment technology has low transhipment costs and can access any load unit at the train. 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 (Trip and Bontekoning, 2002). Suitable are short stops at sidetrack terminals along the route with quick transhipment operations in order to avoid the need for co-ordination of trains and road vehicles at terminals (Woxenius, et al., 2004).

According to Woxenius (2007a), various concepts for small-scale transhipment technologies for meeting these demands have been developed in recent decades. Both horizontal and vertical transhipment technologies exist. They promise low fixed costs and therefore allow for economic operations at comparably low transhipment volumes. The big advantage of small-scale horizontal transhipment compared to small-scale vertical transhipment is that only a small vertical lift is needed to tranship the unit load. This allows slimmer dimensioning since only a small force is needed to tranship the load units horizontally. Furthermore, transhipping under the catenary is possible. However, these advantages often come with the drawback of technical complexity. Most of them require adaptations of load units, rail wagons or lorries as well as human interaction which limits their flexibility. Furthermore, some technologies depend on the simultaneous presence of road and rail vehicles at the terminal. On the other hand, if automated transhipment technologies are used, reduction of terminal cut-off times can be achieved, which can increase the flexibility of the intermodal services (Tsamboulas, et al., 2007).

Figure 2 shows a typical example of the use of an intermediate terminal for transhipment operations in a corridor design. The intermediate terminals can be operated on a rail service track running parallel to the main track. An example is by-pass tracks at railway stations.

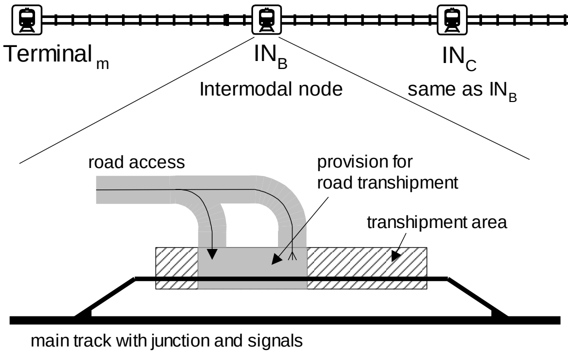

Figure 2 – Intermediate terminal in a corridor network design. Source: FastRCargo (2006)

An example of a small-scale horizontal transhipment technology for automated transhipment of standardised intermodal load units between rail wagons and lorries below catenaries is developed in the project FastRCargo[1]. It is based on automatically handling the intermodal transport units in vertical, transversal and lateral directions. This is achieved by gripping the intermodal transport units at their bottom corners. The terminal design includes a rail track and a sorting track. The concept operates with two sub systems, one handling all vertical load movements with four *load unit lifts*, one at each corner of the load unit, and a second sub system, the *load unit handling tray* handling all transversal and lateral load movements. All movements are automatically controlled and coordinated. Within the project FastRCargo a demonstrator for performing the train loading function is developed. The basic concept is shown in Figure 3. For details about the technology's concept see Unseld and Kotzab (2010) and for details about design and functionality see FastRCargo (2008).

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[1] FastRCargo is a project financed by the European Commission within the 6th framework programme. The project aims at developing a small-scale horizontal transshipment technology for automated transshipments of intermodal loading units below active contact lines.

Figure 3 – Basic concept of the fast and automated transhipment concept. Source: Unseld and Kotzab (2010)

The technology is capable of handling container and swap bodies up to a length of 14.040 mm and tonnage of 34 tonnes. The design provides a short transhipment time since it allows transhipments below active catenaries and can access any load unit on the train. Since there are no dimensional train passing restrictions and road and rail transport vehicles do not require any modifications, the equipment is fully compatible with the existing infrastructure and standardised rolling stock. The scalability of the transhipment equipment allows a capacity design which can be tailored to the demand.

CASE STUDY: INTERMODAL LINER TRAIN BETWEEN GOTHENBURG AND STOCKHOLM

The case

In order to explore the modal shift potential of an intermodal liner train service with intermediate terminals based on fast and efficient transhipments, a theoretical case has been constructed. For transport flows along a corridor, direct road transport is compared with an intermodal alternative using a liner train. The aim of the case study is to analyse the critical transhipment unit costs (TUC) for the mode choice as well as the transhipment unit cost's influence on the minimum distance between the intermediate terminals, i.e. how the transhipment costs that an transport system operator has to pay influence the modal split along the corridor. The case is based on a transport corridor in Sweden starting in Gothenburg and ending in Stockholm. Intermediate terminals are located in Herrljunga, Skövde, Örebro and Västerås (Figure 4).

