Faculty of Economics and Business

Cooperation between seaports concerning hinterland transport

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SYNOPSIS

Seaports are, on the one hand, crucial links in the global supply network. As such, they are important sources of added value, employment and welfare. But on the other hand, they need big investments, often made with public money, and they are places where external costs are generated that are not appreciated by the communities of which they are part. Society demands from ports that in return for this 'licence-to-operate' the ports operate as efficiently as possible. More and more voices demand that through cooperation, this efficiency is improved, and the external costs diminished. Others believe that independence and competition is the best guarantee to make ports as efficient as possible. This thesis studies the possibilities cooperation between competing seaports can offer with a focus on port authorities and how they can cooperate in extending the hinterland.

The viewpoint is that of society, to allow the benefits of all stakeholders to be considered. First, after the introduction, a comprehensive literature review is made starting from cooperation as a general concept and drilling down to cooperation between competing seaport authorities. Next, a conceptual model, based on societal cost benefit analysis, is developed where the welfare effects of different cooperation strategies are analysed. More in detail, the conceptual model focusses on the social costs and benefits of combining hinterland road cargo flows of cooperating ports into a bundled transport mode, thus lowering direct and external costs and increasing the market share of the cooperating ports. This is further developed, in the fourth chapter, into a empiricalized cost model that combines the EU hinterland at NUTS2 level with the road cargo flows of the 104 core TEN-T ports, concluding with a tool that enables the calculation of the direct cost benefits, the effect on the value of time and the potential external cost savings of any cooperation between the 104 core ports.

The fifth chapter applies the model to three potential cooperation cases. The first one consists of a bundling of the road cargo flows of the ports of the recently created North Sea Port towards the NUTS2 region of Düsseldorf. The second case concerns the bundling of the flows of the ports of Rotterdam and Antwerp towards the region surrounding Cracow. The last case calculates the effect of the modal shift facilitated by the cooperation of the four Polish ports towards their main hinterland region. The chapter closes with the strategies that are possible through cooperation for the different port actors. The final chapter concludes with a summary, conclusions and further research.

NEDERLANDSTALIG SYNOPSIS

Zeehavens zijn enerzijds cruciale schakels in het globale, logistieke netwerk, daarmee zorgen ze voor toegevoegde waarde, werkgelegenheid en welvaart. Anderzijds, behoeven ze grote investeringen, vaak met publiek geld, en worden er externe kosten gecreëerd die de gemeenschap, waar ze deel van uitmaken, maar matig apprecieert. De samenleving vraagt van de havens dat ze, in ruil voor hun steun, zo efficiënt mogelijk werken. Meer en meer stemmen gaan op om havens, door samen te werken, hun efficiëntie te laten verhogen en hun externe kosten te verminderen. Anderen zijn dan weer van mening dat onafhankelijkheid en concurrentie de beste garanties zijn voor efficiëntie. Deze thesis bestudeert de mogelijkheden die samenwerking tussen concurrerende zeehavens kan bieden en hoe ze, door samen te werken, hun hinterland kunnen uitbreiden.

De beschouwing gebeurt vanuit een maatschappelijk standpunt zodat de voordelen van alle stakeholders in overweging kunnen genomen worden. Na de inleiding volgt een diepgaand overzicht van de academische literatuur, beginnende met de algemene concepten rond samenwerking en eindigend met samenwerking tussen concurrerende havenautoriteiten. Vervolgens wordt een conceptueel model voorgesteld, gebaseerd op een maatschappelijk kosten-batenanalyse, waarmee de welvaartseffecten van de verschillende samenwerkingsstrategieën geanalyseerd worden. Dit model wordt verder uitgediept met aandacht voor de sociale kosten en baten die kunnen resulteren uit het combineren van wegvervoerstromen van samenwerkende havens in een multimodale oplossing die de directe en externe kosten verlagen. Tegelijk kan dit leiden tot een groter marktaandeel van de betrokken havens. Dit wordt verder uitgewerkt in het vierde hoofdstuk tot een empirisch kostenmodel dat de wegvervoerstromen tussen de 104 kernhavens van het TEN-T netwerk en de hinterlandgebieden, op NUTS2 niveau, beschrijft. Het model laat toe om eventuele besparingen op de directe en externe kosten als gevolg van het bundelen tussen stromen van concurrerende havens naar een multimodale dienst voor een specifieke hinterlandregio te monetariseren. Ook de effecten op de tijdswaarden worden mee in rekening gebracht.

In het vijfde hoofdstuk wordt dit model toegepast op drie potentiële gevalsstudies. De eerste beschrijft de opportuniteiten die bundeling biedt van de wegvervoerstromen van havens van de jonge North Sea Port naar het NUTS2 gebied rond Düsseldorf. De tweede gevalsstudie beschrijft de bundeling van de stromen van Antwerpen en Rotterdam naar de regio rond Krakow. De laatste studie behandelt de stromen van de vier Poolse havens naar hun belangrijkste hinterland regio. Het hoofdstuk sluit af met strategieën die de verschillende havenactoren kunnen gebruiken om samen te werken. Het laatste hoofdstuk sluit af met een samenvatting, conclusies en verder onderzoek.

Chapter 1 **INTRODUCTION**

Reading the headlines of today's newspaper, or any day for that matter, it is difficult to believe that cooperation is an important part of human nature. Even if Hobbes (1651) believed that "Bellum omnium contra omnes" is the human state of nature, humans have survived by cooperating; together, Paleolithic men were able to slay mammoths. It was the cooperation between the cities and the rowers of the Greek ships that brought the defeat of the Persian navy at Salamis in 480 BC (Smith, Carroll, & Ashford, 1995). Darwin was already amazed by the degree of cooperation within a species (Darwin & Beer, 1996). Popper (1966) sees enhanced cooperation as an indicator of an advanced civilization. Fukuyama (2011) shows that the development of civilization goes hand in hand with cooperation. Nevertheless, in management literature, itself a field that came into existence only after WWII, cooperation as a topic only appears in the 80's of the last century. But since then a whole body of knowledge has been developed devoted to cooperation.

Maritime trade has been an important factor in the development of early civilizations: the oldest sea going vessel known today goes back to 1300 BC, and its role has not diminished since then (Stopford, 2009). At the end of the second decade of the 21st century, over 90% of the global trade is carried over sea ('ICS | Shipping Facts', 2019). The ships carrying this cargo have grown into behemoths capable of carrying 500 000 tonnes of ores, 300 000 tonnes of crude and over 200 000 tonnes of containers (Branch & Robarts, 2014). The maritime industry and services able to handle this massive cargo flow have evolved into a truly global service industry (J. Hoffmann, 2015). By then, ports had evolved from destinations and marketplaces into nodes in global supply chains that connected the furthest regions of the globe. These ports became powerhouses for regional welfare with new logistics service industries allowing extant industries to get, at a lower cost, access to supplier and customer markets, acting as such as a nearby, inexhaustible, mine of all raw materials and giving access to almost unlimited markets with customers all over the globe.

This thesis will study the opportunities that cooperation offers for ports, port actors, and port authorities in particular. By cooperating, ports can increase their value added, reduce their internal and external costs and increase the regional welfare. The aim of this work is to apply the general concepts of cooperation on the role that ports play in the global supply network, and more specifically on their hinterland connectivity. After all, competition and cooperation are two sides of the same coin. To be able to compete, companies need to collaborate with suppliers and customers, and in some cases even competitors; furthermore, a company who may be a supplier one day can be a competitor the next.

1.1 Setting the scene and research context

Ports are important links in the global economy, they give access to far flung markets of suppliers and customers. At the end of the fifties people started fearing that sea transport of cargo, especially general cargo, would go down the same road as that of passengers, only used for niche markets (Denholm, 1967). But with the advent of the container the role of the port changed, from a destination and a market it became a link in a global supply chain. In 2017, maritime international trade, with a growth of 4%, reached 10.7 billion tons, which was transported over sea, and, by definition, handled through seaports (UNCTAD, 2018).

This makes ports important economic motors of the region of which they are part and as such they aim to be as attractive as possible for cargo. Efficient ports create additional consumer surplus for importers and producer surplus for exporters (Suykens & Van de Voorde, 1998). Efficiency, in this context, is the proportion between the used resources (private and public) and the output for society. As such a societal cost benefit analysis is, inherently, an efficiency analysis. The economic impact of ports far outreaches the port region itself (Bottasso, Conti, Ferrari, & Tei, 2014). To the surrounding economy, they act as inexhaustible mines of raw materials and insatiable customers. Since the advent of the container, this role has been ever increasing (Donovan & Bonney, 2006; Goss, 1990; Levinson, 2008). Ports have evolved from destinations and marketplaces to links in global supply chains (Pettit & Beresford, 2009; Robinson, 2002, 2003). The hinterland of a port, driven by an increasing containerisation, has been, for most ports, expanding over the past demi-century. More goods travel farther inland than before, using multi-modal transport networks; the more performant and the wider reaching the network, the more attractive the port. This leads to two possible specialisations of a port; it can be a transshipment port, where cargo is changed from one vessel to another or a gateway port, where the cargo is transferred to and from an inland transport mode. A port can combine the two functions, but one piece of cargo will be handled one way or the other. For gateway ports this means that the quality of the hinterland connectivity is crucial for its attractiveness. This connectivity is defined by the quality of the infrastructure and the services offered on this infrastructure.

Different forms of management of ports exist but few will argue that the Hanseatic landlord model, dominant in Northern Europe, is the most successful in terms of growth and efficiency (Cariou, Fedi, & Dagnet, 2014). These ports, managed as they are by local government, have the increase of regional welfare as prime objective. They are continually looking to improve the attractiveness of their port for cargo because an increase in cargo flows is considered a driver for an increase in employment and value added for the port sector and its suppliers. Increased attractiveness can be reached by economies of scale but at a certain point one port can reach the boundaries of the possible scale increases and then it will need to look beyond its own market. One strategy to realise continuing economies of scale is to seek cooperation, where possible, with similar neighbours. By sharing infrastructure and services and by bundling flows, a volume can be realised that would be out of reach if a port would go at it solo.

Economic theory shows that horizontal cooperation involves a basic trade-off: it increases market power (which can be detrimental for the economic value for the customers and suppliers), but it can also create efficiency gains, which then could/should be shared with their customers. If the net result of these gains results in improved welfare, then cooperation should be socially allowed or even facilitated (Álvarez-SanJaime, Cantos-Sánchez, Moner-Colonques, & Sempere-Monerris, 2013). Especially in the case of a port managed by a municipality (or any other local authority), the economic, industrial and logistic importance has expanded way beyond the boundaries of control of the city, some port influences are increasingly overlapping with that of neighbouring ports. This offers an opportunity, even a need, for cooperation with said neighbour (Lacoste & Gallais Bouchet, 2012). The lack of cooperation can lead to and be the cause of a lower growth rate than the neighbouring competitors (de Langen & Visser, 2005).

Cooperation between ports happens all the time and more specifically between the different companies that operate in the different ports (ATKearney, 1995). Hanseatic port authorities, being locally managed, are jealous of their independence and will prefer to keep their neighbours at arm's length. However, in an increasingly globalised world and when competition in a port range and even between port ranges is increasing, cooperation with neighbours becomes a tempting option if it benefits the local port community.

1.2 Aims and research questions

This thesis analyses whether ports, and more specifically European core TEN-T ports, can benefit from cooperating with a neighbour, that (partially) shares a hinterland, and if the port authority of a Hanseatic landlord port is a well-placed actor to facilitate said cooperation. This is done within the paradigm of the global supply network, i.e., in a vertical cooperation added value is created from the source to the end consumer. Ports are an important link in this network and are places where an important part of the added value is created. The theoretical framework of the consumer and producer surplus in welfare economics is used to validate the value created by the seaport cluster. The aim is to detail the benefits from cooperation in the hinterland development. These benefits, when present, are direct and must be shared between the logistic service supplier and the shipper, but there are also external positive effects that benefit the whole port region and its hinterland. The result is a model where any combination of the 104 core TEN-T seaports can be studied on its hinterland bundling opportunities and the resulting direct economic and external benefits. By bundling, a minimal volume, needed for a modal shift, can be attained with the resulting internal and external cost savings. This results in a tool that can be useful for port authorities and port communities (e.g., terminal, road and rail operators) to analyse their hinterland and discover the opportunities for cooperation while at the same time calculating what the monetary and external benefits would be of bundling cargo onto a more efficient transport mode to a specific hinterland region. Hinterland transport is responsible for 30% of the global CO_2 emissions caused by freight transport while comprising only 7% of the volume expressed in tonne-kilometres. This volume is expected to triple between 2015 en 2050 (*ITF Transport outlook 2017*, 2017). This makes any reduction of the external costs of the hinterland connectivity worthwhile. Bundling of hinterland flows, facilitated by port authorities or organised by a consumer driven market, can be one of the strategies to reduce the external costs of the hinterland connectivity.

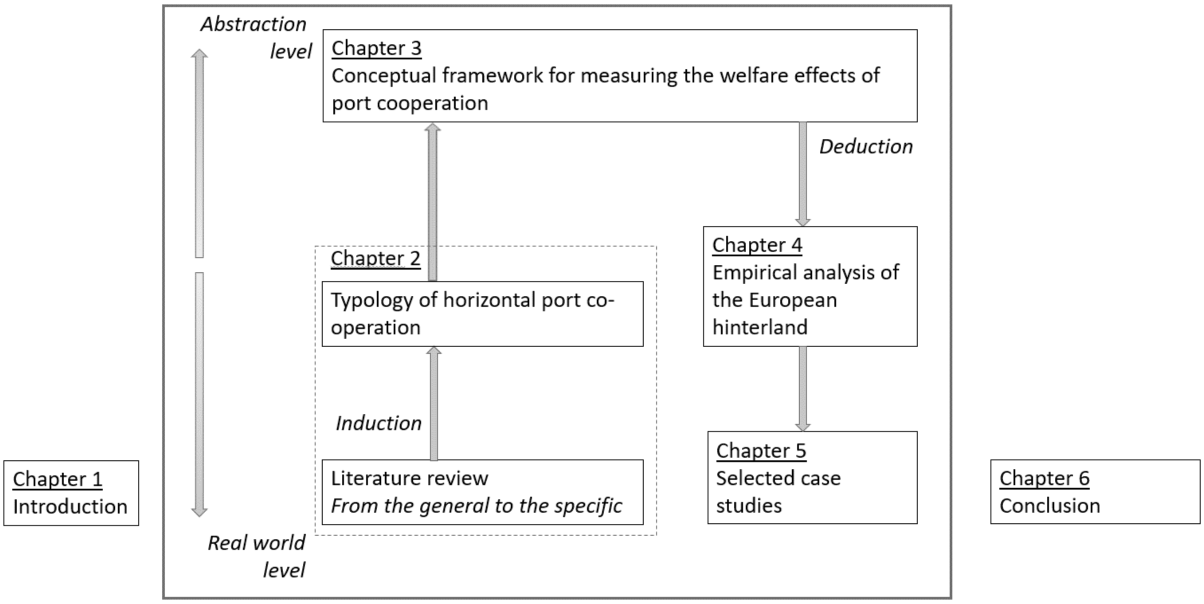
Not only port regions can benefit, the cost savings resulting in an increased throughput, but also the hinterland regions, especially in landlocked countries, will be better off with a lower access cost to overseas customer and supplier markets (Munim & Haralambides, 2018).

The more general, conceptual, research question is: what are the different cooperation tactics and strategies that port authorities have at their disposal, and why can they benefit the port region? This is then further developed in a conceptual question on the detailed direct and external benefits of cooperation in the hinterland. Eventually, this leads to a final, more empirical, research question: where can the 104 core TEN-T seaports cooperate on the hinterland development and how can the benefits of this cooperation be quantified and monetized, including the external benefits?

1.3 Methodology and outline

The structure of the thesis is shown in Figure 1: following the introduction, the second chapter presents the reader with an extensive literature overview that starts from the general cooperation strategy and then increasingly focussing on cooperation in different (service) industries, subsequently on cooperation in the supply chain and finally on cooperation and coopetition in seaports. It proposes a typology on three dimensions: the degree of cooperation, the place in the port triptych where the cooperation takes place and the objective of the cooperation. It closes with an analysis of the success factors and the difference between a top-down and bottom-up approach.

Figure 1 - Outline



The third chapter conceptualises the cooperation between ports and the effects on the demand and supply side of port economics, culminating in the impact it can have on the welfare economics of the implicated regions, using the framework of societal cost benefit analysis (SCBM). One might expect a study on cooperation to use the concepts of cooperative game theory (GT), and, as shown in the literature review, many papers mention indeed GT; of these, many do not more than mention the concepts and do not use its mathematical, quantitative tools. These papers are still cited in the following chapter, often with the mention that they do not include a quantitative analysis, even if they are eventually not part of the methodology but they are needed to motivate the choice of SCBM in chapter 3.

In the triptych that is a port, many opportunities for cooperation are present and a lot of cooperation already takes place, horizontal, vertical and sectorial. Based on the typology in chapter 2, the most promising field for inter-port cooperation is identified: the development of the hinterland. The thesis focusses on cooperation in the development of the hinterland and the role a port authority can play. It uses the paradigm of welfare economics and consumer and producer surplus to conceptually quantify the benefits of bundling hinterland cargo flows. It develops a concept on the welfare benefits of cooperation in the hinterland and details the data necessary as well as a methodology to calculate the value of the consumer benefits and the external effects. A methodology is advanced that makes quantification and monetization of the net benefits possible. The chapter finishes by showing how an improved hinterland connectivity will enhance the attractiveness of the cooperating ports, thus increasing their market share for the specific hinterland region

The fourth chapter empiricalizes the concepts for the core ports of the European Union. Based on data of existing cargo flows linking the 104 core ten-t ports to 1 348 NUTS3 regions, a descriptive model, based on consumer surplus and external costs, is developed that allows to identify opportunities for hinterland cooperation at NUTS2 level between seaports, each NUTS2 region containing between 800 000 and 3 million inhabitants (Eurostat, 2016). It uses the generalized transport cost to take into account not only the out-of-pocket costs for the hinterland operator but also the value of time for the shipper. The closer the seaports are to each other the less costly the bundling operation will be. The chapter establishes a minimum volume that must be reached through the bundling of flows towards or from a specified NUT2 region in Europe. The data focusses on containers and cargo that has the potential of being containerised. The unit of calculation is a container, more specifically, a twenty feet equivalent unit (TEU). A cost model is developed that allows to quantify and monetise the cost of bundling between two or more seaports and the internal and external benefits. The distance between these ports will define the cost of the bundling and when compared with the economies the bundling brings, the opportunity can be evaluated. The model can be used to identify the opportunities for cooperation in the context of the 104 European core TEN-T seaports. Given any of the 281 NUTS2 regions, the analysis of the data will indicate which of the 104 core ports can cooperate to reach a volume sufficient for bundling in a more efficient transport mode. This is then combined with the values of the different cost factors resulting in a cost model that encompasses all 104 core TEN-T seaports and the 281 NUTS2 regions in the hinterland.

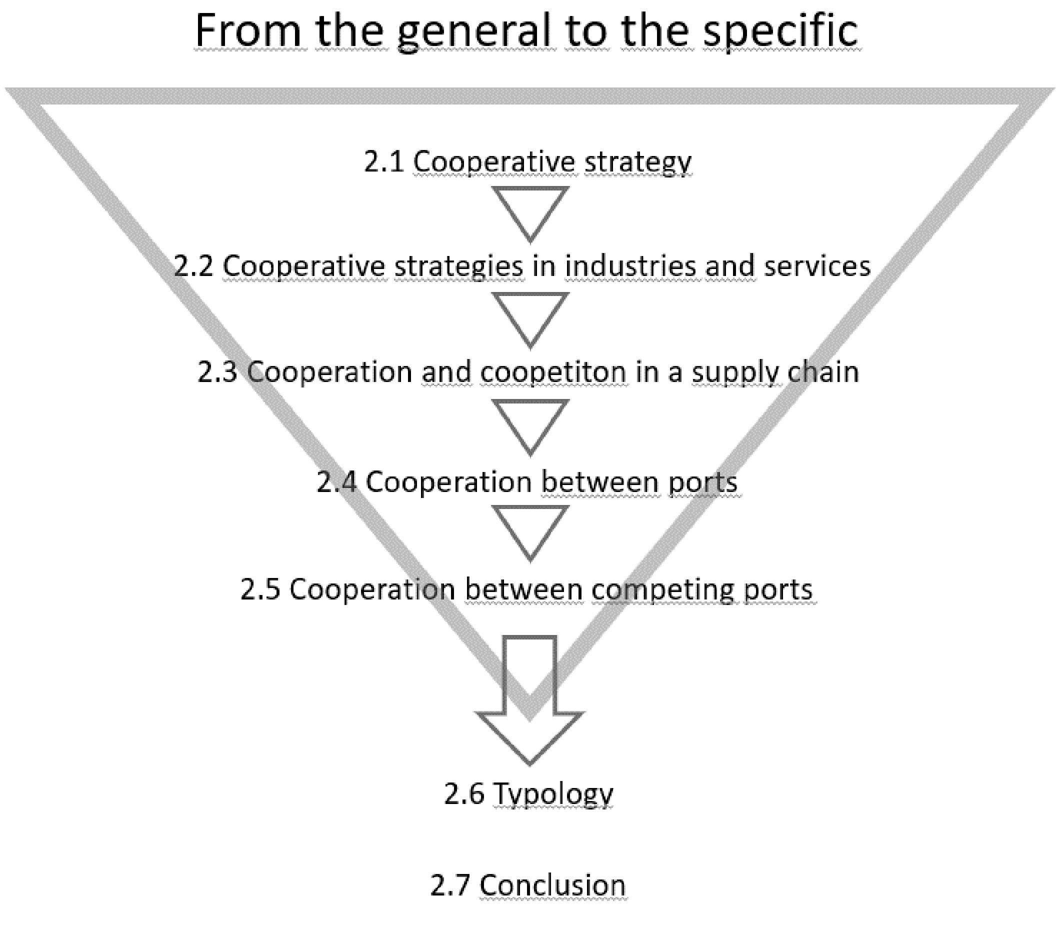
The fifth chapter applies this model to three port clusters of the EU, North Sea Ports, the ports of Antwerp and Rotterdam and the main Polish ports. The cost model analyses where and whether cooperation opportunities for bundling are present. The direct and external net benefit for every case and a specific NUTS2 region are calculated. For every case, a sensitivity analysis is executed that shows the relative importance of variations in the cost parameters. The chapter finishes with implications for the strategies and policies of the different port actors

The sixth and final chapter summarises and closes with conclusions and suggestions for future research.

Chapter 2 COOPERATION, A LITERATURE REVIEW

This second chapter presents an overview of the literature concerning cooperation with a final focus on cooperation between seaport authorities. The first section studies cooperative strategy in general and will be followed by a section overviewing papers and other publications studying cooperation in different economic sectors. The third section focuses on cooperation in supply chains, of which ports can form an element and the fourth and fifth sections give an overview of the literature of cooperation in ports and competing port authorities. Section six which gives a taxonomy of cooperation projects between port authorities and the chapter concludes with section seven.

Figure 2 - Structure of the literature review: from the general to the specific



2.1 Cooperative strategy

A unified theory of cooperation is not, yet, available. Cooperation can take place in many fields and in many forms, so it has too many possible aspects to fit in one model. Cooperation has been the subject of study in fields as diverse as economy, game theory, transaction cost theory, agency theory, network relationships theory, resource dependency theory and organisational theory (Child, Faulkner, & Tallman, 2005). And more can be found in other sciences like biology, ethnography and palaeontology.

