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A conceptual framework for cooperation in hinterland development between neighbouring seaport authorities

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Joost Hintjens (°1962) got his master's degree in Business Engineering at the University of Antwerp in 1986 and started a career in the industry while getting his Master in Management at the University of Ghent in 1993. He worked for several mid-sized European industrial companies with a focus on international marketing and logistics. He was general manager of companies in Belgium, Holland and Czech Republic for a French industrial group when he switched to teaching in 2002. First part-time at the Athenaeum in Antwerp but from 2006 full-time as lecturer Logistics at the ArtesisPlantijn University College. He is currently chair of the course group Logistics at ArtesisPlantijn and researcher at the University of Antwerp at the department Transport and Regional Economics where he is focusing on the role of ports in the supply chain. His interest goes mainly to the role of logistics at mid-sized companies and the relations with their clients and suppliers in controlling the supply chain.

Abstract

The hinterland of a port is probably the most important aspect in the competition between gateway ports. This paper, starting with a literature overview, shows how the port authority can extend its hinterland with the aim of increasing its attractiveness and, eventually, its throughput. To achieve this, it can be advantageous to cooperate with adjacent port authorities. Together, through cooperation, economies of scale can be realised that facilitate a modal shift away from road to a more efficient and more sustainable transport. This would reduce the cost of transport to/from the hinterland region from/to these ports consequently increasing the attractiveness and the market share of the cooperating ports for this region. The paper describes a conceptual method to identify and quantify the opportunities for cooperation in the hinterland. The framework starts, after some basic transport economic concepts, from (theoretically available) hinterland data to locate regions that are at the edge of the contested hinterland of a port region and results in a methodology that can be used to generate a quantified list of regions where cooperation will make a difference. Using this methodology, port authorities (PAs), of any region where hinterland data are available, can list, together with their neighbours, the regions where to prioritise their efforts.

Keywords: gateway seaport, hinterland, cooperation, modal shift

1. Introduction

It is generally acknowledged that it is the objective of landlord port authorities to create local and regional welfare (Suykens and Van de Voorde 1998; Van de Voorde and Verhoeven 2014). Port authorities, who facilitate the cargo flows through a port,, work under the assumption that an increase in cargo throughput will result in an increase of economic welfare in and around the port area (Goss 1990). The landlord type of port authority does not handle cargo but rents out port infrastructure to operators. The more successful these operators are, the more successful the port is as a cluster of economic activity. The higher the economic (port) activity, the higher the economic welfare (Blauwens 1988). Consequently, the port authorities, as facilitating organisms, are continuously searching for ways to pull in additional cargo, or at least to facilitate the port operators in finding additional customers, by increasing the attractiveness of the port. It can be assumed that the shipper, through his (or his agent's) choice of carrier, chooses the port. Even when the carrier chooses the port, he will only have that possibility if he is chosen himself first (Aronietis, Van de Voorde, and Vanelslander 2011).

As part of the global supply chain, the attractiveness of a port is eventually defined by the generalised logistics cost of the supply chain of which said port is a part. The generalised economic cost being the sum of the monetary and the non-monetary costs made to get goods shipped from origin to destination. Non-monetary costs can include time, lack of reliability, lack of security, etc (Van Hassel et al. 2014). Thus, the attractiveness of the port is related to the attractiveness of the supply chain of which it is part. This supply chain is more efficient and thus more attractive if the hinterland part of the chain is more efficient. This is making port authorities realise that they have an interest in facilitating the development of the hinterland of their port. When the hinterland increases, the throughput increases and the economic welfare grows, ceteris paribus. The increased interest in the hinterland is driven by the force that has changed the face of maritime shipping since the 50's of the last century: containerisation (Heaver, Meersman, and

Van de Voorde 2001; Kuipers 2014; Levinson 2008). Containerisation changed the role of the port from a destination to a link in a supply chain and had a strong influence on the development of the hinterland of the ports, making the hinterland the remaining battlefield for the port authority to differentiate from the competition (Blauwens, d' Haens, and van Breedam 2004). The resulting shift from captive to contested hinterland lead to the whole of continental Europe becoming a contested hinterland for all major European ports, (Magala and Sammons 2008; Meersman, Van de Voorde, and Vanelslander 2007; OECD 2008; Robinson 2002; De Langen and Chouly 2004; Van der Lugt 2015). In Asia, the rapid, export driven, growth of the Chinese economy and the role of the Chinese ports in the global supply chain had similar consequences on the connectivity with inland production centres (Wang, Chen, and Huang 2017; Guo and Yang 2017). The changing role of the port consequently changed the role of the port authority (Van der Lugt, De Langen, & Hagdorn, 2013; Verhoeven, 2010).

The issue of port choice has been studied by many authors and a long list of publications addresses the topic (Chou 2010, 2005; Lam 2010; Nazemzadeh and Vanelslander 2015; Panayides and Song 2012; Tang, Low, and Lam 2008; Tongzon 2009; Tongzon and Sawant 2007). All these authors look at the problem from the seaside and with a focus on the shipping line and the maritime link of the supply chain. Malchow & Kanafani (2001; 2004) also include the hinterland distance among the variables but only look at kilometres as the crow flies, without taking into account the availability of infrastructure or services nor the value of time. Slack (1985) already pointed to the importance of the service factor, rather than the price, of the hinterland connection in port selection. Ferrari et al. (2011) show how the quality of the hinterland connection of the Ligurian ports is more important than the distance. Nir et al. (2003) focus on the hinterland connection to the port in studying port choice behaviour and develop a multinomial logit model based on stated preferences. Kupfer et al. (2012) use the same methodology to analyse the choice of airports by freighter operators. Magala & Sammons (2008) write that they are the first to look at port choice from a global supply chain viewpoint and take the overall network performance as a factor in reducing the door-to-door transport cost, as such the cost of the total supply chain is the deciding factor and the hinterland connection is part of this cost. The evolution from port-to-port services to door-to-door services makes that ports with a strong hinterland connectivity have a better value proposition (Van den Berg and De Langen 2014).

