Woxenius, J. ; Bergqvist, R.

Comparing maritime containers and semi-trailers in the context of hinterland transport

Journal of Transport Geography, 19 (4) pp. 680-688

http://dx.doi.org/ 10.1016/j.jtrangeo.2010.08.009

Author accepted manuscript:
Woxenius, J. Bergqvist, R. (2011) Comparing maritime containers and semi-trailers in the context of hinterland transport by rail, *Journal of Transport Geography*, **19**(4), pp. 680-688. doi:10.1016/j.jtrangeo.2010.08.009.

COMPARING MARITIME CONTAINERS AND SEMI-TRAILERS IN THE CONTEXT OF HINTERLAND TRANSPORT BY RAIL

Johan Woxenius

Rickard Bergqvist

Department of Business Administration
School of Business, Economics and Law at University of Gothenburg
Box 610, SE-405 30 Gothenburg, Sweden
+46-31-786 1453, johan.woxenius@handels.gu.se
+46-31-786 5241, rickard.bergqvist@handels.gu.se

ABSTRACT. The purpose of this article is to investigate why rail is used to move semi-trailers to and from seaports to lesser extent than it is used to move maritime containers, and which actions can foster an increase of semi-trailer transport by rail. The two types of load units are obviously used in quite different logistics settings. The two transport segments are compared in terms of the transport markets they serve, the competition they face and the operational and technological principles upon which they operate.

The empirical setting is the transport of general cargo in load units between Scandinavia, Continental Europe and the UK, although the container segment is analysed as an element of deep-sea liner shipping. Empirical findings are drawn from the case of the Port of Gothenburg and its Scandinavian hinterland. Sustained double-digit annual growth has led to a situation where most of the potential market for the hinterland transport of maritime containers has already been realised. The challenge for further growth is now to capture the semi-trailer segment.

Not surprisingly, this analysis shows that rail is more competitive for the hinterland transport of containers than of semi-trailers, but there are still significant opportunities for reaping the benefits of rail transport of semi-trailer transport in the hinterlands of European ports. An increased integration of rail transport and Roll-on/Roll-off (RoRo) shipping will not only require, but also encourage, changes in the overall system design as well as its competitiveness compared to all-road and all-rail services.

KEYWORDS*:* Hinterland transport, intermodal transport, container shipping, RoRo shipping, short sea shipping, semi-trailer.

1 INTRODUCTION

The increased scale of liner shipping vessels and ports is not matched by larger trucks and, as in most other transport networks, costs and lead times are increasingly generated in the capillaries rather than in the arteries. The container segment's business model of maximising the revenue by filling the ships and then “fixing the hinterland operations” is then questionable.

The scale of hinterland transport can be increased by using rail and inland waterways rather than trucks. Compared to trucking, transport by trains and barges comes with advantages such as lower environmental strain, lighter port city traffic, lower transport distance costs, faster throughput in ports and, in most cases, less sensitivity to delays caused by traffic congestion (Roso et al., 2009). The advantages are distributed among most involved actor categories and each of them can find reasons for using alternatives to roads for hinterland transport (Woxenius et al., 2004). Notable disadvantages are demand for more detailed transport planning, dependency on economies of scale, higher costs and longer lead times over short distances and competition for rail capacity with commuter trains around the port cities.

Most main container ports in Continental Europe experience a modal shift from road, but to inland waterways rather than to rail. The UK and Scandinavia are, however, confined to coastal shipping and rail as alternatives to road. In Sweden, the increase of rail shuttles to and from Port of Gothenburg is a frequently cited showcase of rail competition and of recapturing market shares from road transport. The rail volumes have tripled to about 340 000 annual twenty foot equivalent units (TEUs) in seven years and the current 25 rail shuttles with ten different rail operators made up a market share of some 55 percent in March 2010 (Port of Gothenburg, 2010a). Nevertheless, the success of hinterland transport by rail is generally confined to maritime containers; semi-trailers[1] are seen on the tracks to a far smaller extent.

Transport of goods loaded in maritime containers and semi-trailers address different markets and apply different business strategies and technologies, but they very much share the cost, lead-time and sustainability challenges of operating in the hinterland segment of the transport chains. Operators striving for getting semi-trailers onto rail can learn from their colleagues in the container segment, who so far have been more successful; however, just copying their business model would not suffice. Hence, a thorough understanding of what the segments have in common and how they differ is needed.

Consequently, the purpose of the article is to analyse why semi-trailers are not moved to and from seaports by rail at the same rate as maritime containers and the prospects for reaping the benefits of rail transport for semi-trailers. The empirical setting is the transport of general cargo in load units between Scandinavia, Continental Europe and the UK, although the rail transport of full-sized semi-trailers is currently problematic there due to the small rail loading profile in the UK.

The article starts with the scientific and business context of hinterland rail transport and an analysis of the maritime segments involving containers and semi-trailers. The explanatory factors are structured by the geography of the transport markets, operational aims, time aspects, port work content, transport chain organisation and employed technology. This is followed by a more detailed empirical analysis of the setting of Port of Gothenburg and its hinterland connections in Scandinavia. The effects of the current recession on hinterland rail transport are briefly discussed, followed by the concluding remarks.

[1] A maritime container is a cargo box designed for sea, road and rail transport facilitating vertical transhipment between the modes without handling the goods itself. Measures, strength and handling devices are firmly standardised by the International Standardisation Organisation and they are also accordingly referred to as ISO containers. A semi-trailer can be described as a loading platform with rear wheels, designed for road transport but also moveable by rail and sea. Some semi-trailers are equipped for vertical handling but port handling utilises the Roll-on/Roll-off (RoRo) principle.

