INTERMODAL ROAD-RAIL TRANSPORT IN SWEDEN

-

ON THE PATH TO SUSTAINABILITY

Rickard Bergqvist, Logistics and Transport Research Group, Department of Business Administration, School of Business, Economics and Law, University of Gothenburg, Gothenburg, Sweden, E-mail, E-mail: rickard.bergqvist@handels.gu.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

Intermodal road-rail freight transport has long been seen as playing a key role in reducing CO_2 emissions from freight transport. The reduction of CO_2 emission is of great importance to reduce the greenhouse effect and create a sustainable society. However, the full potential of intermodal transport for CO_2 reduction remains to be determined. At first glance, the intermodal transport market has showed modest growth compared to other modes of transport, such as direct road. However, there are segments of the intermodal market, in particular in the road-rail segment that has shown significant growth during the last decade. This article looks at the potential for intermodal road-rail transport and describes the remarkable journey that has taken place in the hinterland road-rail segment, especially in Scandinavia. Furthermore, it includes a brief examination of how current trends affect the role and development of intermodal road-rail transport.

Stakeholders currently face new challenges as a result of the current financial crisis and global recession, however, this article identifies a significant long-term potential for modal shift related to the competitiveness of the road-rail intermodal transport segment. This article also outlines the trends that are likely to realise the identified potential for modal shift and the road-rail intermodal market in Scandinavia.

Based on previous research, a study has been conducted in Sweden on the potential reduction of CO_2 from intermodal transport. The potential of intermodal freight transport has been determined, the associated of CO_2 reduction estimated and the potential effect of future

trends in the industry has been examined. Modelling has been performed using the Heuristics Intermodal Transport Model, HIT-model, on the national Swedish transport system and detailed modelling for the rail shuttles system of Dry Ports in Sweden. To elaborate on the potential identified, the Swedish segment of hinterland road-rail transport and Dry Ports are examined in more detail, as well as future trends and challenges related to intermodal transport.

The current intermodal transport system in Sweden (including port related shuttles) has a 4% market share (4.1 billion tonnekm) and, thus, results in a reduction of 160 000 tonnes CO_2 annually compared to if all-road transport had been used. The segment of port related hinterland road-rail transport constitutes about 25% of that CO_2 reduction. The identified theoretical potentials for intermodal road-rail freight transport and modal shift is up to 50% of the long-haul transport or 1.6 million tones CO_2 using current technology. The Swedish segment of hinterland road-rail transport could constitute a large part of that potential as strategic scenarios indicate possible emission reductions of up to 500 000 tonnes of CO_2 within a foreseeable future.

In sum, modal shift using current technology have a great potential for decreasing CO_2 emissions. The growing segment of hinterland road-rail transport will most probably constitute an important role in achieving this potential. With the help of alternative rail engines, handling equipment, changed operating philosophy, new load unit types, etc. the emission reduction potential may be even greater.

Keywords: Intermodal transport, Modeling, Sustainability, Combined transport, Dryports, terminals, terminal handling

INTRODUCTION

Intermodal road-rail freight transport has long been seen as playing a key role in reducing CO_2 emissions from freight transport. The reduction of CO_2 emission is of great importance to reduce the greenhouse effect and create a sustainable society. However, the full potential of intermodal transport for CO_2 reduction remains to be determined. At first glance, the intermodal transport market has showed modest growth compared to other modes of transport, such as direct road. However, there are segments of the intermodal market, in particular in the road-rail segment that has shown significant growth during the last decade. This article looks at the potential for emission reduction in the transport segment with the help of modal shift to intermodal road-rail transport and describes the remarkable journey that has taken place in the port related hinterland road-rail segment, especially in Scandinavia, as an example of a successful intermodal system. Furthermore, it includes a brief examination of how current trends affect the role and development of intermodal road-rail transport and may contribute to further emission reductions.

BACKGROUND

In relation to the total increase in transport demand, the market share for intermodal transport in EU has been reduced. The large increase in transport demand has in all European countries been absorbed by road transport, while rail transport has remained steady in volumes, but lost in market share. This can be clearly seen in Figure 2.