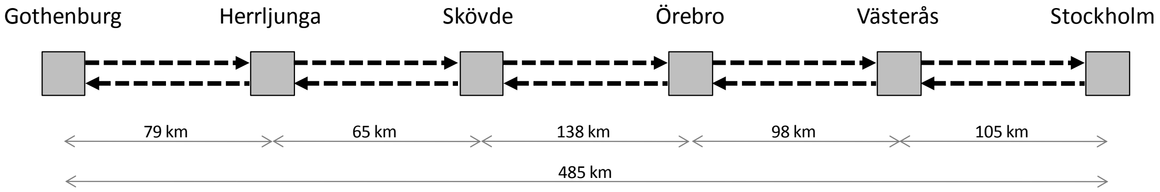

Figure 4 – Corridor between Gothenburg and Stockholm with four intermediate stops

Two train sets are operated overnight, one in the direction from Gothenburg to Stockholm with stops in Herrljunga, Skövde, Örebro and Västerås, and one in the opposite direction. The trains depart in the evening and arrival is in the morning of the following day. One train circulation therefore takes 1.5 days, i.e., departure in Gothenburg in the evening of day 1, arrival in Stockholm at the morning of day 2, departure in Stockholm in the evening of day 2 and, finally, arrival in Gothenburg in the morning of day 3. This service allows overnight deliveries in the same way as unimodal road transport.

The capacity of the train is assumed to be 32 swap bodies, which corresponds to 16 standard container wagons (8 Sdggmrss) and approximately 300 meters of train length using electric traction where the electricity is produced by hydropower. Train cost is calculated at 51.37 Swedish kr (SEK) per trainkm (approx. 4.8 €). For the road, alternative trucks with a capacity of 2 swap bodies are used. The same truck type is also used for pre- and post haulage (PPH) in the intermodal alternative. The truck cost is calculated at 12.25 SEK per km (approx. 1.15 €). All costs are production costs and not price costs. No consolidation is done in PPH, e.g., the flows Gothenburg-Örebro and Gothenburg-Skövde are performed separately with two trucks and are not consolidated even though the capacity of the truck would allow this. The environmental costs are estimated using the cost estimates determined for the national transport planning in Sweden (SIKA, 2005).

The start and end-terminals in Gothenburg and Stockholm are conventional intermodal terminals. Time is not a critical factor since the train remains in those terminals during the day. The intermodal nodes are small-scale side track terminals equipped with a small-scale horizontal transhipment technology. Since the horizontal transhipments can be performed under active catenaries, no shunting of trains is needed and train dwelling times are short.

The transport demand is assumed to be in units of whole swap bodies. Short swap bodies (approx. 7.82 m) are used since these are the most common in domestic Swedish intermodal transport. Trailers are not included since trailers can often not be handled by horizontal transhipment technologies. Neither does the case include maritime containers to and from the port of Gothenburg, since the scope of this study is limited to domestic goods. Therefore, the trains in this case study do not stop at the terminal in the port but at the intermodal terminal in the city of Gothenburg.

It is assumed that one shipper with large transport flows, e.g., a retailer company with a warehouse in Västerås, provides the base flow for the intermodal liner train and accounts for approximately 50% of the total train capacity. The volumes to the other destinations along the corridor are distributed in relation to the population in the respective city. There is a certain unbalance in the transport flow since the retailer mainly uses the liner train service for the flows from Västerås. It is assumed that the flows to Västerås that use the liner train service account for 75% of the flows from Västerås. In addition to the base flow, additional transport demand from various shippers along the corridor is added according to the population in the area.