2 HINTERLAND TRANSPORT BY RAIL

Hinterland transport of vehicles and unit loads is a not a new phenomenon, but transport volumes and transport policy support has clearly increased over the last decades. In 1982, the UN first used the term *Dry Port*, focusing the integration of transport services with different modes under a single contract (Beresford and Dubey, 1990). Hinterland transport research is comprehensive and it increases in intensity. Examples with their main geographical context are: Notteboom and Rodrigue (2005 – USA), Rodrigue (2008 – USA), IBI Group (2006 – Canada), Beavis *et al.* (2007 – Australia), Wang and Cullinane (2006 – Asia), Woodburn (2006 and 2007 – UK), Pettit and Beresford (2007 – UK), Debrie (2004– southwest Europe), Gouvernal and Daydou (2005 – northwest Europe), van Klink and van den Berg (1998 – Rotterdam with hinterland), Bundesamt für Güterverkehr (2005 – Germany), Roso (2009 – Sweden), Roso *et al.* (2009 – global examples), Rodrigue and Notteboom (2010 – comparison North America and Europe) and Rodrigue *et al.* (2010 – also comparison North America and Europe).

All these publications are more or less confined to the container segment, whereas semi-trailers are merely overlooked, although Bundesamt für Güterverkehr (2005), Woxenius and Bergqvist (2008) and Bergqvist and Woxenius (2009) expand the scope of their research past containers. In fact, Pallis *et al.* (2007) found that about half of port research (although not fully comparable to the scope of this article, which focusing on hinterland transport) published in scientific journals 1997-2006, and 70 per cent of the articles published in the latter half of the decade, made explicit reference to container ports and terminals. Other commodities, including RoRo cargo, were dealt with in only 5 per cent of the articles. The rest address more general port management and policy issues without distinguishing between cargo segments. There is obviously also research about RoRo shipping, but mainly regarding RoRo shipping itself and in competition with road transport, e.g., Brooks and Trifts (2008) and Xu and Wu (2007).

Moreover, the major textbooks like Stopford (2009) describe deep sea shipping in much greater detail than short sea shipping. Nevertheless, the trade between EU neighbours still dominates, despite a period of immense growth of the EU-Asian trade. Neglecting the short sea RoRo segment on the basis of negligible volumes is thus unjustified, at least for the UK and Scandinavia. According to the UK Department for Transport (UK Department for Transport, 2009), UK ports handled 4,3 million accompanied and 2,7 million unaccompanied semi-trailers in 2008, corresponding to about 85 million tonnes or about 14 million TEU[2]. This should be compared to the 5,3 million units, about 8 million TEUs of containers and 60 million tonnes, handled in UK ports in. In weight, Lift-on/Lift-off (LoLo) containers accounted for 11 per cent of the total tonnes handled in UK ports in 2008, while RoRo cargo accounted for 15 per cent (*ibid.*).

In Swedish ports, about 800 000 containers (1,3 million TEUs) were handled in 2009 compared to 2,3 million semi-trailers, trucks, trailers and other RoRo units. In weight, the tonnes of the RoRo segment measured almost four times the tonnes of the containerised cargo (Ports of Sweden, 2010). The Swedish statistics are not divided into accompanied and unaccompanied RoRo traffic.

Rail transport of semi-trailers is technically difficult in the UK and depends on the combination of rail corridor, rolling stock and semi-trailer dimensions (cf. Haywood, 2007), but is a fairly extensive business in Benelux, Germany and Sweden. Almost all wagons

[2] Here, a semi-trailer is conservatively assumed to correspond to two TEUs. Semi-trailers allow more than double the cube of a TEU, but sometimes they are not fully loaded in terms of cube and the permissible weight on roads is the same for a semi-trailer and two TEUs on a semi-trailer chassis.

operated by the largest Swedish intermodal operator, CargoNet AB, can carry semi-trailers. The main business is domestic intermodal transport, but in April 2008 CargoNet moved some 7000 semi-trailers to and from Swedish ports with connections to RoRo shipping. Of these, 3000 were related to the Port of Gothenburg (PoG), with RoRo connections to the UK and Benelux, and the remaining 4000 to southern ports connecting Sweden and Germany (Backman, 2008). This corresponds to an annual volume of some 168 000 TEUs or roughly half of the volume of the container shuttles related to the PoG. Finnish hauliers' use of Sweden as a land-bridge with rail between the ports of Stockholm and Gothenburg to reach the UK is a small but fast-growing market (*ibid.*), at least before the financial crises and accompanying recession.

3 THE CONTEXTS OF SEMI-TRAILERS AND MARITIME CONTAINERS

This section examines the different contexts for hinterland transport of maritime containers and semi-trailers respectively. The basis for this analysis is long-distance transport of general cargo in parcel sizes suitable for road transport. Examples of commodities would be manufactured goods, consumables and construction material but also subassemblies and some minor bulks.

It should be noted that liner shipping implies a certain compromise between many different customers' specific demands for transport quality and price. This means that the services are developed over time in negotiation with the major customers and by testing the market's appreciation of incremental changes in different quality parameters and the attached price tag. The two market segments aiming for transport of containers and semi-trailers have matured over many years, and here it is asserted that an analysis of the characteristics of the segments is still meaningful as a step towards analysing the preconditions for hinterland rail transport. The analysis is structured around logistics, market, organisational and technology characteristics. It should be noted that characterising and dividing into factors is a delicate task and a reductionist approach would likely fail, so the division here is made for illustrative reasons rather than for analytic precision. Some attempts at defining causal relations are made, but the complexity of the transport system designs makes also this effort delicate.