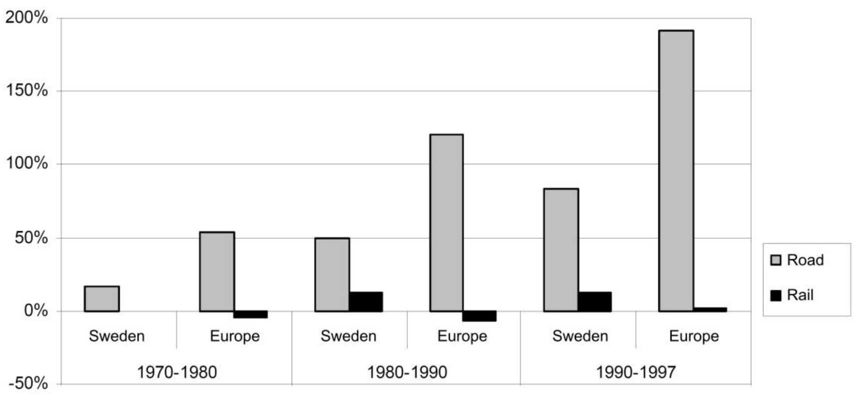

Figure 2 Expansion of goods transport in Sweden and western Europe in tonne-km 1970-1997 (SIKA, 2005, p. 34)

The environmental impacts of this have been negative. Pollution, congestions and societal costs have increased. Intermodal transport is by many viewed as one of the most promising ways to reduce the dominance by road transport. From a political perspective the interest has been great. The EU whitepaper emphasised the importance of a sustainable development and a key factors is modal shift towards rail (European Commission, 2001). An OECD-study found that, of its 28 member countries, 26 have an explicit or implicit policy to promote intermodal freight transport (OECD, 2001)

The volume of the intermodal transport market in Sweden has been fairly steady until a few years back when the success with the port shuttles started increasing the volumes. See Figure 1.

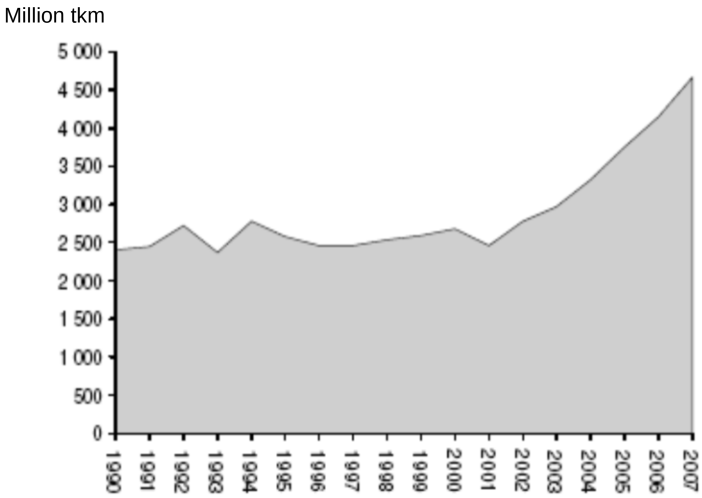

Figure 1 Transport performance by intermodal transport (SIKA, 2008, p. 30)

CO_2 emissions are of particular importance due to the threat of climate change. The reasons for this are obvious. Intermodal transport is believed to greatly contribute to reduced CO_2 emissions due to the low emissions from rail transport and its ability to combine low transport cots and low emissions for rail transport with the flexibility of road transport. However, there is a lack of studies into the potential of CO_2 reduction from intermodal transport. This article tries to fill this gap and to give some suggestions on how the intermodal road-rail transport system can be developed further. The article starts with a general description of potential reductions of CO_2 in the Swedish intermodal transport system, and continues by examining the successful Dry port system. Finally, based on these two presentations, future trends and challenges are analysed.

POTENTIAL CO_2 SAVINGS IN ROAD-RAIL INTERMODAL TRANSPORT IN GENERAL

The potential savings in CO_2 emissions from using an increasing share of intermodal transport is substantial. A comprehensive literature review made by Kreutzberger et al. (2003) shows that intermodal freight transport is environmentally friendlier than road. Previously, this has also been shown by IFEU and SGKV (2002) who calculates, on average, 20-50% less CO_2 emissions for intermodal transport than all-road transport on 19 tested European routes. The savings on Swedish routes are even higher, since the rail sector in Sweden uses 100% renewable energy from wind and water. The emissions from electricity production will, in an international comparison, greatly affect the potential emission savings from an increased use of intermodal transport. However, this paper will focus on the Swedish conditions.