The transport demand in the surroundings of a terminal is distributed randomly to demand locations around the terminal with a distance to the respective terminal from 10 to 50 kilometres. 75% of the demand locations have a demand for 2 swap bodies and 25% have a demand for 1 swap body. No transport demand is assumed to exist between Gothenburg and Stockholm since a successful conventional intermodal transport service already exists on the route. It is not realistic to assume that intermodal liner trains can compete with large scale point to point services. Table 1 shows the total transport demand between the destinations on the corridor.

Table 1 – Origin-Destination matrix of transport demand along the corridor in number of swap bodies per day

From \ To	Gothenburg	Herrljunga	Skövde	Örebro	Västerås	Stockholm
Gothenburg	0	2	3	2	8	0
Herrljunga	2	0	2	2	2	2
Skövde	4	2	0	2	3	3
Örebro	3	2	3	0	4	3
Västerås	13	1	3	5	0	14
Stockholm	0	2	4	4	14	0

Figure 5 shows the distribution of the total demand along the corridor. The demand varies along the route and is biggest between Västerås and Örebro where it is equal to the total train capacity. Hence, the capacity of the intermodal alternative suffices for the total transport demand. Also, the diagram shows the flow imbalances, i.e., that the transport demand towards Gothenburg is bigger than in the opposite direction towards Stockholm.

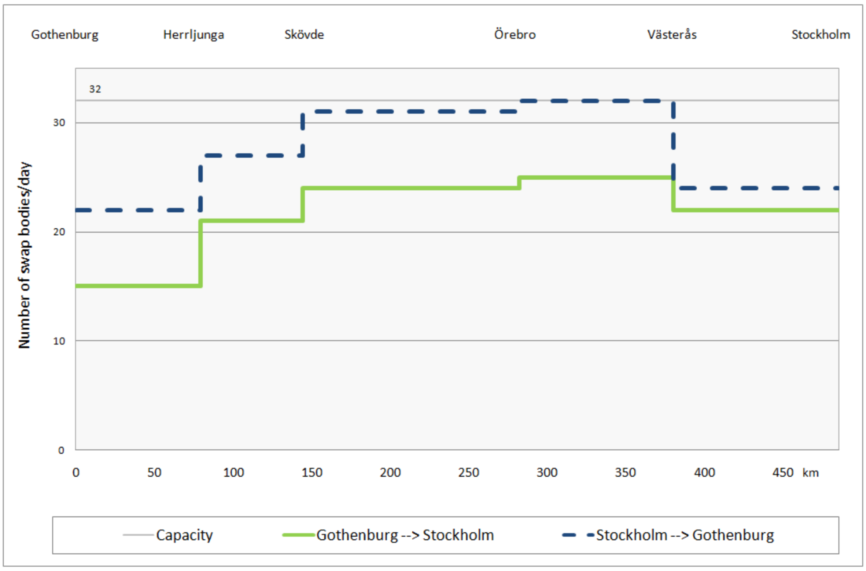

Figure 5 – Daily demand in number of swap bodies along the corridor

The HIT Model

The Heuristics Intermodal Transport model (HIT-model) is a heuristic computer model that takes its starting point in a competitive situation between traditional all-road transport and intermodal transport, where the theoretical potential of intermodal transport is determined by how well it performs in comparison to all-road transport (Flodén, 2007). A transport buyer is supposed to select the mode of transport offering the best combination of transport quality, cost and environmental effects. Given the demand for transport, the model determines the most appropriate modal split and calculates business economic costs, societal costs and the environmental effects of all parts in the transport system. Intermodal transport must match, or outperform the delivery times offered by road transport while offering an equal or lower cost to be selected. Furthermore, the model calculates the emissions of carbon dioxide, nitrogen oxide, hydrocarbon, carbon monoxide, particulate matter and sulphur oxide and energy consumption. It also estimates the economic effect of the emissions. The HIT-model also has further functions which are not used in this case.

Modelling results and analysis

The HIT-model was used to calculate the model split for different transhipment unit costs, TUCs. Since over-night transport is used where the intermodal system matches the delivery times of the all-road transport system, the business costs are the basis for the modal choice. The TUCs are assumed to contain all costs associated with the terminal activities in one terminal. An intermodal transport requires two transhipments, i.e., two times the transhipment costs. In the first scenario transhipment costs were 0 SEK, so that for all transports the intermodal alternative is chosen. Then, additional scenarios are calculated by gradually increasing the TUCs by 50 SEK, i.e., in the 2nd scenario a transhipment costing 50 SEK is used, in the 3rd scenario 100 SEK, and so on until the TUCs reach the level at which for all transports the all-road alternative is chosen. 1 SEK is approximately 0.1€ (February 2010). In the following section the modal split as well as the resulting business costs and external costs of the different scenarios are described and analysed.