The characteristics of the *geographic transport market* for the segments is that semi-trailers serve intra-regional flows in the empirical context within Northern Europe, while the main transport market for maritime containers is the trans-ocean trade. However, the division is not a sharp one, since the design of the latter transport system allows for co-production with intra-European container services and the RoRo ships transporting semi-trailers can also take containers on mafi trailers or semi-trailer chassis. A further complicating fact is then that the shorter intra-European RoRo shipping routes also serve accompanied lorries and passengers. This implies that the demand compromise is wider than for transport of unitised cargo alone, and adds a certain degree of production in the ports by the customers.

The different transport services face different *modal competition*. Some RoRo services act as bridge substitutes with a clear subcontractor role to road and rail operators, while all-road or all-rail often constitute alternatives for semi-trailers in longer range maritime services. This is particularly true after introducing the Channel Tunnel and the Öresund and Great Belt bridges offering fixed connections between the European Continent and the UK and Sweden respectively. The competition will likely stiffen when the MARPOL Annex VI rules for cleaner fuels in the North Sea and Baltic Sea Sulphur Emission Control Area apply fully in 2015, and after the planned construction of the Fehmarn Belt bridge (see, e.g., Woxenius, 2010). Trans-ocean container services mainly compete with air transport, representing extreme ends on the scales of costs and transport time for traffic modes as analysed by

Woxenius (2006). Within maritime transport, container liner shipping increasingly competes with break bulk and bulk shipping after a period when the segments grew apart. This development has been propelled by the significant growth in export from China, which has been matched by return flows of cheap commodities like scrap iron and waste paper as an alternative to empty containers or ballast. The competitive situation for the feeder legs resembles that of RoRo shipping.

The different competitive pressures between modes and between shipping lines implies that the *business priority* for the RoRo operators leans towards providing customer convenience, while the container segment aims at utilising economies of scale. Consequently, the operational element attracting the most attention is port operations for the semi-trailer segment and the maritime leg for the container segment. A practical analogy is that persons moving to another city make significant efforts to compress the household furniture into a limited volume, while those moving within the city limits accept an extra trip. The results in the shipping segments are quick RoRo transhipment, frequent departures and poor utilisation of volume, versus somewhat toilsome LoLo transhipment, well-planned capacity and densely loaded ships. In other words, RoRo's focus can be characterised as being trained on service, while that of LoLo is on low transport costs.

The increasing size of container ships is often cited, but this trend is actually a factor that does not distinguish between the segments. The capacity difference between the Sovereign Maersk of the S-type (6600 TEU) that went into service in 1997 and Emma Maersk of the PS-type (11 000 TEU) entered the Maersk fleet in 2006 (Maersk Line, 2009) is 66 per cent. Incidentally, this is very close to the increase of capacity measured in lane meters of the RoRo ferries serving Dover, which, according to Osborn (2008) has grown by 69 per cent between 1998 and 2008. The new generation of ships entering the North European RoRo shipping market have been further upgraded. Stena Line, for instance, introduces two new so-called "super ferries" with 5500 lane metres for semi-trailers and 700 lane metres for cars on its Hook van Holland-Harwich route. This creates a domino effect, since the older ferries from that route are employed at the Gothenburg-Kiel route, pushing that route's ferries to Stena Line's Karlskrona-Gdynia route (Stena Line, 2010).

The drive for employing ever-larger ships has been the increase of the freight flows rather than a change of operational principles. Other options for increasing the system throughput would then have been to increase the frequency or to serve more routes. This does not seem to have been the case during the shipping boom in the first years of the 21st century. An effect is that the *port geography* is rather stable, although the very largest container ships call fewer ports. The general characteristics are that the container segment operates through a small number of hub ports, combined with feeder services to regional ports, while the lower dependence on economies of scale in the RoRo segment has led to maintained service in a larger number of smaller ports. An obvious effect of increased ship sizes with a maintained port structure is that the ports have been strained to their operational limits.

The modal competition has led to a sharper geographic concentration in the container segment but the modal competition with all-road transport is less fierce, implying larger *hinterland depth* for containers, i.e. they generally travel further inland from each port than the semi-trailers do.

Time is obviously critical when analysing transport services. Regarding the time element investigated by Woxenius (2006), the *transport times* for the two segments are proportional to the distances served, i.e. ships in both segments are typically dimensioned for steaming at slightly above 20 knots. This is regarded as fast in a maritime context. The RoRo segment presents a wider range of speeds in order to align the number of turnarounds at individual routes.

The different transport rhythms mean that shippers require a *precision* in the range of hours for semi-trailers and days for containers. The *order time*, i.e. the time before a departure the service has to be ordered to guarantee service or a certain price, ranges from a few days, or weeks in the peak of the seasonal or business cycle, to virtually none for the shorter bridge substitutes that operate with a substantial over-capacity and merely sell tickets at the gates.

A weekly *frequency* is customary in the container segment, but a customer who can choose between different shipping lines can count on almost daily departures on the main trade routes (*ibid.*). Daily sailings are customary for unaccompanied semi-trailer traffic while the shortest bridge substitutes offer very frequent services.

The frequencies can be interpreted into a typical *cargo dwell time in port.* Loaded semi-trailers dwell in port for a short time, or even a negligible time for accompanied trailers. For full containers, on the other hand, ports are often used for absorbing slack in the transport planning or to bridge the capacity gaps between container ships and the vehicles used in land traffic modes as elaborated by Hultén (1997). The higher value of the semi-trailers as transport equipment also means that they are not left waiting for new tasks at the same rate as containers, hence leading to a shorter *empty unit dwell time*.