The total CO_2 emissions from the transport sector in Sweden were 20 million tonnes in 2006. 17 million tonnes of this is causes by road transport (European Environment Agency, 2009). The majority of this is caused by cars and light trucks. The heavy trucks contribute with 4.4 million tonnes per year (Vägverket, 2009). The emissions from rail transport are very low, due to the use of renewable energy sources. Flodén (2007) uses the Heuristics Intermodal Transport model (HIT-model) to calculate the potential of intermodal road-rail transport in Sweden and its CO_2 emissions in comparison to road. The 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 potential of intermodal transport is determined by how well it performs in comparison with all-road transport. A transport buyer is supposed to select the mode of transport offering the best combination of transport quality, cost and environmental effect. Given a 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. The model also selects the type of load carriers, types of trucks, types of trains and sets the train time table. Intermodal transport must match, or outperform, the delivery times offered by road transport (within user defined time windows) while offering equal or lower cost to be selected. If intermodal transport cannot be used, the model outputs the reason, for each shipment, why intermodal transport could not be selected, e.g. to long delivery time compared to all road. Furthermore, the model calculates the emissions of carbon dioxide, nitrogen oxides, hydrocarbons, carbon monoxide, particulate matter and sulphur oxides and energy consumption. It also estimates the economic effect of the emissions. See Flodén (2007) for a detailed description.

Using a scenario of a national Swedish intermodal transport system, Flodén (2007) calculates a theoretical potential for intermodal road-rail freight transport is up to 50% of the long-haul transport or 1.6 million tonnes CO_2 saving compared to all-road transport using current technology. The CO_2 emissions from intermodal transport is calculated at 5.57 grams per tonnekm including rail haulage, terminal handling, shunting and pre- and post haulage by road. Trains are assumed to use electric traction using the national Swedish electricity mix (2001) with 85% hydropower. CO_2 emissions from road haulage are calculated at 44.55 grams per tonnekm. The current intermodal transport system in Sweden (including port related shuttles) has a 4% market share (4.1 billion tonnekm) and, thus, results in a reduction of 160 000 tonnes CO_2 annually compared to if all-road transport had been used.

It should be noted that the scenario in the HIT-model assumes that all goods can be loaded together in full trucks, that the most efficient trucks and trains are used, unlimited rail and terminal capacity, generous delivery time windows, and that transport buyers are completely rational. Thus, this is a theoretical potential and will never be reached, but is shows that as long as the transport distance is long enough, then intermodal transport is an economic preferable alternative. The study shows that for distances over 500km, intermodal transport is practically always preferable. Between 250-500km, intermodal transport is preferable under the right circumstances. Below 250 km, intermodal transport is seldom preferable, although some exceptions exist, e.g. some of the port shuttles. The challenge for intermodal transport is to meet the delivery times offered by road. When intermodal transport was not chosen by the HIT-model, the most common reason (53%-68% of tonnes not sent by all-road transport) was that the delivery times of all-road transport could not be met. This was further validated by narrowing the allowed delivery time windows which drastically cut the potential of intermodal transport.

The CO_2 emissions in intermodal transport can also be cut by technical and organisational improvements, particularly in the terminals. By reviewing existing technology, a number of potential savings can be identified (Bergqvist and Flodén, 2008). The review is based on a literature review of previous research, focusing on Swedish conditions.

Terminal handling is most often performed by reach-stackers. The advantage of using the heavy and expensive reach-stacker is that it can handle all types of load carriers. However, smaller swap-bodies and empty containers can also be handled by fork lift trucks. The fuel consumption for a fork lift truck is only about 60% of the consumption of a reach-stacker (13 litres/hour and 22 litres/hour) (Bark et al., 2008). The impact on CO_2 emissions from using correctly sized handling equipment is obvious. However, most terminals today only operate one or two trucks/reach-stackers, which they obviously have to dimension for the largest occurring load carrier type. Factors, such as the importance of a uniform fleet of handling equipment, at the terminal also has an impact. The result is that most handling is performed by, in many cases, unnecessarily powerful reach stackers.

The average CO_2 emissions per handled load carrier on an intermodal terminal in Sweden is approximately 3.64 kg per load carrier. This represents about the consumption per load carrier for a road transport of 10-15km. Handling equipment can also be operated by hybrid electric engines. Today diesel is used, but a switch to hybrid engines is estimated to save 40% of diesel consumption, which would result in a reduction in CO_2 emissions of 1.46 kg per load carrier (Bark et al., 2008). Per year this equates to 1 800 tonnes of CO_2 in Sweden with the current market share of intermodal transport. Of course, also methods EcoDrivning and alternative fuels used to reduce emissions from handling equipment.