Cooperation between competitors is an age-old concept. The medieval guilds were essentially cooperating competitors. At the end of the 19th century, most European countries legalised the cooperative union and this was not only used by workers but also by competing smaller companies like bakers and farmers (Rommes, 2014). But after the second world war, competition between companies was the norm and a standard work like "*Competitive Strategy*" (Porter, 1980) does not even mention the notion of cooperation. The seminal article on "economies of scope" (Panzar & Willig, 1981) equally does not discuss the possibility of finding these economies outside one's own organisation. But, nevertheless, right after the end of the second world war, an innovative cooperation project was started to make the, at the time, main industries of coal and steel of the former waring nations, cooperate (Bebr, 1953; Mikesell, 1958). The European Coal and Steel Community was to evolve over time into the present European Union, the biggest market of the world.

2.1.1 Concepts of cooperation

In the 80's, the attention of management theory on cooperation started to change, Astley (1984) proposes to evolve beyond the "battlefield analogy" and states that collaboration has been a neglected variable. He defines collaboration as the "joint formulation of policy and the implementation of action by members of inter-organizational collectives" The "pioneering ethos" sees the faceless environment as a deterministic constraint. A voluntarist view, however, allows the formulation of a "collective strategy" which can influence a turbulent environment. But cooperation will not always increase the competitiveness of participating organisations. It could also lead to dysfunctional consequences and lower the adaptability, increase the impact of external buffetings, attract new entrants and it might reduce competitive behaviour. The dialectical tensions can result in strategic instabilities (Bresser & Harl, 1986).

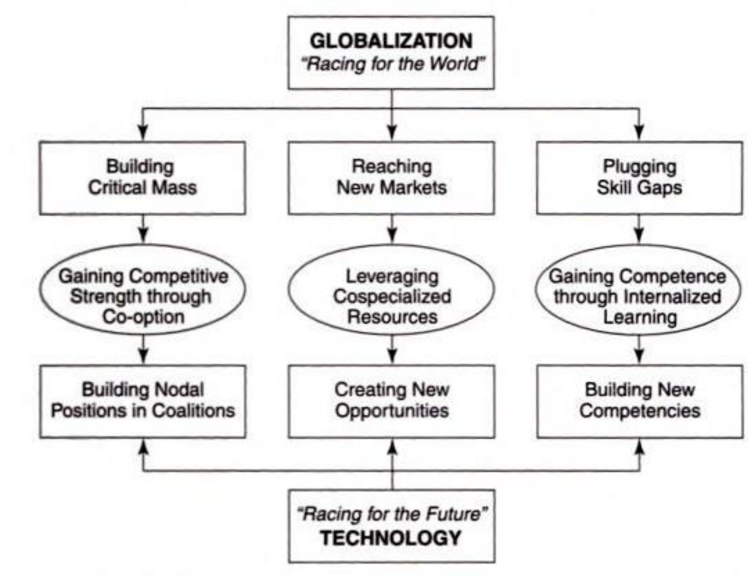
Competition is, according to the neoclassical view of the firm, good for the economy: cooperation might lead to abnormal profits (Lipczynski, Wilson, & Goddard, 2009). There is always the fear that cooperation between competitors will lead to the reduction of competitive behaviour, but this is countered by the possible attraction of new entrants. The contestability of a market is a stimulant for cooperating organisations to remain competitive (Baumol, Panzar, & Willig, 1988). Except in the case of R&D, alliances will be governed by the Treaty of Rome art.85-86 and will only be allowed if they have a positive benefit for the consumers (Dussauge & Garrette, 1999). The European commission formalised this with the economisation of the EC competition rules where emphasis was laid on the structural and economic benefits of cooperative transactions. Economic advantages of cooperation can objectively outweigh the restrictions of competition (European Commission, 2001; Vogelaar, 2002). The legislative bodies of the USA too, are open to the advantages of cooperation between competitors (AAPA, 2008; Levin & McDonald, 2006). To be acceptable, a cooperative project cannot be dyadic with a win-win for the partners and a loss for third parties but it should be multifaceted with a win-win-win where society benefits from the third win (Rusko, 2012). The role of the third party can be more than a passive beneficiary: especially governments can play an active role in promoting cooperation between competitors. They can act as go-between or even as decision makers. (Salvetat & Géraudel, 2012)

Lipczynski et al. (2009) make a distinction between mergers (which are the most extreme form of cooperation) and alliances with profit-maximizing motives on one hand, and those with non-profit maximizing motives on the other. Cooperation projects with profit maximization can have two possible motives, one is to gain market power, the other is to save costs through rationalization, economies of scale, shared research and development or through purchasing economies. However, it must be stressed that economies of scale, when available, could also be made through internal expansion. The non-profit motivated kind often is victim of managerial discretion which has, through the existence of the principal-agent relationship, motives related to status, power or survival of the managers. Nielsen (1988) establishes a classification scheme for cooperative strategies analogue to the classifications of competitive strategies (Galbraith & Schendel, 1983). Starting from evolutionary biology, Nielsen concludes that collaboration is actually more common than the struggle for survival of the fittest. He also refers to the first game theory publications (Von Neumann & Morgenstern, 1947) that develop the concept of a positive sum game. He defines four strategies: pool, exchange, de-escalate and contingency. The pool strategy reduces duplication and redundancy and can help accumulate resources for reaching a necessary threshold for aspired economies of scale. The exchange strategy allows organisations to develop further their own specialisation while sharing it with partners who develop the other necessary specialisation. De-escalation reduces or eliminates attacks between two competitors, which could, unlike the above-mentioned strategies, lead to negative monopolistic effects. Finally, in a contingency strategy, organisations will agree on conditional cooperation based on future events (Nielsen, 1988).

By the end of the 80's, many industries collaborated, e.g., General Motors assembled cars with Toyota parts, Siemens and Philips developed computer chips together, Canon supplied to Kodak, Thomson manufactured VCR players with JVC. These projects did not stop these firms from competing, they both had clear strategic objectives and harmony was not a measure of success but both partners used the alliance to have access to the partner's capabilities and knowledge. One partner wants to acquire technological or marketing know-how and the other partner wants to reduce costs or risks (Hamel, Doz, & Prahalad, 1989).

The objective of a cooperation initiative is value creation for the participants, which can be done by one of three ways. Figure 3 shows how co-option allows firms to combine forces to create a stronger market power. Co-specialisation brings together unique skills and owner specific resources. Learning and internalization are the goals of a cooperation when valuable skills are exchanged in roughly equal proportions. The valuation of each partner's contribution can be difficult because some assets are non-traded, the contribution to success is hard to estimate, the value accrues outside the alliance, the relative value may shift over time and partners may be less than forthcoming in their declarations (Doz & Hamel, 1998).

Figure 3 - The logic of alliance value creation



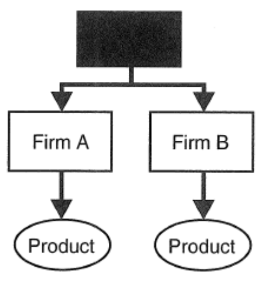
Source: Doz & Hamel, 1998

Using the value capture model (VCM), Ryall (2013) redefines the five forces model of Porter (1980) from five to one : suppliers compete for customers and vice versa. The VCM makes a distinction between value creation and value appropriation. Cooperation between competing service suppliers can increase their power for value appropriation.

Cooperation between competitors can be an offensive strategy to diminish the market share of other competitors or it can be a defensive strategy that raises barriers. It always consists of bringing together similar resources to create economies of scale or scope (Child et al., 2005).

Dussage & Garette (1999) define three different forms of cooperation after analysing 200 cases. Figure 4 shows how two firms, that each have their own interests and goals which are different and maybe even contradicting but share a limited set of common goals which they can enhance through an alliance, can start a shared supply alliance strategy. It consists of a link between two or more independent companies which choose to carry out a project or a specific activity jointly by coordinating the necessary distinctive skills and resources. It shows how they share a common resource but supply two differentiated products.

Figure 4 - Shared supply alliance

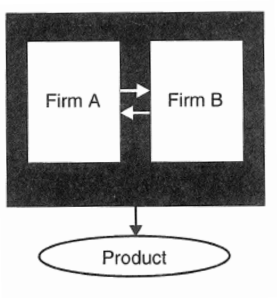


Source: Dussauge & Garrette, 1999

Sharing a resource with a competitor can also persuade a potential entrant not to build his own facility and this limit his activity in the market and act as a deterrent (Z. Chen & Ross, 2000).

Another form (Figure 5) is the quasi-concentration where companies contribute similar capabilities to develop, produce and market a joint product.

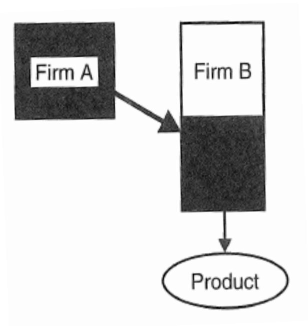
Figure 5 - Quasi-concentration alliance



Source : Dussauge & Garrette, 1999

The third form (Figure 6) is a complementary alliance when partners each contribute different and complementary assets to a joint endeavour.

Figure 6 - Complementary alliance



Source: Dussauge & Garrette, 1999

Child (2005) proposes a make-buy-ally matrix, where strategically important assets that are outside the competences of the firm can be better acquired through an alliance than through a purchase or an in-house development. Starting from a resource-based view of a firm's resources and capabilities that define the competitive advantage, cooperation is a strategy to acquire these when they extend beyond a firm's boundaries. Castañer et al. (2014) show that collaborative governance on make-or-ally choices lead to greater sales but longer development times.

Alliances can be viewed as a lesser form of a merger (Zhang & Zhang, 2006). Alliances are, by definition, limited in time and acquisitions outperform alliances because the consensual decision-making process increases the cost. The reversibility of an alliance limits the extent of rationalisation (Garette & Dussauge, 2000). But both are best suited for different situations: when uncertainty is high, the flexibility of an alliance is to be preferred, whereas when a stable environment brings partners to aim for economies of scale and scope, acquisition is a superior strategy (Choné & Linnemer, 2006; Dyer, Kale, & Singh, 2004; W. H. Hoffmann & Schaper-Rinkel, 2001). Dyer et al. (2004) start from three different types of synergies: modular synergies, when the resources are independently used and only the result is pooled; sequential synergies, when the result of the task of one company is passed on to the other partner to do its bit and thirdly, reciprocal synergies where partners have an iterative sharing process.

To cooperate, organisations must have some common grounds, they must be to some degree close to each other. But this closeness must not necessarily be geographical in nature: besides geography, four other dimension can present grounds for cooperation, i.e. organisational, social, cognitive and institutional (Boschma, 2005).

But size matters: cooperation over a longer period between a very large and a very small partner is unlikely (Child et al., 2005). Not only in size but also in activity are similarities positive indicators for a successful cooperation. But as similarity increases common understanding and compatibility, it also increases competition. These opposing forces are relevant for the success of the cooperation project (Raue & Wallenburg, 2013). A longitudinal study of motion picture studios shows that over a period from 1990 to 2010, smaller studios cooperating with large partners realize a lower growth than those going alone (Vandaie & Zaheer, 2014).

Globalisation has been a driver for cooperation. Firms view it as an alternative for international competition, and although it carries a cost for coordination, it also can bring access to new geographical markets. It will be used when it is perceived as less costly and more effective than developing the resources in-house or through a merger (Porter, 1986).

Dyer and Singh (1998) expand on the resource-based view (RBV) of the firm. RBV goes beyond the industry structure view (Porter, 1980) to explain differential firm performance with firm heterogeneity and emphasize competitive advantages resulting from those resources and capabilities that are owned by a single firm. Dyer and Singh (1998) argue that these critical resources may span firm boundaries. They identify four potential sources of inter-organisational advantage: relation-specific assets, knowledge sharing routines, complementary resources and effective governance. Das and Teng see the pooling of resources as a means to value-creation thus establishing a rationale for alliances (Das & Teng, 2000). Based on the resource-advantage (R-A) theory, that attaches a strong importance to learning, it makes sense for firms to cooperate and share access to heterogeneous and immobile resources to gain a comparative advantage (Hunt, 2010; Hunt & Morgan, 1996). American anti-trust legislation can find in the R-A theory rationalities that allow coopetition and resource sharing that not only benefits the firm but also its customers thus having a legal ground to allow non-collusive cooperation (Levin & McDonald, 2006).

New product development alliances are becoming a major business model (Bicen & Hunt, 2012; Hunt & Madhavaram, 2012). Kock et al. (2004) see especially small and medium sized firms lacking resources while sharing mutual interests with each other which leads them to cooperate. This balance between cooperative and competitive interaction creates a strategic challenge that operates under three different conditions: firstly, the organising of activities; secondly, the intensity and density of interactions and relationships, and thirdly, the social relationships between the managers.

A difference can be made in the cooperation of competing firms between link alliances and scale alliances. Link alliances happen when companies make complementary contributions to the venture, while in the case of scale alliances, the partners bring similar contributions to the cooperation. The former are more volatile because the benefits are more private to the partners. In the case of scale alliances, the benefits are more common than private and this leads to more cooperative behaviour (Dussauge, Garrette, & Mitchell, 2004).

Lobbying towards higher authorities for fiscal support and influencing policy is more effective when done by stronger organisations. This is a typical case where competitors have similar needs and can strengthen each other (Mishra, 2013).

Klein Woolthuis (1998) sees cooperation as a process that starts with the choice of an objective and the selection of the partner(s). Axelrod (1997) confirms that cooperation is an adaptive process that eventually results in collaboration in the interest of competition.

Implications for seaports

In all the aforementioned models, actors share resources, they share risks, they create economies of scale/scope or they increase their leverage towards suppliers or customers, always with the objective to increase their value added or to capture a larger share of the value added, even at the detriment of the actors not part of the cooperation. Competing seaports can share resources, if they are located close enough; examples are common hinterland railways or pilot services. They can share the risk of developing new services or infrastructure such as a joint port community system or synchronising important expansion projects in the foreland, the port or the hinterland. They can increase their facility to capture a larger share of the added value by, for instance, coordinating their terminal award procedures, to the extent allowed by competition authorities of course.

2.1.2 Coopetition

Brandenburger and Nalebuff (1996) expanded on the concept of coopetition and developed it, using a descriptive name allegedly (some references are quite older) coined by Noorda in 1992, then CEO of Novell. Based on the idea that business is war and peace, it postulates that to succeed a firm must allow other firms to succeed too. In their seminal work "*Co-opetition*" the authors develop the concept of value net and define the game with the acronym PARTS: players, added value, rules, tactics and scope. Through game theory they want to identify which partner in the value net brings the added value, and how this can be increased through cooperation. Most of their cases are not based on cooperation between competitors in the strict sense of the word but on cooperation between firms who compete for their share of the added value created in the value net. Coopetition fits in the game theory typology as cooperative non-zero-sum game but the authors do not develop the typical mathematical, quantitative tools. This work and especially the title started its own research stream but many others using the word do not follow the concepts as developed by Brandenburger and Nalebuff. Few go beyond naming, claiming or evoking it (Walley, 2007). Quite a few articles in the following pages mention coopetition but without going into a quantitative analysis based on the concepts of game theory.

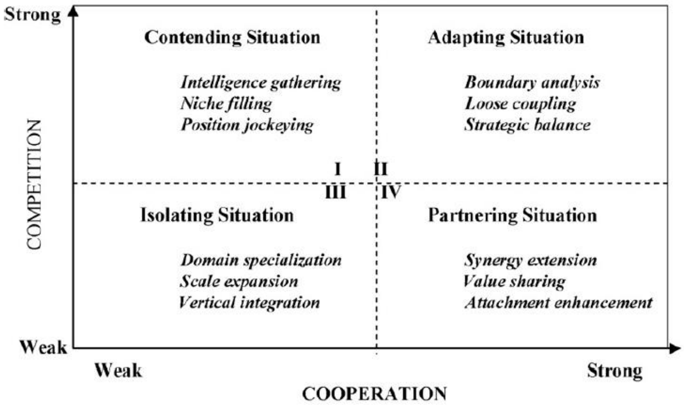
Many authors see coopetition as a marketing tool and use it in vertical channel distribution systems (Osarenkhoe, 2010). Ritala (2012) did a cross-industry survey of 209 Finnish firms and by measuring the number of stated alliances with competitors, and defined an explanatory variable : coopetition alignment. He found that there was a positive correlation between coopetition and firm performance especially under high market uncertainty. It was also beneficial to the firm's innovation and market performance under low competition intensity. But the author does not refer to game-theoretic concepts; instead he uses standard statistic analytical calculations, like means, standard deviations and correlations.

Coopetition is seen as a new paradigm next to the competitive and the cooperative paradigms. Firms do not lose self-interest but get them aligned with the self-interests of others. The dyadic relation is the simplest level of analysis but can be expanded to more players. Uncertainty is a strong driver for cooperation, while at the same time promoting divergent views, but unstable environments lead to uncertain cooperation. It is, like all cooperation projects, a process starting with the selection of partners, followed by strategic interaction, where the strategic direction of the partners is (re)framed, and organizational interaction, where the tasks and resources are structured and integrated. Cooperation entails three different types of knowledge: know-what, i.e. the scientific and technological knowledge; know-how, the organisational knowledge; and know-why, the dominant business logic. The higher the distance in know-what, know-how and know-why, the larger the competitive issues (Padula & Dagnino, 2007). This goes against the idea that the higher the similarities of firms, the more important the competitive forces are (Boschma, 2005; Child et al., 2005; Raue & Wallenburg, 2013).

Bengtsson and Kock (2000) focus on horizontal collaboration and also see firms cooperating and competing simultaneously. Starting from a business network view, they also see it as a dyadic relationship with two diametrically different logics of interaction that can bring three advantages: complementarity, cost and risk reduction, and technology transfer. This relationship is defined as coopetition. They see the cooperation happening far from the customers and the competition close to the customers. This results in different levels of cooperation in different business units. Although the authors label their analysis as coopetition, they, too, do not apply the mathematical tools of game theory nor do they refer to the work of Brandenburger and Nalebuff (1996). Their use of the title of coopetition covers a completely different concept. In an earlier article, they also specified that exchanges between coopetition partners do not have to be economic. One form of cooperation is co-existence, where there are no exchanges, and goals are established independently. Another is cooperation, where common goals are defined and pursued. The most competitive is competition, where similar suppliers are relied upon and the same customers are targeted. And finally, there is coopetition, where non-core activities, often invisible for the customer, are jointly developed. (Bengtsson & Kock, 1999).

Luo (2007) specifies that firms compete for inputs as well as outputs and can cooperate for mutual gain in the most diverse fields and at different levels from business units to corporate. The difference between coopetition and other cooperation forms like alliances, where the unit of analysis is the alliance itself, is that coopetition entails that rivals cooperate in some fields while competing in others. The coopetitive behaviour seeks the positive sum of efficiency enhancing effects of competition and cooperation. It is reinforced by market commonality and resource asymmetry. Especially in the case of innovation and product development, coopetition can reduce the risk, the cost and the uncertainty. By increasing the variety of options, coopetition can increase strategic flexibility. Especially in the battle to establish technical standards, coopetition is a valuable weapon. But the dynamic nature makes that the coopetition project will evolve over time due to changes in the internal or external environment. The author proposes a four-quadrant matrix to classify coopetition based on intensity of cooperation and the intensity of competition. Again, this paper uses the title of coopetition but abstains from using game theoretical concepts.

Figure 7 - Intensity of coopetition



Source: Luo, 2007

Dowling et al. (1996) warn for the lack of reciprocity when firms coopete in a multifaceted relationship where buyers can also be competitors or where partners form a consortium. This can be the result of the desire to reduce dependence on rare resources or the wish to reduce transaction costs. Concentration reduces the number of partners that need to participate in the venture. Less munificence (the availability of resources) promotes coopetition, highly regulated sectors are more likely to have coopetition, and the same goes for global industries; all these external factors influence the likelihood for successful coopetition ventures. Internal factors like essential supplier/buyer relations, transaction-specific assets and opportunistic suppliers can push towards a coopetitive relation in a vertical relationship. The authors, also, using a qualitative approach, do not apply the game-theoretical tools to prove the propositions.

López-Gómez and Molina-Meyer (2007) apply the mathematics of game theory to prove that coopetition might provoke an explosive increment in productivity and stability but apply it to the tropical ecosystems. Gnyawxali, He and Madhavan (2006) show that resource asymmetries lead to coopetition and make a case study of the Japanese steel market.

Implications for seaports

Song (2003) has written a (one might even state : the) seminal paper on coopetition between ports, but this will be covered in chapter 2.5.1, further on. He uses the “Bengtsson” concept of coopetition and avoids game theory mathematics.

Seaports do not have to stop competing, and thus striving to improve services while lowering costs, when they cooperate on specific projects with a competing neighbour. Of course, in the case of a full merger, competition is stopped, but many cooperating projects are possible that fall short of a full merger. Examples can go from the mundane, like organising a bicycle race, to the strategic, investing jointly in hinterland railway infrastructure.

2.1.3 Top-down versus bottom-up

Cooperation, and coopetition in particular, does not always originate as a chosen strategy with one or more partners. With a focus on the formation of coopetition strategies, Mariani (2007) goes back to the ideas of Mintzberg (1988) that make a distinction between deliberate and emerging strategies. He proposes the possibility of an emerging coopetitive strategy where organisations, driven by a changing environment, end up, without having planned to, cooperating with their competitors. This would be the result from a learning process in the organisations, a factor which is ignored by the other authors. The Finnish tourism industry in Lapland went through such an evolution (Kylänen & Rusko, 2011)

Regulatory authorities would be expected to be wary from cooperation between competitors because of the fear for collusion and a lessening of quality or increase of price as a result. But in some cases, governments are the driving factor for cooperation. Salvetat and Géraudel (2012) describe this as the tertius, the third actor in a coopetition scheme who has no direct benefit from it. This third actor could be a (supra)national government body but also a big customer who expects better performance from two suppliers. Either as a tertius gaudens, who benefits from others, or a tertius iungens, who brings together partners without benefiting himself, they see two roles for the tertius. One role is the go-between, who, as an intermediary, encourages trust and reduces the risk of opportunistic behaviour. The other role is the decision maker where the tertius has favoured access to information. In this case, the tertius dominates the competitors and imposes cooperation due to an asymmetry of information.

In their case study of SEMATECH (Browning, Beyer, & Shetler, 1995), it is shown through the use of grounded theory, that in the case of uncertain and unclear environment, a bottom-up process assures that the goals of the cooperation are realistic, limited and accepted by all participants. But Mazzucato (2011) stresses the important role the US government played as a provider of start-up financing.

It is also possible that a government reduces its coordinating role between competitors thereby giving them more freedom to operate and independence from each other with the objective of increasing efficiency and competition (Cariou et al., 2014).

Implications for seaports

Especially Hanseatic seaports are weary of cooperation with competitors forced on them by supervising national authorities, they proudly value their independence and their local roots. At the same time, they draw support from higher authorities and compete with their neighbours for the limited resources available at the higher government levels. A bottom-up process driven by demand from their customers has a much higher chance of success. In the case of privately-owned ports, shareholder value drives mergers with little or no attention for the consequences of the port users and the surrounding communities; in Great Britain this has led to large companies managing several ports. In the case of more centrally-managed port systems, for instance in Southern-Europe or China, cooperation projects and even full merger can be enforced from national or provincial governments, the local port managers and port users are not necessarily in favour, but they have little say in the matter.

2.1.4 Cooperation as a continuum

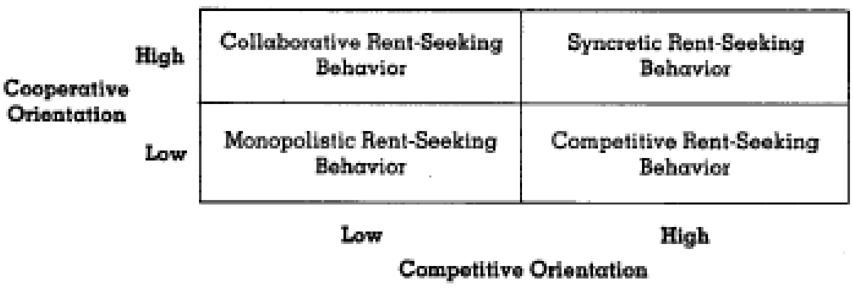
There are many ways for competitors to cooperate and many different names are used. All can be put on a continuum from an ad-hoc non-strategic project to a full-fledged merger.