Researchers are not the only ones with a particular interest in the container segment. The higher *port work content* and investments for container operations make ports focus on this segment, whereas accompanied semi-trailers driven over RoRo ramps by truck drivers come with very little business to the port. Hence, container operations are often over-rated by the ports, overlooking the potential of increasing their turnover from RoRo traffic.

Schramm (2006) has shown that the success of intermodal transport chains is highly dependent on who is acting as *transport service co-ordinator* and how well the operations are integrated. Container transport chains are typically organised by the shipping lines, their agents or specialised sea forwarders. They are used to thinking in chains split between modes, whereas the road hauliers or road-based forwarders, dominating the organisation of transport chains involving semi-trailers, typically plan for the same vehicle throughout the transport chain when using sea as a bridge substitute. The planning and operation barriers for rail are accordingly higher for semi-trailers.

The physical characteristics of the unit load types evidently affect the technology that surrounds them and there is a clear element of transport technology redundancies, especially for intermodal trains on vessels and for bridge substitutes. The *road technology* for semi-trailers in terms of tractor units is very simple and widely accessible in Europe. Containers can be moved by most flat-bed lorries or dedicated container lorries, but containers come with the disadvantage of being awkward to pick up at the consignors' or deliver at the consignees' location. An alternative is then to use a side-loading lorry or a semi-trailer tractor with a semi-trailer chassis as an interface.

Reversely, the employed *rail technology* as well as the *road-rail transhipment technology* is very complicated and costly for semi-trailers, but simple for containers. The awkwardness of semi-trailers is caused by the height and weight that limit it to vertical transhipment in Europe, although some variants of horizontal techniques have been developed, and require four-axle pocket wagons (Bergqvist and Zuesongdham, 2010). Hence, the semi-trailer is a bit of a cuckoo in the nest for rail transport. As mentioned above, the limited rail loading profile complicates rail transport of standard-sized semi-trailers in the UK.

The above rendering is summarised in the table below.

Table 1. Comparison between the container and semi-trailer shipping segments.

	Container	Semi-trailer
Geographic transport market	Transocean/deep sea/short sea	Intra-European/short sea
Modal competition	Air for deep sea leg Rail and road for feeder leg	Rail and road + fixed connections
Business priority	Utilising economies of scale	Providing customer convenience
Port geography	Few large hub ports + feeder ports	Many ports – partly bridge substitute
Hinterland depth	Deep	Shallow
Transport time/speed	Fast	Fast
Precision	Day	Hour
Order time	Week	Day/minute
Frequency	Weekly	Daily/hourly
Transport service co-ordinator	Shipping line, line agent or sea forwarder	Shipper, road haulier or general forwarder
Cargo dwell time in port	Days	Accompanied – minutes or none Unaccompanied - hours
Empty unit dwell time	Days/weeks	Hours/days
Port work content	Substantial	Limited
Rail technology	Very simple – flat wagon/twist locks	Complicated – pocket wagon/king-pin box
Road technology	Awkward at end points	Simple and accessible
Road-rail transhipment technology	Fairly simple – automation possible	Dimension factor in weight and handling

It is thus obvious that semi-trailers meet quite different preconditions for hinterland rail transport than containers do. Further examination requires a narrower empirical context and the following sections analyses the situation for the Port of Gothenburg.

4 AN ILLUSTRATION: PORT OF GOTHENBURG

The development of dry ports and rail shuttle services related to the Port of Gothenburg (PoG) has been substantial during the last decade. The system currently has rail shuttles to more than 20 different dry ports in Scandinavia offered by ten different rail operators (Port of Gothenburg, 2010b). Over the years, shuttles have been added and subtracted and the frequencies of services have varied over time. A few of the shuttles operate once or twice a week in each direction, the majority five to seven days a week and the most frequent one operates 14 times a week in each direction.

Figure 1. The Port of Gothenburg rail shuttle system as of December 2008. (Source: Port of Gothenburg, 2010b).

Most shuttles operate on moderate distances typically dominated by road transport. However, the shortest shuttle, about ten kilometres within Gothenburg, serves a stuffing and stripping terminal, and a previous service to Uddevalla, about 100 kilometres from Gothenburg, moved the stuffing and stripping activities out of the port area.

The current container rail shuttle services moved 340 000 TEU in 2008 with a turnover of approximately €60 million. As mentioned above, the system handles about 55 per cent of all containers to and from PoG. The current rail shuttle system decreases transport costs by about €6 million annually (Bergqvist, 2007). The system also relieves the streets of Gothenburg and decreases CO_2 emissions by about 42 000 tons every year. In total, the system employs about 400 persons (Bergqvist, 2008). The development of the port rail shuttles has received substantial media attention as well as industry awards.

The growth of the system has been driven by a systematic process that started with a decision by the board of directors at PoG that half of the growth in the container segment should enter or leave the port by rail. The rail shuttle system has surpassed this goal, and over the last seven to eight years has grown by about 15 per cent annually. It should be kept in mind that this growth has occurred during a period of extraordinary growth in container liner shipping and positive general trade outlooks. At the beginning of 2009 the Scandinavian rail shuttle system had increased its market share to 45 percent, up from 40 percent compared to 2008, and PoG expects this share to grow even further, as proved by the figures for 2010 with a market share for rail of about 55 per cent (Thorén, 2010).