The hinterland of a port is a dynamic concept. The captive hinterland of ports is shrinking as a result of the increased containerisation; at the same time, the contested hinterland is growing. It will change over time and can decrease as well as increase (Notteboom 2008). Paardenkooper-Suli (2014) has studied the evolution of the Rotterdam hinterland and notices a decline over the years. She shows a decrease the years of the distance travelled by the hinterland flows of the Port of Rotterdam. The coordination between the different actors of the hinterland chain is complex and does not happen spontaneously (Van der Horst and de Langen 2008). De Langen (2007) shows that in a contestable hinterland (Austria) distance is less important than quality and reliability of service, he indicates that ports in pairs might offer economies of scale. In an earlier article, De Langen sees the hinterland as the last remaining field for a port to create a competitive advantage since terminal efficiency is rapidly becoming a commodity (De Langen and Chouly 2004). In their case study of the port of Zeebruges, Sys et al. (2012) clearly show the importance of the hinterland connectivity for the port attractiveness. Song and Panayides (2008) confirm that terminal efficiency is expected which makes supply chain issues the battlefield for competition between ports and terminals. Nevertheless, according to the interview-based analysis of Wiegmans et al. (2008), hinterland connectivity is only marginally important, but the data collection method makes this counter-intuitive conclusion unconvincing. The primary maritime actors to extend hinterland services beyond the port are the shipping lines and the terminal operators (TOs). They have incentives, both from a transactional cost point of view as from a resource-based view, to grab a larger value share of the supply chain (Franc and Van der Horst 2010).

As shown by Zhang (2008), increasing the corridor capacity of the hinterland has a direct and positive impact on the throughput of the port and its market share. However, when expanding the road capacity, the increase of throughput and profit is not guaranteed due to potential offsetting effects of locally induced traffic and the subsequent congestion.

Historically speaking, PAs always have had a clear view of the maritime origin and destination of the cargo going through their ports. The hinterland part of the supply chain is less well known and only recently are PAs trying to quantify the geography of their hinterland and trying to develop a proactive strategy (Newton, Kawabata, and Smith 2011; Van den Berg and De Langen 2011). But, as shown above, the hinterland connectivity (or lack thereof) makes up an important part of the port attractiveness (Ferrari and Musso 2011).

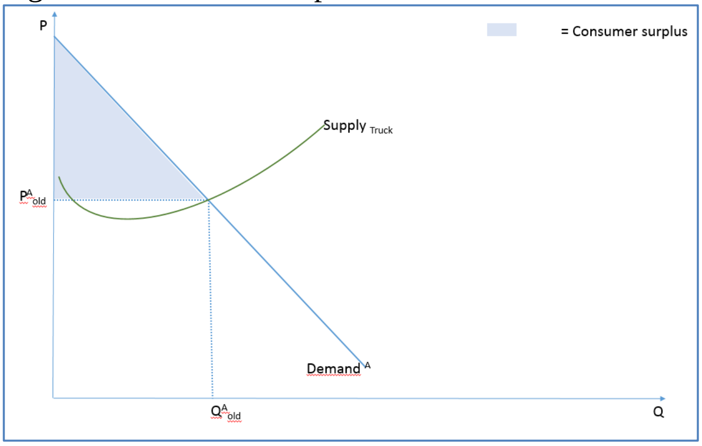
Starting from a given hinterland, based on existing infrastructure and availability of services, a port will get a certain market share in the contested hinterland. A landlord type port authority will not, normally, organise any logistic services nor construct hinterland infrastructure outside the port area, but it can facilitate the supply of services on the existing infrastructure and lobby for the financing of the construction of additional infrastructure with higher regional, national or supranational authorities. The PA of Antwerp, for instance, subsidised in 2014, for a three-year period, a barge service towards South-East Holland, with the assumption that after this period the service will have proven to be economically viable and thus will be continued by the private partner (Port of Antwerp 2014). At the same time, it is lobbying with the national Belgian government, the Dutch government and the European Commission to reactivate the Iron Rhine, a railway track through The Netherlands linking the port to its German hinterland in the Ruhr area.

The paper is organised as follows. In section 2, the effect on welfare, that can be realised by the expansion of the hinterland through cooperation, is conceptually developed and eventually the external effects are added. In section 3, the effect of the hinterland extension on port choice is studied. This is followed by the role of the PA in section 4. Section 5 describes in detail a methodology to quantify these effects and section 6 and 7 close with some remaining questions and conclude

2. Extending the hinterland through cooperation and the effect on economic welfare

When a region is near the outer edge of the contested hinterland of a port, only a limited volume related to this region will go through said port. This small volume will not allow bundling so the services to deliver this throughput will be costly in internal as well as in external costs. External costs are costs born not by the shipper but by society as a whole, they comprise costs like congestion, pollution, accidents and wear of the infrastructure (Gibson, Korzhenevych, and Bröckner 2014). The consumer surplus of the services used to handle this volume can be graphically presented as follows. *P* represents the price of a commodity and *Q* the quantity. The supply curve gives the combinations of quantities that suppliers are willing to provide given a specific price. In a first phase, the price drops due to economies of scale but increases afterwards because congestion increases the production costs. The demand curve gives the quantities that customers are willing to buy given a certain price, the lower the price the higher the demand. P^A_{old} and Q^A_{old} represent the price and quantity were supply and demand are in equilibrium for port A in a situation before cooperation (old). This is shown in Figure 1.

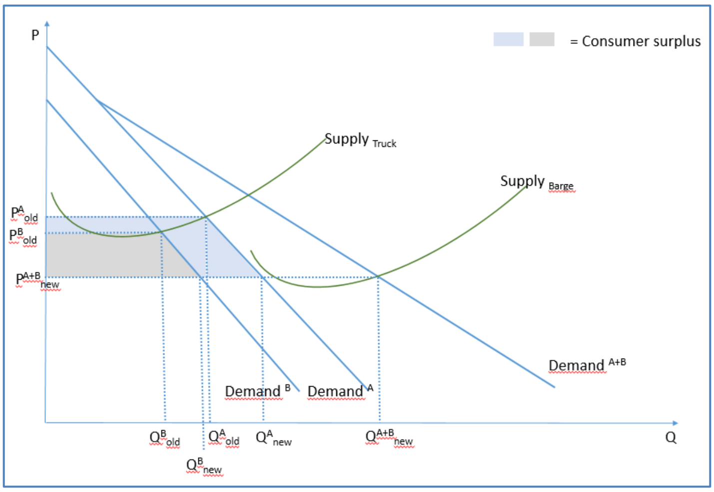
Figure 1 - Consumer surplus



Source: Blauwens (1988)

The high cost of the transport to/from the region leads to a small market share in the region and a small volume. If two neighbouring ports each have a small market share in an inland region that can be serviced by other ports (that are not adjacent) then they can facilitate the bundling of their cargo streams. This bundle would then be sufficiently voluminous to allow for a modal shift to a more cost-efficient transport mode. This cost reduction would then not only result in a lower internal cost for the shipper but also in a lower external cost for the port region and the hinterland in general. Graphically, this is presented in Figure 2.