The number of lifts made per load carrier at a terminal is also an important factor. Approximately 50% of the load units at a terminal is handled twice (Woxenius, 2003) when it first put down on the ground to later be lifted on the train, or truck. This is done when a direct lift between truck and train is not possible, e.g. when the truck does not arrive at the terminal at the same time as the train. It may also be necessary to move a load carrier to gain access to another. Can the number of lifts at the terminals be reduced, e.g. by load carriers being moved directly between trucks and trains, then the CO_2 emissions will be reduced accordingly. Handling time at the terminals will also decrease since it takes longer to transport a load carrier to the storage area than to load it directly. It is not realistic to assume that all load carriers can be loaded directly, but if about half of the "unnecessary" the lift was removed, then the CO_2 emissions would be reduced by approximately 15%. Per year this equates to 690 tonnes of CO_2.

The choice of load carrier made by the transport company also has a big impact, since the emission from terminal handling is largely linked to the number of lifts. A transport system with several small load carrier requires more lifts, i.e. increased CO_2 emissions. The importance of choosing the right handling equipment is thus even greater in those systems.

The CO_2 emissions from rail transport is of course largely dependent on the length, weight and load factor on the train. This will ultimately depend on the number of customers for the transport service and cannot (directly) be influenced by the transport operator. However, the transport operator should try to use electric traction as much as possible and an electricity mix with a large share of renewable resources (e.g. hydropower). More direct savings can be made in the shunting operations, which are performed by diesel engines. Many diesel engines are old with poor environmental performance. It is estimated that modern diesel engines has about half the emission of NO_x, HC and PM compared to the most common Swedish diesel engine today (type T44) (Banverket et al., 2002). A recently decided modernisation of the engines is expected to cut CO_2 emissions by 20% (Green Cargo, 2007) Trials are taking place with locomotives that use alternative fuels. Hybrid engines for diesel/battery power, which could save up to 40-50% in fuel during shunting is also under development (Bark et al., 2008).

Shunting with a T44 locomotives currently emits 208 kg of CO_2 per hour (Banverket, 2005). Emission per load carrier is difficult to estimate since the engines are used for different periods of time, the trains are of different lengths and types of engines may vary. Using a general assumption is that a shunting engine (T44) is used for at total of one hour for shunting in and out of the terminal and a train length of 70 TEU (66 load carriers, 40% trailers/containers and 60% swap bodies), CO_2 emissions for shunting can be estimated at 2.97 kg per TEU or 3.71 kg per load carrier. With a total of 1 261 000 handled TEUs at the Swedish terminals in 2005 (Banverket, 2007), and a 20% reduction in emission this corresponds to a CO_2 saving of 750 tonnes. This could be doubled if hybrid engines where used. To further reduce the need for shunting, it is necessary that the terminals have long enough track to accommodate trains of maximum length (about 650m), so that the trains do have to be split to fit in the terminal.

The potential reduction in CO_2 emission from these technical and organisational changes can be summed up as:

Hybrid powered terminal handling equipment: 1.46 kg per load carrier
Reduced number of lifts at a terminal: 0.55 kg per load carrier
Modern shunting engines: 0.74 kg per load carrier
Total: 2.75 kg per load carrier

With a current emission of 7.35 kg per load carrier for terminal handling and shunting, this corresponds to a saving of 37%. The total saving for the current intermodal transport system in Sweden would be 3 240 tonnes annually. This can be further increased by hybrid rail engines, changed operating philosophy, load unit types etc. In comparison with the total emission from heavy road traffic of 4.4 million tonnes, this constitutes a saving of 0.07%. This might seem small, but in comparison with the total emission from intermodal transport it constitutes a large share. Flodén 2009 estimates that the average emission of CO_2 from intermodal transport in Sweden is 5.57 grams per tonnekm, which translates into a total emission for the Swedish system for intermodal transport of 23 088 tonnes. The saving is then 14%. However, these numbers are very much dependant on how the electricity for the rail transport is produced. It must be noted that the Swedish rail system has very low emissions since electricity from renewable sources is used.

There are potential CO_2 improvements that fairly simple can be introduced in the industry, e.g. hybrid powered reach-stackers. However, the structure in the industry in Sweden, in particular the port related rail shuttles, is built around many small terminals. These terminals are often very simple, just consisting of an open area with gravel by a rail siding and a used reach-stacker. There is also a current trend in Sweden to continue to build a large number of small terminals. This is caused by local initiatives by industry and municipalities that want an intermodal terminal as they believe it would to increase the competitiveness of their region. To remain competitive, in particular on short transport distances and with low transport volumes, a low transhipment cost is of utmost importance. These characteristics and an overall tough price competition in the transport industry make it difficult to motivate the investment in new and expensive equipment. Research has shown that the environmental factor is given low importance in the modal choice, and in particular that customers are not willing to pay extra for it (Lammgård, 2007, Saxin et al. 2005, Björklund, 2002, 2005, Lundberg 2006). Intermodal transport already has a very good environmental image which would further reduce the incentives to pay extra for further environmental improvements.

