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Assessing the Effects of Longer Vehicles: The Case of Pre- and Post-haulage in Intermodal Transport Chains

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ABSTRACT *The demand for inland freight transport in Europe is mainly met by road transport, leading to unsustainable impacts such as air pollution, greenhouse gas emissions and congestion. Since rail transport has lower externalities than road transport, a modal shift from road to rail is an accepted policy goal for achieving a more sustainable and competitive transport system. However, intermodal road–rail transport is mainly competitive for long-distance transport, and as a consequence, the potential for modal shift is limited. The cost efficiency of road–rail intermodal transport is particularly sensitive to pre- and post-haulage (PPH) costs, since this activity typically has a larger cost compared with its share of the total distance in the transport chain. For intermodal transportation over shorter distances, for example, below 300 km and where there are substantial PPH activities at both ends of the chain, the competitiveness of the intermodal transport system compared with that of direct road is low. Improving the efficiency of PPH activities is, therefore, of utmost importance for the competitiveness of the intermodal transport system. This paper looks into the issue of improving the cost efficiency of an intermodal transport chain by implementing an innovative and flexible legal framework regarding the PPH activities in the chain. By extending the legal framework with exemptions for longer vehicles in PPH, the cost efficiency could be greatly improved. The purpose of such a framework is to allow and enable, for PPH exclusively, the use of 2 × 40 foot or even two semi-trailers using only one vehicle in the context of the Swedish regulatory framework. This paper develops a strategic calculation model for assessing and investigating the consequences of such a framework and investigates the framework's potential in terms of cost efficiency. The model in combination with a sensitivity analysis of input variables gives a comprehensive understanding of the effects of PPH under different circumstances. From the results, it is evident that there are substantial positive effects associated with a PPH framework of longer vehicles. Results indicate that a typical shipper may experience cost reductions of about 5–10% of the total costs of the intermodal transport chain. In summary, a more innovative and flexible legal framework regarding vehicle length in the PPH links can contribute to a greater modal shift, improved cost efficiency and more environmentally friendly transportation systems.*

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1. 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. Since the increase in freight transport demand is mainly met by road (European Commission, 2006), it imposes significant negative impacts on society, the economy and the environment. Alternative fuels and more fuel-efficient, cleaner and quieter vehicles have reduced the externalities per kilometre driven, but these environmental benefits have been offset by sharply increasing total vehicle-kilometres, as logistics systems become ever more transport intensive. Technological innovation in the road freight sector is, therefore, unlikely to be the sole answer to the environmental problems.

European transport policy recognizes the importance of intermodal transport and especially combined road–rail transport as a means of addressing this problem. Transport policy was one of the first policies included in the European integration process. The Commission's first White Paper on the future development of the common transport policy, published in December 1992, emphasized the opening and integration of the European Union (EU) transport market (European Commission, 1992). In 1997, it was acknowledged that the "business-as-usual" approach to transport policy cannot solve the transport-related problems. Instead, a systems approach was needed and the promotion of intermodality was recognized as a policy tool. This was a vital step forward in the development of intermodal transport in Europe (Lowe, 2005). The next policy milestone was 2001 when the EU Commission published its Second White Paper "European transport policy for 2010: time to decide" (European Commission, 2001). While the guiding principle of European transport policy was the opening up of the transport market in the 1990s, the 2001 White Paper recognized that the response to continuously increasing transport volumes cannot be limited to building new infrastructure and liberalizing markets. Sustainable development was emphasized, focusing, among other things, on modal shift from road to rail and inland waterways.

However, despite a series of initiatives aiming at revitalizing rail freight (e.g. the Marco Polo Programme), little has been achieved in increasing the market share of rail in EU-25, with some exceptions in specific countries. Traditionally, intermodal transport has a medium-to-high market share for large flows over long distances, for goods to and from seaport, for flows between production plants and to depots and for bulk commodities and dangerous goods (Bontekoning and Priemus, 2004). Intermodal transport provides good transport quality and cost efficiency in these markets, but the short- and medium-distance transports remain the domain of the road transport sector (Bärthel and Woxenius, 2004).