Figure 2 - Increased consumer surplus



Source: author

The superscript A and B refer to two cooperating ports. The subscript "old" refers to the situation before the cooperation, the subscript "new" stands for the market after cooperation. As suggested by the graph above, the volumes of the two ports together allow using bundling which results in two complementary effects. On the one hand, the combined volumes bring a reduced cost of transport because the bigger volumes now make the use of a more efficient, bundled, transport mode possible, in this example a shift from truck to barge takes place but it could be towards a train instead of a barge. On the other hand, this reduced cost of transport leads in turn to an increase in market share and an increase in volume.

$$P_{new}^{A+B} < P_{old}^{A} \; ; \; P_{old}^{B}$$

$$Q_{new}^{A+B} > Q_{old}^{A} + Q_{old}^{B}$$

The market price P in the new situation where port A and B combine cargo streams is lower than the old prices that were in force before the cooperation. The combined quantity Q of A and B in the new situation is greater than the sum of the old individual quantities. The increased consumer surplus is the sum of the increase in each port. For each port, the surface of the tetragon that represents this increase is as follows:

$$\textit{Increased consumer surplus port A}$$

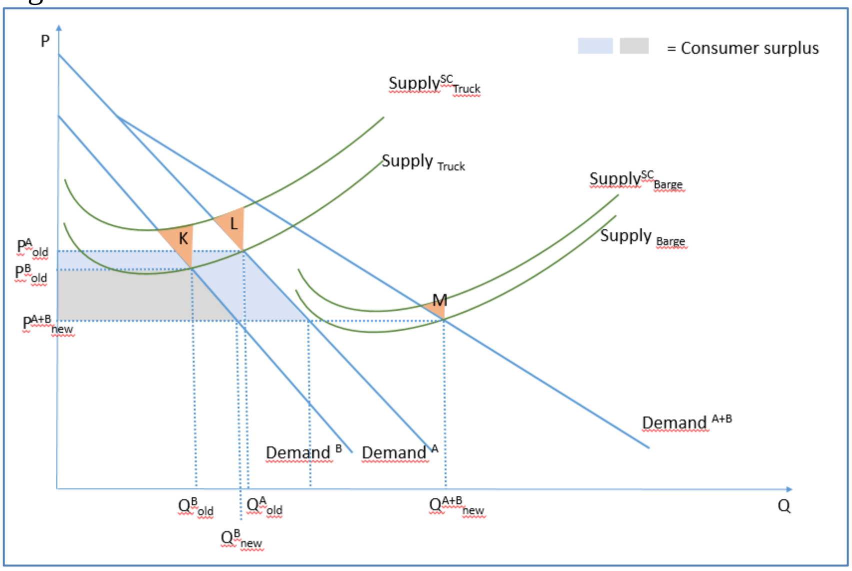
$$= [(P^A_{old} - P^A_{new}) * Q^A_{old}] + \left[(Q^A_{new} - Q^A_{old}) * \frac{(P^A_{old} - P^A_{new})}{2}\right]$$

$$\textit{Increased consumer surplus port B}$$

$$= [(P^B_{old} - P^B_{new}) * Q^A_{old}] + \left[(Q^B_{new} - Q^B_{old}) * \frac{(P^B_{old} - P^B_{new})}{2}\right]$$

If the external costs are added to the graph, it becomes apparent (Figure 3) that the difference between the private marginal cost and the social marginal cost is, most probably, smaller after merging the two volumes and shifting towards a bundled hinterland service than when the ports service the hinterland region separately - even if the bundled volume is bigger than the sum of the unbundled volumes, as is represented by Figure 3.

Figure 3 - External costs



Source: author

Depending on the difference of the external cost between the modes *before* and *after* bundling, it is very likely that, even with a higher volume, the total external costs *after* bundling are lower than *before*. The external costs associated with the bundled mode (barge or train) (M) will be lower than the external costs associated with the unbundled mode (truck) (K and L).

$$K + L > M$$

3. Extending the hinterland and the effect on port choice

The volume going through a port and coming or going from/to a specific hinterland region is defined by two aspects. Firstly, the available cargo of said region and secondly, the attractiveness of the port for this specific region. The attractiveness of a port A (P_A) from a hinterland connectivity point of view can be defined as follows:

$$P_A = \frac{e^{-\alpha(HC_A+OC_A)}}{\sum_i e^{-\alpha(HC_i+OC_i)}}$$

This discrete choice probability calculation starts from the triptych concept of the port (Vigarié 1979) where a port has a foreland, with its associated costs, the port operations, with their respective costs and a hinterland. The foreland cost and the port cost of port A are represented together by OC_A and the hinterland cost is singled out with the term HC_A which stands for the generalised hinterland connection cost from port A to the region and HC_i is the similar cost for every port (i) connected to the region. OC_A stands for all other supply chain costs linking the Port A with the studied region and OC_i is the similar for all gateway ports (i) to the region. This supply chain approach, which takes into account the generalised logistics cost from the point of supply to the point of consumption (Meersman, Van de Voorde, and Vanelslander 2012), allows studying the effect of changes in the hinterland costs, *ceteris paribus.*

The HC_i cost starts when the goods leave the port and continue until final delivery. This can materialise by any combination of transport modes, each with its own cost: road cost c^r, rail cost c^t and barge cost c^b (even pipelines but since they are often privately owned by the shipper and little market information is available they are not taken into account). If use is made of multimodal solutions then, of course, transshipment costs (T_r^t or T_r^b) must be added for the transshipment between road and train and road and barge respectively. So, HC_i is the sum of the cost of all used hinterland transport modes c^k and the transshipment costs T^{k-1} from each mode

$$HC_i = \sum_k c^k + T^{k-1}$$

Or

$$HC_i = c^r + c^t + c^b + T_r^t + T_r^b$$

Through the bundling of flows in port A and port B, a modal shift can materialise towards more efficient modes with lower internal and external costs. The more efficient barge or rail mode replaces the road transport, but at the same time it generates an additional transshipment cost because rail and barge rarely go door-to-door.

$$HC_A^{new} \leq HC_A^{old}$$

$$HC_B^{new} \leq HC_B^{old}$$

$$c^{r^{new}} + c^{t^{new}} + c^{b^{new}} + T_r^t + T_r^b \leq c^{r^{old}}$$

The use of the ≤ and ≥ serves two purposes. Firstly, the benefit needs to materialise in one port only as long as the second port has no negative effects because, secondly, even when there is only equality, there will be additional external benefits. The result is a win, win, win because not only will each port (and subsequently its respective users) benefit but also society at large.