Just shy of the merger is the coalition which is defined as a long-term alliance between firms that link aspects of their businesses. The motives can vary and include risk avoidance, search for economies of scale, need for technology or market access and government pressure (Porter, 1986).

A cooperation can also be classified along the level of its objectives. They can be operational, where the aim is to support the daily operations; tactical where the project can support the management objectives; or strategic, where the cooperation aims at creating a long-term competitive advantage. Alternatively, it can be classified based on the intensity of the cooperation where five levels of increasing intensity can be defined : every organisation keeps control of its own operations, a project will be jointly executed, a long term relation is contractually established, a relation is co-developed and the highest level of cooperation results in the integration of activities (Klein Woolthuis, 1999).

So, cooperation is not dichotomic, it is not only any point between the two extremes of cooperation and competition but a multidimensional variable in an orthogonal structure between competition and cooperation (Padula & Dagnino, 2007). This was already stated by Lado, Boyd and Hanlon (1997) who describe a four cell typology based on the dimensions competition and cooperation. The authors call a combination of competitive and cooperative behaviour "syncretic" (because it combines seemingly contradictory behaviours) and see it as non-zero-sum behaviour that increases efficiency and/or reduces costs and risks.

Figure 8 - A syncretic model of rent-seeking strategic behaviour



Source: Lado et al., 1997

Few agree on the different names given to different practices of horizontal partnerships and sometimes the same word can have different meanings, the most obvious being coopetition as defined by Brandenburger & Nalebuff (1995) with references to game theory on the one hand and Bengtsson & Kock (2000) on the other, with their focus on upstream supply chain management. Not only are terms like cooperation, collaboration, alliance, partnership, service agreements, joint ventures, consortia etc. interchangeable, their boundaries are vague. Only the extremes : arm's length relationships and merger, are agreed upon (Cruijssen, Cools, & Dullaert, 2007; Polenske, 2004).

Implications for seaports

The possibilities for cooperation are endless. Not all of them necessarily benefit the port users or the surrounding community, which should be the only criterion since it is the raison d'être of a (public) port authority, but if ports want to work together, there is always a level of cooperation that suits the needs.

2.2 Cooperative strategy in non-logistic industries and services

Globalisation is one of the main drivers for cooperation (Child et al., 2005; Hunt, 2010; Porter, 1986). Some manufacturing industries were, in search for economies of scale, first adaptors of cooperation strategies. Few cases are more obvious than the, already mentioned, European steel and coal sector. It was one of the first post second world war fields were the need for cooperation between competitors was recognised (Bebr, 1953; Mikesell, 1958). This started an evolutionary process which culminated in a strong global player after a long series of mergers.

The Japanese economy and its success on the global market is based on cooperation in large industrial structures called Keiretsu (Aoki & Lennerfors, 2013). This model survived, with some modifications, the upheaval of the second world war and expanded beyond its original homeland. Sony coopetes with JVC to enhance the benefits from technological development (Gnyawali & Park, 2011).

Another global market which has seen an ever-evolving set of cooperation initiatives is the car industry. At R&D level, as well as on product development level and market development level, cooperative strategies have been used by the actors (Bickerstaffe, 2012; Dussauge et al., 2004; Kurstjens, 2013). By cooperating, the car manufacturers aim to reduce demand uncertainty and uncertainty due to competitive interdependence (Burgers, Hill, & Kim, 1993). Thus, competitors evolve into a supplier-supplier relationship as is the case in the Japanese and German car industry (Wilhelm, 2011).

The European defence and aeronautic manufacturing sector also had a need for cooperation between smaller, national actors to be able to compete against the bigger American producers (Bigliardi, Dormio, & Galati, 2011; Dussauge & Garrette, 1995, 1999). Working together leads aircraft manufacturers to longer development times but higher sales (Castañer et al., 2014).

High-tech sectors with their high risk, high cost R&D strategies have a logical tendency for cooperation to mitigate these factors. Through the use of grounded theory, Browning et al. (1995) study the reaction of the American semiconductor industry to the, at the time, ever gaining Japanese competitors. Bahinipate et al. (2009) use an analytic hierarchy process fuzzy logic model to study horizontal collaboration in the semiconductor manufacturing industry and develop a collaboration intensity index. The focus of these cooperation projects is always linked to the development of new technology through the sharing of jointly created knowledge, be it by sharing equity or by an exchange of technology.

But even sectors that are definitively low tech, like the Finnish forest industry, can benefit from coopetition especially if they are active on a global market (Rusko, 2011). The author makes a point of differentiating between coopetition and collusion. In the case of the latter, the objective is to increase producer surplus through price increases and monopoly power, thus decreasing the consumer surplus. Coopetition on the other hand, aims not only at a mutual benefit but also at a benefit for the consumer.

With the rise of the service industry, here also, cooperation became a more common strategy. The banking industry went through a wave of mergers and acquisitions (the most extreme form of cooperation) which led to increased profits through market power, not through increased efficiencies. This did not lead to an improved service level for most customers, except the biggest companies, but to an increase in systemic risks. (Berger, Demsetz, & Strahan, 1999). Rochet and Tirole (2002) study the cooperation between competing banks when forming payment card associations and its welfare effects. They show that the successful introduction of credit cards is in large the result of all banks accepting each other's cards through reciprocal agreements. If every bank would have created its card in a stand-alone model, it would have to negotiate separately with all merchants, even world-wide, for acceptance. This would result in very high transaction costs.

Dranove (1998) uses economies of scale to prove that, up to a certain point, cooperation and mergers between hospitals will bring benefits. But once a certain size is reached, only small efficiency gains can be made, and they will be offset by nominal price increases. Another study of the service industry is the already mentioned paper on the Lap tourism industry (Kylänen & Rusko, 2011). As already mentioned, Vandaie and Zaheer (2014) use a longitudinal dataset covering 1990-2010 to study the effect of size in cooperation in the motion picture industry. They conclude that small firms that make alliances with bigger studios to get access to financial resources end up with lower growth benefits than those who stay independent.

Mariani (2007) uses grounded theory to study coopetition between Italian opera houses, while Browning et al. (1995) use the same methodology to study cooperation in the American semi-conductor industry which had gotten under pressure from the Japanese. The firms in this industry came to the conclusion that they had to work together (under guidance of the US government (Mazzucato, 2011)) and 14 companies created a joint venture called SEMATECH and thanks to the efforts of a charismatic and industry-wide respected CEO, this firm was able to attract capable employees from its members with the aim of developing manufacturing processes and common standards that would benefit all members. The authors, using grounded theory, discovered three conditions that enabled the development of the cooperation. Early disorder and ambiguity brought, through a bottom-up planning process, the focus of the members on a limited set of achievable goals. From this process, a moral community evolved which led to a common framework facilitating interactions.

Lastly, there is a whole body of knowledge on cooperation between private industry and governments. Public-private partnerships (PPP) are often seen as a panacea to solve the perceived differences in efficiency between government and industry while at the same time allowing governments to organise the funding through other means than public debt. Even where PPP projects typically are more expensive, they, generally, produce higher-quality infrastructure and complete more often on time whilst avoiding underinvestment due to budget constraints of the implicated governments. (Buffie, Andreolli, Li, & Zanna, 2016)

Implications for seaports

Cooperation is just as often the case in service industries as in manufacturing. Actors in a seaport being, mainly, services suppliers can find many examples in other service sectors, the common denominator being that the objective of the cooperating partners must be compatible, often serving the same client base and finding network effects. But some projects might generate more extra expenditure, for instance on coordination, than they bring savings. It is possible that such a cooperation exhausts the economies of scale and eventually has negative effects on the objective: increase regional value added.

2.3 Cooperation and coopetition in a supply chain

Many authors study cooperation between supply chain partners. Most cover vertical cooperation between partners in the supply chain. If vertical partners are competing, then the competition is about the share of the added value (Khaji & Shafaei, 2011; Lambert, Emmelhainz, & Gardner, 1999). The procedures for establishing a successful horizontal cooperation are the same but the aim of the venture is radically different. Leitner et al. (2011) describe the process of the development of a horizontal logistic cooperation, starting with the design of the chain, next a coordinator is required to ensure overall satisfaction. They do not discuss the sharing of the gains resulting from this cooperation nor the payment of the coordinator. Naesens et al. (2007, 2009) use an analytical hierarchy process (AHP) to evaluate different horizontal collaboration projects starting from the observation that cooperation within one supply chain, vertical cooperation, is widespread but cooperation between different supply chains, horizontal cooperation, is less developed. Horizontal cooperation can be between non-competing or competing supply chains. The authors define a framework to measure the strategic fit between potential partners of a horizontal collaboration as the first step in a three-level process of establishing a cooperation. After having defined the goal of the cooperation, the first level consists of the choice of potential partners. Secondly, for every potential partner the costs and benefits are identified. Thirdly, the implementation and sustaining of the partnership is considered, taking aspects like trust into account.

It is often assumed (Kock et al., 2004; Walley, 2007) that coopetition that occurs in upstream activities is more beneficial for consumers, while downstream coopetition often has a negative influence on pricing and tends to collusion. Upstream coopetition would be in the domain of R&D, purchasing, processing of raw materials. Downstream coopetition would entail distribution, services and marketing. But even downstream coopetition does not exclude fierce competition on aspects like brands, quality or service (Rusko, 2011). Rusko (2011) establishes a typology on two dimensions: the direction along the supply chain and the degree of coopetition (see Table 1).

Table 1 - Typology of coopetition

Type of coopetition		Upstream moves Input activities/ cooperation		Downstream moves Output activities/ competition
		Typically cooperation-dominated Relationship	Equal Relationship	Typically competition-dominated Relationship
HIGH	1) Coopetition with rivals	Dyadic upstream and factor-based coopetition, with rivals without closeness of customers	Dyadic mid-stream coopetition, e.g. in semi-finished products, with rivals	Dyadic product- and market-based downstream coopetition with rivals, and with closeness of consumer market
Degree of external coopetition	2) Coopetition with a government	Multifaceted factor-based coopetition with rivals and a government	Multifaceted mid-stream coopetition with a government	Multifaceted downstream coopetition
	3) Coopetition with alliance partners	Internal factor-based coopetition with alliance partners	Internal mid-stream coopetition with alliance partners	Internal downstream coopetition with alliance partners
LOW	4) Coopetition within a company	Intra-firm factor-based	Intra-firm mid-stream coopetition	Intra-firm downstream coopetition

Source: Rusko, 2011

In an in-depth study of airline networks, Zhang (2005) examines horizontal, vertical and hybrid strategic alliances, hybrid being a combination of vertical and horizontal. Network-oriented industries like airlines, shipping and logistics often have strategic alliances which are "medium- to long-term partnerships of two or more firms with the goals of improving partners' competitive advantages collectively vis-à-vis their competitors". Each partner maximises his own profit and, to some extent, that of his partners through economies of scale and scope, through improvements of quality or customer service. By building one model for vertical partnerships and another for horizontal and hybrid alliances, Zhang shows that since vertical cooperation projects are complementary, the increased profit of one partner has a positive effect on the profits of the other partner while at the same time increasing output and thus lowering prices which leads to a gain in general welfare. In a horizontal cooperation, however, the partners are substitutable instead of complementary. Cooperation in this case will, according to Zhang, lead to a reduction of supply and an increase in price (Zhang & Zhang, 2006). Surprisingly, the authors ignore in their analysis any effects of economies of scope or scale. De Langhe et al. (2018) study cooperation in and between European airports.

Opportunities for horizontal cooperation in a supply chain can be found in reduction of costs and increase in productivity, increases in customer value added and in the strengthening of the market position. Impediments to horizontal cooperation are the lack of suitable partners, the division of the gains, the negotiation process and the coordination, especially of ICT systems. In this article Cruijssen, Cools, et al. (2007) make a difference in cooperation in the supply chain between vertical cooperation, which is the daily work of supply chain managers; horizontal, which is between companies operating at the same level(s) in the market, and lateral, which is a combination of vertical and horizontal (which is called hybrid by Zhang (2005)). Logistic service providers (LSP) can decrease costs and increase service levels through cooperation or they can protect their market position - which is similar to the motives as described by Lipczynski (2009). As supply chain activities are often less visible to the final customer, they are a good opportunity for cooperation in the form of coopetition. Contrary to the maritime sector or aviation, the generally competitive landside transport sector with its large number of players has less opportunities for collusion. The market power of the actors is much weaker than in aviation or shipping, which benefit often from domestic preferential treatment in the case of the former or have high entrance barriers due to capital intensive investments in the latter (Cruijssen, Dullaert, et al., 2007).

Cooperation between competing logistics service providers has an inherent potential for conflict. When a conflict occurs, this has, obviously, a negative effect on the financial performance but conflict has a positive impact on the innovativeness of the cooperation (Wallenburg & Raue, 2011).

The transport industry itself sees advantages in horizontal cooperation, especially in times of low economic growth. By cooperating, LSPs can increase the load factor of the vehicles, thus increasing their profitability and by sharing services, customers will benefit from a higher frequency without the need for one LSP to have to invest in services that will only be partially used. It is a way to increase service levels and can create profit even when growth is lacking. It does demand an important mind switch from the actors. Exchanging cargo is one way but it goes against the DNA of most operators, sharing warehousing or joining networks are other ways of collaborating. A study of Dutch LSPs shows that 64% of them already cooperate with competitors in a more or less formal manner. 70% have formalised this cooperation, 30% have not. 51% show this cooperation to the market using a common logo or brand. The primary reason is an improvement of service (34%) with growth and profit coming in second and third with 20% and 19%. More than 60% of the cooperating firms would lose customers if they would not cooperate. (Kindt & van der Meulen, 2013)

Wallenburg & Raue (2011) find that more than 60% of the German LSPs cooperate of which 28% plan an increase in cooperation in the future. Vertical and horizontal cooperation in a defined geographical space can lead to the formation of a logistic cluster with the positive effects clusters entail (Kapros, 2014; Sheffi, 2012).

When studying the competition between maritime freight transport and road transport Álvarez-SanJaime et al. (2013) conclude that cooperation between competitors for the maritime part of the supply chain results in economies of scale effects which leads to lower prices, higher margins and higher output.

Heaver (2014) sees a role for the (supranational) government in facilitating collaboration between logistics companies as a way to be better adapted to the ever faster changing economic environment and to handle the increasing uncertainty. The increasing uncertainty can in a more rigid "muscular" approach, where the dominant party ignores mutual gains in favour of self-interest; that, in the long run, is less successful than a more flexible and mutual beneficial "benign" or "credible" approach, where the parties will search for common, mutual beneficial, solutions for contractually unforeseen, and unforeseeable problems (Williamson, 2008).

Implications for seaports

PAs can look at cooperation with a competing neighbour either in the upstream or downstream process. When the typology of Rusko (see Table 1) is applied to port coopetition Table 2 emerges.

Table 2 - Typology of coopetition between port authorities

Type of coopetition	**Upstream**	**Downstream**
High degree	Projects that are part of the core business of the port but where the effects are not obvious for the user. E.g., a common port community system.	Projects that impact visibly the port user and that are part of the core business. E.g., develop an inland or dry port (a bundling/unbundling point with minimally road, and often rail, connections) together.
Low degree	Projects that the port user doesn't experience and that are only marginally important for the port. E.g., lobbying at a supranational level.	Projects that directly affect the port user but are not crucial to the business. E.g., develop a communication campaign for students.

Source: own composition based on Rusko, 2011

Cooperation projects that are transparent for port users, being more upstream, will bring less criticism of collusion, while more downstream projects will need more local support and a clearer distribution of benefits to avoid getting bogged down by opposition.

2.4 Cooperation between ports

Ports are important links in the supply chain. The success of a port cannot be separated from the success of the supply chain(s) of which it is part (Bichou & Gray, 2004; Carbone & De Martino, 2003; Meersman & Van de Voorde, 2014; Meersman, Van de Voorde, & Vanelslander, 2007; Notteboom, Ducruet, & De Langen, 2009; Robinson, 2002, 2003) . The competition has shifted from struggle between individual companies to that of competition between logistics chains (Van de Voorde & Vanelslander, 2008, 2014). One of the important causes was the advent of containerisation, which led to scale increases in shipping and ports and extended the hinterland which increasingly overlapped. This increased competition and lowered the generalised cost (E. Musso, 2009). De Borger et al., (2008) through the use of game theory, prove that investment in the hinterland makes a port more attractive, leading to higher prices and more congestion in the port and to less congestion and lower prices at the competing port. Supply chain integration in a port and between ports is far from complete, leading to port operations sometimes being a destructor of value, rather than a creator (De Martino, 2018)

2.4.1 Port and port authority

Even in academic literature, the term port is not always used in a unanimous way. Simply put, a port is a geographical point where cargo or a passenger changes transport vehicle, often even transport mode. In a seaport, one of these vehicles will be a sea-going vessel. Any but the smallest seaports will consist of more than one terminal, where these activities take place

(Meersman, Van de Voorde, & Vanelslander, 2006; Olivier & Slack, 2006). In such a port, many companies and organisations are active, many of them will cooperate, mostly in a vertical fashion thus constituting a supply chain (Coppens et al., 2007; Meersman, Van de Voorde, & Vanelslander, 2003). Trust between these firms is important, so as to reduce transaction costs (De Langen, 2004). Inside a port, companies will compete for market share and/or for value added share. Besides intra-port, there is also inter-port competition and cooperation between companies and organisations. Many actors in the port belong to large global groups and they will have suppliers, customers and competitors in other ports with which they compete for market share or added value share.

One of the key players in a port is the port authority (PA), which should not be confused with the port which is a more or less formal group of companies and organisations surrounding the interface between water and land. Many types of port authorities exist (The Worldbank, 2003, 2007; Verhoeven, 2011; Verhoeven & Vanoutrive, 2012), but in Europe the landlord type has proven to be well adapted to the changes of the past decades (Cariou et al., 2014; Zheng & Negenborn, 2014). It remains to be seen how the present landlord port authority will need to adapt for the future (Janssens, Meersman, & Van de Voorde, 2003; Meersman & Van de Voorde, 2002; Meersman, Van de Voorde, & Vanelslander, 2009; Van der Lugt, De Langen, & Hagdorn, 2013; Verhoeven, 2010).

The Latin type of the landlord type differs from the Hanseatic one in its more national government management structure (Meersman & Van de Voorde, 2002; E. Musso, Ferrari, Giacomini, Scuras, & Demartini, 2014; Verhoeven & Vanoutrive, 2012). This could be seen as a form of centralised, top-down cooperation between competitors. Spain, Italy and France, seeing the dominance of the Hanseatic North-European ports, are going through a process of transferring more power to local management (Cariou et al., 2014; Castillo-Manzano & Asencio-Flores, 2012; SRM, 2016; Ferrari & Musso, 2011; Lacoste & Douet, 2013; A. Musso, Piccioni, & Van de Voorde, 2013).

Another important actor is the port operator (PO), who in some cases might be the same as the PA, as in a service port, but in a landlord type port, it is mostly a (container) terminal operator ((C)TO).

Hanseatic landlord port authorities, often closely linked to the city administration of the port, have very strong local historical and economic roots (Suykens & Van de Voorde, 1993; Van Hamme & Strale, 2012). They want to maximize the public utility for the local community while, at the same time, reduce the externalities (De Martino, 2018) The influence of a port however extends today much further than the borders of the town of even the surrounding community (Olivier & Slack, 2006). This brings the PA to the realisation of the need to cooperate with other ports in the region and the world.

As has been mentioned earlier, competition between companies is evolving in competition between supply chains. A company can only be successful if it has strong partners up and down its supply chain. Following the concept of ports as a link in the supply chain (Meersman & Van de Voorde, 2002; Meersman et al., 2007; Robinson, 2002, 2003; Zhang, 2008), it is obvious that two types of relations between ports are possible and that they are mutually exclusive. Either two ports belong to the same supply chain or they belong to competing supply chains, although in the case of transshipment a port could be both, but never for the same shipment.

2.4.2 Complementary ports

Complementary ports work together in getting goods from the source to the consumer. They can geographically be found at either end of a large body of water like a sea or an ocean or they can be on the same continent, even in the same country. When viewed from a supply chain perspective, ports and inland ports complement each other in the getting the goods from supplier to customer and they constitute only a fraction of the total end-to-end cost. But, when serving the same hinterland, from the same or even opposing ranges, they become substitutable and will have fierce competition (Meersman & Van de Voorde, 2002). If neighbouring ports service different cargo flows destined for (or coming from) the same hinterland and/or foreland, they are sometimes called complementary (Clark, Jørgensen, & Mathisen, 2014; Notteboom, 2009) but in reality these flows are separate and share little in common. Their physical difference will often inhibit the use of common LSPs or infrastructure. If complementary ports share commercial activities, like overseas sales offices, these will probably address different customer niches.

The benefits of cooperation between ports along the supply chain and across the ocean or the sea, represent a research gap although many cases are known. A few examples are: the cooperation between the Port of Hamburg and the Port of Los Angeles ('Port of Los Angeles and Hamburg Port Authority ink collaborative agreement', 2013); Zeebruges concludes an agreement with Forth Ports ('Forth Ports and Zeebrugge enter strategic agreement', 2013); the Port of Rotterdam and the Port of Gothenburg cooperate in the field of LNG bunkering ('World Maritime News—EU Supports Rotterdam-Gothenburg LNG Initiative', 2013). The Port of Antwerp has a nine year agreement to manage the Port of Cotonou in Benin with the objective of developing local management skills and strengthening the overseas link, as well as making the Port of Cotonou no longer the least efficient port of West-Africa. (L. Hintjens, 2018)

A lot of academic attention is given to cooperation between gateway ports on the one hand and feeder ports, inland ports and dry ports on the other hand (Bergqvist, Wilmsmeier, & Cullinane, 2013; Flämig & Hesse, 2011; Kapros, 2014; Rodrigue, Debrie, Fremont, & Gouvernal, 2010). Under pressure from concentration by forwarders, shipping lines and terminal operators and the emergence of 4PL service providers and the blurring of the distinction between these sectors, a shift from port-to-port to door-to-door has taken place. Inland transport is an important link in this chain and the relative importance of the port has diminished. As a consequence, a port-to-ILT (inland terminal) proposition becomes a competitive advantage (Van den Berg & De Langen, 2014). This increased hinterland has caused a new phase in port development which now includes the link to inland hubs (Notteboom & Rodrigue, 2005). The United Nations Conference on Trade and Development (UNCTAD) (1999) calls this the fourth-generation port where the PA or the PO facilitates or organises links to inland destinations (Paixão & Marlow, 2003; Verhoeven, 2010). But the hinterland of a port is more than a geographical zone on a map. The development of the hinterland is more driven by actors offering complementary services than by spatial developments (Monios & Wilmsmeier, 2012, 2013; Wilmsmeier, Monios, & Lambert, 2011).

Ports can also be complementary on cargo streams, servicing the same geographical customer base: one port can, for instance, specialise in roro traffic while its neighbour concentrates on containers. Other cargo types that can make neighbouring ports complementary are dry bulk, liquid bulk or special projects cargo. Each needs its own specialized handling equipment, which makes a switch from one cargo type to another difficult and expensive. By choosing for complementary activities, two (or more) neighbouring ports can each create economies of scale and avoid overinvestment in expensive facilities.