The competitiveness of rail-based intermodal transport very much depends on the costs of the pre- and post-haulage (PPH) (e.g. Niérat, 1997; Kreutzberger *et al.*, 2006). This paper addresses the possibility of improving the competitiveness of intermodal transport services by improving the cost efficiency of the PPH activities. It does so by constructing a strategic calculation model that provides an insight into the potential of longer vehicles for PPH activities. This paper also addresses possible effects of an alternation to the regulatory framework on the transportation system. The principal idea is to implement flexible regulations to allow longer vehicles to be used for specific goods flows between the location of major shippers and the nearest intermodal terminal, where PPH circumstances currently make intermodal road–rail transport solutions unfavourable. The regulatory exemption as defined in this paper applies the same regulatory restrictions related to maximum payload and load per axle.

The following sections address previous research on PPH in intermodal transport chains (Section 2), the existing regulatory framework for PPH (Section 3) and a Scandinavian perspective on modal shift (Section 4). In Section 5, the strategic calculation model is presented, followed by a sensitivity analysis in Section 6. The paper ends with strategic interpretations and conclusions (Section 7).

2. Frame of Reference

2.1 *PPH in Intermodal Transport*

Intermodal transport is the combination of two or more transport modes in one transport chain. This paper applies the United Nations Economic Commission for Europe (UNECE, 2001) definition of intermodal transport:

> The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport, without moving the goods itself in changing modes.

The rationale and aim are that the service and cost advantages of each transport mode combined improve the overall efficiency of the transport system (Jensen, 1990). The predominant modes of transport for the longest links in the intermodal transport chain are rail, inland waterways, short sea shipping or ocean shipping where the units are consolidated with other shipments and economies of scale apply. Road transport, as part of an intermodal transport chain, is often assigned to short haul and collection and distribution of goods (i.e. PPH). Intermodal transport thus enables economies of scale and enhances the cost efficiency of the transport system.

In the intermodal transport chain, PPH operations involve the provision of an empty intermodal loading unit (ILU) to the shipper and the subsequent transportation of a full ILU to the intermodal terminal (Macharis and Bontekoning, 2004). Kreutzberger *et al.* (2006) evaluated the cost performance of PPH and identified the critical factors for the cost performance; the location of shippers around a terminal (i.e. haulage distance); the freight volumes per shipper or area; the resource productivity, for example, labour or fuel costs; and the network productivity, for example, number of roundtrips per load unit and loading/unloading times. In Europe, most PPH operations around inland terminals have a distance of 0–25 km (in one direction), only a few trips exceed a distance of 100 km, and the number of terminal visits per day of a truck is 1.4–2.1 (Kreutzberger *et al.*, 2006).

PPH operations are very fragmented, with various PPH companies serving each terminal. Distribution and pick-up trips to and from shippers are not coordinated, resulting in many additional empty trips (Morlok *et al.*, 1995). In addition to low capacity utilization, due to the empty running, which is inherent in pick-up and delivery traffic, the centralized intermodal production system leads to concentrated PPH flows and longer waiting times at large-scale intermodal terminals (Walker, 1992). In addition, since terminals as well as consignor and consignees are usually located in, or in the vicinity of, urban areas, PPH is affected by urban congestion. Given a reliable and fast dedicated train service, PPH is the primary source of both long transit times and transit time unreliability, leading to serious problems in the intermodal chain's service quality (Morlok *et al.*, 1995). Furthermore, PPH accounts for a large fraction (between 25% and 40%) of the total cost of moving an ILU, despite its relatively short distance compared with the rail line haul (Macharis and Bontekoning, 2004).

PPH operations, therefore, seriously affect the quality and profitability of intermodal transport and, in doing so, significantly limit the markets in which it can compete. The development of efficient PPH operations can improve the attractiveness of intermodal transport. However, despite its influence on the performance of intermodal transport, little research has been conducted on this aspect (Bontekoning *et al.*, 2004; Caris *et al.*, 2008). Morlok *et al.* (1995) showed that a decrease of 30% in PPH costs reduces the break-even distance by 42% for intermodal transport compared with direct road and concluded that PPH improvements are clearly the key for enlarging the intermodal market, since improvements in other parts of the transport chain will not lead to the same proportional decrease in costs.

Given the large costs associated with PPH, there is substantial potential for operational improvements and improved cost efficiency. However, as previous research has illustrated, it is difficult and challenging to achieve improvements to the organization of haulage (Niérat, 1997). As a result, changes to the regulatory framework might be necessary and even desirable. The regulatory framework for the transport market determines to a large extent the cost level of PPH, since it is a complex business burdened by a large number of restrictive government directives and regulations, including maximum vehicle dimensions and weights, operator licencing and limits on driver working times (Lowe, 2005). Moreover, environmental regulations affect PPH operations, since accessing of consignors and consignees to and from terminals often takes place in urban areas where additional regulations apply (Woxenius, 2001).