The lower hinterland cost after the bundling can subsequently be used as input in the discrete choice model.

$$P_A^{new} = \frac{e^{-\alpha\left(HC_A^{new}+OC_A\right)}}{\sum_i e^{-\alpha(HC_i+OC_i)}} \geq P_A^{old} = \frac{e^{-\alpha(HC_A^{old}+OC_A)}}{\sum_i e^{-\alpha(HC_i+OC_i)}}$$

The higher probability leads to a higher volume, which leads to a higher added value in the port region, QED. Moreover, there is the additional benefit that, in all likelihood, the higher volume will have lower external costs by reducing the truck-kilometres travelled as shown for the Los Angeles – Long Beach port cluster by Rahimi et al. (2008).

4. Bundling and the role of the port authority

The act of bundling the streams will generate some additional costs; these are represented by the transshipment costs that occur when cargo is switched between modes of transport and by the costs of bringing the cargo to a bundling point beyond a straight line connecting the port to the hinterland. They consist potentially of administrative costs for the organising entity; costs to bring the cargo to a common bundling location; and, of course, the handling costs that go with the offloading and loading of the cargo at the transfer point. All these costs reduce the benefit of the economies of scale of the more efficient transport mode and as such they reduce the attractiveness of the bundling solution. This reduces the potential for the extension of the hinterland and the attractiveness of the cooperating ports for cargo destined to this remote region. This is where the role of the PA comes in, it can cover a part of these costs. Even if, as described in section 3, the PA has no direct operational role in the hinterland connectivity, it can play a facilitating role. . The rationale being that, besides the internal cost saving, there is also a reduction of external costs. This external benefit should motivate the public landlord port authority to carry a part of the bundling cost as a way of partially internalising the external benefit for the users of the port. Also, the increased throughput resulting from the expanded hinterland will increase revenues from port dues.

PAs become dependent on multimodal operators to ensure their hinterland (Notteboom 2008) but by facilitating the bundling of streams of two (or more) adjacent ports they can create additional business for these operators, consequently reinforcing the attractiveness not only for maritime but also for land-based logistics operators. By facilitating more extensive hinterland services, the PA reinforces the competitiveness of the port. Some PAs even see their role evolving to that of supply chain coordinator (De Langen 2008; Van der Horst and Van der Lugt 2011).

Most ports combine a transshipment function with a gateway function towards their hinterland. Transshipment takes place when incoming sea cargo is transhipped to another seagoing vessel to continue its voyage; a gateway port takes sea cargo and puts it on a land-based transport mode to continue towards an inland destination (or vice versa). Pure transshipment ports have, by definition, no hinterland since none of their cargo leaves overland. Adjacent ports, serving an overlapping hinterland have, de facto, a multi-port gateway function. Their locational relationship means that the flows serving each port will share, for a large degree, a common transport network. Each port will have a market of providers of forwarding and transportation services and some of these suppliers are even active in more than one port. Each port will have a market share but due to the dilution of the volume, destined for the smaller regions located further away, transport will be handled by road. The private operators, based in each port and servicing different shippers, will have no incentive and even less resources and information that will bring them to cooperate and merge streams going through different ports and handled by different operators. Inside one port, using a port community system (PCS), consolidators, like forwarders, might see an opportunity and bundle some flows. But when the bundle is still too small to make a switch to a more sustainable and more cost-efficient transport mode, the effect on the port attractiveness will be limited. However, when the flows of the two ports are sufficient to make the switch possible, the resulting drop in price will make the ports more attractive. The resulting increase in volume will at the same time result in a relative drop in external costs. Since the market cannot always assure the bundling where it would bring an advantage, other organisations need to stimulate it. Two adjacent PAs are a logical partner to facilitate, if not organise, this co-operation between transport service providers. When it becomes logical for a PA to facilitate bundling in its own port, consequently it becomes logical for adjacent PAs to facilitate the bundling of flows by combining smaller flows in each separate port. This can even result in seaport authorities becoming interested in combining their forces to acquire large inland ports (‘Uni-Muenster – Nachrichten Januar 2011 - Wirtschaft: Häfen Antwerpen Und Rotterdam Wollen Sich in Duisburg Einkaufen’ 2011).

5. Quantifying the potential for cooperation between seaports in the hinterland

How would one go about locating the opportunities for PAs to facilitate the bundling of transport flows as well as to quantify the consumer surplus resulting from the bundling? These opportunities will be present at the edge of the contestable hinterland which will be served by the two (or more) adjacent ports and one or more distant ports located somewhere on the continent. Focussing on containers, the total number of TEU coming and going to the region will be divided over all relevant ports.

To quantify this, the incoming and outgoing container streams of each region in the contested hinterland must be mapped together with the market shares of all relevant ports and their respective modal split. PAs. Based on this map and the underlying data, which will be needed to be collected specific for the region where the methodology will be applied, it becomes possible to identify those regions that are serviced by several ports, none of which is dominant enough to offer services to bundle the stream, resulting in small to mid-sized flows of road transport. Next, from this sub-set, one needs to select the regions where two adjacent ports together would have a combined volume sufficient to shift to a bundled mode. For this region, the cost of one TEU transported by truck should then be compared with the cost of a TEU transported by the bundled mode. The cost difference can then be multiplied by the number of containers shipped through both ports plus, based on the price sensitivity, the number of containers that will change their port of choice due to the more competitive proposition made by the service providers of the cooperating ports. Finally, multiplying the number of containers with the drop in external cost per container will quantify the effect on society at large.