Even when complementary ports are not competing for cargo, they still could be competing for money from local, regional, national or supranational governments (Meersman et al., 2006)

2.4.3 Competing ports

Verhoeff (1977, 1981) defined four levels of seaport competition: intra-port competition between firms offering similar services in one port; inter-port competition between ports serving the same regions; competition between port clusters and competition between port ranges. The deregulation of the 90’s has intensified port competition but the competition between firms operating in the port industry is much more important than the competition between ports or rather port authorities because many competition factors are outside the reach of PAs (Fleming & Baird, 1999). As such, ports and port authorities are less the real competitors than the companies that make up and differentiate a port or the supply chains of which a port is a part (Meersman, Van de Voorde, & Vanelslander, 2010). One of the determining factors in the competitiveness is the availability and the cost of the hinterland infrastructure that links the port to the supply chains of which it is a part (OECD, 2008; Zondag, Bucci, Gützkow, & de Jong, 2010). The increasing complexity of the port-centred supply chains requires coordination mechanisms that go beyond the pricing mechanism (Van der Horst & Van der Lugt, 2011). Port authorities have an active role to play in facilitating an improvement of the hinterland access (De Langen, 2008).

Intra-port competition fosters specialisation, innovation and diversity while resulting in lower prices and profits. Whereas inter-port competition keeps pressure on efficiency. When the number of competing terminal operators increases, the charged price drops. Van Reeven (2010) confirms this intuitive result through the use of game theory. This would mean that, should two port authorities co-operate together, even merge, the number of the competing TOs in the fused port would be higher than in either of the original ports, this should then lead to lower terminal charges.

The relative market share of a terminal influences intra- and inter-port competition (Kaselimi, Notteboom, & Saeed, 2011). By using a two-stage, non-cooperative, game theoretic model Kaselimi, Notteboom & Saeed (2011) prove that when one large terminal operator, that has economies of scale, uses its market power to increase its prices, this leads to a reduced demand in that terminal but lower user costs because they will need less time to be handled. The customers choosing for lower out-of-pocket costs will go to the significantly smaller terminal that will increase its price following the increased demand. A terminal in an adjacent, competing port, will benefit from the lack of competition. In an earlier work, Saeed & Larsen (2010) showed how the, tacit or explicit, collusion between two ports, by increasing their prices, does benefit a third, non-participating, port. Economic rents of seaports will increase when competition is absent, but an exception should be made for quasi-economic rents (who are, by definition, short lived because they do not constitute a sustainable competitive advantage, being copiable) which will be the result of short-term advantages resulting from technical efficiencies resulting from equipment, training or marketing (Goss, 1999).

Competition, whether it is intra- or inter-port, is as much a concern of the terminals which make up the port, as of the port authority that is the landlord of these terminals (Heaver, 1995; Notteboom & Yap, 2012; Vanelslander, 2005). Terminal operators prefer to control more terminals in any region while port authorities, when having sufficient market power, prefer inter- and intra-port competition (Yip, Liu, Fu, & Feng, 2014).

Some of the world's biggest ports are close neighbours and compete at inter-port level. Examples are: Hong Kong and Shenzhen (Z. Guo & Chen, 2003; Song, 2002); the Pearl river delta (Lam & Yap, 2011; J. J. Wang & Slack, 2000); Los Angeles and Long Beach (Jacobs, 2007); Seattle and Tacoma (Fleming, 2009); Antwerp and Rotterdam (Paardenkooper-Suli, 2014); Hamburg and Bremen (Senatskanzlei, 2009). New York and the ports of New Jersey competed before merging (in 1921) into one authority (Slack & Pinder, 2004).

Competition between ports has intensified mostly through containerisation which has made cargo traffic more footloose while at the same time extending the hinterland. This led to an overlapping of hinterland of neighbouring ports and even of neighbouring port ranges (Slack, 1985). One of the ways that ports can increase their competitiveness is by investing in hinterland connections. Doing so increases the port's output and its profit while reducing that of its competitor. Using game theory, in a Cournot-Nash setting (a non-cooperative game where ports compete by choosing quantities that maximise their profit), it has been shown that this rivalry leads to over-investment which induces local commuter traffic. This in its turn reduces output and profit. Each port maximising its own interest may not lead to an optimum solution for the whole chain. Coordination on pricing and investments between the ports that, partially, share a hinterland, might improve on this (Zhang, 2008).

While ports in one cluster compete, they will cooperate in competing with other port clusters. But the definition of a cluster is flexible. The Flemish ports compete as a cluster against the Dutch ports, while the ports in the Flemish-Dutch Delta will compete together against the ports in North-Germany or the North of France (Nijdam et al., 2014; Vanelslander, Kuipers, Van der Horst, & Hintjens, 2011). The ports of Seattle and Tacoma compete against the ports of Los Angeles and Long Beach (Talton, 2012) while the Western-Canadian ports compete against Seattle and Tacoma (Heaver, 2001). Some port operators can be part of several port clusters simultaneously. Shipping lines, and also terminal operators, can have activities in neighbouring, competing ports. For these actors, port cooperation is not always interesting, on the contrary, it might diminish their capacity to play off ports against each other.

Ports in one range will work together to compete with ports in another range. The ports in the Hamburg-Le Havre range have lobbied together on the extension of the SECA rules to southern Europe and against the allocation of European TEN-T funds to other ranges. The ports on the North American Eastern Seaboard compete against those on the western seaboard (McCalla, 1999). The Hamburg-Le Havre Range competes with the Mediterranean range and increasingly with the Baltic ports (Acciaro, Bardi, Cusano, Ferrari, & Tei, 2015, 2017; Ng, 2009).

2.5 Cooperation between competing ports

The research topic of port cooperation was, until recently, underdeveloped. In their overview of all research done in the field of port economics, policy and management. Pallis et al. (2010) did not include port cooperation as a separate topic in their literature analysis; it is not even mentioned as a subtopic under port competition or port policy. Neither does the literature review by Woo et al. (2012) mention cooperation even if it has several references towards management disciplines. Some academic authors have nevertheless published papers on the topic but most of these are abstract or conceptual. Still the publication of Ports in proximity (Notteboom et al., 2009) and the more recent special issue of Research in Transportation Business and Management (RTBM) on port cooperation (Notteboom, Knatz, & Parola, 2018) indicate that the topic has started to receive some academic interest. However, already in 1983 did Fleming write about the need for ports to rise above community pride and use complementary characteristics to search for economies of scale and scope (Fleming, 1983). And as early as 1938 a book was written to advocate the cooperation between Antwerp and Rotterdam as a balancing force against the German ports (Lambreghts, 1938).

The European Union (EU) and European ports have been trying to come to a common port policy, sometimes top-down, sometimes bottom up (Suykens, 1989, 1995, 1996). But a European port policy has remained elusive so far. The EU still continues to try and develop a policy on port governance which aims at establishing a level playing field (Verhoeven, 2009). Fleming (1983) describes USA ports as complementing each other and competing and cooperating. He also sees port complexes competing between each other and the ports in one complex cooperating.

From 1985 onward, UNCTAD published a series of reports listing the areas of cooperation between ports authorities. These were: the harmonization of port statistics, the harmonization of port tariffs, joint dredging and marine salvage, know-how exchange, training and others (CNUCED, 1985; Trade and Development Board Committee on Shipping, 1990; Trade and Development Board Group of Port Experts, 1986; UNCTAD, 1996). Although the focus of the first report was on ports in developing countries and the second on Mediterranean ports, the list is still actual today for all ports that have neighbours. As an example: Eurostat is, at the time of writing, working with European ports to develop a badly needed hinterland statistics (Lund, 2014).

The competitive position of the port is under pressure from the increase in scale of and the cooperation agreements between shipping lines. The vertical integration between shipping lines and terminal operators even increases this pressure. Port authorities are still struggling to find a new role in this changing environment (Heaver, Meersman, Moglia, & Van de Voorde, 2000; Notteboom & Winkelmans, 2001; Van der Lugt et al., 2013; Verhoeven, 2010). Cooperation between ports might be a way to create economies of scale but especially in the case of larger ports this might be viewed as anti-competitive (Heaver, Meersman, & Van de Voorde, 2001). But it is doubtful if cooperation between port authorities, especially of the landlord type with limited operational responsibilities, would run afoul of anti-trust authorities (AAPA, 2008; Deutscher Bundestag, 2016). Since ports become interchangeable and because port costs grow relatively to shipping costs, it is necessary for ports and port operators to cooperate so they can increase efficiencies but without lowering competition (E. Musso, Ferrari, & Benacchio, 2000). Ports are part of a supply chain but the process of cargo moving through a port is a supply (sub)chain in itself (Coppens et al., 2007). Horizontal cooperation is taking place on all levels in the supply chain that is a port, this reduces the power of the port authority (Van de Voorde & Vanelslander, 2008). Vitsounis and Pallis (2012) see co-creation between players in the port value chain, and the port authorities in particular, as a way to pool interdependencies to create either economies of scale or economies of scope depending on the resources being identical or similar.

Heaver (2011) advocates the coordination between port actors and the integration of investments and operations. This can increase visibility and reliability in a variable and uncertain environment.

The effects of port cooperation on welfare economics are many. They can be categorized in lower internal costs, lower external costs and indirect effects. Through the bundling of flows, a higher degree of occupation of the port and of the hinterland infrastructure can lead to lower costs. Joint investment plans can optimize (government) investments, by the sharing of commercial, ICT and R&D services economies of scale can be realised. Specialisation can lead to advantages of scale and scope. External costs are costs borne not by the shipper but by society as a whole; they comprise costs like congestion, pollution, accidents and wear of the infrastructure (Gibson, Korzhenevych, & Bröcker, 2014). They can be reduced through an optimised use of infrastructure and through bundling of cargo flows to more sustainable transport modes. Joint R&D can accelerate innovation, creating indirect effects on port operators. Indirectly, cooperation can increase the critical mass of ports thus increasing the competitiveness which allows attracting additional cargo, thus increasing regional value added and welfare, and/or increasing port dues. A national government can facilitate or even require the decrease or internalisation of external costs through cooperation while at the same time guaranteeing competition. (Wortelboer-Van Donselaar & Kolkman, 2008).

Stevens et al. (2012) build a typology of port cooperation starting from the different motives that drive cooperation between port authorities : industrial-economic (efficiency and market position) and societal. The authors also list the barriers against cooperation: legislation, funding, cultural differences and differing standards.

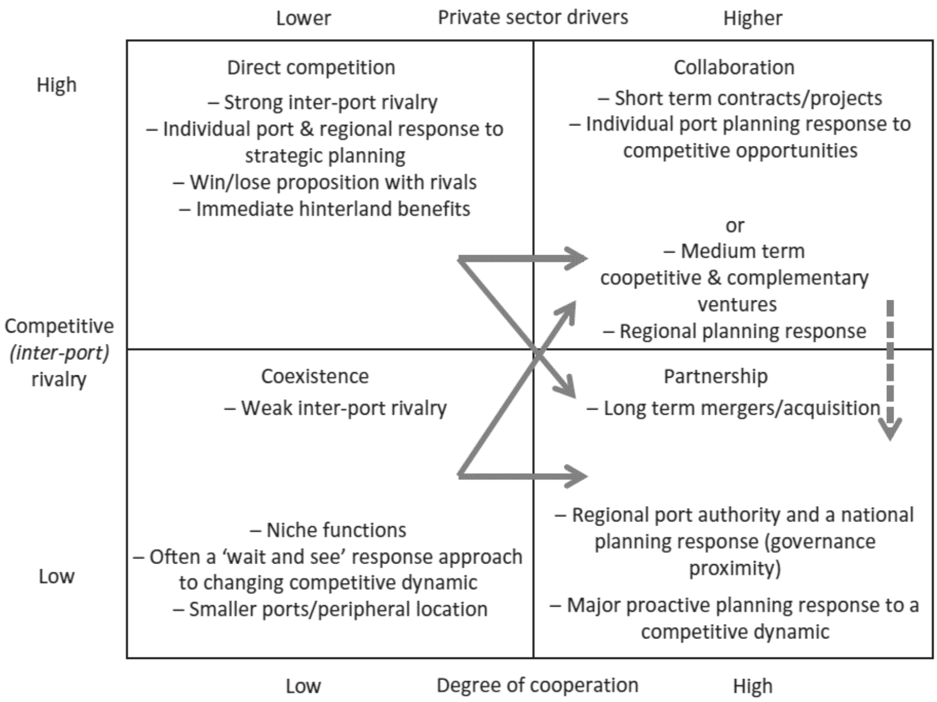
2.5.1 Port coopetition

The seminal article on port coopetition is surely written by Song (2003). While the author does not really specify his focus, he is actually describing port operators and terminal operators in particular, rather than port authorities. He sees coopetition as an instrument to establish a countervailing power against the ever-growing market power of shipping lines. Coopetition can bring economies of scale and additional sales through expanded services or increased customer service. It can reduce the bargaining power of the customers and/or the competition among current competitors as defined by Porter (Porter, 1980). Many authors cited elsewhere expand on the ideas of Song (Brooks, McCalla, Pallis, & Van der Lugt, 2010; Magala, 2004; Verhoeven, 2010; Walley, 2007; Woo et al., 2012; Wortelboer-Van Donselaar & Kolkman, 2010).

The concept of coopetition is applied to several port regions. Song (2003) describes the case of Hong Kong and South China and sees many joint ventures between operators in the different ports of the region. He also describes the situation in Korea (Song, 2004). Brooks et al. (2011; 2010) study the case of coopetition for the Canadian Atlantic Ports.

Mclaughlin and Fearon (2013) adapt the updated concepts (Figure 9) of Bengtsson and Kock (Bengtsson, Eriksson, & Wincent, 2010; Bengtsson, Hinttu, & Kock, 2003) to the seaports and conclude that first, direct competition is not a sustainable strategy; second, ports co-existing beside each other will need to find complementary synergies; and last, short and medium term opportunities for collaboration is one way but long term partnerships are also possible.

Figure 9 - Cooperation/competitiveness framework

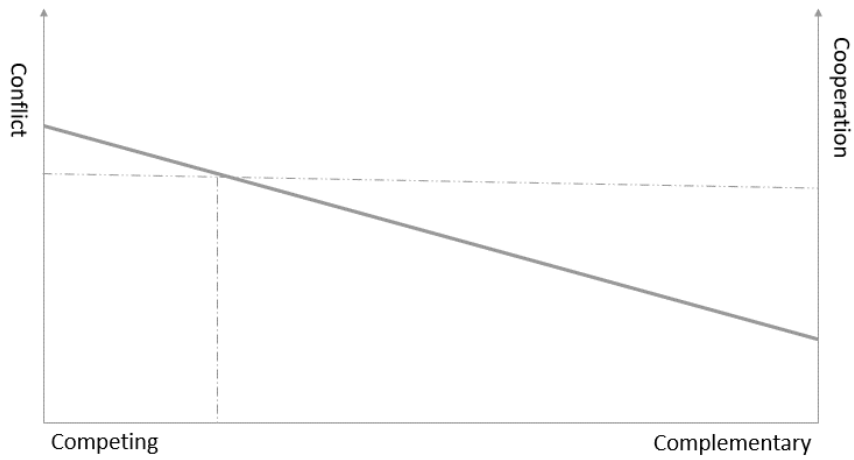


Source: Mclaughlin and Fearon, 2013

2.5.2 Cooperation between adjacent ports

Wortelboer-Van Donselaer & Kolkman (2008, 2010) find, based on interviews, that half of the Dutch port authorities are in favour of port cooperation on a commercial level and suggest a national promotion service of all Dutch ports. For neighbouring ports to cooperate there must be a delicate balance between complementarity and substitutability. As mentioned before, Raue and Walleburg (2013) state that, for horizontal cooperation between supply chains partners (which ports are), similarities have a positive influence on the outcome of the partnership. But similarity also increases the competitive forces that inhibit cooperation. If this is applied on the concept of complementarity and substitutability of ports (Notteboom, 2009) it becomes clear that to cooperate, ports that are complementary have less inhibitors but also have less opportunities of scale. They do, however, have opportunities of scope. Substitutable ports are in the inverse situation with possibilities for economies of scale but with strong competitive forces that limit the drive for cooperation. This is shown in Graph 1, where a high level of competition (as represented by the vertical dotted line) leads to a high potential for conflict, but also a high potential for cooperation (as represented by the horizontal dotted line). And vice versa for a high level of complementarity where there is not a lot of potential for conflict but neither for cooperation. When ports are highly competing, the opposite happens and there is a lot of opportunities for cooperation but also for conflict. The vertical line shows a possible low level of complementarity and consequently a high level of competition and as a result a high potential for conflict and a low potential for cooperation.

Graph 1 - Relation between conflict, cooperation, competition and complementarity



Source: own composition

Brooks and Pallis (2012) see the need for all types of port authorities to cooperate so they can optimise economic development, local or national. This is, according to the authors, the most frequently chosen objective. This cooperation can be within the geographic region or even beyond and can optimize the port performance in the supply chain. Hall and Jacobs (2010) apply the concepts of the already mentioned paper of Boschma (2005) to ports and conclude that the many dimensions of proximity, many non-spatial, have shrunk in the era of global supply chains, leading to collective actions between ports and port companies. Port regions vie for ever increasingly distant contestable hinterlands, this has led to regional cooperation between ports as well on the foreland, through cooperative marketing efforts, as on the hinterland, through corridor formation (Notteboom, 2010).

Asgari et al. (2013) use game theory in a model where the shipping lines are leaders and the POs are followers that define the price in a non-cooperative way in regards to the shipping line, following the port choice of the shipping line, the shipping line can than modify its decision after having learned the new price. They study the effect of cooperation between two hub ports, where the port is also the operator, and conclude that the total revenue of both ports increases through cooperation. Zhuang, Luo and Fu (2013) also use a Stackelberg game theory model to prove that neighbouring ports should cooperate to avoid overcapacity. This analysis is rooted in the fast-growing Chinese ports. Lam, Ng and Fu (2013) see a need for port governance and planning at cluster level, a cluster being a regional port system. The authors want a large number of regional stakeholders, amongst which the port authorities, to be included in this process, since all participate in the services that make up the supply chain surrounding the port cluster. This is applied in a qualitative study of the Pearl River Delta. Wang et al. (2012) use game theory to study the potential for alliance formation in South China. The model suggests that a strategy that combines ‘price raising effects’, resulting from a reduced competition, and ‘output switching effects’ to the lower cost partners in the cooperation, thus avoiding loss of traffic for the whole cluster after the price increase, maximises the economic gains for the partners and has the highest likelihood of being successful. Homsombat et al. (2013) use game theory to prove that regional cooperation in establishing an environmental taxation system leads to higher social welfare and lower pollution.

Some academic studies go beyond the abstract and study real cases of cooperation between competing ports. Already before the second world war, collaboration between the competing ports of Antwerp and Rotterdam was suggested to strengthen their position against further-off, German, competitors (Lambreghts, 1938). Suykens (1973) shows how a cooperation project between the ports of Rotterdam and Antwerp, consisting of building a canal connecting both ports, has a strong beneficial effect on the throughput of both ports. The port of Antwerp and the port community published a series of studies on cooperation between the Flemish ports written by actors in the port (De Wilde, 1989; Huts, 1989). Gagnon (1988), at the International Port conference in Ghent, promoted interregional cooperation between ports. Notteboom and van Klink (1996) published a study describing potential fields for cooperation between Antwerp and Rotterdam based on complementarity.

In their comparative study of port reform in Taiwan and Australia, Chen and Everett (2013) describe how, eventually, in a top-down approach the Taiwanese government merged four PAs in one state-owned PA. In South Australia, al ports were privatised and then sold to one single owner, resulting in a top-down merger. The authors did not mention the, then already planned and meanwhile executed, consolidation of seven Australian (out of eight) PAs into four regional PAs and distributing twelve smaller among them. This was also done in a top-down fashion (Ports Legislation Amendment Bill 2013, 2013). Other countries have, on the contrary, chosen for a decentralisation of the management of their ports.

The South-European ports, originally adhering to a more centralised Latin approach, are, under pressure by the success of the North- and West-European Hanseatic ports, moving slowly to a more decentralised port management. This move from a top-down approach to a more local management opens opportunities for cooperation between neighbouring ports. In Italy and France, these opportunities are forced, in a way, by the central governments that, while handing down management to more regional authorities, at the same time oblige these ports to cooperate and even merge with their neighbours. (Cariou et al., 2014; Ferrari & Musso, 2011)

Trujillo and Serebrisky (2003) study the possible effects of mergers between privatized ports in Argentina. Driven by overcapacity, the, now private, operators want to merge although the original statutes explicitly forbid this in an anti-trust spirit. Horizontal mergers between terminal operators and shipping lines were allowed but horizontal mergers needed to be examined to be assured that enough competition remained. A study of a joint investment, initiated top down by the central government, of the competing ports of San Antonio and Valparaiso in Chile shows a win-win if one port builds a large scale port extension and cooperates with the other port for specialization in larger vessels, since there is not enough volume for two large scale ports and two smaller ports would be less efficient, resulting in less profit for both ports (Trujillo, Campos, & Pérez, 2018).

Shinohara and Saika (2018) develop a typology of port cooperation applied to the Japanese ports. Kobe and Osaka were the first Japanese ports to form an alliance and were followed by the ports of Tokyo, Kawasaki and Yokohama, resulting in a bay wide cooperation (Inoue, 2018).

A vast number of articles in professional non-academic publications refer to cooperation between competing ports. Real, full mergers have been happening oftener between small and mid-sized ports than between global hubs. The best-known recent case is the one of Malmö and Copenhagen although eventually the two PAs choose together one TO for both ports but kept the landlord function of the PA separately. This case also clearly shows the effect of an external event (the building of the Øresund bridge) as a motivator for cooperation. ('CMP - Copenhagen Malmö Port', 2015; Röstin, 2011). The merger of the two Swedish timber ports of Halmstad and Varberg into Ports of Halland is a lesser known example of small, municipal, ports merging (Hallands Hamnar Port of Halland, 2012; 'Two Swedish ports to merge', 2013). In France the cooperation between Le Havre, Rouen and Paris resulted in a unified brand called HAROPA ('HAROPA | Ports de Paris Seine Normandie', 2018). A larger merger is the creation in 2017 of North Sea Ports, joining the ports of Ghent (in Belgium) with the already merged ports of Flushing and Terneuzen (in the Netherlands). This cross-border merger results in a truly multinational, while at the same time being a Hanseatic style, locally run and owned, seaport authority (Vandevoorde, 2017).

Other examples of port cooperation across the globe are : the cooperation between the Port of Los Angeles and the port of Long beach in the development of the Alameda corridor, a 20 miles long railway hinterland connection ('Alameda Corridor Transportation Authority', 2016). Another case of medium sized ports intensifying their cooperation, while at the same time refraining from a full merger, are the ports of Seattle and Tacoma who are joining their commercial management in the PNW Seaport Alliance (Yoshitani, 2018). This cooperation resulted in the revitalisation of a defunct container terminal (The Seattle Times editorial board, 2019; Watkins, 2019). Lam and Yap study the complementarity of ports in the Pearl River Delta (Lam & Yap, 2011). But the biggest merger is surely found in the People's Republic of China where five ports (Ningbo, Zhousan, Jiaxing, Taizhou and Wenzhou) merged into one, two of them are the busiest in the world and Ningbo was even quoted on the Shanghai Stock Exchange (Knowler, 2015; 'World's Busiest Port Duo Complete Merger', 2015). In the following section, these and other real-world cases will be used to exemplify the typology.