Table 2. Statistics of Port of Gothenburg. (Source: Port of Gothenburg, 2010a)

Statistics Port of Göteborg, january-dec 2008 and 2009

	2008			2009		
	Export	Import	Total	Export	Import	Total
Container (teu)						
full	353 128	360 706	**713 834**	347 810	295 722	**643 532**
empty	72 358	76 403	**148 761**	62 796	111 289	**174 084**
Total	**425 486**	**437 109**	**862 595**	**410 606**	**407 011**	**817 616**
Ro/ro						
Units	327 646	297 155	**624 801**	258 734	245 145	**503 879**
rteu*	682 093	616 507	**1 298 600**	539 633	512 875	**1 052 508**
Cars	173 292	96 867	**270 159**	84 712	72 580	**157 292**
Oil (1000 tonnes)	8 764	14 008	**22 772**	10 812	10 283	**21 095**
Passengers (1000)			**1 862**			**1 754**
Total (1000 tonnes)	20 095	23 212	**43 307**	21 404	18 079	**39 483**

* rteu is a ro/ro unit that makes it possible to compare the ro/ro volumes at different ports. An rteu is equivalent to a 20-foot ro/ro unit.

As can be seen from the table above PoG also handled more than 500 000 RoRo units annually in terminals at both banks of the river Göta that flows through the city. The dedicated RoRo freighters of shipping lines like DFDS Tor Line and Cobelfret call at the terminals on the north bank, where a substantial container terminal with a throughput of 818 000 TEU in 2009 is also located (Port of Gothenburg, 2010a). Stena Line uses its own terminals on the south bank for both dedicated RoRo freighters and ferries carrying passengers. The fleet of vessels operated by Stena and deployed in Gothenburg is primarily of RoRo/passenger (RoPax) character. From Gothenburg, Stena calls Fredrikshamn in Denmark and Kiel in Germany daily.

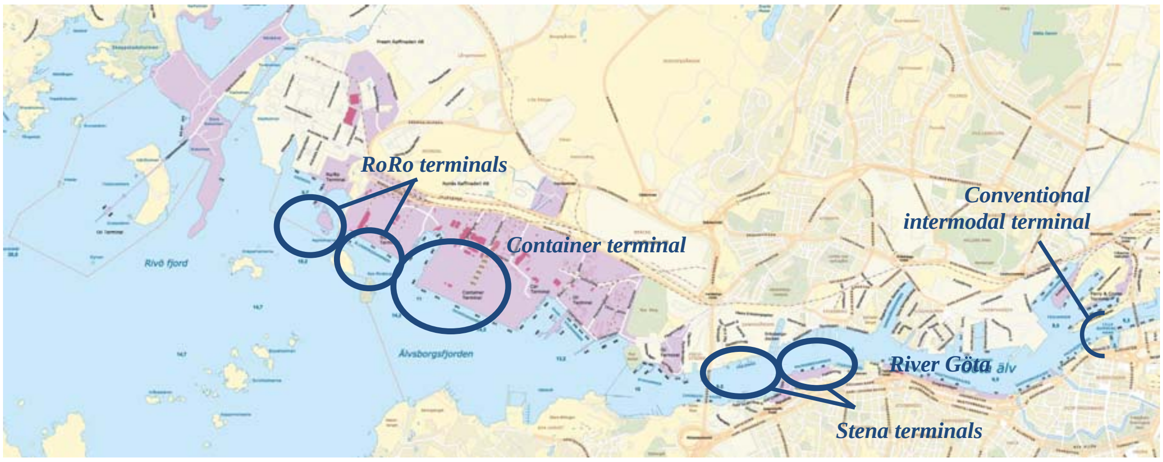

Figure 2. The Port of Gothenburg. (Source: Port of Gothenburg, 2010a).

About 50 000 of the semi-trailers transported by Stena Line are transported via the conventional intermodal terminal in the city centre, about 5 kilometres from the docks, for rail transport throughout Scandinavia by CargoNet (Backman, 2008). The empirical analysis is, however, here delimited to on-dock rail at the north bank terminals, which accounts for just one third of the RoRo flows, but contains a larger share of unaccompanied semi-trailers and is more realistic for on-dock rail. The lease contract of the Stena terminal in the city centre is soon to be renegotiated with the municipality of Gothenburg and there is a debate in the city on whether to move the terminal to the north bank. Locating the terminal on the north bank would facilitate a good hinterland connection by rail and would immediately triple the potential market for hinterland rail transport.

In 2006, which is regarded as the last representative year, the total volume handled in the RoRo terminals at the north bank was about 100 000 units for export and about 105 000 for import. The semi-trailers originate or have their final destination in one of 22 main regions, defined by PoG as the catchment area around a major intermodal terminal. The share of empties has not been obtained in the statistics in Table 3, but the work content for the ports and the sea and rail operators is basically the same for loaded and empty units.

Table 3. Semi-trailer volumes via the north bank terminals of Port of Gothenburg in 2006 (unpublished data from Port of Gothenburg).

	Export			Import		
Distance	Share of total semi-trailer volume	Number of regions	Average volume per region	Share of total semi-trailer volume	Number of regions	Average volume per region
0-150	54%	3	18 329	60%	3	20 758
151-250	25%	8	3 156	22%	8	2 890
251-400	12%	7	1 726	15%	7	2 210
>401	9%	4	2 302	3%	4	866
Total	100%	22	4 615	100%	22	4 742

As shown in the table above, there are more than 20 Scandinavian regions involved in the transport of semi-trailers, but the flows are far from evenly distributed between them. For rail, it is unfortunate that about 60 per cent relates to the three closest regions. Although some of the container shuttles connecting PoG prosper at transport distances of less than 150 kilometres, the closest distance range is here deemed to be virtually out of reach for semi-trailers on rail due to the semi-trailers' strict turn-around schedules. Nevertheless, one semi-trailer shuttle of just 50 kilometres was considered in 2004, as the petrochemical industry in Stenungsund had to adhere to an emission cap when extending their production facilities (Bärthel, 2004), but the shuttle has not been realised. Lacking special conditions that foster the competitiveness of rail for very short distances, the 100 000 semi-trailers transported further than 150 km should still be within competitive reach for rail.