The following paragraphs will detail the conceptual methodology needed to analyse the hinterland data. It starts by listing which data are needed to build an ideal model on which the analysis can be made. The subsequent paragraphs show how these data are then winnowed down to an analytic model. The unit of analysis is the TEU, but in many cases data will be available in tonnes and in cases where TEUs are not available, the tonnes of 'containerable' cargo will need to be translated into TEU. Not all cargo that is transported by road before the bundling needs to be in containers to have a potential for a modal shift. Some cargo is 'containerable' in the sense that its current form allows it to be efficiently shipped in containers. As an example: Eurostat road data is collected with ten types of cargo (2016) (see Table 1).

(a) CARGO

Cargo Type code

0	No cargo unit (liquid bulk goods)
1	No cargo unit (solid bulk goods)
2	Large freight containers
3	Other freight containers
4	Palletized
5	Pre-slung
6	Mobile self-propelled units
7	Other mobile units
8	(Reserved)
9	Other cargo types

Table 1- Types of cargo (European Commission and Eurostat 2011)

Categories two, three, four and five could all be in containers if a competitive container service would be available; up until now they have been loaded in trucks (often tractor and trailer type) and but they could just as well be loaded in containers. By using the average loaded weight of a container, the tonnes can be translated in TEU's and vice versa. Other regions will have differently styled dataset, if any. Since this paper is conceptual in nature, the EU data are not further used.

When working with the annual data that are available, one needs to be circumspect when using them for detailed operational analysis. It is presumed that there is little fluctuation in the weekly volumes. Analysis by Rashed (2016) shows that the difference between the busiest month and the least busy month in the container throughput of the port of Antwerp is less than 10%. So, one can assume that the annual data can be used as a approximation for weekly data by simply dividing them by 52.

6.1 Data collection and assembly

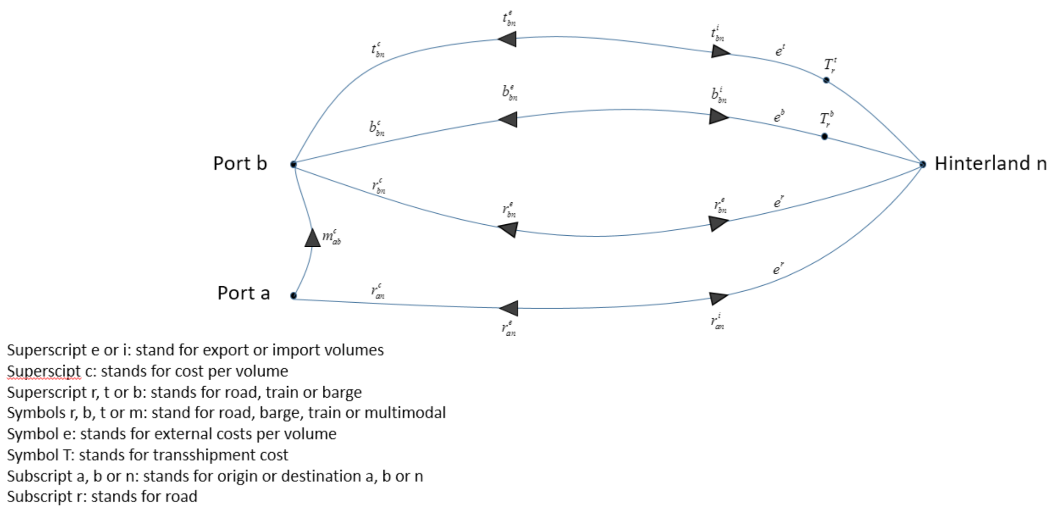
To get an exhaustive model which is sure to contain all possible cooperation opportunities, following data need to be assembled.

1. OD tables, for each mode and separately for export and import

$$\begin{pmatrix} r^e{}_{11} & \cdots & r^e{}_{1n} \\ \vdots & \ddots & \vdots \\ r^e{}_{m1} & \cdots & r^e{}_{mn} \end{pmatrix};\begin{pmatrix} r^i{}_{11} & \cdots & r^i{}_{1n} \\ \vdots & \ddots & \vdots \\ r^i{}_{m1} & \cdots & r^i{}_{mn} \end{pmatrix};\begin{pmatrix} t^e{}_{11} & \cdots & t^e{}_{1n} \\ \vdots & \ddots & \vdots \\ t^e{}_{m1} & \cdots & t^e{}_{mn} \end{pmatrix};\begin{pmatrix} t^i{}_{11} & \cdots & t^i{}_{1n} \\ \vdots & \ddots & \vdots \\ t^i{}_{m1} & \cdots & t^i{}_{mn} \end{pmatrix};\begin{pmatrix} b^e{}_{11} & \cdots & b^e{}_{1n} \\ \vdots & \ddots & \vdots \\ b^e{}_{m1} & \cdots & b^e{}_{mn} \end{pmatrix};\begin{pmatrix} b^i{}_{11} & \cdots & b^i{}_{1n} \\ \vdots & \ddots & \vdots \\ b^i{}_{m1} & \cdots & b^i{}_{mn} \end{pmatrix}$$

Following conventions apply: subscripts m = all seaports in the region; n = all hinterland regions. r, t and b stand for the volume transported annually by road, train and barge by inland waterway (IWW), while superscripts e and i stand for export and import. The ports will be defined by the region of which they are part. It can be presumed that any cargo in the port region can be brought to the port for hinterland transportation even if, strictly speaking, the cargo did not originate from or terminate in the port. The data with the volumes by rail and barge are of secondary importance and would only be used as a controlling parameter. As long as the volume by road is higher than the break-even point (see below), bundling presents an opportunity, whether grouped services are already available or not. Figure 4 summarises these conventions.

Figure 4 - Formulation convention



2. Break-even points between transport modes for every port m-region n OD pair

To be able to offer a competitive service in a bundled hinterland multimodal transport mode, a sufficient volume needs to be attained. To make sure the market follows the shift from road to rail, a twice weekly service would be a minimum.

This break-even volume between road and train will be indicated by the symbol B_r^t.

The break-even volume between road and barge will be indicated by the symbol B_r^b.