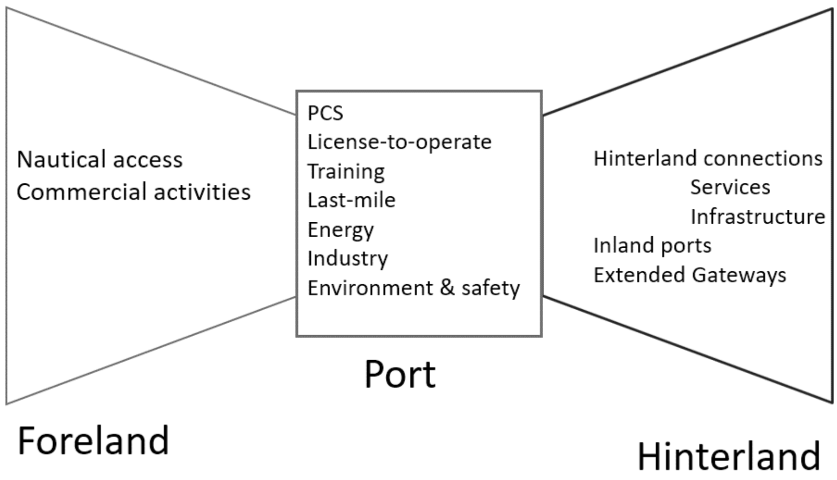
2.6 Taxonomy, a framework to differentiate cooperation projects

The following section describes a classification system rooted in three dimensions which can be used to analyse cooperation between adjacent seaport authorities. In transport economics the term most often used is typology with a list of different subjects, with different characteristics. In natural sciences a word commonly used is taxonomy, the difference being that a taxonomy is, by definition, exhaustive. All possible cases must be able to fit in one or another category. A typology is more flexible, less stringent, and allows for cases to be added in new types, thus expanding the typology. The following classifications strive to be al encompassing, to be comprehensive, so they are taxonomies rather than typologies. Firstly, cooperation projects are classified by the link in the port supply chain the project aims to optimise; secondly, the desired objective of a cooperation is used as a classifying variable and thirdly, projects are ordered by the degree of cooperation they entail.

2.6.1 The triptych of the port: opportunities for cooperation

A seaport can generally be described as a triptych (Vigarié, 1979) that has operations in a foreland, the port proper and a hinterland, thus constituting a (sub)supply chain bringing goods from/to the seaside to/from the supplier/customer in the hinterland. Every link in the part of this chain, that a port represents, offers opportunities for cooperation. In the following paragraphs the type of opportunities that each link can offer will be analysed.

Figure 10 - Cooperation opportunities in the triptych



Source: own composition

2.6.1.1 Foreland side cooperation

The foreland of the triptych that is a port has two zones, the zone that is far away from the port and that is the source or destination of the flow of goods that are coming to or leaving from the port and the zone near the port which is the access area to the port. Both present opportunities for collaboration between adjacent seaports.

Looking at the region across the sea or the ocean, most port authorities organise commercial activities to promote their port. The globalisation has driving this task towards the port authority because they have a stronger interest in pulling supply chains into their port than the global port operators or even shipping lines who are footloose and often are under instruction not to compete with their sister companies in neighbouring seaports.

When port authorities combine their efforts, they aim for an increasing result. This is, for instance, a request from Dutch port users (Wortelboer-Van Donselaar & Kolkman, 2008, 2010). When, conceptually, the effect of commercial activities is analysed, they should lead, if done properly, to an increased market share. But this effect decreases when the market share is large already (Metz, 2010). With a decreasing return to scale, looking at a given market or foreland, when a high level of market share is reached, it takes a strong effort to increase it further.

Market share depends on the definition of market. It makes sense to define overseas markets for ports on two dimensions: region and product. Trade regions are often divided in Far-East, Middle East, Mediterranean, Europe, North America, South America and Africa. Based on the speciality of the port they can be further divided in smaller sub regions. Products are categorized on the first level by appearance, i.e. in liquid bulk, dry bulk, roll-on-roll-off traffic (roro), containers and other general cargo. This market definition leads to a two-dimensional matrix combining region with product. When a port has a large market share in one cell, the potential for cooperation with another port, aimed at the same cell, becomes less obvious. These two ports could be seen as being substitutional and competing. It would make sense for a small port, with a small market share, to cooperate with a bigger port, but the decreasing return makes can make it into a nearly zero-sum game for the larger port. Economies of scale in one cell will only be realised when all cooperating ports have a small to medium market share, the cooperative marketing effort will then result in a bigger impact than when they would have when done separately. But, when two ports that target the same region but in different trades cooperate then economies of scope always apply, these ports can then be labelled as being complementary.

Table 3 shows that a cooperation between ports A and B has inherent sources of conflict: if both ports are mid-sized then economies of scale are possible but the divisions of the spoils of the cooperation will be fraught with discussions. Ports C and D on the other hand can share or combine a regional sales office and the resulting cargo flows will automatically go to the right partner. Port E and port F, lastly, have no reason for a commercial foreland cooperation, the marketing efforts are geographically dispersed, so no economies are possible and if there would be cooperation the result would lead to disputes as to the beneficiary.

Table 3 - Trade-regions combinations

	Liquid bulk	Dry bulk	Roro	Containers	Other general cargo
North & Middle America	Port E				
South America	Port F			Port A & Port B	
Africa			Port C	Port D	
Europe					
Middle East					
Far East					

Source: own composition

Thus, a cooperative marketing effort in a region will be more effective if the portfolio of services offered, i.e. the different trades, is larger and the marketing presence can be used for more services simultaneously. An interesting, and exceptional, case is the North Adriatic Port Association (NAPA). It has been shown that when a ship calls on one port in the region, it calls on (almost) all ports. But not enough ports call on the region at all to satisfy the ambitions of the involved port authorities. So, when they prospect for new clients together, they benefit all together (Stamatović, de Langen, & Groznik, 2018).

Remains the problem of dividing the result and benefits of the combined marketing effort. Overmeire (2014) studied the application of the Shapley value to optimise the results of horizontal cooperation in a supply chain, the results of which are applicable on sea port authorities. Each port should be rewarded for its effort, out of the benefits, in proportion to the value they bring to the cooperation. Bergantino & Coppejans (2000) find the Shapley approach cumbersome and the solutions unrealistic since it does not allow for difference in price sensitivity between port users.

The immediate foreland (access area) is another field for cooperation between adjacent seaports, since they share a geographical space. Seaport authorities need to keep the access lanes to their ports open and the associated costs as low as possible. This reduces the generalized cost of shipping for the goods destined to or originating from their ports thus increasing the attractiveness of the port and consequently, the throughput. This is clearly a non-zero-sum game for the cooperating ports because it will deviate traffic to them together that would otherwise have been lost to all of them. The cost of dredging or ice-breaking an access route to a port will drop radically for each port when shared by two or more ports. This is common practice in the Gulf of Bothnia where ports will combine their needs for ice-breaking so one ice free canal can service several ports at once. Exactly the same principle, although less seasonal, applies for dredging access routes and rivers to ports. Pilot and tugboat services can similarly be offered under one contract serving several ports, e.g., the Great Lakes in North America (John C. Martin Associates, 2017). It is obvious that the cost per ship and per cargo unit will be lower if the services can be offered to more customers by combining the needs of more than one port. The only condition being that the ports are located on the same access route and are servicing similar ship sizes. Even if the services offered are traded on a free and open market as can be the case of tugboat services and even pilot services, although this is not always happening, by combining markets, the ports can facilitate a bigger market, with more service providers thus resulting potentially in a lower price per unit. This lower foreland cost will result in an increased consumer benefit as will be developed in chapter 3.2.

Short sea shipping (SSS) deserves a special mention. When a port serves as a hub in a hub-and-spoke model for intercontinental (container) lines, smaller ports could cooperate to create one hub amongst them thus increasing their accessibility for the deep-sea traffic. In this case SSS could be seen as a hinterland connection. But ports can also serve intra-continental (container) transport and as such compete with road and other modes of transport, by cooperating, e.g., exchanging best practices, ports can increase the efficiency of SSS, thus increasing their SSS throughput, port pricing is crucial to reach this objective, it needs to allow SSS to compete with road transport. (Pettersen Strandenes, 2014; Suarez-Aleman, 2014)

2.6.1.2 Port side cooperation

Within the port itself, several opportunities for cooperation present themselves. All operations related to security of people and the environment should not be subject to competition. Neighbouring ports, and the society of which they are part, have an interest in a level playing field when it comes to environmental and security laws and regulations. These are largely governed by (supra)national bodies, but PAs should and do coordinate the implementation within their respective ports to avoid creating a competitive advantage at the expense of the society surrounding the port. Especially when the competing ports are subject to different national legislation, cooperation is needed to avoid a race to the bottom. Port users expect a level playing field (J. Hintjens & Vanelslander, 2018).

Ports that are close to each other in a geographical and cultural sense can also create economies of scale by cooperating in the organisation of education and training, many ports suffer from a lack of attractiveness for students and young employees. When different ports are serving the same educational culture, they can combine their investments towards this target audience. They can work together on their image and the maintenance of their licence to operate, e.g., the ports of Antwerp and Rotterdam organise a bicycle race, the World Ports Classic, together ('World Ports Classic', 2015).

An interesting but not very likely project for cooperation, also due to very dissimilar laws and procedures (Ferrari, Parola, & Tei, 2015), would be the concession awarding process. It is one of the primary activities of a landlord port authority to award concessions to port operators (PO). This crucial element in the operation of a port has long term strategic consequences on the attraction of the port. The process will define the quality of the services offered as well as the price at which they are offered. The globalisation of the POs has changed the balance of power between the PA and the PO. This change has led to a bigger share of the created added value being grabbed by the PO. Cooperation between port authorities could be a way for the PA to regain a part of their negotiating power. By coordinating their concession procedures and especially the planning of the awarding of the consecutive concessions, they would avoid being in a situation like the three Curiatii brothers (Livius, 1849) who lose the battle because they act in disarray. Through the lack of coordination between the PAs the POs have the upper hand in the process of the separate concession awarding procedures by bidding for every concession separately. The increased power the PAs could realise through coordination, can be used in two ways or a combination of both. Either each PA can claim higher concession fees without leaving room for the PO to increase the fees it charges its customers because competition between POs of the cooperating ports would avoid an increase in handling charges. Alternatively, the PAs could use the power to force the PO to charge lower fees for their services. The added value creation by the TOs would not change, but the value capture ability of the PA and, in the case of a public landlord PA, society would increase. Added value which is captured, and exported, by a foreign operator is lost for society from a welfare economics point of view. Additionally, when the number of players offering services in a market increases, the price can be expected to drop, and the quality can be expected to increase. By combining the market for TOs of two ports, the number of suppliers available to the combined market would be bigger than in each market separately. But as can be deduced from (Notteboom, Verhoeven, & Fontanet, 2012), even the exchange of best practices in concession awarding procedures between POs is not a current practice. The recent mergers of the Italian ports had concession management as one of the main objectives, the other being investment planning (Ferretti, Parola, Risitano, & Vitiello, 2018).

Ports can cooperate in the creation of a port community system (PCS). Through the networking effect, information increases its value when shared by more actors and, additionally, when ports are sufficiently similar, the fixed cost of creating a PCS can be carried by a bigger user base (Carlan, Sys, & Vanelslander, 2016; Mclaughlin & Fearon, 2014). It is the cooperation project with the highest preference amongst small and medium sized companies of the Antwerp port community (J. Hintjens & Vanelslander, 2018; 'KMO's liggen niet wakker van samenwerking tussen havens', 2016).

Many ports who have historically originated in the centre of cities have seen their location shift steadily to the edges of the cities. One of the effects of the ports moving away from the city centres is that potential employees might forget the job opportunities a port might offer. This happens at the same time when there is an increased demand for higher trained personnel, which can be hard to find. Most PAs have programs to draw the attention of young people and students, some even have training programs for (overseas) personnel. PAs can fulfil their coordinating role by aggregating the needs of the port companies and presenting them to the education authorities. Since neighbouring ports will often share the same educational system they would be more effective by doing this together, also the training programs run by PAs can be organised more efficiently if done conjointly. Increased effectiveness in promoting the port as a workplace and in organising training also helps the PAs to maintain their licence to operate.

A more general cooperation potential project is the combining of procurement, but it remains to be seen if the additional bureaucracy doesn't outweigh the benefits of the increased purchasing power. The synergies and economies of scale, as well as the enhanced negotiating power that is the result of the bundling of purchases is obvious. However, the hidden increased costs of bureaucracy can outweigh the benefits, especially in the case of low value goods where an even important relative decrease in purchasing price will not compensate for the additional administrative procedures, and their related fixed costs, that are the result of bringing the purchase orders together. The resulting gain in purchasing power and economies of scale might actually be lost through an increased transaction cost. Haralambides et al. (2001) suggest that unified accounting procedures would result in positive welfare effects especially in a cost-plus pricing model.

2.6.1.3 Hinterland side cooperation

The more extensive the hinterland of a port(region), the more attractive it is as a gateway port(region) (Dooms, Haezendonck, & Verbeke, 2010; European Commission, 2014b; Fleming & Hayuth, 1994; Meersman & Van de Voorde, 2014). Containerisation resulted, among other effects, in the extension of the hinterland. Containerised goods can be transported to or from the hinterland more efficiently, faster and at lower cost (Woodburn, 2010). The longest distances and cheapest transport modes demand bundling of flows so that bigger transport vehicles like trains and barges can be used. For smaller ports or for more distant destinations, and origins, the volumes might not be large enough to make bundling a possibility, thus actually marking the border of the hinterland for this port. The hinterland, particularly, can have a strong influence on the development of a port (Meersman, Van de Voorde, & Vanelslander, 2016). By cooperating, PAs can facilitate the combining flows thus arriving at larger volumes and enabling bundling. PAs can facilitate or even organise the final mile of railroad transport in their ports and by combining the final mile part of two adjacent ports, the increased handled volume will lead to an economy of scale inside the port part of the railroad while at the same time bringing together larger volumes of freight which enables more long-distance train connections to be economically viable. Vanoutrive (2012) quantitatively shows, the correlation between the size of the port and its hinterland connectivity.

Eventually, these bundled flows of train and inland shipping need to be handled somewhere closer to their final destination. These inland ports for barges or dry ports for trucks or trains, need minimum volumes to be economically viable. Cooperation between PAs can facilitate the bundling of flows to inland ports thus creating sufficient volumes to facilitate additional and more distant inland ports. In the case of existing inland ports, cooperation can create economies of scale and make more use of what are largely fixed costs in infrastructure. The expansion of the use of an existing inland port through cooperation will result in a more efficient use and the resulting economies, if transferred to the user, will reduce the generalised cost. If a new inland port is created, where without cooperation there would not have been enough volume to make this possible, then the result will be an increased attractiveness of the concerned ports through an expansion of the market and the hinterland, while at the same time the bundling will allow expensive road transport to be replaced by cheaper (internal as well as external costs) rail or barge transport.

This hinterland can be extended by the development of infrastructure e.g., the Alameda Corridor, developed by the port authorities of Long Beach and Los Angeles (‘Alameda Corridor Transportation Authority’, 2016). But most infrastructure is financed by national and supranational governments and PAs can then cooperate in lobbying for their common projects. Ports can cooperate in developing inland ports and dry ports. The Port of Antwerp and the Port of Rotterdam tried to acquire together the German inland port of Duisburg in 2010. The German ports and national authorities did not favour the idea of the foreign “west ports” acquiring a controlling interest in what they consider is a critical part of German infrastructure (Uni-Muenster, 2011).

Landlord port authorities do not offer services linking the port to the hinterland, but they can facilitate their offering. PAs can financially support the launch of new, bundled, service to the hinterland or the operation of transfer points where flows from two or more ports can be bundled. An example can be found at the port of Antwerp where the PA helps in kick-starting a new barge hinterland connection (‘Antwerpen wil kleine containervolumes in binnenvaart helpen bundelen’, 2015). Although, so far, this has not increased the port’s competitiveness, it might have avoided a loss in attractiveness if the services would not have been developed (Haezendonck & Langenus, 2019). In cases where one port alone has not enough cargo destined for a particular hinterland region, it might be profitable to combine cargo with a neighbouring port.

Table 4 - Summary of cooperation in the triptych

Foreland	Port	Hinterland
Marketing Dredging Ice-breaking Pilot services Tow services	Procurement PCS License to operate Training Concession allocation	Infrastructure Services Inland ports Dry ports

Source: own composition

The hinterland being the remaining battlefield for ports (De Langen & Chouly, 2004) and the relatively increasing importance of the cost of hinterland connectivity, the hinterland will be the main focus of the conceptual model of chapter 3. It offers opportunities for improving the competitiveness of the participating ports while at the same time augmenting the consumer surplus of their users and as a result increasing the regional welfare. The rapid growth of maritime shipping and consequently the growth of many ports over the last decades has led in many port regions to bottlenecks in the hinterland connectivity leading to increased supply chain costs through inefficiencies and increased external costs (Woodburn, 2010). Increased road haulage as a result of increased port throughput is an important driver of increased congestion in port areas (Zhang, 2008). Representing the larger part of the maritime supply chain, with 7% of the volume (in tonne-kilometres) but 80% of the cost and 30% of the CO_2 emissions, hinterland transport offers the biggest savings in direct and external costs (*ITF Transport outlook 2017*, 2017) .

2.6.2 The objective: reasons for cooperating

Another way to classify cooperation between seaport authorities is by the motivation for the project. This motive can be profit or non-profit and the gain could be destined for the PA or for society at large. There are several motives that can drive cooperation but eventually they can be summarised in a dichotomous taxonomy: profit or non-profit.

2.6.2.1 Profit motives

Any cooperation project will require an investment of money and time, so against these costs, some results are needed to justify the expense. The first beneficiary of the gain can be the port authority. Through cooperation, two or more PAs can strive for a reduction of operational costs by sharing services, or by combining specific marketing or public image campaigns. These synergies will result in operational costs savings (Lipczynski et al., 2009) which will increase the profitability of participating PAs. More strategically, PAs can, through cooperation, reduce the risk linked to investments in the development of new services and infrastructure. While at the same time increasing their revenue through the new offerings. By joining forces with competing neighbours, ports can share the burden of the risk of a project. As shown in the literature review earlier, sharing the risk of R&D and investments is a main motivator for horizontal collaboration in many industries. One of the oft-mentioned projects where ports cooperate in the development phase is a port community system (PCS)('IPCSA - International Port Community System Association', 2019). Also, cost savings can be made by cooperating in the commercial development of new (geographical) markets.

Another way to increase profitability is to increase the market power (Lipczynski et al., 2009) of the PA by cooperation with its neighbouring competitors. By presenting a common front towards the direct customers, i.e. shipping lines and terminal operators, PAs can reinforce their position against threats by footloose customers of taking their business elsewhere. When applied during the concession allocation process this would allow the PAs to negotiate and capture a higher share of the value added created in the port and, considering that the profit made by foreign shipping lines and terminal operators is exported, it would have a positive impact on welfare economics of the region. Obviously, this is the cooperation project which runs the highest risk of falling foul of anti-collusion legislation. The increased level of seller concentration is only one of the uses of market power; another use that is relevant in the port sector is increased buyer concentration. Cooperation between PAs would also increase the purchasing power when procurement of high-ticket items would be done jointly. The effect of the use of market power depends on the easy of entry of new players; in the port sector, with its geographic constraints, this entry can be very difficult and even impossible for new ports in a developed region.

Cost savings can also increase the profitability of cooperating PAs by rationalizing production, through specialization of the partners, by economies of scale and by sharing R&D costs. The above-mentioned buyer concentration can lead to purchasing economies (Lipczynski et al., 2009).

But some benefits of cooperation accrue outside the PA, in the regional economy surrounding the port. The Hanseatic landlord PA, with regional development as its main purpose, is of course also motivated by the social profit effect. Job training and career promotion for the port sector doesn't profit the PA directly but benefits the port stakeholders. Such projects can be more efficient and effective if neighbouring port authorities execute them jointly. Infrastructure investment in docks, locks and quays often create a large leap upward in capacity and result in a (often temporary) overcapacity. Adjacent ports would, therefore, benefit from synchronising their infrastructure planning as to stagger the introduction of large capacity increases, while still maintaining the needed free capacity to allow gradual expansion. This is, of course, easier said than done but the societal benefit of avoiding long periods of overcapacity is obvious, especially when they are financed with public means. In a top-down cooperation, a higher, subsiding authority can optimise the allocation across different ports when these ports, voluntarily or not, coordinate their investments.

But probably the most important reason to cooperate is to extend the hinterland connectivity, this allows a reduction of the generalised transport cost which benefits all customers of the collaborating ports and increases their attractiveness for cargo. By facilitating the bundling of cargo of two (or more) neighbouring ports the PAs can make the cargo flow achieve a critical mass that allows a modal shift to a more efficient and more sustainable transport mode. This does not only benefit the port authority and the port users but society as a whole, due to the lower ecological footprint of the transport system. This increase in cargo flows, besides leading to higher revenues for the participating PAs, will have a self-reinforcing effect of attracting more service suppliers, which in turn will lower the prices of these service which will increase the attractiveness of the port complex.

2.6.2.2 Non-profit motives

Finally, there are also non-profit motives for cooperation. Many find their origin in the principal-agent relationship which divorces ownership from control. This can lead to a pursuit of goals which are not the ones originally chosen by the shareholders (Lipczynski et al., 2009), which in the case of a public landlord port, are the local or national government. Possible projects falling in this category are mergers without any economic benefit eventually but who extend the manager's realm. This could inversely also be a non-profit reason not to cooperate, thus protecting the position of the incumbent management or shareholders.

Table 5 - Summary of cooperation by motive

Profit motive			Non-profit motive
Internal to the PAs		External to the PAs	
Cost saving/revenue increase	Market power	Social profit	Managerial hubris
• Joint image campaign • Shared services • Joint investments • Joint R&D • Joint PCS • Joint commercial development	• Concession allocation • Joint procurement	• Job training • Career promotion • Synchronised planning • Hinterland development	

Source: own composition

2.6.3 The degree of cooperation: ways of cooperating

Lastly, cooperation projects can be classified on a unidimensional scale of intensity, by looking at the level of commitment and integration a project entails: they can range from a one-off ad-hoc project to a full-blown merger.

2.6.3.1 Ad-hoc cooperation

Sometimes an opportunity or challenge presents itself where adjacent seaports will benefit from an allied approach. e.g., the ports of Antwerp, Rotterdam and Hamburg joined forces (unsuccessfully) to try and extend the ECA zone also to the North-Mediterranean. They also lobby together, joined by the smaller ports in the Hamburg-La Havre range, at the European commission against a fragmentation of infrastructure investment in a multitude of small (South-European) ports because they believe these investment will be less efficient and less environmentally friendly then when they would be done in the large, efficient (Hamburg-Le Havre range) ports that already have an extended hinterland connectivity (‘Rapport doet strijd tussen havenranges weer oplaaien’, 2014).

2.6.3.2 Project-based cooperation

Competing ports can together develop a long-term project when the resources and the benefits transcend one port. The USA ports of Long Beach and Los Angeles have developed together the Alameda corridor to diminish congestion surrounding the ports. The New-Zealand ports of Auckland and Tauranga decided, after advise from common customers, to integrate their separate PCS into one (MacIntyre, 2013). The North-German ports of Bremen and Hamburg try to get a freight railway built connecting them both to the German heartland (‘Hamburg und Bremen zahlen für Y-Trasse’, 2010). The development of the hinterland connections of a port region like the Alameda railway reach a break-even point of volume faster if two or more port authorities cooperate in facilitating the bundling of cargo flows. Joint projects do not have to be mission critical as the already earlier mentioned project of a bicycle race between the ports of Rotterdam and Antwerp shows.

2.6.3.3 Institutional cooperation

Many projects bring competitors together with other ports in institutional cooperation initiatives like the International Association of Ports and Harbors (IAPH), the American Association of Port Authorities (AAPA), the European Seaport Association (ESPO), the North-Adriatic Ports Association (NAPA), Flemish Port Area (FPA), the newly formed North-West Seaport Alliance (Which consists of the ports of Tacoma and Seattle) (‘Seattle and Tacoma unite in new alliance’, 2015). Some of these regional associations can be an embryo for a more intensive cooperation down the road. The list of regional associations is endless. Their aim is mostly to lobby with the authorities to influence regulation, and to hold the pen of whomever is writing legislation or at least influence the process.