3. Regulatory Framework for PPH

There are three main types of ILUs: ISO containers, swap bodies and semi-trailers. The most common ISO containers are 20-, 40- or 45-foot long (5.98, 12 and 13.50 m). For swap bodies, two classes can be distinguished. For carriage on road trains, "Class C" swap bodies with lengths of 7.15, 7.45 and 7.82 m are used. For articulated vehicles, "Class A" swap bodies with lengths of 12.50 and 13.60 m are the most important. For semi-trailers, the typical length is 13.60 m, which is also their maximum length (Vrenken *et al.*, 2005).

The maximum size of vehicles in intra-national and international traffic, as well as the weight limits in international road freight traffic, is regulated by the EU. Council Directive 1996/53/EC restricts vehicle lengths to 16.50 m for truck–trailer combinations and to 18.75 m for articulated vehicles. The maximum permissible weight of 40 tons can only be exceeded to 44 tons when carrying 40-foot containers to and from intermodal terminals.

These load units and vehicle dimensions permit the following carrying capacity of intermodal vehicles. Articulated vehicles can carry one "Class A" swap body, one "Class C" swap body, two 20-foot containers or one 40-foot container. Road–train combinations can carry two "Class C" swap bodies or two 20-foot containers (Lowe, 2005).

Exemptions from the rules for road freight vehicles which exceed the size limits of current heavy good vehicles of 16.50 m/18.75 m are subject to special permissions given by national governments. The Council Directive 1996/53/EC allows member states to legalize longer and heavier vehicles (LHVs), so long as they conform to the standard modular dimensions, which are defined in the directive. The short module 7.82 m, which is a CEN standard for swap bodies, also includes other standardized load units such as 7.45 m, 7.15 m and 20 foot. The long module 13.6 m, which is the European semi-trailer length, includes the 40-foot ISO container. These vehicle units are coupled together in combinations in order to achieve a total loading length that is a multiple of the module lengths 7.82 and 13.6 m (Doll *et al.*, 2009). These exemptions, however, are only valid for transports within their national borders and do not apply for border crossing traffic. Some countries generally allow a vehicle length of 25.25 m and a weight of 60 tons (Doll *et al.*, 2009). Sweden and Finland generally allow the use of LHV combinations consisting of the longest semi-trailer, with a maximum length of 13.6 m, and the longest load carrier according to "Class C", with a maximum length of 7.82 m, is allowed in the EU. This results in vehicle combinations of 25.25 m, which is significantly longer than the maximum length of 18.75 m within the rest of Europe. These vehicle combinations are known as the European Modular System (EMS).

Concerning weight limits, different exemptions from the current maximum weights of 40 tons have been tested or are in use. Sweden and Finland generally allow a maximum vehicle weight of 60 tons. In some states in Germany, trials that allow vehicle lengths of 25.25 m, but not exceeding the current weight limit of 40 tons, have been conducted (Doll *et al.*, 2009). The Netherlands have carried out two LHV trials between 1999 and 2003 and between 2004 and 2006, and the results were considered sufficiently positive to justify the general legalization of LHVs (McKinnon, 2008). Since November 2007, longer vehicles with a weight of 50 tons have been allowed, and since May 2008, 60 tons and 25.25 m LHVs have been allowed on Dutch roads (Doll *et al.*, 2009).

The European Commission is considering a revision of the regulatory framework on weights and dimensions of heavy commercial vehicles, which would also allow the use of LHVs in international transport. The recognized benefits are a reduction in vehicle operating costs and a reduction in lorry traffic, which would help to alleviate environmental impacts and congestion. However, the reduced operating costs may also have negative environmental effects, since they can induce a modal shift from rail to road and induce additional demand for transport. Furthermore, they affect safety and have implications for road transport infrastructure.