Modal split

The modal split of the calculated scenarios is depicted in Figure 6. Generally, the transhipment costs have a significant impact on the potential of intermodal liner trains. The higher the TUCs the lower the share of the intermodal alternative. If TUCs are lower than 100 SEK, intermodal transport is competitive for all transports. This is also the case for TUCs of 150 SEK except for the transport flow between Herrljunga and Skövde (65km). For 200 and 250 SEK, the modal share of intermodal transport significantly decreases. Hence, a cost range of 200 to 250 SEK is identified as a critical TUC. For this cost range, the liner train is not competitive on the links between two terminals with very short distances (65 km and 79 km). Intermodal transport is partly competitive for transports between adjacent terminals where the distance is somewhat longer (98km). For borderline cases, the competitiveness also depends on the number of swap bodies on the truck. In case of one swap body, intermodal transport is competitive. In case of two swap bodies the all-road alternative is chosen, since these transports have double transhipment costs at the terminal. The different PPH distances do not have any major effect on the competitive situation since the differences are relatively small. For a TUC of 300 SEK, intermodal transport is not competitive on any relation.

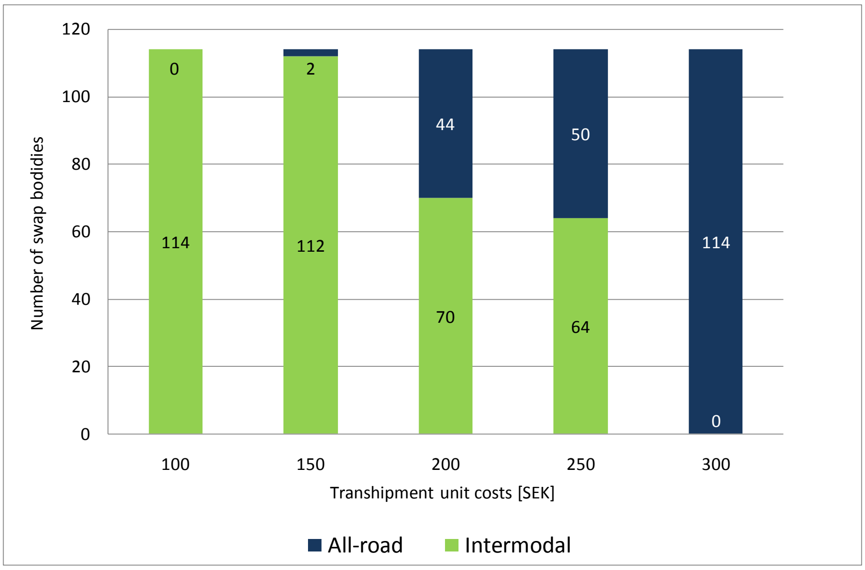

Figure 6 – Modal split for different TUCs

Train capacity utilisation

With growing TUCs less freight is transported intermodally, and consequently the cargo capacity utilisation (CCU) of the intermodal liner train decreases. Figure 7 depicts the CCU of the liner train for TUCs of 200 SEK.