5 CHALLENGES FOR SEMI-TRAILERS ON RAIL TO AND FROM PORT OF GOTHENBURG

A major drawback for on-dock rail is that the RoRo handling is not concentrated in one terminal as container handling is, but is instead spread around the port area. This impedes the mix of containers and semi-trailers in the rail shuttle services; either the handling area in the port has to be designed for multipurpose handling, or the set of wagons has to be separated into semi-trailers and containers. Both solutions require some investment, planning and movement between the terminals on road or rail.

A less attractive, but more realistic, alternative is to have different rail shuttles for the different load units. The most favourable solutions, from a rail operator's perspective, is to combine different types of load units in order to facilitate capacity utilisation and flexibility by mixing different segments that ultimately lead to increased profitability. This is also the current situation for PoG, as they have trials for different rail shuttles in which containers and semi-trailers are mixed in the trains (Thorén, 2010).

A major issue for many European ports and for PoG in particular is how to design and develop the in-house rail terminal in order to improve the system based on the distribution of containers and semi-trailers transported by rail. As elaborated above, the different segments put completely different demands on the handling operations and the design is essential for the port's total efficiency, including movements of straddle carriers, etc.

One major factor limiting the market potential of semi-trailers on rail shuttles to and from PoG is the lack of railway tracks. The Stena terminal was designed for easy access for passengers by public transport or cars, as well as for truck drivers, so there was little effort made to facilitate on-dock rail. There are no plans for future rail connections at the current site, but re-localisation of the Stena terminals is, as mentioned, under discussion. The tracks along the northern bank are also used by Volvo Cars and the port access track lacks capacity for a significant increase. There is a current planning process for addressing this capacity problem, but new capacity will not be realised for many years. While awaiting a direct solution in terms of infrastructure, there is a need to change the way rail shuttles are consolidated and coordinated. Coordination is a key issue when the containers and semi-trailer segments differ significantly. Besides purely technical issues, transhipping between rail and sea is more time-consuming for semi-trailers than for containers, and from a port perspective, semi-trailer handling is more labour-intensive.

Although most Swedish intermodal terminals can handle semi-trailers, there is a technical and logistics barrier in the sense that a relatively small proportion of semi-trailers are fitted for vertical handling by gantry crane or reach-stacker, although even large-volume semi-trailers, so called mega-trailers, can now be moved by rail. Another technical barrier is the Swedish rolling stock, which, except for the CargoNet fleet, is often confined to carrying containers.

6 POTENTIAL FOR A SCANDINAVIAN RAIL SHUTTLE SYSTEM FOR SEMI-TRAILERS

Here, the overview of the possibilities of the rail shuttle system for semi-trailers is widened by comparing road and rail in terms of cost efficiency and CO_2 emissions. The aim is to estimate the potential volumes and the relative financial and environmental performance of a full-scale rail shuttle system for semi-trailers. Cost parameters are based on interviews with actors in the current rail shuttle system and from models and publications related to intermodal transport (e.g. Flodén, 2007 and Bergqvist, 2008).

The cost evaluation is to estimate the share of semi-trailer volumes that can be transferred from road. In the current container rail shuttle system there are profitable shuttles for distances of less than 100 km. Given the fact that almost 100 000 semi-trailers are transported further than 150 km, there is substantial potential incorporated into the market segment of semi-trailers on rail. Another positive aspect is that the geographic pattern of semi-trailer and container hinterland transport roughly overlaps. This implies synergies for co-loading both on pickups and delivery routes[3] as well as between the terminals.

[3] The maximum permitted length of Swedish road trains is 25,25 metres, allowing for the combined carriage of a 20-foot maritime container and a 13,6 metre semi-trailer.

For hinterland transport, calculations are made on 20 individual dry ports and the Scandinavian dry port system including terminal handling costs. The cost calculations are based on the following assumptions and methods:

- The system is evaluated under stationary conditions, and the resource consumption measured in cost terms.
- The resources in the transport system are assumed to have alternative use and can be engaged and disengaged by the system at market prices.
- The above elaboration of semi-trailer transport by rail, suggests that somewhat longer distances are required for competitiveness against all-road transport. The break-even point is estimated to be at 150 km.
- The railway shuttle between a dry port and the PoG will normally run a fixed number of trains per week according to a fixed schedule in a yearly train plan. The number of trains per week will be determined by the average demand per week. The following notations are adopted:
  - Expected demand per year (TEUs) per dry port = Y
  - Average train utilization factor = U*100%
  - Number of trains per week = T
  - Maximum number of TEUs per train = H
  - Number of production weeks per year = W

  With these parameters the scheduled number of trains per week in the yearly train plan is determined as T = integer part of (Y/W)/(U*H)
- Road transport is assumed to be used in order to reduce costs in case of insufficient train capacity. This method allows running trains with high load factor and accepting a minor additional cost of road transport in infrequent cases of lack of train capacity. The costs of the extra road transport is set equal to the average cost per TEU of road transport between the dry port and the sea port multiplied by the expected number of containers carried by truck.
- The potential performance and output of a semi-trailer based system is hard to estimate due to aspects of synergies and the necessary infrastructure development at the endpoints of the rail transport. The necessary infrastructure investments associated with semi-trailers is assumed to be compensated by synergies from mixing containers and semi-trailers in the shuttles.