Various studies have been undertaken and they have arrived at different conclusions on the relative economic and environmental costs and benefits of longer road vehicle combinations. In Scandinavia, the experience of using EMS vehicle combinations is mostly positive. A study done by Åkerman and Jonsson (2007) indicates that the use of LHVs with EMS in Sweden and Finland has had a positive effect on the economy and environment while not affecting traffic safety negatively. Furthermore, the Dutch trials indicate that it is possible to operate with LHVs on a limited road network. On the other hand, Doll *et al.* (2009) concluded that a general extension of the provisions of directive 1996/53/EC towards extra-long and possibly extra-heavy lorry combinations would result in a considerable shift in the mode of transport to road (between 10% and

30% of rail containers), with negative consequences for the environment, climate and safety. Additional potential negative effects are the generation of new freight traffic if companies respond to the reduction in freight costs, a possible increase in the severity of accidents as a result of the greater weight and size and a possible increase in expenditure on road infrastructure to accommodate LHVs (McKinnon, 2008).

Hence, increasing the maximum length and weight of road vehicles is one of the most controversial issues in the context of transport policy. McKinnon (2008) highlighted the difficulties in assessing the net benefits and extrapolating the experience from national trials to the EU as a whole.

4. A Scandinavian Perspective

Scandinavia, in general, and Sweden, in particular, have difficulties in achieving a substantial modal shift (Figure 1). However, the development during the last decade related to road–rail intermodal transport in Scandinavian and Sweden has been remarkable. Statistics of the development of rail-based intermodal transport clearly illustrate a new trend, emerging since 2001 (Figure 2). The development from 2001 and onwards is to a large extent based on the expanding system of rail shuttles and dry ports in Scandinavia. At the heart of the system is the Port of Gothenburg (PoG) with 26 different rail shuttles to destinations and dry ports in Scandinavia currently.

In 2008, the system of shuttles and dry ports handled about 350,000 20-foot equivalent units (TEUs) with a turnover of about €60 million (Bergqvist, 2009). In 2008, the PoG handled 860,000 TEUs, which means that the container rail shuttle system handled about 40% of all containers to and from the port.

Surprisingly, large shippers have not utilized the rail shuttle system as expected. One of the main reasons for this is that the goods flows of large shippers are often the platform for the distribution network of many carriers. This means that large shippers often enjoy very low transport costs, and occasionally, even at rates below operating costs. Addressing the regulatory framework for PPH could improve cost competitiveness and facilitate continued modal shift. The issue, of course, is under which circumstances this regulation could be applied, for

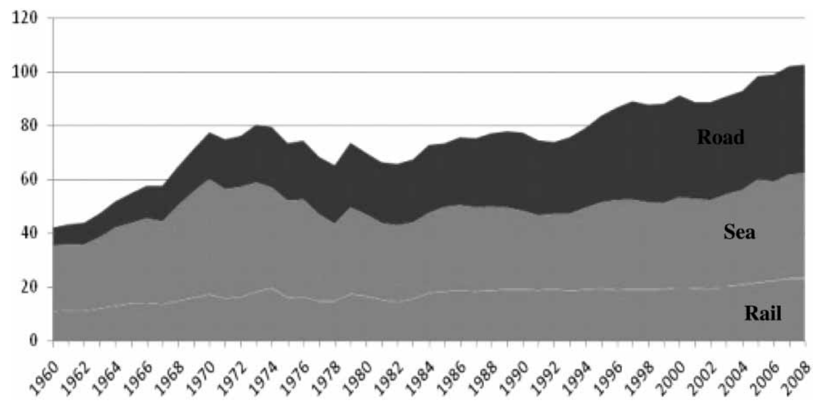

Figure 1. Road-, rail- and sea-based freight transport performance in Sweden (billion tonkm). *Source*: SIKA (2008, p. 17)

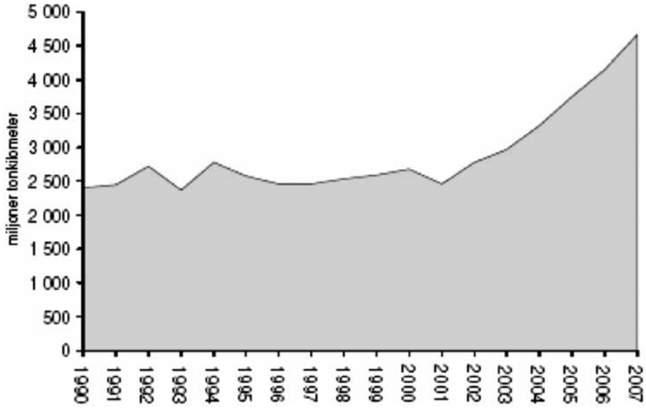

Figure 2. Rail transport performance by intermodal road–rail transport in Sweden (million tonkm). *Source*: SIKA (2009)

example, specific routes, time of day and warning signs. More importantly, the issue of when it should be applied is difficult to address without in-depth knowledge of the cost structure of such a setup. Therefore, it is necessary to develop a model that can provide an insight into this issue.