The transport industry is also an overall very conservative industry. Particularly in the rail sector is it difficult to introduce innovative changes (Bärthel and Woxenius, 2004, Bontekoning and Priemus, 2004). Also the road industry is conservative. Nehls (2003) has made an ethnological study into the attitudes and values of truck drivers and found them to be very conservative and strictly focused on “trucking”. This mindset has to be lightened if these new innovations should be introduced successfully and the CO_2 emissions reduced.

THE SCANDINAVIAN SYSTEM OF HINTERLAND ROAD-RAIL TRANSPORT AND DRYPORTS

The development of Dry Ports and hinterland rail shuttles in Scandinavia has been remarkable during the last decade. At heart of the system are Port of Gothenburg (PoG) and 26 hinterland rail shuttles to different destinations and Dry Ports in Scandinavia. Some eleven different rail operators exist in the system (Port of Gothenburg, 2009a), an impressing number given that the rail sector in Sweden started its deregulated in 1988. Most of the shuttles have a frequency of five or more departures per week in each direction. The most frequent one supports the retailer H&M’s central warehouse in Eskilstuna, and operates 14 times a week in each direction.

Figure 1. The Port of Gothenburg rail shuttle system as of December 2009. (Source: Port of Gothenburg, 2009c).

Most shuttles serve distant dryports and conform to traditional hinterland transport. However, the system also comprise of shuttles serving much shorter distances, traditionally, operated by road. The reason for its competiveness over short distances lies in innovative operation planning where capacity of shuttles travelling longer distances are utilised trough means of collaboration. This setup allows for balancing of goods flows in combination with utilisation of overcapacity. In situation of decreasing volumes, capacity surplus is evident, however, since the system often expands there is enough critical capacity/shuttles and available unutilized capacity in times of increasing volumes as well. The rationale for this is that when operators adds capacity it can be done either by adding wagons or increasing the frequency, either way, there is possibilities for available capacity at intermediate nodes and stops. The shortest shuttle runs a distance of about 10 kms within the city Gothenburg.

The system of shuttles and dryports handled about 350,000 twenty-foot equivalent units (TEUs) in 2008 with a turnover of about €60 million. In 2008, PoG handled 860,000 TEUs, which means that the container rail shuttle system handled about 40 percent of all containers to and from the PoG.

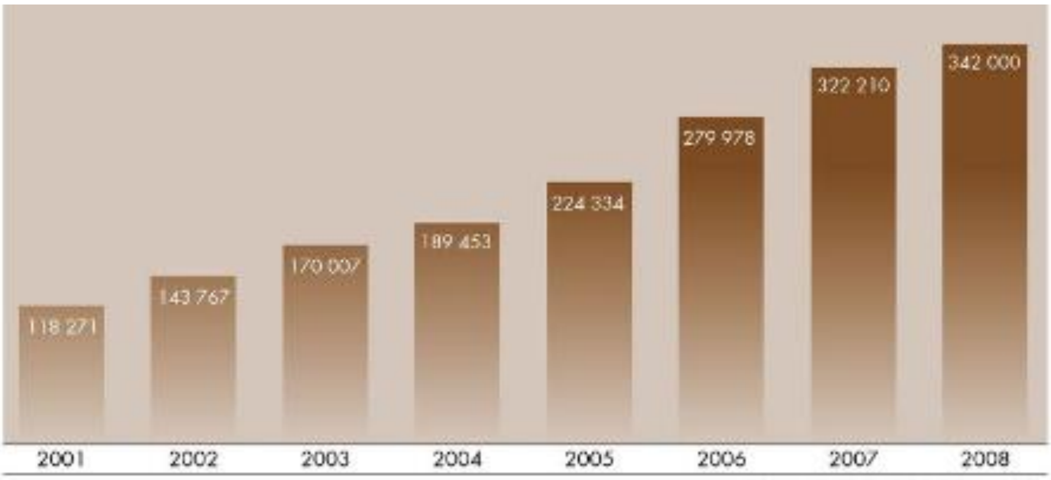

Figure 2. Rail volumes (TEUs) to and from Port of Gothenburg. (Source: Port of Gothenburg, 2009a).