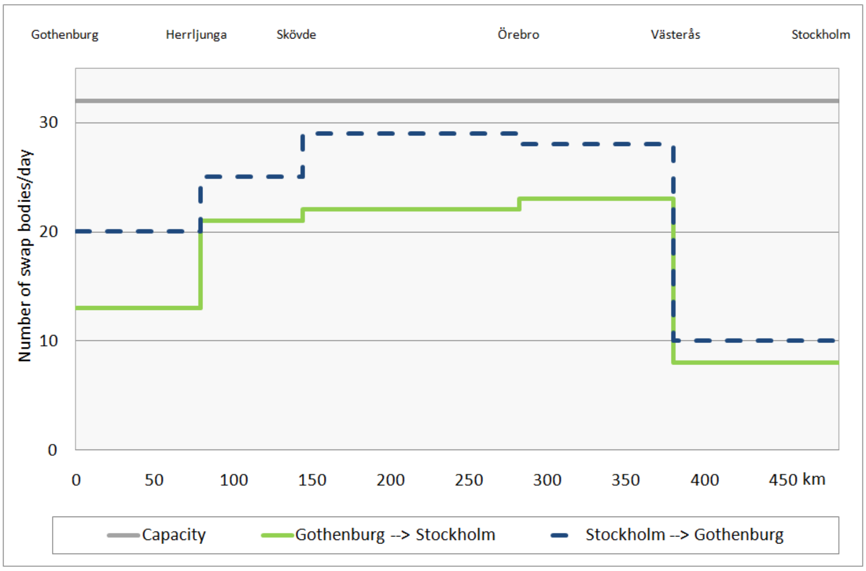

Figure 7 – Train capacity utilisation for transhipment unit costs of 200 SEK

The CCU is still close to the maximum capacity on large shares of the corridors, while near the start and end-terminals of the corridor, especially between Stockholm and Västerås, the train has a large number of empty spaces. This has an impact on the competitiveness of the liner train, since a fewer number of swap bodies must carry the fixed cost of the train and empty wagons, thus resulting in a higher transport cost per swap body. This “vicious circle” causes intermodal transport to rapidly lose competitiveness when the CCU decreases.

Business costs

The business cost of the entire transport system, i.e., the sum of all costs for road, rail and terminal operations to transport all freight flows are displayed in Figure 8. Naturally, the business costs are lowest for a high modal share of intermodal transport, since intermodal transport is only chosen for a transport if it is cheaper than the road alternative. Consequently the business costs increase with growing TUCs and are highest (approximately 192,000 SEK) for a TUC of 300 SEK since in this case all freight flows are transported by road. In the critical TUC range, i.e., 200-250 SEK, total business costs are approximately 150,000 SEK, which accounts for a savings of ca. 40,000 SEK or ca. 20% in comparison to the all-road scenario.

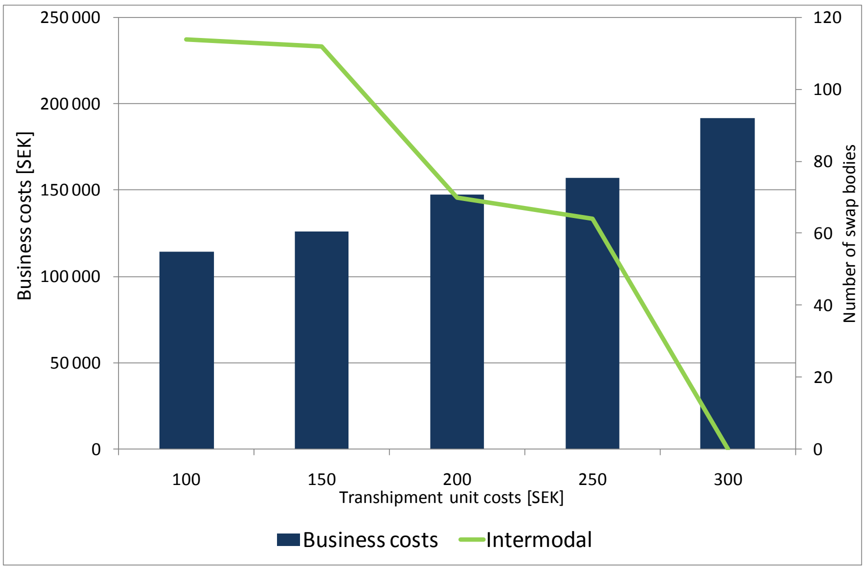

Figure 8 – Total business costs of the entire transport system for different transhipment unit costs. The bars show the business costs (left axis). The green line shows the number of swap bodies transported by the intermodal alternative (right axis)

In absolute cost, the cost of rail transport is the same in all scenarios. The total PPH costs decreases with the reduction in volumes sent by intermodal transport. The total transhipment cost is more complex as it is affected by both the number of units transhipped and the transhipment cost per unit. The total cost is the highest for TUC 150, followed by TUC 250 (95% of highest cost), TUC 200 (83%), TUC 100 (68%) and TUC 50 (34%).