5. Strategic Calculation Model

5.1 *A Systems Comparison*

Strategic economic calculation models are useful tools in analysis, the purpose of which is to identify threats or opportunities in a future development or to find promising areas for more precise analysis in a setting where little empirical data may be gathered. These models are useful for sensitivity analysis and scenarios. Sensitivity analysis and scenarios represent possible states or courses of events that are well defined in a few key dimensions and computed with reasonable mathematical precision, but more vaguely expressed in other dimensions. The important thing is that they can give a picture that is sufficiently clear and relevant for drawing strategic conclusions. The primary reason for using precise mathematical models in strategic analysis is not the quantitative precision they deliver *per se*, but that they facilitate transparent expression of assumptions and methods and allow systematic manipulation. However, it is important to integrate the most important factors and to make the model flexible in terms of allowing sensitivity analysis (cf. Jensen, 1990).

The problem analysed here involves a comparison between two designs of an intermodal transport chain. The difference between the designs lies in the haulage setup. In the "regular" haulage system, the PPH activities in the chain are carried out under current regulations for vehicles and their combinations. In the "double" haulage system, the haulage activity can be carried out under exemptions from current regulations. The two versions of the intermodal transport chain are illustrated in Figure 3.

When designing the comparison as a strategic calculation between the two systems, all cost components that do not differ between the two system designs will cancel out, a fact that simplifies comparison and model building.

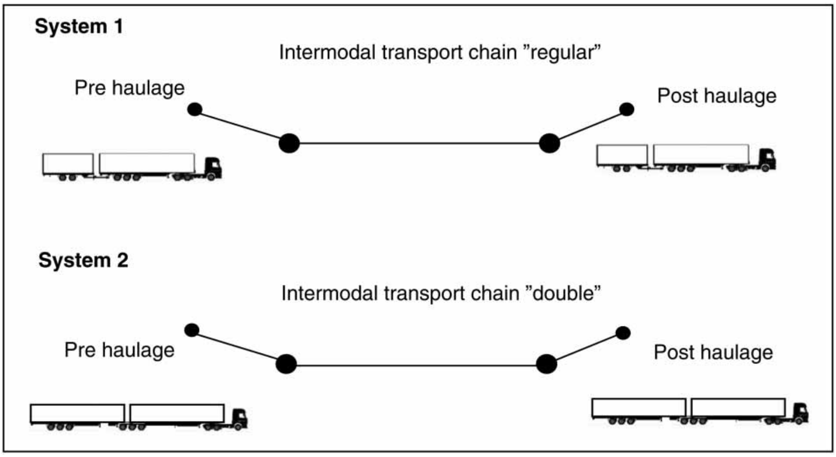

Figure 3. Two system designs of an intermodal transport chain regarding PPH regulations.

The total cost differentiation of the intermodal transport chain, given the two systems defined in Figure 3, depends on many factors. The differentiation model developed in this paper and the associated sensitivity analysis are especially focused on the underlying prerequisites for cost-efficient haulage, for example, goods volumes, volume distribution over time, distances and average shipment size. The model assumes that exemptions from the standard regulations are given on an individual shipper basis, that is, exemptions cannot be based on combinations of shippers. In order to construct a valid strategic calculation model, transport-related costs, such as the distribution of fixed and variable costs and the haulage costs as a share of the total transport costs, need to be defined.