The bundling between two (or more) adjacent ports offers the additional advantage of the possibility to balance import and export streams. If one seaport is an import port (which would result in empty containers coming back to the port) and the neighbouring port has an export stream (which results in empty containers going to the hinterland for stuffing) than in combination the ports would have substantially less containers travel-ling empty.

In literature, more attention is given to the break-even distance for a modal shift than to the break-even volume. As Meers's (2016) literature review shows, different authors es-timate the break-even point between the extremes of 57 km to 1400 km. This very large interval shows that local conditions have a large impact on the feasibility of the modal shift. Even for a short distance, when sufficient volume is available, a modal shift can be advantageous, especially in regions which are plagued with congestion and when taking external cost savings into account. From this it can be concluded that no distance, however small, should be excluded from the analysis. This is supported by analysis of the white paper of the EU European Commissions' (2011) white paper: 'Roadmap to a Single European Transport Area' where only 11% of the road transport goes beyond 300 km (Tavasszy and Van Meijeren 2011). The cost-benefit comparison for every case will indicate whether bundling makes sense.

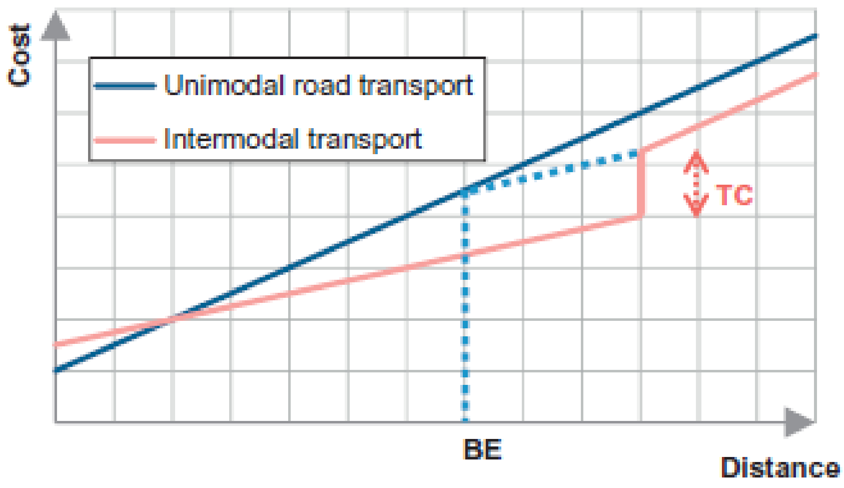
3. *Mono- and multimodal transport cost between each port and every continental region*

$$\begin{pmatrix} r_{11}^{c} & \cdots & r_{1n}^{c} \\ \vdots & \ddots & \vdots \\ r_{1m}^{c} & \cdots & r_{mn}^{c} \end{pmatrix};\begin{pmatrix} t_{11}^{c} & \cdots & t_{1n}^{c} \\ \vdots & \ddots & \vdots \\ t_{1m}^{c} & \cdots & t_{mn}^{c} \end{pmatrix};\begin{pmatrix} b_{11}^{c} & \cdots & b_{1n}^{c} \\ \vdots & \ddots & \vdots \\ b_{1m}^{c} & \cdots & b_{mn}^{c} \end{pmatrix}$$

The superscript *c* stands for the generalised cost of transporting one TEU from port *m* to the hinterland region *n* by road r_{ij}^{c}, or multimodal using truck and train t_{ij}^{c}or barge b_{ij}^{c}. Not only the monetary transport-related costs have to be taken into account. It is necessary to look at the general logistics costs, adding the value of time. However, the difference would probably be small for two reasons. Firstly, the time lost through bundling and transshipment in a multi-modal supply chain would be negligible when compared to the time spent on the total supply chain; even if a day or two would be lost between a direct hinterland transport and a bundled one. Secondly, with the use of concepts like synchro-modality (Platform Synchromodaliteit 2014), this lost time can be minimised. The value of time, also, might not be very high compared to all other logistics costs. As discovered by Acciaro et al. (2015), the ports in the North-Adriatic give access, for cargo coming from the Far-East, to the Southern-German and Austrian markets, saving days or even weeks when compared to the Northern-European ports. But still their market share remains small for many other reasons that outweigh the gain in time.

When there is no infrastructure available to offer a particular mode, the cost of that mode should be set extremely high. If sufficient volume is available, bundling into a mode with even bigger bundles becomes a possibility. This volume-enabled bundling will lead to a lower transport cost if the savings in cost per distance compensate for the extra cost of bundling, as is shown in Figure 5.

Figure 5 Break-even distance for intermodal transport



Source: (Meers, Vermeiren, and Macharis 2014)

Generally, the cost per TEU.km decreases when the bundling increases, or:

$$r_{ij}^{c} > t_{ij}^{c} > b_{ij}^{c}$$

The marginal cost of one TEU for one kilometre by road is higher than that of rail which is in itself higher than that of barge but the fixed transfer cost goes in the other direction, so a minimal distance is needed to compensate for the higher set-up cost.

4. *Transport costs between the seaports based on the optimal multimodal transport mode*

$$\begin{pmatrix} c_{11}^{m} & \cdots & c_{1m}^{m} \\ \vdots & \ddots & \vdots \\ c_{m1}^{m} & \cdots & c_{mm}^{m} \end{pmatrix}$$

m_{ab}^{c} is the generalised (multimodal) cost per TEU, to transfer the cargo from seaport *a* to *b* (out of *m* seaports) for bundling in *b*. This matrix is, of course, symmetrical. This is necessary to calculate the extra cost created by bringing the cargo together for bundling. The streams between two (or more) adjacent ports could even bundle more than one cargo stream leaving the port region. But this additional benefit will not be considered in this model although it is assumed that the volume from *a* to *b* will always be large enough to allow for bundling.

5. Establish the cost to transfer a container from one mode to another.

If the transfer cost between transport modes in the multimodal solution is not included in the abovementioned costs t_{ij}^{c} and b_{ij}^{c}, then it will have to be separately added with T_r^t and T_r^b representing respectively the transfer cost between road and train and between road and barge.

6. The distances in km between the ports m and the hinterland regions n and between the ports m themselves

$$\begin{pmatrix} d_{11} & \cdots & d_{n1} \\ \vdots & \ddots & \vdots \\ d_{1m} & \cdots & d_{nm} \end{pmatrix}; \begin{pmatrix} d_{11} & \cdots & d_{m1} \\ \vdots & \ddots & \vdots \\ d_{1m} & \cdots & d_{mm} \end{pmatrix}$$

This will be needed to calculate the external costs which are dominantly proportional to the distance. These matrices are, of course, symmetrical.