Given the above mentioned cost model and assumptions, the potential transport cost savings related to semi-trailer on rail shuttles would be about 10 per cent, as in the current rail shuttle system. Addressing the market of distances longer than 150 km implies that the system could transport about 80 000 semi-trailers annually; an assumption based on the rail market share for container hinterland transport over long distances. This would significantly add to the annual turnover of the rail shuttle system and imply substantial transport cost savings.

The evaluation of environmental performance is based on the method of “NTMCalc,” developed by the non profit organisation The Network for Transport and Environment, and focusing on establishing a standard for calculating environmental performance for different traffic modes (NTM, 2009). The method is in turn based on previous research regarding pollution and environmental impact of transport (e.g. Blinge, 1998 and Flodström, 1998) and continuously updated with new parameters from industry and academia in order to provide a contemporary evaluation tool. In comparison to the assumptions and methods for the cost calculations, the following additional assumptions and methods apply:

- We assume an electric power supply of the locomotives. Since the rail service is of such great scale we assume that there is the possibility for the electric locomotives to directly connect to the rail handling terminals without any need for diesel powered shunting locomotives.
- The source of electricity is based on Sweden's electrical power mix since the principal part of the transport route is located in Sweden.

The environmental performance is measured in CO_2. Addressing the market of distances further than 150 km and a modal shift of about 80 000 semi-trailers would reduce CO_2 emissions with about 15-20 000 tonnes annually.

A third and equally important aspect of a semi-trailer rail shuttle system is the transport time. Much of the road infrastructure in central Gothenburg is strained and the congestion problems are increasingly severe. This is crucial for semi-trailers, since the peak in demand for semi-trailers being delivered into the port coincides with road traffic rush hour. Rail transport would relieve the road infrastructure and foster a smoother flow of semi-trailers to and from the port. In summary, there is great potential for a rail shuttle system for semi-trailers in terms of cost, transport time and environmental performance.

7 CONCLUSIONS

There are obviously large differences between container shipping and RoRo-shipping and rail is admittedly more competitive in the hinterland transport of containers than in the transport of semi-trailers. Still, there are also significant opportunities to reap the benefits of rail transport for the large flows of semi-trailers to and from European ports, and trends point in the direction of more semi-trailer trains. The empirical basis of this article is transport between Port of Gothenburg and its Scandinavian hinterland, but the issue is also highly relevant for Europe at large, with a similar mix of containers in deep sea and short sea shipping (mainly by feeders) and semi-trailers in short sea shipping. A well-developed hinterland system based on rail shuttles has the potential to strengthen overall door-to-door logistics efficiency, strengthen the short-sea-shipping segment and produce an overall environmentally efficient transport chain. The necessary conditions for growth and development are technical innovations and implementations related to rolling stock and handling that contribute to short lead-times and efficient handling, especially in ports. When this evidence is combined, it is clear that the potential for semi-trailers on rail is substantial, and can have an important future role in ensuring a competitive and sustainable logistics system — under the conditions that such transport is able to cope with the challenges presented in this paper.

Many of the world's dry ports and rail shuttle services have developed and prospered during the recent years' booming demand, supported by macro trends like outsourcing and globalisation. The currently slow economy poses new challenges to the future development and design of dry port systems. As the immediate need to supply transport capacity for increased demand is reduced, more focus can be put on improving existing business. The development of the scope of business has thus expanded in an attempt to increase revenues and counterbalance the crisis. By expanding the scope of service to the semi-trailer segment, more emphasis is put on efficiency as a tool to achieve increased profitability.

REFERENCES

Backman, H., 2008. Director of Market and Products, CargoNet. Telephone interview, 2008-06-05.

Beavis, P., Black, J., MacGill, I., Woxenius, J., Moore, S., 2007. Interface design for the coordination of container freight infrastructure with urban logistical services. 11th World Conference on Transport Research, Berkeley, 24-28 June.

Beresford, A.K.C., Dubey, R.C., 1990. Handbook on the management and operation of dry ports, UNCTAD, Geneva.

Bergqvist, R., 2007. Studies in Regional Logistics - The Context of Public-Private Collaboration and Road-Rail Intermodality. PhD thesis, University of Gothenburg, Gothenburg.

Bergqvist, R., 2008. Evaluating road-rail intermodal transport services - a heuristic approach. International Journal of Logistics Research and Applications, 11, 179-199.

Bergqvist, R., Woxenius, J., 2009. The development of hinterland transport by rail - the story of Scandinavia and the Port of Gothenburg. The International Business Research Conference, Jacksonville, Florida, 13-14 February.

Bergqvist, R., Zuesongdham, P., 2010. Intermodal Freight Transport - Infrastructure and Technology. BAS Publishing, Gothenburg.

Blinge, M., 1998. ELM: Environmental assessment of fuel supply systems for vehicle fleets. PhD thesis, Chalmers University of Technology, Gothenburg.

Brooks, M.R., Trifts, V., 2008. Short sea shipping in North America: understanding the requirements of Atlantic Canadian shippers. Maritime Policy & Management, 35, 145-158.

Bundesamt für Güterverkehr, 2005. Marktbeobachtung Güterverkehr - Sonderbericht zum Seehafen-Hinterlandverkehr (Market observation freight transport - special story about seaport hinterland transport), Cologne.