The system has improved the congestion situation in the city of Gothenburg and the modal shift has contributed a carbon dioxide (CO_2) emission saving of about 42,000 tons annually. In 2008, the PoG received the Schenker award, the oldest and most prestigious prize in the logistics industry in Sweden, for their achievements and innovations related to the rail shuttle system.

The system took off after a systematic process was initiated with a decision by the board of directors at the PoG to set the goal that half of the growth in the container segment should enter or leave the port by rail. The rail shuttle system have been able to surpass this goal and gained market shares at a rapid pace. The rail shuttle system has achieved an annual growth of about 15 percent over the last seven to eight years and during last year's recession been able to keep volumes stable. However, most of this development has occurred during a period of substantial growth in container liner shipping. In late 2009, the Scandinavian rail shuttle system recorded all-time high and the market share increased to 60 percent, which is up from 40 percent in 2008 (Port of Gothenburg, 2009c), and the PoG expects this share to grow even further (Thorén, interview, 2009). However, one cannot avoid wondering if PoG's system of rail shuttles and dryports is running out of potential destinations.

Despite its successful historical development and good geographical coverage, the system still has the potential to develop. Expanding the system of rail shuttles to the segment of semi-trailers is a possibility that could substantially increase the scale of the Scandinavian rail shuttle systems. However, such a development poses some significant challenges since the semi-trailers segment is very different from containers in many aspects (Woxenius and Bergqvist, 2010). Up to now, the system has focused on transportation and increased volumes, and surprisingly few value-added services, such as storage of containers, customs clearance, and track and trace, have been transferred from the main port to the dryports despite the ambitions of the PoG. By extending the development of the shuttles system with the segment of semi-trailers and Dry Port interconnected shuttles, current research

(Bergqvist, 2009), suggest a possible further emission reduction by up to 500 000 tonnes CO_2, maybe as soon as 2025 given the historical development.

Future trends and challenges

As previously discussed, the segment of semi-trailers could significantly increase the modal shift of the Scandinavian rail shuttle system. A market-share of about twenty percent for the semi-trailer segment could increase the volumes of the port related rail shuttle system by about 100%. PoG faces some challenges in meeting the demand for handling rail shuttles loaded with semi-trailers. Preferable dedicated services should ensure high productivity, however, a combination of services with containers and swap-bodies could facilitate profitability and rapid gain of market shares. Challenges related to market expectations, customer requirements, attitudes, and “old habits” are another risk in addition to the quality performance of services at the PoG. However, these factors are to a large extent the same type of factors that previously was perceived as barriers for the growth of containers in the traditional intermodal road-rail segment. It is therefore likely that the semi-trailer segment will show similar “threshold” pattern as the container segment. Success-stories may play an important part to overcome barriers of attitudes, exactions and “old habits”.

The need for system management and control increases as the system of dryports expands (cf. Van der Horst and de Langen, 2008). For the principal port (Port of Gothenburg), this is a new and more complex role, especially given the current franchise setup of today’s Scandinavian rail shuttle system. Considering that the system contains about 26 Dry Ports and 11 different operators this coordination and control is challenging. Given that each dryport may offer a large scope of service often together with subcontractors, the PoG may need to deal with more than 50 different interfaces and business situations. Hence, the need for standardised communication is urgent.

Close range Dry Ports (cf. Roso, et.al. 2009) can play a very important role in the future as the rail shuttle system expands. Close Dry Ports are often located at or close to principal railway lines that are used by many rail shuttles. Hence, the close Dry Ports has the opportunity to utilise shuttles from distant Dry Ports using the same main railway line. This enables utilisation of overcapacity of different rail shuttles and improves the profitability of the system as a whole. This arrangement facilitates competitive intermodal road-rail solutions for short distances where intermodal services are normally unattractive and a greater modal shift can be achieved.

Through synchronisation of load units, sets of wagons and entire rail shuttles at the Dry Port, the system can be optimised with regard to the handling equipment and the current status at the principal port. Examples include sending blocks of wagons instead of full length shuttles, separating different types of load units and consolidating load units for a specific destination or individual ship (cf. Bärthel and Woxenius, 2004).

Bulk goods are increasingly moved in load units suitable for intermodal transport. Previously, integrating these goods into the intermodal transport chain has been a challenge. New innovative load units in combination with loading techniques have improved the interoperability. However, this type of goods is often not time-sensitive and usually enjoys attractive pricing from transport service providers due to its flexibility. As the rail shuttle operators and Dry Ports expands their perspective on services and differentiate also its transport service they have recognized the importance of this type of goods for dealing with lumpy demand and unbalances in their regular flow of load units. As the operators get more experience and local knowledge of possible goods flows more solutions of ramp-freight (time-insensitive goods) are realised.