2.6.3.4 (Near-)Mergers

The farthest-reaching form of cooperation is a merger. Already in 1921, the bi-state port authorities of New York and New Jersey merged but they oversee much more than just the port activities (Levinson, 2008). Other mergers between ports are of a much smaller scale. The most visible in recent years was the supposed merger between the ports of Copenhagen and Malmö. Supposedly, because eventually the two PAs remained apart but selected one port operator for both ports which operates the ports under one name (‘CMP - Copenhagen Malmö Port’, 2015). The ports of Vlissingen and Terneuzen merged into one port, named Zeeland Seaports, and this port merged across the Belgian-Dutch border with the neighbouring port of Ghent, creating a truly international, but still Hanseatic, locally owned and managed, landlord port authority, the North Sea Port becoming one of the European top ten ports. Its first year of operation has resulted in a strong growth (Vandevoorde, 2018b).The case of CMP inspired more Scandinavian ports; the Swedish ports of Halmstad and Varberg merged into the Port of Halland (‘Two Swedish ports to merge’, 2013). A cross border merger was realised by the Swedish port of Umea and the Finnish port of Vaasa (‘Getting in with the neighbours’, 2014). The French port of HAROPA is the union of the ports of Le Havre, Rouen and Paris, stretching all the way inland and maximising economies of scale and scope (‘HAROPA | Ports de Paris Seine Normandie’, 2018). They were joined by the ports of Cherbourg and Caen (‘Caen et Cherbourg rejoignent Haropa’, 2014). This union generated a record growth in 2013 and 2018 (‘Haropa snelste groeier in containertrafiek in 2013’, 2014; Martel, 2015; Vandevoorde, 2018a). But the cooperation is hindered by internal conflicts partially due to particularism, where the constituent parts prioritise their own short term, often managerial, interest, and a rotating presidency (Peeters, 2017) The regional government of Western Australia merged its eight port authorities into four regional ones (‘Western Australia’s Port Authorities Merger under Review’, 2014). This was driven by a need for investment in port operations which the public sector was no longer willing to carry (‘Amalgamating the Ports’, 2013) .

The already mentioned devolution in Italy from a centralised governance to a local management has resulted in the creation of multi-site gateway ports merging the 24 PAs to 15 “Port System Authorities” (Ferretti et al., 2018). But the contradiction between centrally forced local cooperation lacks the flexibility to adapt to local particularities (Parola, Ferrari, Tei, Satta, & Musso, 2017). In France, a similar strategy resulted in establishing cooperation mechanisms and enhancing merger projects in four regional port systems in the hexagon:

Seine, Hauts-de-France, Méditerranée and Atlantique. (Fourneyron & Revet, 2016; Secrétariat général de la mer - Premier ministre, 2018)

But the biggest merger in recent history is, for the moment but hard to top, the union of five ports in China. The ports of Ningbo and Zhoushan were already amongst the biggest in the world but with three smaller ports (Jiaxing, Taizhou and Wenzhou), they merged into Zheijang Port with a combined volume of 873 million tons. The port of Ningbo was even quoted on the Shanghai stock exchange (Knowler, 2015; 'Port Strategy—China brings major ports together', 2015; 'Ports of Ningbo and Zhoushan Complete Merger | World Maritime News', 2015; Zhong, 2015). The merger was already mentioned in 2005 and took more than ten years to be realised ('Chinese Seaport Ningbo Port merges with Zhoushan Port', 2005). The port stretches over a distance of 350 km from north to south but are all situated in one province (Wu & Yang, 2018). If this mega-port would merge with its, also massive, neighbour: the port of Shanghai, the resulting economies of scale would further increase its competitiveness against other, foreign, ports (Li & Oh, 2010). The aforementioned authors believe that a merger and the resulting increase in concentration of container throughput, as measured by the Hirschman-Herfindahl-index (HHI), would automatically result in scale economies. The effects on prices and service levels of such a merger for the users remains to be analysed. With the Belt and Road Initiative, the push by the national government for Chinese ports to cooperate will not abate (Huo, Zhang, & Chen, 2018).

Mergers seem easier in privately owned ports, the privatisation under Thatcher in the eighties of most ports in the UK was followed by a wave of mergers resulting in a few large port operators having several ports in their portfolio e.g., ABP which controls over 20 private service ports (Baird, 2013; 'British Ports Association', 2016; 'The United Kingdom Major Ports Group Limited (UKMPG)', 2016).

2.6.3.5 Failed cooperation initiatives

Obviously, not all cooperation projects become successful. The unsuccessful projects are of course not often given a lot of public exposure. Following examples have come to light. The port of Ravenna pulled out of NAPA after two years, they found their interest insufficiently represented. The port of Zeeland started a close cooperation with the port of Rotterdam which could have evolved into a merger, but in 2006 the port of Zeeland decided "to end the marriage but to remain friends" (*Einde havenhuwelijk geen ramp*, 2007). Dropping throughput figures at the ports of Ostend and Zeebruges brought the local authorities to the idea of merging the two Hanseatic landlord ports. A study showed that the water between the two was, for the present, still too deep and the project was shelved. The ports of New-Zealand went through a period of amalgamation in the 70's, but they decentralised in the 80's and privatised as of the 90'. Local control seemed better suited to respond to the needs of the economy; the top-down approach of this merger was the main cause of its failure (Pyvis & Tull, 2015). A merger proposal in 2001 by the port authorities of the Port of Houston and, the nearly bankrupt, Port of Galveston was rejected through a referendum by the inhabitants of Galveston. The inhabitants of the city with the smaller and economically weak port did not trust the big port authority of Houston and feared that they were being sold out and were getting a bad deal (Galvao, Gharehgozli, & Mileski, 2018).

2.7 Driving forces, success factors and conclusions

The last section of this chapter concludes with an analysis of the initiator (the actor that gives the impetus for a cooperation project) of the cooperation and concludes with an analysis of the factors that need to be present for the cooperation to be successful.

2.7.1 Top-down vs bottom-up: the driving force

As discussed in section 2.1.3 a cooperation project can be initiated by a participating partner or by a third party, who can be beneficiary (tertius gaudens) or simply bring the participating partners together (tertius iungens), which can stimulate the competitors to work together and reduce the risk of opportunistic behaviour. When applied to ports, the third party can be a regional government or an important port user. The actor that drives the cooperation can have an important effect. Some of these projects emanate from the port authorities themselves or their users, they can be considered to be bottom up and carried by the local actors. This is the case for most of the project-based cooperation ventures. The merger of the ports of Ghent and Zeeland was entirely driven by the CEOs of the respective PAs.

Some mergers, or projects for mergers that have not (yet) been realised, come from regional or national governments that are driven by a lack of funds to sustain the high need for investments. The already mentioned mega-fusion of the five Chinese ports was done at the demand of the local, regional, government of Zheijang Province. In Germany, politicians of the regional governments request the creation of a "Deutsche Bucht". This should intensify the cooperation, especially for the hinterland development, of all North-German ports but especially Bremen/Bremerhafen and Hamburg (Harms, 2012; Senatskanzlei, 2009). The Los Angeles Commission 2020 suggested a merger between the ports of Los Angeles and Long Beach but this was forthwith rejected by the port authority of Long Beach ('Long Beach dismisses proposed Los Angeles merger', 2014; Los Angeles 2020 commission, Mickey, & Austin, 2014). The cooperation between the Flemish ports has always been favoured by the successive regional ministers of mobility (De Lloyd, 2013; Flows, 2015) and even some of its bigger users (Huts & Van Bochelt, 2015) but the PAs and the local city councils that control the PAs remain cautious (Port of Antwerp, 2012). The cross-border merger of the Flemish/Belgian port of Ghent with the Dutch Zeeland Seaports probably put a term to the project of the Flemish Port Area, Zeeland Seaports being out of the jurisdiction of the Flemish government. PAs are mostly hesitant to be part of a top-down forced cooperation project as can be seen in Flanders, Germany and California. When, like in the case of the, already described, French and Italian ports, where very recently port mergers have taken place, a national government forces ports to merge with neighbours, this is actually a case of a centrally controlled port system decentralising its power to local ports, but making them big enough to be efficient.

On the other hand, sometimes (supra)national authorities might discourage or even outright forbid cooperation between PAs for fear of anti-competitive behaviour: just getting permission to exchange information might be problematic ('Competition authorities say no to Basque port cooperation', 2014; 'Seattle, Tacoma Ports Get FMC Blessing to Share Information', 2014).

It can be concluded that in the case of Hanseatic PAs the regional or national government does not have the necessary power to force, top-down, an unwanted cooperation, let alone merger, on unwilling port authorities. Only in the case of strong nationally controlled port governance, as is the case in France, Italy and China, can cooperation and mergers be initiated in a top-down fashion. So, for a cooperation project to be successful, a strong local initiator and local benefits are important to create the necessary success factors. This will sustain the hinterland cooperation developed in chapter 3 and further.

2.7.2 Success factors

More than shared resources, neighbouring Hanseatic landlord PAs have a shared mission: enhancing the economic welfare of the surrounding, often overlapping, region. Surely, if two or more ports have the same, non-competing, objective, it becomes logical to try to enhance each other's actions. This creates opportunities to reinforce each other in attaining these objectives, making the resulting effort bigger than the sum of the parts. Looking at the different level of cooperation projects and the different cases where they were, or were not, successful, the following success factors can be discerned.

Competing ports are more likely to cooperate if they have a delicate balance between similarity and diversity. If they are too different in size, cargo type or regional focus few opportunities for cooperation will be present and if they are too similar then the competition force will drive them apart.

Different stakeholders might have different reactions to specific cooperation projects. A service provider for customs clearance might actually prefer complex regulations differing between adjacent ports because this allows maximising his value added. A shipping line or a terminal operator might praise 'divide et impera' and will prefer to have different PAs to play against each other. But the shipper will want fast and frequent hinterland connections that necessitate the bundling of flows of adjacent seaports. Cooperation projects, especially in the case of publicly owned ports, must, therefore, be viewed from a welfare economics viewpoint. Does the project benefit the regional economy, more than just one group of actors? This will also be the focus of the methodology developed in the following chapters.

From the literature review and all the different cases mentioned in this chapter, a conclusion can be drawn on the potential for a cooperation project to become successful. A cooperation project can be **feasible**, from a legal or technical point of view. For instance, if two ports are legal entities with different shareholders, it is legally feasible to exchange shares between shareholders or create a joint holding company that holds the shares of what then becomes subsidiaries, which is the approach of the newly formed North Sea Port.

A cooperation project can be **likely**, if most stakeholders are in favour; if a large majority of port users sees a benefit, this increases the likelihood that a project becomes reality and that the community champions a cooperation project. For instance, port users of two ports might ask for a joint PCS.

A cooperation project can be **desirable** from a welfare economics point of view. If the regional economy, through an increased attractiveness or a savings in investment, benefits from a cooperation project, then the representatives of this regional economy, i.e., the local politicians, will support and promote the project. For instance, German politicians want the North German ports to bundle forces.

But a project can be desirable and feasible but still not likely to happen if a strong stakeholder is opposed. For instance, the main shareholder of a port might not want to share its profits with other ports because it might fear a dilution of power or financial return, even if it would be legally feasible and would be desired by the large community. Alternatively, if one of the partners, often the junior one, feels disrespected and fears to be swallowed entirely without enjoying the benefits, this partner will oppose the project.

For a cooperation project to have a chance of succeeding the three conditions: feasibility, likeliness and desirability must happen simultaneously. Projects that extend the hinterland of a port region will benefit all port users and society as well, so they will face the least opposition. Not only will they reduce the total generalised logistic cost, thus increasing the port attractiveness and increase consumer surplus but also allow a modal shift which will reduce the ecological footprint of the supply chain. This reduces the external costs and facilitates the port’s licence to operate. This will be further developed in the following chapters.

2.7.3 Conclusion

In times of uncertainty or under increasing competitive pressures, organisations can look at their competitors to join forces to alleviate these problems. For ports, these pressures can come from customers, like shipping lines, that through mergers, increase their bargaining powers. Uncertainties can come from a changing economic environment due to infrastructure that is planned or because investment budgets from governments are reduced. Ports, and port authorities, can respond by starting cooperation projects with a specific aim, like lobbying at a higher level, or motivating youngsters to start a port-oriented career. Alternatively, they can go all the way and start a merger and create a new, bigger, port. Between these two extremes many formats can be conceived. Many activities in the port triptych have potential for cooperation, but the remaining battlefield for ports, and consequently a promising field for cooperation, is the hinterland connectivity. This will be shown in the following chapters.

Chapter 3 DEVELOPING A CONCEPTUAL FRAMEWORK TO MEASURE THE WELFARE EFFECTS OF COOPERATION BETWEEN SEAPORTS

This chapter discusses in detail the welfare effects of port cooperation, based on the social cost benefit analysis and the concepts of consumer and producer surplus. It starts with a rational for the choice of the methodology and finishes with a detailed, conceptual, analysis of the welfare benefits of cooperation in the hinterland development.

3.1 Choice of methodology

As is apparent from the literature review in the preceding chapter, cooperation is often analysed using game theory, port projects are often researched through societal cost benefit analysis, the following section discusses the merits of each and concludes with a motivation of the choice made. The following paragraphs succinctly cover those methodological papers covering cooperation, transport and ports.

3.1.1 Game theory

Many papers, already cited in chapter two, show how game theory is often used to quantify the effect of cooperation. In their seminal work "*Theory of games and economic behaviour",* von Neumann and Morgenstern (1947) postulated more than a few revolutionary concepts, one of which was the non-zero-sum game. This work was the basis for the development of game theory and inspired a whole research field which amongst other topics studies and quantifies the effects of cooperation. McCain (2008) emphasizes the difference between non-cooperative and cooperative games, where the non-zero-sum games of the latter makes cooperation logical. Axelrod (1997) expands on his earlier work when he develops the tit-for-tat strategy from a two-person game to a n-person game. Shapley (1953) proposes a way to calculate the unique solution to share the benefits from such a cooperative game, but when this is applied to more than a few players, the method becomes quickly unwieldy (Vanovermeire, 2014). Game theory makes use of simplifying assumptions which make real world applications with cooperative organisations difficult (McCain, 2008).

Still, game theory is useful when a whole industry is locked in destructive competition and competitors started to realise that they have to cooperate whilst competing, turning a lose-lose in a win-win. Competitors can be complementors as well as substitutors and this can evolve over time. It is possible through cooperation to change the rules of the game and the scope which defines the boundaries of the game (Brandenburger & Nalebuff, 1995).

Several authors, mentioned in the preceding literature review, use game theory to analyse cooperation in the supply chain or between ports, for instance: (De Borger et al., 2008; Kaselimi et al., 2011; van Reeven, 2010; Yuen, Basso, & Zhang, 2008; Zhuang et al., 2013). All these papers start from abstract realities that allow for simplifying assumptions needed to apply the complex formulas. The high level of abstraction makes the results are difficult to apply to real world cases. Other cited paper use it in a qualitative analysis without using the mathematical concepts thus without quantitative application. The objective, however, of the present research is to quantify the effect in an EU-wide model.

3.1.2 SCBA in transport economics

As shown in the earlier chapters, cooperation between neighbouring port authorities can come in many shapes and sizes. They will have wanted and unwanted effects on the economy of the region of which they form a part. The port is a complex cluster of companies which is part of a supply chain and whose workings are regulated by a PA. All the suppliers of services related to transport in and around the port and the users of these services form a market which is subject to supply and demand. It is an amalgamate of many submarkets that are more or less influenced by each other and that can be difficult to separate. This complexity makes a societal cost-benefit analysis (SCBA) a well-suited methodology because it allows to capture the complexity and makes it possible to integrate the interests of all stakeholders. The aim of a cooperation project should be a win-win-win and this methodology allows to also capture the benefits for the third party, being society in the guise of the regional economy.

Few authors use societal cost benefit analysis (SCBA) to study the effects of cooperation between port authorities. This is surprising because most authors agree that the ultimate goal of a PA is the economic development of the region surrounding the port by increasing producer and consumer surplus (Goss, 1990). Wortelboer-Van Donselaer and Kolkman (2010) mention this methodology in their title "Societal costs and benefits of cooperation between port authorities" but their paper does not go into a quantitative analysis but rather stays descriptive. Nevertheless, SCBA is a popular methodology to evaluate transport projects. Some examples are the extensions of the port of Antwerp (Blauwens, 1971, 1986, 1988a, 1996; Blauwens, De Brabander, & Van de Voorde, 1993), the construction of a cargo airport in Brussels (Blauwens & Van de Voorde, 1983), the privatisation of Canadian Railways (Boardman, Laurin, Moore, & Vining, 2013), the benefits of the Stockholm metro system (Börjesson, Jonsson, & Lundberg, 2014). And even if there is criticism directed at the methodology because it neglects the non-economic aspects (Van Wee, 2011) almost every country has a how-to manual, as does the European Commission (Directorate-General for Regional Policy, 2008, 2015).

3.1.3 Conclusion

To quantify the effects on a whole range of stakeholders, the SCBA methodology is better suited than game theory which becomes quickly unwieldy once more than two or three players are concerned (Walley, 2007). The high level of abstraction often necessary in game theory, and the presence of many implicated actors makes the latter less suited for a Europe-wide applicable real-world case. But the results of SCBA are strongly influenced by the limits chosen to measure the effects (Blauwens, 1988b; Boardman, Boardman, Greenberg, Vining, & Weimer, 2018). Most SCBA analysis is conducted on a national or sub-national level (Boardman et al., 2018). In the case of the welfare effects of seaports, they often spill over across borders, especially with the cross-border expansion of the hinterland due to containerisation.

While SCBA is used to analyse whether investment projects should be undertaken, and if funds are limited, which one (Mishan & Quah, 2007), its wide search for costs and benefits makes it a tool suited to analyse the effects of cooperation between PAs because these too can range wide and far.

3.2 The welfare effects of port cooperation

It is generally acknowledged that it is the objective of landlord port authorities to create local and regional welfare (Suykens & Van de Voorde, 1998; Van de Voorde & 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 welfare in and around the port area (Goss, 1990). While not all cargo handling activities create the same added value, the higher the economic (port) activity, the higher the economic welfare (Blauwens, 1988b). Consequently, they 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, & Vanelslander, 2011).

As part of the global supply chain, the attractiveness of a port is eventually defined by the generalised logistic 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, Meersman, Van de Voorde, & Vanelslander, 2016). 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 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 et al., 2001; Kuipers, 2014; Levinson, 2008). As is mentioned earlier, 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, & van Breedam, 2004; Robinson, 2002, 2003). The resulting shift from captive to contested hinterland led to the whole of continental Europe becoming a contested hinterland for all major European ports, (De Langen & Chouly, 2004; Magala & Sammons, 2008; Meersman et al., 2007; OECD, 2008; 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 (L. Guo & Yang, 2017; C. Wang, Chen, & Huang, 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, 2005, 2010; Lam, 2010; Nazemzadeh & Vanelslander, 2015;

Panayides & Song, 2012; Tang, Low, & Lam, 2008; Tongzon, 2009; Tongzon & 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 & De Langen, 2014).

The hinterland of a port is a dynamic concept. Sargent (1938) already wondered whether Poland and Czechoslovakia were part of the hinterland of Antwerp. 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. She shows a decrease over 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 & 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 & 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 & 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 (De Borger et al., 2008).

Based on the increase in consumer surplus, the increase in welfare due to cooperation projects will developed in the following paragraphs, first by examining the supply side effects and next by studying the demand side effects of cooperation projects.

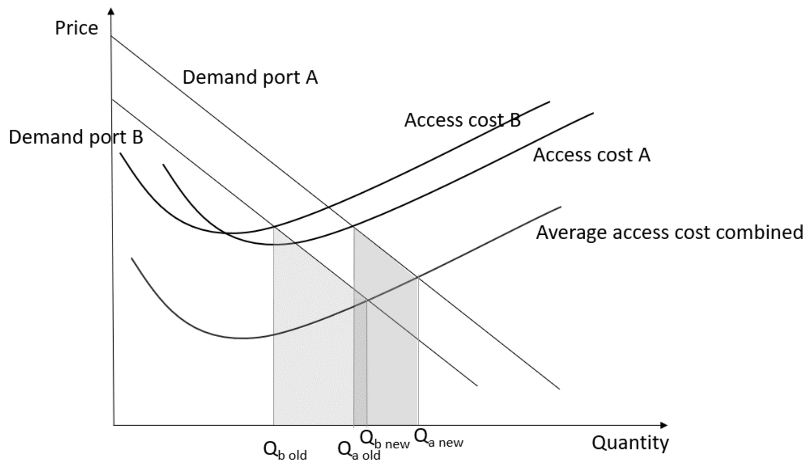
3.2.1 Supply side effects on welfare

Cooperative projects can have an effect on the cost structure of the port and the port authority in particular. Cooperation can decrease the generalised cost of a specific port operation through a combination of scale economies, synergies and economies of scope, depending on the type of service. An example can be found in the newly created, already mentioned, fusion of the ports of Ghent and Zeeland, itself a merger of Flushing and Terneuzen. The project of North Sea Port had a long preparatory history (De Langen, Braun, Nijdam, & Otgaar, 2006) but eventually resulted in a cross border merger and the first year the growth accelerated compared to the individual growth years before the merger (NSP, 2018). The new port has economies of scale through, amongst other projects, a shared PCS (Haven Gent, 2014), synergies through a combined sustainability approach (Schalk, 2019) and economies of scale through, for instance, the combination of liquid bulk cargo flows in Terneuzen and dry bulk cargo flows in Gent, both sharing the same foreland access system.

As a result of such projects, the supply curve will move to the right and/or downward thus improving the efficiency of the port, by offering a better input/output ratio of the service. The port can offer the same level of services at a lower price (moving the supply curve downward) or offer more service without increasing the price (moving the supply curve to the right). Alternatively, the actor in the chain that benefits from the increased efficiency can increase its profitability. One of the examples of a cooperation project with supply side effects is the combining of access services, like pilots, dredging or ice breaking, in the near foreland of the adjacent seaports, as is already mentioned in 2.6.1.1. The example mentioned was how the Finnish ports in the Gulf of Bothnia cooperate to organise the icebreaking operations necessary to insure access in wintertime. They will have one canal opened-up that bifurcates when coming to the neighbouring ports. This reduces the cost of icebreaking and thus avoids the supply curve moving further to the left/upwards in winter times.

Cooperation on access routes and piloting can reduce the cost of maintaining these services, if this cost reduction is passed on to the users, then this will move the supply curve to the downward and to the right as is shown in Graph 2. For a particular service, e.g., the above-mentioned icebreaking, the demand of both ports can simply be aggregated, all users will join the common, lower cost, solution. Port A has its own access cost that is different from that of port B: it could for instance be that port A is closer to the unfrozen water than port B, which has a different demand. The combined service will, on average, be lower than the individual services. Whether this lower cost is also passed on to the customer in a lower price depends on the power relation between the buyer and the seller (Meersman et al., 2010).

Graph 2 - Benefit from access cooperation



Source: own composition, based on Blauwens, 1988b

The cost of the cooperative access service is lower per service than when offered disjointly. This leads to an increased demand in each port and results in an increased consumer benefit in each port, this is represented by the shaded area for every port.

Congestion, or more precisely the absence thereof, is one of the main attractions of a port. Congested ports with non-congested competitors will lose traffic, if this traffic can be diverted to neighbouring ports that are part of the same economic region then this loss will not have a negative impact on the region. Congestion increases the generalised cost of the port, moving the supply curve to the left/upward, thus diminishing the welfare of the region. By cooperating, and optimising the planning of the port calls, the PAs can diminish or even avoid congestion thus restoring the supply curve back to its original position.