The distribution of the business costs of the intermodal transport system for the different TUCs is displayed in Figure 9. The share of rail transport does not significantly change for different TUCs and accounts for approximately just under half of the total costs while PPH and transhipment costs together account for the other half. However, the cost share of transhipments increases with the TUCs (from 20% for TUCs of 100 SEK to 29% for TUCs of 250 SEK), while the relative share of PPH decreases (from 37% to 27%).

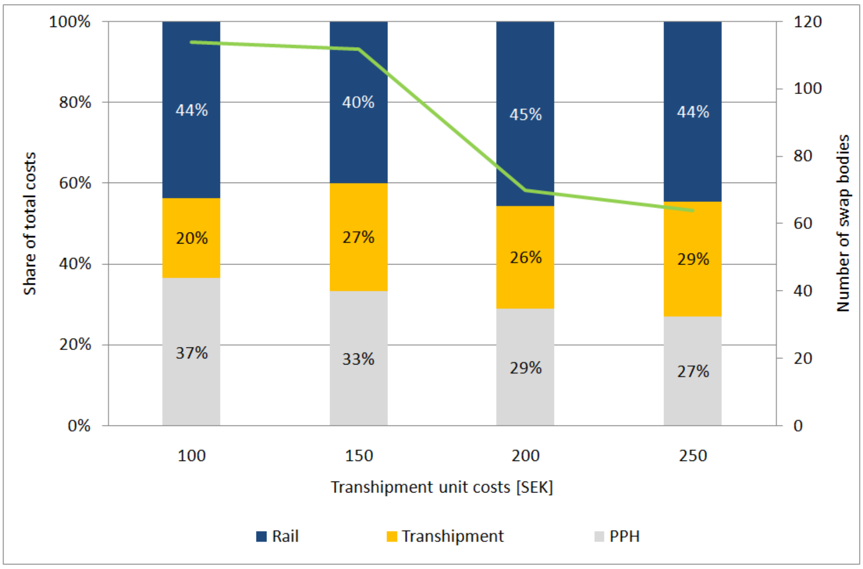

Figure 9 – Distribution of the intermodal transport business costs. The bars show the business costs (left axis). The green line shows the number of swap bodies transported by the intermodal alternative (right axis)

Environmental impact

The development of the total transport system's carbon dioxide (CO_2) emissions is shown in Figure 10. Not surprisingly, the results show the same picture as for the business costs, i.e., the higher the modal share of intermodal transport, the lower the CO_2 emissions of the total transport system. The CO_2 emissions are highest (approximately 15 tonnes) for TUCs of 300 SEK since in this case all freight flows are transported by road. In the critical TUC range, i.e., 200-250 SEK, the total CO_2 emissions account for approximately 6 tonnes which results in a savings of ca. 9 tonnes in comparison to the all-road scenario (ca. 60%). The external costs, i.e., the monetary valuation of the transport system's emissions to air, including CO_2 but also nitrogen oxide, hydrocarbon, carbon monoxide, particulate matter and sulphur oxide also follows the same direction as the CO_2 emissions. The external costs are highest (approximately 30,000 SEK) for TUCs of 300 SEK. In the critical TUC range the external costs account for approximately 13,000 SEK resulting in a savings of ca. 17,000 SEK (60%) compared to the all-road scenario. Hence, in the critical TUC range both the CO_2 emissions as well as external costs savings are significantly higher (60%) than the business cost savings (20%).