Contrary to what many expected, large shippers have not utilised the rail shuttle system to the expected extend. The reason for this is often that their large scale goods flows are the basis for many carriers distribution networks which means that shippers often enjoys very low transport costs, sometimes, even at a rate below real costs. Several projects, especially in Sweden, address this issue with the aim of improving the cost-efficiency of the intermodal transport service for this type of situations. The main problem related to the competitiveness of the intermodal service is the pre- and post- haulage to and from the Dry Ports and the location of the shipper. In Sweden, current traffic regulations allows for the maximum possible transport of three TEUs in one single truck haulage. What many projects and actors, such as the Swedish road authority, are discussing is to allow for special regulations for specific large goods flows between location of shipper and nearest intermodal terminal of a maximum length of truck that allows for four TEU truck haulage setup. The issue of course is under which circumstances this regulation could be applied, e.g. specific routes, time of day, warning signs, etc. No consensus has been achieved for this regulation yet but there are substantial potential associated with this type of regulation worth mentioning.

Currently, almost all Dry Ports and rail shuttles have the same single business idea of transporting containers to and from PoG. In the future, there are great possibilities for differentiation and specialisation not only related to containers but also the segments of semi-trailers, swap-bodies, bulk, stripping and stuffing, reefers, express goods, specific industries (e.g. furniture, groceries), etc. Other interesting possibilities now starting to show is the interest by other sectors such as bio fuel, round timber, etc. To locate close to Dry Ports to utilise the same infrastructure and exploit synergies related to terminal and railway productivity.

CONCLUSIONS

The current reduction in CO_2 emissions annually in Sweden that is caused by the use of intermodal transport instead of all road transport. is 160 000 tonnes The segment of port related hinterland road-rail transport constitutes about 25% of that CO_2 reduction. The identified theoretical potentials for intermodal road-rail freight transport and modal shift is up to 50% of the long-haul transport or 1.6 million tonnes CO_2 using current technology. The Scandinavian segment of hinterland road-rail transport could constitute a large part of that potential as strategic scenarios indicate possible emission reductions of up to 500 000 tonnes of CO_2 within a foreseeable future. Further savings of approximately 3 000 tonnes can be gained by using new, but existing, technologies in the terminals.

It can be seen that the potential for reduced CO_2 emission from an increased use of intermodal road-rail transport is substantial. However, many challenges remain if any substantial part of this potential should be reached. This includes technical developments, attitude change among the actors and differentiated business models. However, the tough competition in the transport sector today and the low value transport customers attribute to the environmental factors makes it difficult to motivate any high investment costs to reduce emissions. Also the operating principles need to be developed to better match the market requirements.

ACKNOWLEDGEMENTS

The writing of this paper is funded by the Swedish strategic transport initiative and Handelsbankens research foundation.

REFERENCES

Banverket & SIKA, 2002, *Nya banavgifter? Analys och förslag*, Statens institut för kommunikationsanalys, SIKA rapport, 2002:2 Stockholm

Banverket, 2005, Beräkningshandledning: hjälpmedel för samhällsekonomisk lönsamhetsbedömning av järnvägsinvesteringar, Banverket, Handbok BVH 706, Borlänge

Banverket, 2007, *Strategiskt nät av kombiterminaler - intermodala noder i det svenska godstransportsystemet*, Redovisning av Näringsdepartementets uppdrag N 2006/3928/TP, dnr F07-10649/TR20,

Bark, P. & Jonsson, R. & Nelldal, B.-L., 2008, Intermodala komponenter - System, utrustning, metoder och miljö, TFK - TransportForsK AB, Rapport 2008:2, Stockholm

Bergqvist, R., 2009, Hamnpendlars betydelse för det Skandinaviska logistiksystemet, BAS Publishing

Bergqvist, R. & Flodén, J., 2008, Överföringspotential för gods till kombinerade transporter och hamnpendlar, In Vierth, I. & Melin, A., editors, *Svensk godsstudie baserad på nationell och internationell litteratur*, Stockholm, VTI rapport 629

Björklund, M (2002) *Environmental Considerations when Selecting Transport Solutions – A contribution to shippers' decision process*. Licentiatuppsats, Institutionen för teknisk ekonomi och logistik, Lunds universitet. Lund

Björklund, M (2005) *Purchasing practices of environmentally preferable transport services: guidance to increased shipper considerations*. Doktorsavhandling, Institutionen för teknisk ekonomi och logistik, Lunds universitet. Lund

Bontekoning, Y. M. and Priemus, H. (2004). Breakthrough innovations in intermodal freight transport. Transportation Planning and Technology, 27, 335-345.