Given this background, the following strategic calculation model is constructed:

Formula 1. Strategic calculation model

$$TCC_{chain} = TCC_{haulage} * \frac{1}{(1+CS_{road})},$$

$$TCC_{haulage} = FCC_{haulage} * FCC_{haulage} + (1 - FCC_{haulage}) * VCS_{haulage},$$

$$FCC_{haulage} = (NS_{double} + NS_{reg}) * \frac{Av_{reg}}{Vol_{TEU}},$$

$$VCC_{haulage} = (VCD_{haulage} * NS_{double} * D + NS_{reg} * D) * \frac{AV_{reg} * D}{Vol_{TEU}},$$

$$NS_{double} = Vol_{Teu} * \frac{SS_{>3TEU}}{4},$$

$$NS_{reg} = \frac{Vol_{TEU} * -(NS_{double} * 4) * SV_{40f}}{2} + \frac{(Vol_{TEU} - NS_{double} * 4) * (1 - SV_{40f})}{AV_{reg}},$$

where TCC_{chain}, total cost change for transport chain (%); CS_{road}, haulage costs as a share of the total cost of the chain (%); $TCC_{haulage}$, total cost change for the haulage part of the chain (%); $FCC_{haulage}$, fixed cost change for the haulage part of the chain (%); $FCS_{haulage}$, fixed cost share for the haulage part of the chain (%); $VCS_{haulage}$, variable cost share for the haulage part of the chain (%); NS_{double}, no. of possible shipments with double haulage (No.); NS_{reg}, no. of shipments required with regular haulage setup (No.); $VCC_{haulage}$, variable cost change for the haulage part with the chain (%); $VCD_{haulage}$, variable cost share for double compared with regular haulage setup (%) (given); D, distance from origin to terminal (km) (given); Vol_{TEU}, total volume on transport link (TEU) (given); $SS_{>3TEU}$, share of shipments with more than 3 TEU (%) (given); NS_{reg}, estimation of the number of shipments required with regular haulage setup (No.); $SV_{40\ f}$, share of volume with shipments of 40 or 45 foot (%) (given); AV_{reg}, average shipment size for regular haulage setup (TEU) (given)

NS_{reg} is to be regarded as an estimation, since the number of shipments is dependent not only on the average shipment size in TEU but also on the statistical distribution over time. Here, shipment sizes are assumed to be very stable in relationship to the average shipment size (e.g. no trend or seasonal patterns). Furthermore, this variable is closely linked with the variables SV_{40f} and $SS_{>3TEU}$.

6. Sensitivity Analyses

For the sensitivity analyses, we used default numbers based on an estimation of the situation of a typical large shipper (cf. Bergqvist, 2007). Given the previous strategic calculation model, it is interesting to investigate the impact that certain variables have on the total cost change of the intermodal transport chain. The examples of cost-related variables are haulage costs as a share of the total cost of the chain CS_{road} and fixed and variable cost share for the haulage part of the chain $FCS_{haulage}$ and $VCS_{haulage}$. Other more physically dependent variables that are interesting to analyse are distance between origin and terminal *D*, total volume on the transport link Vol_{TEU}, share of shipments with more than 3 TEU $SS_{>3TEU}$, share of volumes with shipments of 40-foot units SV_{40f} and average shipment size for regular haulage setup AV_{reg}.

The default values given in Table 1 were used in the sensitivity analysis for each variable.

The other variables were derived on the basis of the above-defined default values. The variables marked (sensitivity analysis) are the variables modified in the sensitivity analysis. The sensitivity analysis focused on the single variable analyses; hence, no combinations of variables were systematically treated in the sensitivity analysis at this stage. Such combinations were dealt *ad hoc*. For example, there was a high correlation between the variables $SS_{>3TEU}$, SV_{40f} and

Table 1. Default values for the sensitivity analysis

$CS_{road} = 20\%$ (Sensitivity anlysis)
$FCS_{haulage} = 10\%$
$VCD_{haulage} = 30\%$ (Sensitivity anlysis)
$D = 20$ kms
$Vol_{Teu} = 1000$TEU
$SS_{3TEU} = 20\%$ (Sensitivity anlysis)
$SV_{40f} = 30\%$
$AV_{reg} = 3$ TEU

Table 2. Results obtained from the sensitivity analysis

Sensitivity analysis 1		Sensitivity analysis 2		Sensitivity analysis 3	
CS_{Road} (%)	TCC_{chain} (%)	$VCD_{haulage}$ (%)	TCC_{chain} (%)	$SS_{>3TEU}$ (%)	TCC_{chain} (%)
5.0	105.8	100.0	89.2	10.0	94.2
10.0	101.0	105.0	89.7	15.0	93.4
15.0	96.6	110.0	90.3	20.0	92.5
20.0	92.5	115.0	90.9	25.0	91.7
25.0	88.8	120.0	91.4	30.0	90.9
30.0	85.4	125.0	92.0	35.0	90.1
35.0	82.3	130.0	92.5	40.0	89.3
40.0	79.3	135.0	93.1	45.0	88.4
45.0	76.6	140.0	93.7	50.0	87.6
50.0	74.0	145.0	94.2	55.0	86.8
55.0	71.6	150.0	94.8	60.0	86.0
60.0	69.4	155.0	95.4	65.0	85.1

AV_{reg}, so the result of the sensitivity analysis for one of them is likely to yield similar results as for the other two closely related variables.