7. The external cost for every transport mode

The external costs per TEU.km for the three transport modes, road, rail and barge are symbolised respectively as:

$$e^r;\ e^t \text{ and } e^b$$

6.2 Analysis

1. Eliminate ports that serve no hinterland

Island ports and ports that are almost exclusive transhipment ports serve no hinterland so bundling of hinterland streams is not a feasible option. In the road OD matrices, the cells that refer to the other regions than the port will have very small values or be zero. In the rail and barge matrices the rows refer to these ports will be empty.

2. Eliminate the regions that are too small to present a bundling opportunity

If $\forall n: \sum_i r_{in}^i < \left(B_r^t; B_r^b\right)$

and

if $\forall n: \sum_i r_{in}^e < \left(B_r^t; B_r^b\right)$

then the sum of all road traffic is too small even summed up over all ports *i* (subscript *i*) in import (superscript *i*) and export for bundling to make a modal shift to any port economically feasible. It is presumed that in those cases the relevant cells in the OD matrices for train and barge (if available) will be zero.

3. Eliminate the regions where bundling is already a part of the hinterland connections

If $\forall m,n\left(t_{mn}^e \wedge t_{mn}^i\right) \vee \left(b_{mn}^e \wedge b_{mn}^i\right) > 0$

then the volume of rail import t_{mn}^i and export t_{mn}^estreams or the volume of barge import b_{mn}^i and export b_{mn}^e streams is already large and this means that hinterland bundling is already offered to one or more ports *m* for region *n* and bundling through cooperation constitutes no additional competitive advantage. Either barge or rail is, after all, already offered. From the point of view of a port authority it might still be advantageous to, together with neighbours, facilitate a bundled service to a specific hinterland region when none is available, from their ports, even if it is already offered by a competing port cluster. However, from a societal point of view, the benefit might be minimal. Because it will only lead to a shift of streams from one port cluster to another be it at a lower cost.

4. Define which regions offer opportunities for cooperation and which ports are likely partners

If $\forall(a,b): r_{an}^{e} + r_{bn}^{e} \wedge r_{an}^{i} + r_{bn}^{i} \geq B_{r}^{t} \wedge B_{r}^{b}$

then the bundling on the one hand of the import of two ports (*a* and *b*) and on the other hand of the export of these ports to/from region *n* will lead to a volume bigger than the break-even volume needed for a modal shift on the flows from *a* and *b* to *n*. The resulting stream will be able to benefit from the economies of scale that a modal shift brings. If the sum is larger than the break-even volume for rail B_r^t , a rail service should be facilitated. If the sum is larger than B_r^b and if the infrastructure allows for a barge service, then this will be an even more beneficial proposition. The same can be eventually be realised by combining the flows of three, even four, neighbouring ports.

The import and export stream both must be large enough to be bundled, otherwise there would exist a problem of filling the return vehicles. Bundling can result in two ports combining an import stream from one port with an export stream of a neighbour, thus substantially reducing the proportion of empty containers being transported. If the bundle is medium sized, a transfer to rail is possible; if the bundle is large and if barge services are available then the shift can be made to inland waterways.

5. *Establish whether the additional consumer surplus realised by the bundling and the consequently lower cost, outweighs the cost of the additional transport and handling to the bundling point.*

This is true when either or both of the following statements are true.

$$r_{an}^{e}.r_{an}^{c}+r_{bn}^{e}.r_{bn}^{c}>\left(r_{an}^{e}+r_{bn}^{e}\right).t_{bn}^{c}+r_{an}^{e}.m_{ab}^{c}+T_{r}^{t}$$

and

$$r_{an}^{i}.r_{an}^{c}+r_{bn}^{i}.r_{bn}^{c}>\left(r_{an}^{i}+r_{bn}^{i}\right).t_{bn}^{c}+r_{an}^{i}.m_{ab}^{c}+T_{r}^{t}$$

And/or

$$r_{an}^{e}.r_{an}^{c}+r_{bn}^{e}.r_{bn}^{c}>\left(r_{an}^{e}+r_{bn}^{e}\right).b_{bn}^{c}+r_{an}^{e}.m_{ab}^{c}+T_{r}^{t}$$

and

$$r_{an}^{i}.r_{an}^{c}+r_{bn}^{i}.r_{bn}^{c}>\left(r_{an}^{i}+ri\right).b_{bn}^{c}+r_{an}^{i}.m_{ab}^{c}+T_{r}^{t}$$

If so, then the multimodal cost $m_{ab}^{c}$of bringing cargo from port *a* to port *b* added to the train cost $t_{bn}^{c}$to bring the export cargo $r_{an}^{e} and\ r_{bn}^{e}$ from port *b* to the hinterland and the cost of transferring cargo from road to rail T_{r}^{t} will be inferior to the cost of transporting these volumes by road. If the second set of equations is true, then it is cheaper to use IWW than railways. The rail or barge transport costs $t_{bn}^{c}\ or\ b_{bn}^{c}$ being lower than the road cost r_{bn}^{c}, the difference between them should outweigh the additional bundling cost m_{ab}^{c}, needed to bring the goods from port *a* to *b* and the additional transfer cost in the multimodal terminal T_{r}^{t} or T_{r}^{b}.