As already mentioned before, PAs could cooperate in the concession awarding process. Increased concession fees would, of course, not have an effect on the supply curve but in the case of the PO being a foreign company it would increase the welfare by leaving a larger part of the added value for the local economy, without it the PO would surely transfer these profits to the mother company overseas. Alternatively, when the combined PAs would bring the PO to charge lower fees for their services, these lower fees would clearly move the supply curve downward, because charging lower handling fees would reduce the cost of the services thus moving the supply curve to the right or downward. This would make the equilibrium slide down the demand curve to a lower point with a higher throughput at a lower price per unit.

Although ports are an important part of the economy by providing competitive access to export markets and by supplying efficient access to overseas resources, the public often does not appreciate that the hindrance the ports create, serves a purpose. Many historical ports have moved away from city centres, making the activities often invisible for the population who is, nevertheless, being confronted by the traffic and pollution created by port operations. This creates a problem when this public is asked for public funds to invest in the port. This motivates PAs to enforce regulations that diminish the negative environmental effects of the port operations. This way, they keep their licence to operate. But it increases the cost of operations, which is a competitive handicap and it forces the supply function to the left/upward by internalising, at least partially, the external costs. By cooperating, the PAs can at least avoid the competitive handicap thus reducing the loss of traffic to a minimum by creating a level playing field.

3.2.2 Beneficiaries from supply side effects

The increased efficiency can take place within the port authority (PA). The PAs can, by combining their services, benefit from economies of scale or scope, or from synergies. The case of North Sea Port mentioned in paragraph 3.2.1 is a convincing show case of these effects. This can result in either lower port charges (action 1), or either higher dividends (action 2); or, of course, a combination of both. This direct effect of increased efficiency on the port cost can be labelled as a first-tier effect. If the benefit is used to lower port charges, it will have a knock-on effect on the port users like shipping lines; this second-tier effect can push the supply curve further downward. These lower port charges can have a positive effect on shippers by lowering the import cost of goods, parts and raw materials or by increasing the competitiveness of exporting industries: this is the third-tier effect. At the next level, it can increase the purchasing power of the consumers or the demand for labour. This is the fourth-tier effect.

Table 6 - Supply side effects of port cooperation

	Actor	Action 1	Effect 1	Beneficiary 1	Action 2	Effect 2	Beneficiary 2
Tier 1	PA	Lower prices	Increased demand	Port users	Increase profit	Increased attractiveness investments	Shareholders
Tier 2	Port users	Lower prices	Increased demand	Shippers	Increase profit	Increased attractiveness investments	Shareholders
Tier 3	Shippers	Lower prices	Increased demand	Consumers	Increase profit	Increased attractiveness investments	Shareholders
Tier 4	Consumers	Higher purchasing power	Increased demand		Increased savings		

Source: own composition

PAs of the landlord type play a facilitating role towards the firms active in the port. Some cooperative programs will have little or no direct effect on the functioning of the PAs themselves but are aimed at the operators in the port e.g., two PAs can come together to facilitate hinterland flows. Together, the flow towards and from a specific destination and origin might be large enough to become interesting for an operator to service. Thus, a regular connection might be established where before only irregular services were available. The economies of scale thus realised move the supply curve of these services to the right. The first-tier efficiency effect on port operators will have a second-tier effect on shippers because they will pay less for the transport services to and from this particular hinterland. Eventually this will have an influence on the welfare for the population in this hinterland.

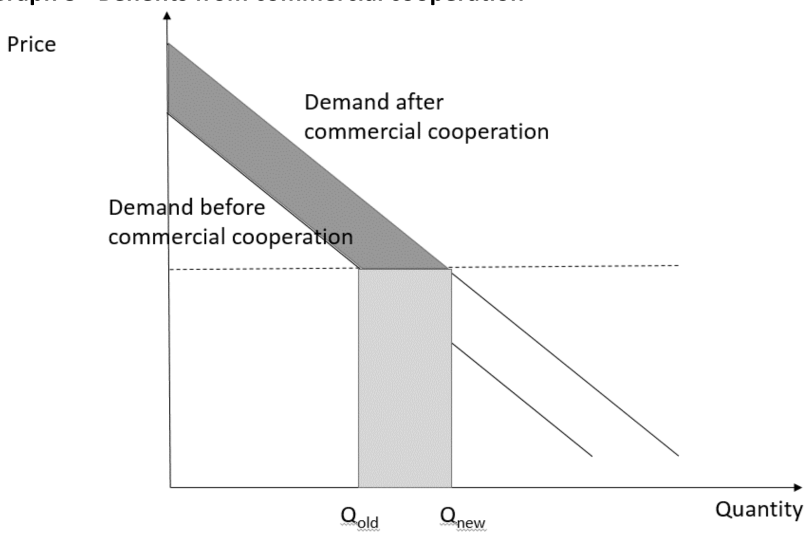
The cooperative programs can also have a direct effect on the community surrounding the port. A typical example is environmental regulations. To make sure that there is a level playing field while at the same time installing stricter environmental legislation, neighbouring PAs can coordinate their environmental and safety regulations, or the procedures used to verify that port users are in concordance (supra)national regulations. Tougher rules might have a negative effect and push the supply curve to the left, but the loss of welfare should be less than the external costs generated by the lack of environmental control, otherwise the rules are nonsensical.

3.2.3 Demand side effects on welfare

As already described in 2.6.1.1 Foreland side cooperation, ports could increase their brand recognition by combining their commercial activities, making the cluster of ports more attractive thus bringing more cargo to their main direct customers, the shipping lines and the terminal operators. PAs play a role in commercialising the port oversees and in the hinterland, to get more brand recognition, to make to port “top of mind” with the decision makers in shipping lines, shippers and forwarders (Pando, Araujo, & Maqueda, 2005). By combining the market of two ports, the sum of available cargo might entice shipping lines to divert bigger or more vessels to the combined port. This would then bring more hinterland cargo to the port because more shipping opportunities would be available. This could start a self-feeding, ever-increasing growth process which would expand the hinterland of the combining ports until an increasing congestion, in the port and or the hinterland, starts to decrease the attractiveness. Increasing brand awareness is typically a demand side effect. It will push the demand curve to the right.

The effect on social welfare of an increased attractiveness due to commercial cooperation in overseas markets case is represented graphically in Graph 3. The demand for the services of each of the participating ports will be increased by a successful commercial cooperation. It is assumed in the graph that the increase will not be so large as to increase the price of the port services. This assumption is justified as long as the maximum handling capacity of the port is not approached, the available capacity has enough leeway to easily accommodate additional demand without leading to price increases. If there is little room for growth due to capacity restrictions then it does not make sense to increase the port attractiveness, as this will only lead to congestion.

Graph 3 - Benefits from commercial cooperation



Source: own composition, based on Blauwens, 1988

The increased attractiveness, resulting from the increased marketing efforts, pushes the demand curve to the right, thus increasing consumer benefit, but additionally, at the same price it leads also to higher throughput bringing the volume from Q_{old} to Q_{new}. This does not differ from the effect of commercial activities of a stand-alone port but as shown earlier, the effect will be stronger if the cooperating ports have a small to medium market share or are active on complementary markets. Smaller ports especially will realise a bigger effect through cooperation, whereas for a well-known port the cooperative effect will be smaller, surely when seen from a relative viewpoint.

3.2.4 Demand and supply effects combined into welfare effects

Imagine two ports A and B, located close to each other and competing on the container market, where also other ports than A and B are active. They both have a small service to an inland terminal C located in middle or long distance. Each port supplies weekly 50 containers from different shippers to destination C. Due to the small volume and the different shippers this is done by lorry. The cost per container is high which keeps demand low and because the available volume is low there is not enough demand to use cheaper bundling solutions. If port A and B would merge their markets the volume would jump to 100 containers weekly making a barge or train shuttle economically viable. This would substantially reduce cost. The new services will be offered at a much lower unit cost; this pushes the supply curve right/downward. The increased supply of services will also make the port more attractive for new cargo (from an increased market share, shifting cargo from the non-participating ports), thus pushing the demand curve right/upward. Additionally, the modal shift can also result in a lowering of the external cost per transported unit. This is further developed in the following sections.

In a perfect world, the market would organise this bundling spontaneously, but for several reasons, this might not be happening. Firstly, shippers and shipping service suppliers do not always have the necessary knowledge of cargo flows outside their purview but this should present an opportunity for service suppliers that can coordinate cargo flows, even of competitors (Palhazi Cuervo, Vanovermeire, & Sörensen, 2016). Secondly, smaller service suppliers, and they are very common on hinterland services, have rarely the capability of offering multimodal transport services, so bundling would lose them a customer. Thirdly, some of the cost savings are external costs, which does not benefit the shipper or service supplier but society at large for which the PA has a fiduciary responsibility as a public port authority. The Hanseatic PA has a strong motivation to realise this external cost saving.

3.3 Hinterland, the port and regional welfare

As mentioned earlier, the hinterland is the remaining battlefield for the port authority to differentiate from the competition (De Langen & Chouly, 2004; Robinson, 2002, 2003; Van der Lugt, 2015). The relative lowering of the cost of the maritime part of global supply chain, as a result of increased scale in the shipping industry, has resulted in a consequently increased proportion in the cost of the land part of said chain. The increased importance of the land part of the transport network impacted on its role in the competitiveness of a global supply network.

With the shift from captive to contested hinterland due to containerisation leading to the whole of a continent becoming a contested hinterland for all major ports, it raises the question if neighbouring ports cannot extend their hinterland through cooperation thus reinforcing together their market share in more distant regions. The premise is that through cooperation, economies of scale can be realised that facilitate a modal shift away from road to a more efficient and more sustainable transport mode like rail or inland waterway (IWW). This would reduce the cost of transport to/from the hinterland from/to these ports, consequently increasing the attractiveness and the market share of the cooperating ports for a particular region. The following sections describe a method to identify and quantify the opportunities for cooperation in the hinterland. The conceptual framework starts from hinterland data to locate regions that are at the edge of the contested hinterland of a port region and results in a conditional system that will indicate where opportunities for cooperation are in any given hinterland. When applied on any port region it will result in a list of regions where cooperation can make a difference, in decreasing order of importance. Such a list can help neighbouring PAs to prioritise their efforts. This method is will then be applied in the next chapter on the European Union (EU).

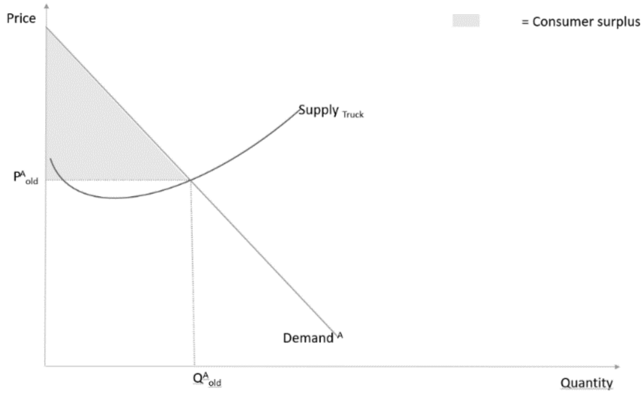
Historically speaking, ports and, specifically, PAs always have had a clear view of the maritime origin and destination of the cargo going through their ports. The hinterland part of the supply chain is less well known and only recently PAs are trying to quantify the geography of their hinterland and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

3.3.1 Extending the hinterland through cooperation and the effect on welfare

The hinterland accessibility defines in a large part the throughput of a seaport (Guerrero, Laxe, Seoane, Montes, & others, 2015). 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 borne not by the shipper but by society as a whole; they comprise costs like congestion, pollution, accidents and wear of the infrastructure (Gibson et al., 2014). The consumer surplus of the services used to handle this volume is graphically presented in Graph 4. *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 cost. 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).

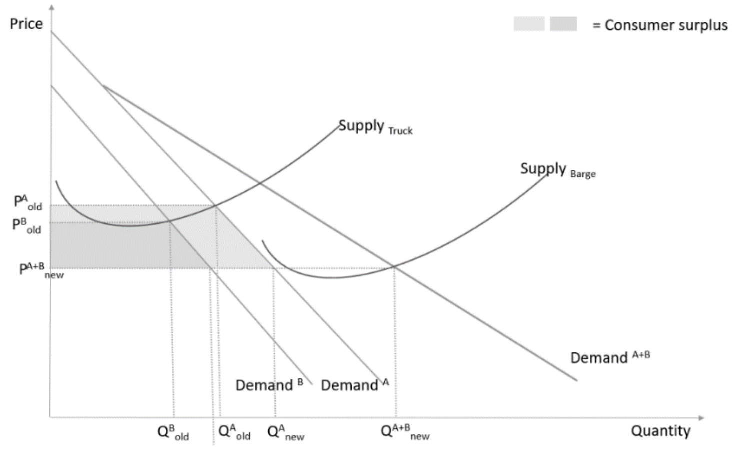
Graph 4 - Consumer surplus



Source: Blauwens, 1988b

The high cost of the transport to/from the (further away) region leads to a small market share in the volumes of cargo being brought to this 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 flows. 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 Graph 5.

Graph 5 - Increased consumer surplus



Source: own composition

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 bundling which results in two complementary effects. On the one hand, the combined volumes, through economies of scale, bring a reduced cost of transport because the bigger volumes now make use of a more efficient, bundled, transport mode. 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 demand for transport services and market share of cargo shipped to/from the hinterland region, resulting in an increase in volume. Unless the non-participating ports are prepared to lower their margins to keep their original market share, thus trading profit for markets. It remains to be seen, on a case-per-case basis, if the competing ports have, at all, margin to give away. It is unlikely that, in the competitive market that road transport is, the existing pricing for road transport services would allow for a price reduction that would restore its competitiveness with a newly offered, bundled, transport mode.

$$P_{new}^{A+B} = P_{new}^{A} = P_{new}^{B}$$

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

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

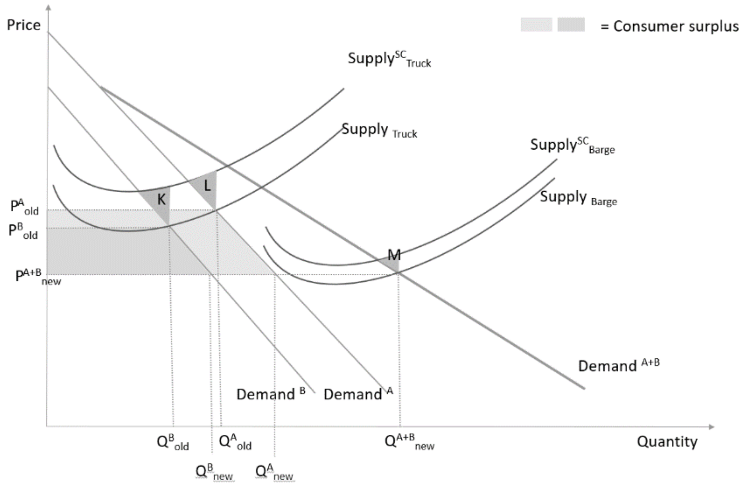
The market price P_{new} in the new situation where port A and B combine cargo flows is lower than the old prices that were in force before the cooperation. The combined quantity Q of A and B in the new situation is greater than the sum of the old individual quantities. The increased consumer surplus is the sum of the increase in each port. For each port, the surface of the tetragon that represents this increase is as follows (based on Blauwens (1988b)):

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

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

If the external costs are added to the graph, it becomes apparent, as shown in Graph 6, 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.

Graph 6 - External costs



Source: own composition

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.* This is, for instance, the case for the seaports and hinterland of Campania, in Southern Italy. A system of internal dry ports, coined interports (i.e. extended gateways: the cities Nola and Marcianise), in the hinterland of Napels and Salerno, where unbundling and customs clearance of containers would take place, would result in a reduction of CO_2 and other air pollutants. The used interport model assumes an internalization of external costs for inland transport flows. (Iannone, 2012)

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).

$$K + L > M$$

3.3.2 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, in relation to all the ports i serving the same hinterland, can be defined as follows:

$$P_A = \frac{e^{-\alpha(HC_A+OC_A)}}{\sum_i e^{-\alpha(HC_i+OC_i)}} \quad (i = 1,2,3,\dots,n; all\ ports\ serving\ the\ same\ hinterland)$$

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, per cargo unit, 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 specific region and HC_i is the similar cost for every port (i) connected to the said region. OC_i stands for all other supply chain costs (foreland and port) linking the relevant foreland for all gateway ports (*i*) relevant for the studied hinterland 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, & Vanelslander, 2012), allows studying the effect of changes in the hinterland costs, *ceteris paribus.*

$$OC_i = PC_i + \sum_K k_K \; x \; FC_K \;\; (K = 1,2,3, \dots, n; all\ foreland\ ports\ of\ port\ i)$$

For each of these ports the generalised connection cost, per cargo unit, of the port to the region (HC_i) , based on the actual proportion of the different transport modes, as well as the generalised foreland and port cost (OC_i), based on the actual market share of the different foreland regions, needs to be calculated. The port handling cost (e.g., port dues, tug boats, …) per cargo unit is PC_i and the maritime cost of each unit is represented by FC_K for every foreland port *K* multiplied by a weighing factor *k* representing the share of that particular overseas port in the cargo flows in the port *i.*

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, i.e. road: r^c, rail: t^c and barge: b^c (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 cargo unit cost consisting of the sum of the costs of all the used hinterland transport modes and the transshipment costs from each mode:

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

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. If, in a particular case, a bundled transport service is already offered then through the additional bundling of the road freight flows of two or more ports, the latter will optimise the use of the barge or rail and increase the volumes shifted away from road.

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

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

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

The use of the inequalities, $\leq$ and $\geq$, serve 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.

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

The higher probability leads to a higher volume, which leads to a higher added value in the port region. 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), and by reducing external costs by as much as 82%, as shown for Southern-Italy by Iannone (2012).

The cooperating ports, becoming more attractive through a lower hinterland connection cost, will benefit from a greater volume passing through their port complex, as is shown above. This will benefit all companies operating in and around the port and indirectly the whole community and all stakeholders. This growth is the effect of the price elasticity but is driven by three distinct factors. Firstly, there is the obvious increased demand through a lower price, one could say: the price elasticity in sensu stricto, but this effect is probably small, transport being a derived demand. Secondly, there is the hoped for and more important modal shift as a result of the lower cost. This will have also little or no effect on the throughput, as it is in itself a modal shift that does not increase the port throughput, it simply uses a different transport mode. Beuthe et al. (2014) made a detailed review of a number of studies on the price elasticity and modal cross-elasticity with a focus on the Rhine market. It concludes that elasticities are influenced by the chosen data and methodology and differ according to region, commodity and distance. This makes it case-specific and not applicable for an EU-wide application.

The real throughput gain will be the result of a market share shift. To quantify this effect in a specific hinterland it is necessary to have the actual data on the cargo from all the different ports serving the region. Shippers, using LSPs and having little to no own investments in ports, have little to no loyalty to a port and will switch when a lower cost is offered (Vermeiren & Macharis, 2016). Based on the ratios between the cargo flows from the different ports to one specific hinterland region, the α of the discrete choice formula above can be calculated.

Knowing that

$$P_A^{old} = \frac{Q_{old}^A}{\sum_i Q_{old}^i}$$

but also

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

Given the probability (P_A^{old}), starting from the attractiveness that corresponds to the actual market share of the cargo shipped to/from the chosen hinterland region, the α [1] can be calculated once all other data are collected.

[1] In the case of a simple two port system the value of ∝ can be calculated as follows, more ports give a more complex solution:

$$\propto = \frac{\log\left[{}^{P_A}/_{1-P_A}\right]}{(HC_B + OC_B) - (HC_A + OC_A)} = \frac{\log[Q_A/Q_B]}{(HC_B + OC_B) - (HC_A + OC_A)}$$

If for the cooperating ports, where the cooperation results in a modal shift, the new generalised hinterland cost (HC_A^{new}) is used to calculate the new attractiveness probability (P_A^{new}) then a new market share and increased throughput can be deduced. It can be assumed that $\sum_i Q_{old}^i = \sum_i Q_{new}^i$ and that α remains the same because, as mentioned above, an increase in total market demand is unlikely or minimal due to the derived nature of transport demand. When the bundled generalised transport costs are known they can be applied to calculate the new attractiveness probability with the already aforementioned formula:

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

Next, the increased market share can easily be used to calculate the increase in throughput and the inherent market share elasticity of the hinterland transport cost as follows.

$$\sum_i Q_{old}^i = \sum_i Q_{new}^i$$

and

$$Q_{new}^A = P_{new}^A \cdot \sum_i Q_{old}^i$$

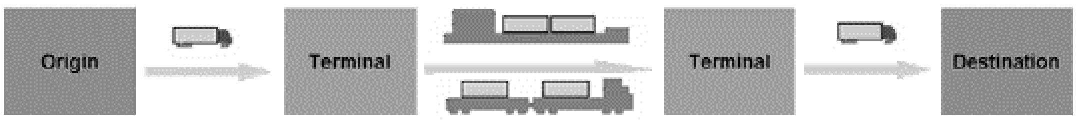
Using the old generalised chain cost and the corresponding old throughput volume as well as market share, and, having calculated the new generalised chain cost and the resulting new market share and new throughput volume, the elasticity can be calculated, and is valid, at least, for the relevant market section, in the following manner.

$$\frac{dQ}{dP} = \frac{\Delta Q}{\Delta P} = \frac{Q_{old}^A - Q_{new}^A}{\left(HC_A^{old} + OC_A\right) - \left(HC_A^{new} + OC_A\right)}$$

3.3.3 Extending the hinterland through a modal shift and intermodality

If a port (or ports) want to extend its (or their) hinterland, it (they) needs to lower the generalised cost of the hinterland connectivity, as shown in the preceding paragraphs. One way of reducing this cost is to shift towards a bundled transport mode. However, this would entail, in most cases, an additional cost of bringing the cargo to a bundling point and an additional cost of transferring cargo from one transport mode to another. When cargo is transported through the use of more than one transport mode, but without the transport being opened (e.g., containers), this is called intermodal transport (Macharis, Caris, Jourquin, & Pekin, 2011).

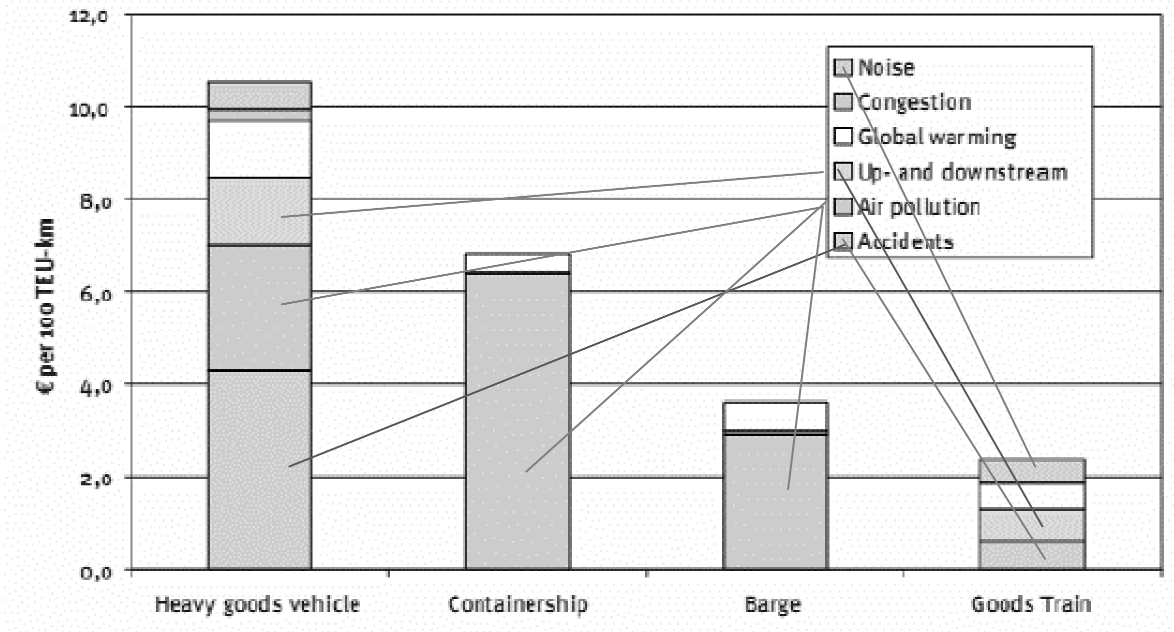
Figure 11 - Intermodal transport chain



Source: Macharis et al., 2009

When the cargo is piecewise loaded from one transport to another (e.g., pallets), then the transport mode is called multimodal. The process of using bundled transport modes like rail or barge instead of direct road connections, thus taking cargo off the road, is called modal shift. It has not only the advantage of potentially resulting in a lower direct and even generalised cost but also in lower external costs, especially in congested areas (Macharis et al., 2009).