From the sensitivity analysis results (Table 2), some interesting observations can be made. As expected, the haulage costs as a share of the total cost of the chain (CS_{road}) had a rather substantial influence on the total cost change (TCC_{chain}). The share of shipment sizes over 3 TEU ($SS_{>3TEU}$) had a greater impact on the total costs, suggesting that the average shipment size for regular haulage (AV_{reg}) and the share of volume with shipments of 40 foot (SV_{40f}) also had a large impact on the total cost change. The most interesting observation, however, was the relative robustness of the relative haulage costs ($VCD_{haulage}$), which implied that there is quite a buffer to deal with the factors that increase the cost of "double" haulage compared with the "regular" haulage. This would give the exemption setup some room for additional costs, such as special regulations on speed and route, without losing too much of its cost advantage compared with the "regular" haulage setup. However, it should be recognized that it may interact with other variables outside the scope of this sensitivity analysis.

7. Strategic Interpretations and Conclusions

From a Scandinavian perspective, the haulage costs of intermodal transport services suggest a great potential associated with the regulatory exemptions for more efficient PPH setups. The strategic calculation model developed here and the default values for a typical shipper's situation indicate a total cost of about 90% of that of a "regular" haulage setup. This implies that new regulations related to vehicle setups for haulage have the potential to decrease the total cost for intermodal transport services for a typical large-scale shipper by about 5–10% when the haulage accounts for about 20% of the total cost of the transport chain. This change might not seem that impressive, but this change can be enough to achieve a substantial modal shift as the break-even point is moved and intermodal road–rail transport becomes competitive and attractive in new market segments. When combined, such exemptions from the regulations have the possibility of improving the cost efficiency and environmental performance of the overall transportation system.

Overall, this paper has found that there is a substantial potential associated with flexibility in the regulatory framework of intermodal transport. More generous rules on vehicle length, etc., may contribute to better cost efficiency for intermodal transport by addressing the problem of the "last mile" efficiency. As long as there is a potential for improved cost efficiency and environmental performance, regulatory exemptions related exclusively to intermodal haulage activities, as opposed to regular door-to-door road traffic, deserve to be taken seriously and viewed with open minds by policymakers.

The issue of feasibility is left to be addressed. Given the potential of such new regulations, it is important to address possible negative effects thoroughly before any regulations are adopted and become widespread. The main goal of this paper has been to construct a feasible strategic calculation model and give some indications on the potential associated with changed regulations for PPH and not primarily on the possible negative effects of such regulations. However, it is important to stress some factors and aspects that should be addressed in the process of implementation, such as the impact on terminals. Given that intermodal terminals, as well as the customers of intermodal transport, are often located in cities, these negative effects are most palpable in urban areas which constitute the living environment of the vast majority of the population.

Given that any modified regulatory framework as evaluated with this work may adversely affect safety (though one might argue that it is better to meet one vehicle instead of two), there are some possible conditions which may be applied to the exemptions that should be used as a means for addressing safety issues:

- the speed at which the vehicle may travel,
- the route it may travel,
- the time of day it may travel,
- the time of year/month/week it may travel,
- the use of an accompanying car for warning traffic and
- the number of shipments allowed to be carried out per year under the exemption.

In summary, this research has illustrated that there is a substantial potential associated with a modified regulatory framework for PPH. However, investigation of the circumstances and context of such regulations further to better understand the feasibility of such regulations and policies is of utmost importance. It is essential to take the urban context of PPH into account. Finally, it should be stressed that it is only for certain circumstances, such as high volumes, large shipment sizes, high concentration of 40- or 45-foot units and a high share of haulage cost in the total transport chain cost, that "double" haulage outperforms the regular haulage setup. Double haulage should not be regarded as a "quick fix" for addressing haulage costs and intermodal freight transport competitiveness. As this research illustrates, each situation is unique and should be analysed and addressed independently. In this context, the proposed strategic calculation model can act as a useful tool for analysis.

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