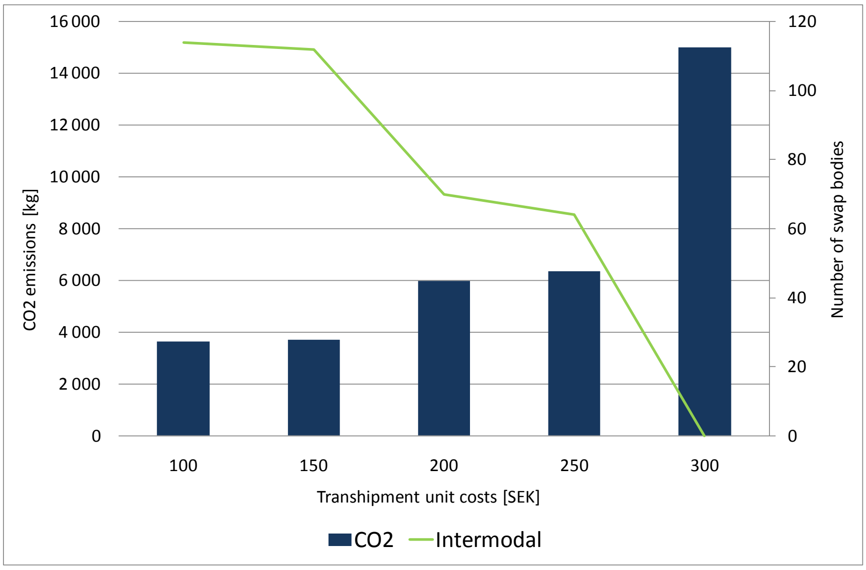

Figure 10 – Total carbon dioxide emissions of the entire transport system for different transhipment unit costs. The bars show the carbon dioxide emissions (left axis). The green line shows the number of swap bodies transported by the intermodal alternative (right axis).

DISCUSSION

Since the case is based on theoretical data it does not reveal the potential of a liner train in the described corridor in the real world transport system. However, the results described in the previous section confirm that *in theory* intermodal liner trains can provide competitive services on short and medium transport distances in case TUCs are kept low. For the competitiveness of intermodal liner trains the critical TUCs have been identified as 200 to 250 SEK. Note that this refers to the production cost and not the price. In this cost range, intermodal liner trains are competitive for transport flows over distances of approximately 100 km and more. Another critical parameter is the size and type of load carrier used as several smaller load carriers have a higher transhipment cost than one large load carrier with the same loading capacity. This assumes of course that the same handling equipment is used, which is normally the case in most terminals.

The critical cost level for the TUC of 250 SEK can be achieved by conventional terminals today, but under different operational conditions. In the present rail production paradigm which is characterised by economies of scale through full trains that are operated between large scale terminals, the transhipment operations in the terminals are adapted to the conventional rail operations with transhipments concentrated around morning arrivals and evening departures. A competitive liner train requires that these low TUCs are achieved for operations at night and for low transhipment volumes. According to Ballis and Golias (2004), each terminal design is effective for a certain cargo volume range. Due to the required high fixed costs of terminal investments, which for conventional terminals account for about 50% of the total terminal costs, relatively high TUCs are usually related to low cargo volumes and the TUCs decrease as volumes increase. Hence, if the transhipments in the intermediate nodes in a corridor are executed by conventional terminals, the TUCs would be too high since transhipment volumes in these nodes are low. It is therefore of paramount importance that the fixed costs of the transhipment equipment in the intermediate nodes are as low as possible.

To address this challenge various terminal concepts have been developed that allow quick and reliable transhipments with small-scale horizontal transhipment technologies at sidetrack terminals along the corridor. In the Swedish Light-Combi project intermodal liner trains were operated between 1998 and 2001. The swap bodies were transhipped under the catenary using a standard forklift truck carried by the train and operated by the rail engine driver. Although the service did not pass the commercial pilot phase, it was proven that using simple and conventional technology at unmanned terminals with intermediate storage racks technically works and fulfils the shipper's logistical demands (Bärthel and Woxenius, 2003). In Switzerland, the liner train concept Cargo Domino is operated today in several cases (Arend-Heidbrinck, 2006). The transhipment technology is based on a double fork mounted on a conventional road truck. It can load and unload swap bodies and ISO containers from rail to road and vice versa. The lifting equipment can be equipped on a conventional truck and by that transform the truck into a kind of mobile terminal. No further infrastructure is needed; the only requirement is available space along the rail sidings. Swap bodies as well as rail wagons need certain adaptations to allow for transhipments (Rudel, 2002).