Bärthel, F., 2004. Förstudie järnvägsterminal Stenungsund (Prestudy rail terminal Stenungsund). Chalmers University of Technology, Gothenburg.

Cullinane, K., Wang, T.-F., 2006. The efficiency of European container ports: A cross-sectional data envelopment analysis. International Journal of Logistics, 9, 19-31.

Debrie, J., 2004. Hinterland connections of ports and Transeuropean networks' evolution - The case of south-western Europe. The 10th World Conference on Transport Research, Istanbul, 4-8 July.

Flodén, J., 2007. Modelling Intermodal Freight Transport - The Potential of Combined Transport in Sweden. PhD thesis, University of Gothenburg, Gothenburg.

Flodström, E., 1998. Environmental Assessment of Freight Transportation. Communications Research Board, Stockholm.

Gouvernal, E., Daydou, J., 2005. Container railfreight services in north-west Europe: Diversity of organizational forms in a liberalizing environment. Transport Reviews, 25, 557-571.

Haywood, R., 2007. Britain's national railway network: fit for purpose in the 21st century? Journal of Transport Geography, 15, 198-216.

Hultén, L.A.R., 1997. Container Logistics and its Management. PhD thesis, Chalmers University of Technology, Gothenburg.

IBI Group, 2006. Inland container terminal analysis - Final report, Vancouver.

Maersk Line, 2009. The A.P. Moller-Maersk Group Fleet List 2008. <http://about.maersk.com/en/Fleet/Pages/Fleet.aspx>, Accessed 2009-01-23.

Notteboom, T.E., Rodrigue, J.-P., 2005. Port regionalization: towards a new phase in port development. Maritime Policy & Management, 32, 297 - 313.

NTM, 2009. The Network for Transport and Environment. <http://www.ntm.a.se/>, Accessed 2010-06-11.

Osborn, S., 2008. Congestion in RoRo ports - a shared problem? RoRo 2008, Gothenburg, 20-22 May.

Pallis, A., Langen, P.D., Vitsounis, T., 2007. Port research: Research networks, themes and methods in port economics, management and policies. The 11th World Conference on Transport Research, Berkeley, 24-28 June.

Pettit, S., Beresford, A., 2007. An analysis of logistics distribution patterns from major container ports and proposed container port developments in Great Britain. The Logistics Research Network Annual Conference 2007, Hull, 5-7 September.

Port of Gothenburg, 2010a. The port in short. <www.portgot.se/>, Accessed 2010-06-06.

Port of Gothenburg, 2010b. Rail services. Brochure. Gothenburg.

Ports of Sweden, 2010. Godsslag - hanterat över kaj (Freight types - handled over the quay). <www.transportgruppen.se/>, Accessed 2010-06-05.

Rodrigue, J.-P., 2008. The Thruport concept and transmodal rail freight distribution in North America. Journal of Transport Geography, 16, 233-246.

Rodrigue, J.-P., Debrie, J., Fremont, A., Gouvernal, E., 2010. Functions and actors of inland ports: European and North American dynamics. Journal of Transport Geography, 18, 519-529.

Rodrigue, J.-P., Notteboom, T., 2010. Comparative North American and European gateway logistics: the regionalism of freight distribution. Journal of Transport Geography, 18, 497-507.

Roso, V., 2009. The emergence and significance of dry ports: the case of the Port of Gothenburg World Review of Intermodal Transportation Research, 2, 296-310.

Roso, V., Woxenius, J., Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, 17, 338-345.

Schramm, H.-J., 2006. Governance of multimodal transport chains: a brokerage roles approach. The Logistics Research Network Annual Conference 2006, Newcastle, 6-8 September.

Stena Line, 2010. Investing billions takes ferry travel to a new level, Press release 2010-03-09. <www.stenaline.com/en/stena-line/corporate/media/press-releases/investing-billions-takes-ferry-travel-to-a-new-level/>, Accessed 2010-03-10.

Stopford, M., 2009. Maritime Economics, 3rd Edition. Routledge/Taylor and Francis, London.

Thorén, S.-G., 2010. General Manager Business Area Rail, Port of Gothenburg. Interview, 2 June 2010.

UK Department for Transport, 2009. Transport Statistics Report – Maritime Statistics 2008. TSO, London.

van Klink, H.A., van den Berg, G., 1998. Gateways and Intermodalism. Journal of Transport Geography, 6, 1-9.

Woodburn, A., 2006. The non-bulk market for rail freight in Great Britain. Journal of Transport Geography, 14, 299-308.

Woodburn, A., 2007. The role for rail in port-based container freight flows in Britain. Maritime Policy & Management, 34, 311 - 330.

Woxenius , J., 2006. Temporal elements in the spatial extension of production networks. Growth & Change: A Journal of Urban and Regional Policy, 37, 526-549.

Woxenius, J., 2010. Flexibility *vs.* specialisation in European short sea shipping. International Association of Maritime Economists (IAME) conference, Lisbon, 7-9 July.

Woxenius, J., Bergqvist, R., 2008. Hinterland transport by rail - a success for maritime containers but still a challenge for semi-trailers. the 13th Annual Logistics Research Network Conference, University of Liverpool, 10-12 September.

Woxenius, J., Roso, V., Lumsden, K., 2004. The Dry Port Concept – Connecting Seaports with their Hinterland by Rail. Dalian, 22-26 September.
Xu, M., Wu, M., 2007. The evaluation of Ro-Ro shipment in Yangtze river and its development policy. The Logistics Research Network Annual Conference 2006, Newcastle, 6-8 September.