Bärthel, F. and Woxenius, J. (2003), "The Dalecarlian girl - evaluation of the implementation of the Light-combi concept", paper presented at Alliance for Global Sustainability Annual Meeting, 24-27 March, Tokyo.

Bärthel, F. & Woxenius, J. (2004) Developing intermodal transport for small flows over short distances, *Journal of Transportation Planning and Technology,* 27(5), pp. 403-424.

European Commission (2001). White Paper - European transport policy for 2010: Time to decide. Brussels.

European Environment Agency (2009). Transport at a crossroads TERM 2008: indicators tracking transport and environment in the European Union European Environment Agency Copenhagen.

IFEU & SGKV, 2002, Comparative Analysis of Energy Consumption and CO2-Emissions of Road Transport and Combined Transport Road/Rail, International Road Transportation Union (IRU), Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL), Institut für Energie- und Umweltforschung Heidelberg (IFEU), Studiengesellschaft für den kombinierten Verkehr (SGKV)

Flodén, J. (2007). Modelling intermodal freight transport : the potential of combined transport in Sweden, Doctoral thesis, School of Business, Economics and Law at University of Gothenburg, BAS Publishing, Göteborg. http://hdl.handle.net/2077/17141

Green Cargo, 2007, Pressrelease: Bombardier och Green Cargo tecknar miljardkontrakt, June 15

Kreutzberger, E. & Macharis, C. & Vereecken, L. & Woxenius, J., 2003, *Is intermodal freight transport more environmentally friendly than all-road freight transport? A review*, Paper presented at The NECTAR conference no. 7, Umeå, Sweden

Lammgård, C., 2007, *Environmental marketing of freight transports - the intermodal road-rail case*, Doctoral thesis, School of Business, Economics and Law at University of Gothenburg, Göteborg

Lundberg, S (2006) Godskunders värderingar av faktorer som har betydelse på transportmarknaden. Licentiatuppsats, Institutionen för Transport och samhällsekonomi, Kungliga Tekniska Högskolan. Stockholm

Nehls, E., 2003, *Vägval : lastbilsförare i fjärrtrafik - perspektiv på yrkeskultur och genus*, Göteborg, Umeå universitet, Etnologiska föreningen i Västsverige

OECD, 2001, *Intermodal freight transport: institutional aspects*, Paris, Organisation for Economic Co-operation and Development (OECD)

Port of Gothenburg (2009a) *Rail, Road & Logistics*, brochure, Gothenburg.

Port of Gothenburg (2009b) *The port in short*, web page: www.portgot.se, accessed 2010-01-22.

Port of Gothenburg (2009c) *Rail services*, web page: www.portgot.se, accessed 2010-01-22.

Roso, V., Woxenius, J. & Lumsden, K. (2009) The Dry Port Concept – Connecting Seaports with their Hinterland by Rail, *Journal of Transport Geography*. 17(5), pp. 338-345.

Saxin, B. & Lammgård, C. & Flodén, J., 2005, Meeting the Demand for Goods Transports - Identification of Flows and Needs Among Swedish Companies, Paper presented at NOFOMA 2005, Copenhagen, Denmark

SIKA, 2005, *Transportprognoser sedan 1975. En översiktlig uppföljning*, Statens institut för kommunikationsanalys, SIKA Rapport 2005:4, Stockholm

SIKA, 2008, *Bantrafik 2006*, Statens institut för kommunikationsanalys, SIKA Statistik 2008:2, Stockholm

Thorén, S.-G. (2009) Manager of rail services, Port of Gothenburg, Interview, 2009-12-11.

Van der Horst & de Langen, M., P. (2008) Coordination in hinterland transport chains: a major challenge for the seaport community. *Maritime Economics & Logistics*, 10(1-2), pp. 108-129.

Woxenius, J., 2003, Intermodala transporter och SJ/Green Cargos utvecklingsprojekt Lättkombi, Institutionen för transportteknik, Chalmers tekniska högskola, Meddelande 117, Göteborg

Woxenius, J & Bergqvist, R. (2010) Hinterland Transport by Rail – Comparing the Scandinavian Conditions for Maritime Containers and Semi-trailers", *Journal of Transport Geography*, forthcoming issue, available online

Vägverket (2009). Minskade utsläpp från vägtrafiken men stora utmaningar väntar, Vägverket, Borlänge.