The simple operational design of these small-scale horizontal transhipment technologies keeps the costs at a low level, but the drawbacks are in some cases needed adaptations of resources as well as handling speed and operational flexibility limitations due to the need of human operations. Automatic handling processes, on the other hand, promise better handling speed, handling damage reduction, and cost reduction and they allow for operation at uneasy working hours (FastRCargo, 2006). Terminal concepts with automated transhipments, integrated operation and compact layouts, also denoted as "new-generation terminals" (Bontekoning, 2000) have been developed and tested and promise greater efficiency and quality. However, with very few exceptions no innovative concept has been implemented because of their high investment costs (Vrenken, et al., 2005). There are obviously various institutional, organisational and economic reasons for this, one of them being the fact that automated operations often come with the drawback of technical complexity (Woxenius, 2007a) which is likely to increase the investment costs. Due to the complex nature of innovative terminal solutions, investment decisions have become much riskier since the cost structure of these terminals is unclear. The performance evaluation is complex since the function and location of the terminal in the intermodal network needs to be taken into account (Bontekoning, 2000). Hence, there is still a high uncertainty regarding the real economic performance of these innovative concepts. Further research is needed to determine whether these innovative concepts can achieve the required TUC in the operational context of intermodal liner trains.

In case the problem of fast and cheap transhipment operations can be solved, a successful intermodal liner train system entails business opportunities for rail transport operators in markets that are dominated by road transport today. At the same time, transport customers could benefit from lower transport costs and society from lower externalities. Furthermore, liner trains can further contribute to reaching policy goals, e.g., regional development of far-off regions. From a city's perspective, inter-regional freight transport networks play an increasing role in their economic success, since logistics and freight transport is important for their economic development (Bergqvist, 2007), and they are a frequently used argument in city marketing aiming at attracting more economic activities and settlements in a global economy (Lindholm and Behrends, 2008). Hence, companies in regions with intermodal terminals can benefit from additional transport options, reducing the dependency of road transport and potentially protecting them from higher costs and unreliable services caused by increasing fuel prices and increasing congestion in the long term. As a consequence, intermodal terminals are an important location factor that can attract distribution and transport companies and even industrial activities.

However, despite the potential and positive outcomes of technological and economic feasibility studies, the implementations of rail innovations remain problematic (Bontekoning and Priemus, 2004) and initiatives in the rail industry are generally lacking. Bärthel and Woxenius (2004) argue that this is due to the fact that the current know-how inside the intermodal transport industry blocks innovation that can lead to a more flexible railway system. According to the general mindset of the dominating railway undertakings, short and medium distance transports remain the home ground of road. Implementing intermodal liner trains requires a shift of the intermodal technological and organisational paradigm (Rudel, 2002, Bärthel and Woxenius, 2004), which is supported by Bontekoning and Priemus (2004) who argue that both technical and organisational breakthrough innovations are a necessity but are very difficult to achieve since they affect various layers and components of the intermodal transport system. According to transition researchers, e.g., Geels (2002), radical change is restricted since practices of the dominant actors draw chiefly on existing competencies and past investments and patterns of behaviour are locked in. The implementation of innovations requires “unlearning” of old mental patterns; however, this unlearning has not taken place yet, since transport policy and operators are still guided by the dominating mindset that rail freight only works for large flows over long distances (Rudel, 2002).

CONCLUSIONS

The study confirms that low transhipment costs are a prerequisite for integrating short and medium distance transport in the intermodal transport system. Naturally, a lower transhipment cost increases the potential, but of even greater importance is the ability to increase the number of terminals at a reasonable cost, as this decreases the door-to-door transport time for a shipment which increases the transport volumes that are potentially suitable for intermodal transport. Thus, fast and efficient transhipment technologies can open business opportunities for operators and cost saving potential for shippers in a market segment which is dominated by road transport.

However, there is still high uncertainty regarding the real economic performance of these innovative concepts. Further research is needed to clarify whether and under which operational circumstances the required transhipment costs can be achieved. Furthermore, implementing intermodal liner trains is not only a technological challenge but also requires organisational and institutional innovation. Further research is needed to develop implementation strategies. Identifying the barriers that hinder and the drivers that can foster the necessary organisational and institutional changes can facilitate the design of alternative policy approaches for achieving the desired modal shift which also entails possibilities for regional economic development.

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