6. *Calculate the consumer surplus realised by the modal shift*

Once it has been established that the generalised cost, including all additional costs for bundling, is lower than the road transport cost, the effect on demand can be calculated by applying the price elasticity of demand. The new export flow from hinterland *n* to port *b* (but now bundled and multimodal) $r_{bn}^{e^{new}}$ can be calculated by taking the volume

$r_{bn}^{e^{old}}$ and adding the decrease in generalised cost $(c_{bn}^t + T_r^t - c_{bn}^r)$ multiplied with the prices elasticity of demand. As is shown below, in case of a shift from road to rail:

$$r_{bn}^{e^{new}} = r_{bn}^{e^{old}} + (c_{bn}^t + T_r^t - c_{bn}^r).\frac{dQ}{dP}$$

For the export flow from hinterland *n* to port *a*, the extra cost of bringing the cargo from *a* to *b*, m_{an}^c, needs to be added to the formula as follows:

$$r_{an}^{e^{new}} = r_{an}^{e^{old}} + (c_{bn}^t + T_r^t + m_{ab}^c - c_{an}^r).\frac{dQ}{dP}$$

For the import volumes, the same formulas are valid after replacing the superscript *e* by *i* as is shown below for port *a*.

$$r_{an}^{i^{new}} = r_{an}^{i^{old}} + (c_{bn}^t + T_r^t + m_{ab}^c - c_{an}^r).\frac{dQ}{dP}$$

If the bundled volumes are sufficient to realise a shift to barge then the formulas stay identical when the superscript *t* is replaced with *b* but the effect will be, of course, bigger. The formulas below, again, are for flows coming from port *a* and being bundled with port *b* in port *b*.

$$r_{an}^{e^{new}} = r_{an}^{e^{old}} + \left(c_{bn}^b + T_r^b + m_{ab}^c - c_{an}^r\right).\frac{dQ}{dP}$$

$$r_{an}^{i^{new}} = r_{an}^{i^{old}} + \left(c_{bn}^b + T_r^b + m_{ab}^c - c_{an}^r\right).\frac{dQ}{dP}$$

When the combined volumes and corresponding generalised costs are combined with the individual road ones, the consumer surplus can be calculated as follows (based on Figure 2):

$$Increased\ consumer\ surplus\ port\ A$$

$$= [(P_{old}^A - P_{new}^A) * Q_{old}^A] + \left[(Q_{new}^A - Q_{old}^A) * \frac{(P_{old}^A - P_{new}^A)}{2}\right]$$

$Increased\ consumer\ surplus\ port\ B$

$$= [(P_{old}^{B} - P_{new}^{B}) * Q_{old}^{A}] + \left[(Q_{new}^{B} - Q_{old}^{B}) * \frac{(P_{old}^{B} - P_{new}^{B})}{2}\right]$$

7. Calculate the external benefit by the modal shift

The difference, and, most likely, reduction, in external costs for the export flows can be calculated as follows for a shift from road to rail through bundling:

$$((r_{an}^{e^{old}} + r_{an}^{i^{old}}).d_{an} + (r_{bn}^{e^{old}} + r_{bn}^{i^{old}}).d_{bn}).e^{r} - (r_{an}^{e^{new}} + r_{bn}^{e^{new}} + r_{an}^{i^{new}} + r_{bn}^{i^{new}}).d_{bn}.e^{t} + (r_{an}^{e^{new}} + r_{an}^{i^{new}}).d_{ab}.e^{t}$$

The road volumes are multiplied with the distances and the external cost per TEU.km for road. From this, the combined volumes multiplied with the distances and the (lower) external cost per TEU.km for barge or train is deducted. This formula presumes that the bundling from *a* to *b* is done by rail. In case of bundling by barge, obviously, another parameter for the external cost of the transport mode from *a* to *b* must be used. If the bundling is done through barge rather than train, then a similar formula applies but with the superscript *t* replaced by *b.*

$$((r_{an}^{e^{old}} + r_{an}^{i^{old}}).d_{an} + (r_{bn}^{e^{old}} + r_{bn}^{i^{old}}).d_{bn}).e^{r} - (r_{an}^{e^{new}} + r_{bn}^{e^{new}} + r_{an}^{i^{new}} + r_{bn}^{i^{new}}).d_{bn}.e^{b} + (r_{an}^{e^{new}} + r_{an}^{i^{new}}).d_{ab}.e^{b}$$

6. Remaining Questions

Should short sea shipping (SSS) be considered as a hinterland mode. Can this be part of this analysis? Two (or more) ports could use SSS as a transport mode of bundled cargo streams. This could make an additional transport mode for improved hinterland connections.

It remains to be seen where this bundling would take place. The formulas above start from a worst-case approach where the cargo from port *a* is carried all the way to port *b* for bundling. If *b* is located on a straight line between port *a* and hinterland *n* than this is of course the optimal bundling location. If, however, the line *ab* is perpendicular to the line *bn*, then there will be locations situated in the triangle *abn* that would be more efficient, thus even improving the already positive effects of the bundling. Sensitivity analysis and scenario analysis could further advance the understanding of the advantages of bundling.

Remains the question of the role of the private service providers, why are they not filling the need? Many of these providers are organised with a focus on each port separately, and therefore they might not be able to combine easily the demand from different ports. Also, their motivation is in increasing business, but they do not have an interest in the social effects of this increase. Lastly, the logistics sector is a combination of a small number of very large players and a multitude of very small players (Blauwens, Van de Voorde, and De Baere 2012). Especially the latter do not have the managerial resources to create bundling processes. The market, using money as coordinator, can, in some cases, not handle the complexity of extended hinterland supply chains and cannot value the external benefits (Van der Horst and Van der Lugt 2011).
Which regions can provide the necessary hinterland data to execute the analysis? The author is working on a EU wide dataset.

7. Conclusion

This paper, starting from a literature review, shows how the hinterland connectivity of a port is an important factor influencing port choice and how PAs can use the extension of the hinterland to increase their throughput and market share consequently increasing the value added the port brings for its stakeholders. For the further away and less serviced regions, it can be necessary to combine forces with adjacent PAs to achieve economies of scale that allow a shift to a bundled transport mode. The bundling leads to a modal shift which, on the supply side, lowers the price of the hinterland connections. This lower price results in a higher consumer surplus, while at the same time increasing the port's attractiveness. This consequently leads to a higher demand, again increasing the consumer surplus. This is shown through a graphic representation of the supply and demand functions and their evolution. The result is not only an increasing consumer surplus for the users, but also an opportunity to reduce the external costs per unit, consequently creating a win, win, win for the port, the shippers and society. If the increased competitiveness leads to the aimed for increase in market share, then the competing ports outside the cooperation would lose throughput and value added. Eventually, the modal shift would also lead to a reduction of demand for road transport. This conceptual paper shows the possibility for gains through cooperation. For many regions, it should be possible to find the data that allow calculating the direct and external effects of such cooperation and to apply the conceptual framework of this paper. The stakeholders of the ports, going from operators over logistic service providers to the general population and the regional governments would all benefit from an increased throughput and a modal shift to more sustainable transport modes.

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