Graph 7 - External costs of freight transport



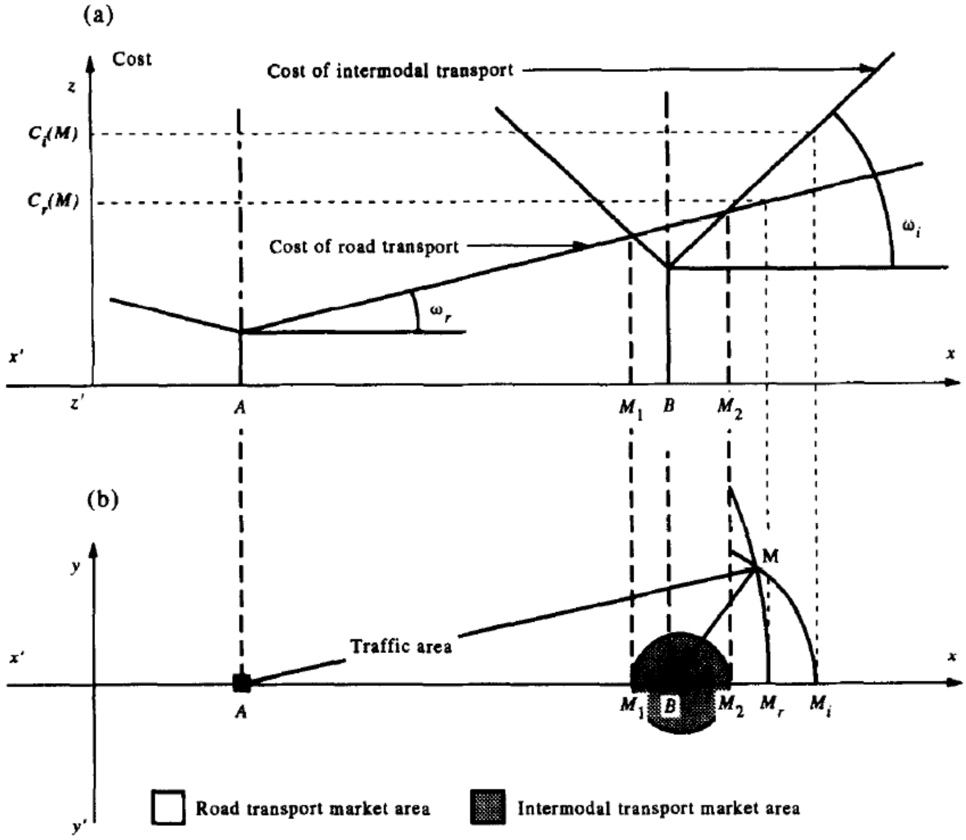
Source: Macharis et al., 2009

The lower cost of the bundled hinterland transport must compensate for the cost of bundling and the, potential, increase in time spent on route. Graph 8 shows how, for a given distance, the road-only solution (A), with a given fixed cost for loading and starting the truck, is more economical but for another distance (from M_1 to M_2) the intermodal solution (B) with a higher fixed cost for bundling, is more economical. The distance M_1 to M_2 is dependent on the cost of the bundling; the kilometre cost, based on the operating conditions of the operators, of the different transport modes (ω_r and ω_i); and the position of the bundling point. (Niérat, 1997)

Niérat (1997) does not discuss the factor of time, looking at it from an operator viewpoint, but the graphs can be interpreted from a shipper's viewpoint too and can be seen as representing the generalised costs as well.

This supply side approach, focussing on the costs, ignores the availability of cargo. Even if the bundled generalised cost is lower than the road cost, bundled cargo flows need minimum volumes to be commercially viable. The market area and the optimal location of transfer hubs based on a cost, and thus supply side, approach (Limbourg & Jourquin, 2010) could lead to a situation where a service would be competitive but not available due to a lack of demand. This is where a port authority (or any other interested port actor) can bring value added by bundling cargo flows of two or more ports, that are geographically near each other, into one volume that would be sufficiently big to create a demand needed to match the supply.

Graph 8 - Intermodal transport market area

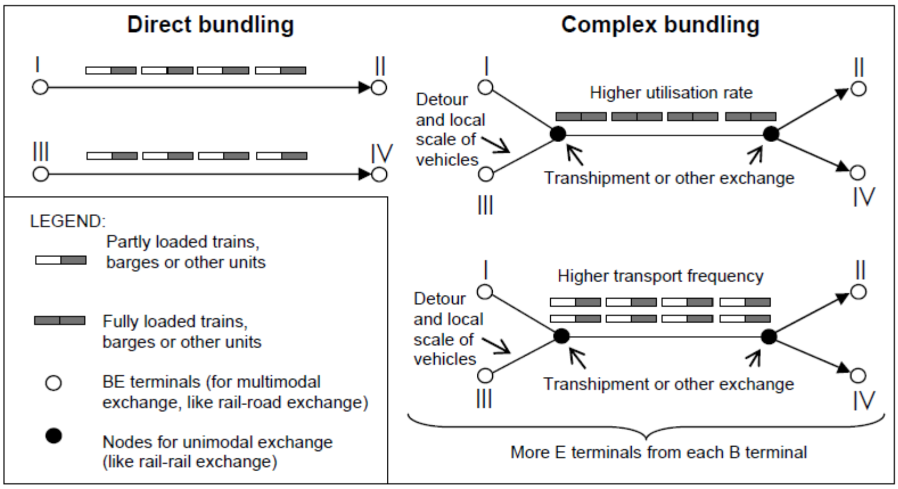


Source: Niérat, 1997

The idea of bundling cargo onto rail in a hub-and-spoke concept was the core of the twin hub network where, through bundling, frequencies can be increased, and more destinations can be serviced. The project focussed on the ports of Antwerp and Rotterdam as hubs and used a minimum volume of 20,000 TEU annually in each direction and a load factor for the trains of 90% one way and 60% in the other direction. Eventually, the pilot project was discontinued by the operators although the competitiveness of some routes was clearly proven. (E. D. Kreutzberger, Konings, Macharis, & Meers, 2014; 'Twin hub network', n.d.)

Multimodal transport can improve its efficiency and effectiveness if freight trains are bundled together with other trans and exchange containerized cargo or wagons to multiply the number of serviced origins and destinations as show in Figure 12 (E. Kreutzberger, 2010). The use of a hub-and-spoke rail system to service the hinterland improves the performance of the rail product (E. Kreutzberger & Konings, 2016). Bundling flows from neighbouring ports can allow attaining volumes necessary to make these strategies more accessible.

Figure 12 - Bundling of freight trains



Source: Kreutzberger, 2010

Surprisingly, the role of the handling cost is only marginal, notwithstanding the attention it gets in the literature, but economies of scale do have an impact: large intermodal freight terminals have a lower average handling cost than smaller ones (Wiegmans & Behdani, 2018).

To reach the targets set in EU white paper of 2011 (European Commission, 2011) the market share of rail freight has to double. Added to the expected growth, this means a volume increase of 3 to 4 times. To be competitive the services have to improve their capacity, by more and longer trains and better capacity utilization, and their lead times and reliability, by improving the transfer operations and increasing train speeds, thus leading to lower generalised costs (Islam, Ricci, & Nelldal, 2016). Bundling smaller flows between ports and less serviced hinterland destinations, can contribute to reaching these objectives, if free capacity is available on the network. The increased demand for bundled transport services to a destination will lead to a lagged response of the supply where operators will have to increase their service capacity to fulfil the demand. This can be done by increasing the train size or speed (if the network permits) or the frequency. A higher frequency will lead to an increased attractiveness, due to a resulting drop in generalised cost, thanks to a reduced waiting time. This increased attractiveness can have a lagged response on the demand and lead (again) to an increased demand. This can have a lagged response on the side of the suppliers who will increase capacity, through increases in speed, train size or frequency. The increased revenue for the operators might even lead, if demand is sufficient, to an increased investment in the network, leading to, again, an increased capacity but also reliability.

Many port authorities are aware of the importance of achieving this modal shift and have made it a part of their strategic plans and see the need for investments in infrastructure and the promotion of multimodal services to organise the inter-terminal transport to railway terminals and subsequently towards the hinterland (Hu, Wiegmans, Corman, & Lodewijks, 2019). One strategy to facilitate the use of multimodal corridors is the development of an ICT system that makes interoperability of existing ICT system possible, thus establishing a unique ICT multimodal corridor (Cepolina & Ghiara, 2013). This implicitly implies cooperation between the concerned port clusters.

3.3.4 The role of the port authority and an incentive policy

The act of bundling the cargo flows will generate some additional costs; these are represented by the transfer cost that occur when cargo is switched between modes of transport and by the cost 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 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, substantial, reduction of external costs. This external benefit could 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 and increase the regional value added. Because doing so would increase the 'licence to operate' that the public gives the PA and the increased revenues will please the shareholder, which is the same public, indirectly.

PAs become dependent on multimodal operators, in the port cluster, to ensure their hinterland, but by facilitating the bundling of flows 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.

Most ports combine a transshipment function with a gateway function towards their hinterland. Transshipment takes place when incoming sea cargo is transshipped 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, little or no hinterland since (almost) none of their cargo leaves overland. Adjacent seaports, serving an overlapping hinterland form, de facto, a multi-port gateway. 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 flows 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, assuming competition will assure that the economies of scale being transferred to the customer, will increase consumer surplus, regional welfare and 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 cooperation 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, 2011).

Of course, the whole objective of the cooperation is to create a win-win-win for the cooperating ports, their actors and the regional economy. The cooperation will only be continued if all participating ports see a gain. If the unwanted situation would arise where, as a result of the cooperation and the improved hinterland connectivity, large maritime cargo flows would shift from one participating port to another then the losing port would pull out of the project. However, it can be expected that, as a result of the improved attractiveness, throughput for the combined ports will increase, this being the objective of the cooperation, and that the bigger pie would allow all participants to get a bigger slice.

One might wonder why the market and private service providers (e.g., rail and barge operators but also terminal operators) are not filling the need? Because many of these providers are organized 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 et al., 2016). 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 & Van der Lugt, 2011).

Public port authorities are ideally suited to develop an incentive policy to facilitate the bundling of road cargo flows towards rail or barge. As will be shown in the case studies in chapter five, the savings in external costs are an important motivator to bundle hinterland flows between adjacent seaports. But to overcome the direct costs resulting from the bundling as well as to stimulate a mental shift with the forwarders and shippers, incentives would be helpful. Port and other regional authorities often lack the judicial instruments to force the internalization of external costs. Even if they would have the tools, they would be very reluctant to be responsible for the creation of the competitive disadvantage that the negative incentive policy, like smart local road pricing, would be. But, the opposite approach, with a positive incentive, could be very effective. The port authority, who, as a neutral actor amongst competing LPSs, that make up the port community, can have access to knowledge of cargo flows and operators. As a neutral partner, the PA can collect and process data from different, competing actors, and use the result to create an incentive policy that captures the external benefits and uses them, even partially, to compensate for the bundling costs thus incentivizing the operator to offer a competitive bundling service and/or motivate the shipper to use a bundled service even if it increases his value of time. The possible strategies and incentive policies for the different port actors are further developed after the case studies at the end of chapter five.

3.4 Applying the framework and establishing a methodology to quantify the welfare effects on hinterland cooperation

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) cargo flows of each region in the contested hinterland must be mapped together with the market shares of all relevant ports and their respective modal split. Based on this map and the underlying data, 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 flow, resulting in small to mid-sized flows of road transport. Next, from this sub-set, one needs to select the regions where two (or more) 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, however small. 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 ‘containerisable’ 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 ‘containerisable’ in the sense that its current form allows it to be efficiently shipped in containers.

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 an approximation for weekly data by simply dividing them by 52.

3.4.1 Data collection and assembly

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

3.4.1.1 OD volume tables

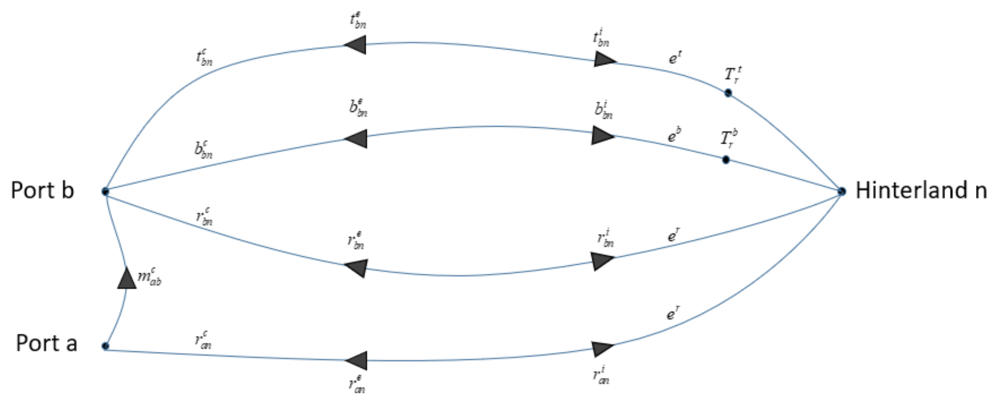
For every mode and as well for export as for import the OD tables with the transported volumes need to be established as follows.

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

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

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 (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 bundled 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 13 summarises these conventions.

Figure 13 - Formulation convention



Superscript e or i: stand for export or import volumes
Superscript c: stands for cost per volume
Superscript r, t or b: stand for road, train or barge
Symbols r, b, t or m: stand for volumes of road, barge, train or multimodal transport
Symbol e: stands for external costs per volume
Symbol T: stands for transshipment cost
Subscript a, b or n: stand for origin or destination a, b or n
Subscript r: stands for road

3.4.1.2 Break-even points between transport modes

For every combination between the valid transport modes, break-even points need to be established. 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 would entail an average waiting time of 1.75 days, which is acceptable relatively to the average dwell time of a container in Europe, which is between 4 and 7 days (Rodrigue & Notteboom, 2009). This break-even volume, the volume where a shift towards a bundled transport mode becomes technically feasible, 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 break-even point is assumed to be stable being based on costs, not prices. These costs are not easily nor quickly changed. Would they change then, of course, the break-even point changes too. At the same time, the costs are considered unrelated to the total volume, the costs for one vehicle can assumed to be constant, independent from the number of vehicles that are being used. An increase in the number of vehicles, to respond to an increased demand, will have little influence on the costs per vehicle. Working with a fixed load factor makes this assumption realistic. Load factors, in the case of containers, are mainly decided by the shipper, not by the LSP.

The bundling between two (or more) adjacent ports offers the additional advantage of the possibility to balance import and export flows. 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 flow (which results in empty containers going to the hinterland for stuffing) than in combination the ports would have substantially less containers travelling empty. This happens when a deep-sea loop uses one port as a first port of call, which will then be an import port, and its neighbouring port as a last port of call, which will then be an export port.

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 estimate 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 (Meers, Macharis, Vermeiren, & van Lier, 2017). 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 & Van Meijeren, 2011). The cost-benefit comparison for every case will indicate whether bundling makes sense.

3.4.1.3 Mono- and multimodal transport cost

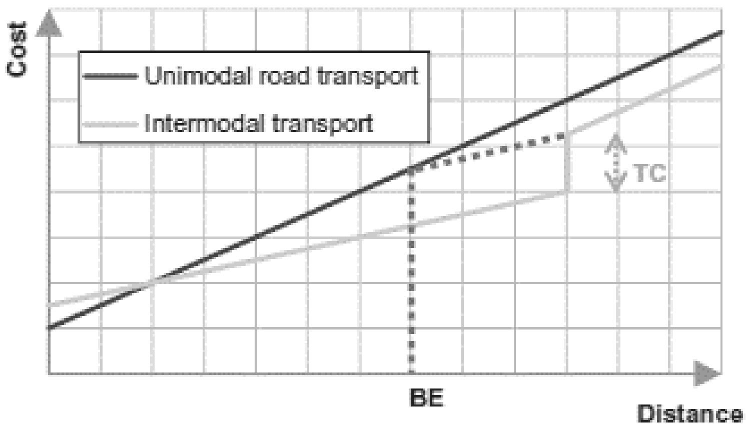
For every pair, consisting of a seaport and a hinterland region, the transport cost per volume needs to be established for every mono- and multimodal transport mode. The following matrices depict the costs for road or multimodal transport using train and barge transport between the ports *m* and the hinterland region *n*.

$$\begin{pmatrix} r_{11}^c & \cdots & r_{1n}^c \\ \vdots & \ddots & \vdots \\ r_{m1}^c & \cdots & r_{mn}^c \end{pmatrix};\begin{pmatrix} t_{11}^c & \cdots & t_{1n}^c \\ \vdots & \ddots & \vdots \\ t_{m1}^c & \cdots & t_{mn}^c \end{pmatrix};\begin{pmatrix} b_{11}^c & \cdots & b_{1n}^c \\ \vdots & \ddots & \vdots \\ b_{m1}^c & \cdots & b_{mn}^c \end{pmatrix} \quad \forall\, i \in \{1,..,m\}, \forall\, j \in \{1,..,n\}$$

The superscript *c* stands for the generalised cost of transporting one TEU from port *i* to the hinterland region *j* by road r_{ij}^c, or multimodal using truck and train t_{ij}^cor truck and barge b_{ij}^c. Not only the monetary transport-related costs have to be considered. 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. On the other hand, when looking at only one leg of the whole end-to-end route, the time lost might be significant when compared to the time of that particular leg. As discovered by Acciaro et al. (2015, 2017), 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 besides 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 (i.e. barges instead of trains) 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 by the factor TC in Graph 9. This depends on the location of the origin, the destination and the transfer terminal (Niérat, 1997). The transfer cost depends on the type of cargo, and the way it is loaded on the bundled transport mode. (see also 3.3.3 and 4.4.5 for more detail).

Graph 9 - Break-even distance for intermodal transport



Source: Meers, Vermeiren, & Macharis, 2014

Generally, the cost per TEU.km decreases when economies of scale are realised through a modal shift made possible through the bundling of cargo.

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

3.4.1.4 The transport cost between the seaports

Also, between every pair of seaports the transport cost must be established for the optimal, lowest cost, multimodal transport mode.

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

m_{ab}^c is the generalised (multimodal) cost per TEU, to transfer the cargo from seaport *a* to *b* (out of *m* seaports) so it can be bundled 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 flows between two (or more) adjacent ports could even consist of more than one hinterland cargo flow leaving the port region, thus combining the cargo flows that go to separate hinterlands but travel together between the cooperating seaports. This additional benefit is inherent in this model because it is assumed that the volume from *a* to *b* will always be large enough to allow for bundling. Essentially, it can be assumed that the cooperating ports will bundle the cargo flows for more than one hinterland together.

3.4.1.5 The cost to transfer a container

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, also known as transshipment.

3.4.1.6 The distances between the ports and the hinterland

The distances in kilometres between the ports *m* and the hinterland regions *n* as well as between the ports *m* themselves need to be established. These are two different matrices, because the hinterland regions might be geographically much larger than the region of the port.

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

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

3.4.1.7 The external cost for every transport mode

The external transport cost per vehicle.km for every transport mode needs to be defined. The external costs per TEU.km for the three transport modes, road, rail and barge are symbolised respectively as:

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

3.4.2 Steps in the analysis

The following paragraphs will detail the necessary steps to build a comprehensive cost model that allows to detect and evaluate cooperation projects that consist of bundling hinterland flows.

3.4.2.1 Eliminate ports that serve no hinterland

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

3.4.2.2 Eliminate hinterland regions with limited cargo flows

Some regions, more often far into the hinterland, a longer distance from the port, will have a too small population, industry base and commerce sector to generate cargo flows that have sufficient size to present a bundling opportunity from any port.

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

then the sum of all road traffic volumes is too small even summed up over all ports *i* (subscript *i*) in import (superscript *i*) and export (superscript *e*) 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.

3.4.2.3 Eliminate regions that already benefit from bundling

Some regions will already have bundled services connecting them to a combination of ports.

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

then a volume of rail import t_{mn}^i and export t_{mn}^eflows or the volume of barge import b_{mn}^i and export b_{mn}^e flows is already present 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 own ports, even if it is already offered by a competing port cluster. However, from a larger societal point of view, the benefit might be minimal. Because it will only lead to a shift of flows from one port cluster to another be it at a lower cost. But this increased consumer benefit will be a lot smaller than in the case where a new bundling service is offered for a hinterland where before none was available.

3.4.2.4 Identify the regions with opportunities for cooperation

The next step consists of defining 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 flow will 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 flow 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 flow from one port with an export flow of a neighbour, thus substantially reducing the proportion of empty containers being transported.

3.4.2.5 Compare the additional bundling cost with the gain in direct cost

Subsequently, it needs to be established 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 equations are true.

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

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

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

and

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

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}.

3.4.2.6 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, expanding the calculations in 3.3.2. It is assumed that all cargo will switch to the bundled transport mode, if the generalised cost of the bundled mode is indeed lower, it would be illogical for a shipper to choose the higher generalised cost of a road only solution. This effect is visible on destinations where efficient and reliable rail or barge service is offered, consequently the road service market share is very low.

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, rather than rail, then the formulas stay identical with only the superscript *t* being 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 (based on Graph 5) as follows:

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

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

3.4.2.7 Calculate the external benefit realised by the modal shift

The difference, and, most likely, reduction, in external costs for the export and import 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.*

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

3.5 Conclusion and remaining questions

This chapter shows how the hinterland connectivity of a port is an increasingly important factor influencing port choice and how ports can use the extension of the hinterland to increase their throughput and market share and consequently increasing the value added the port brings for its stakeholders. For the more distant 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 benefit, while at the same time increasing the port attractiveness. This consequently leads to a higher demand, again increasing the consumer benefit. This is shown through a graphical representation of the supply and demand functions and their evolution. The result is not only an increasing consumer benefit for the users but also gives an opportunity to reduce the external costs per unit consequently creating a win-win-win for the port, the shippers and society.

It remains to be seen where this bundling would take place, and if the decision maker will be convinced by the benefits. The method developed 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. The former will be applied to the case studies of Chapter 5.

The necessary steps are resumed in Table 7.

Table 7 - Summary of methodology

Step 1	Data collection	OD-volume tables Break-even volumes Transport costs for every OD pair, port pair and transport mode Transfer costs for bundling of cargo External costs of cargo
Step 2	Eliminate ports with little or no hinterland	
Step 3	Eliminate hinterland regions with little or no port related cargo flows	
Step 4	Identify the regions with bundling opportunities	
Step 5	Calculate bundled and unbundled transport costs	
Step 6	Calculate the consumer surplus created by bundling	
Step 7	Calculate the external cost savings	

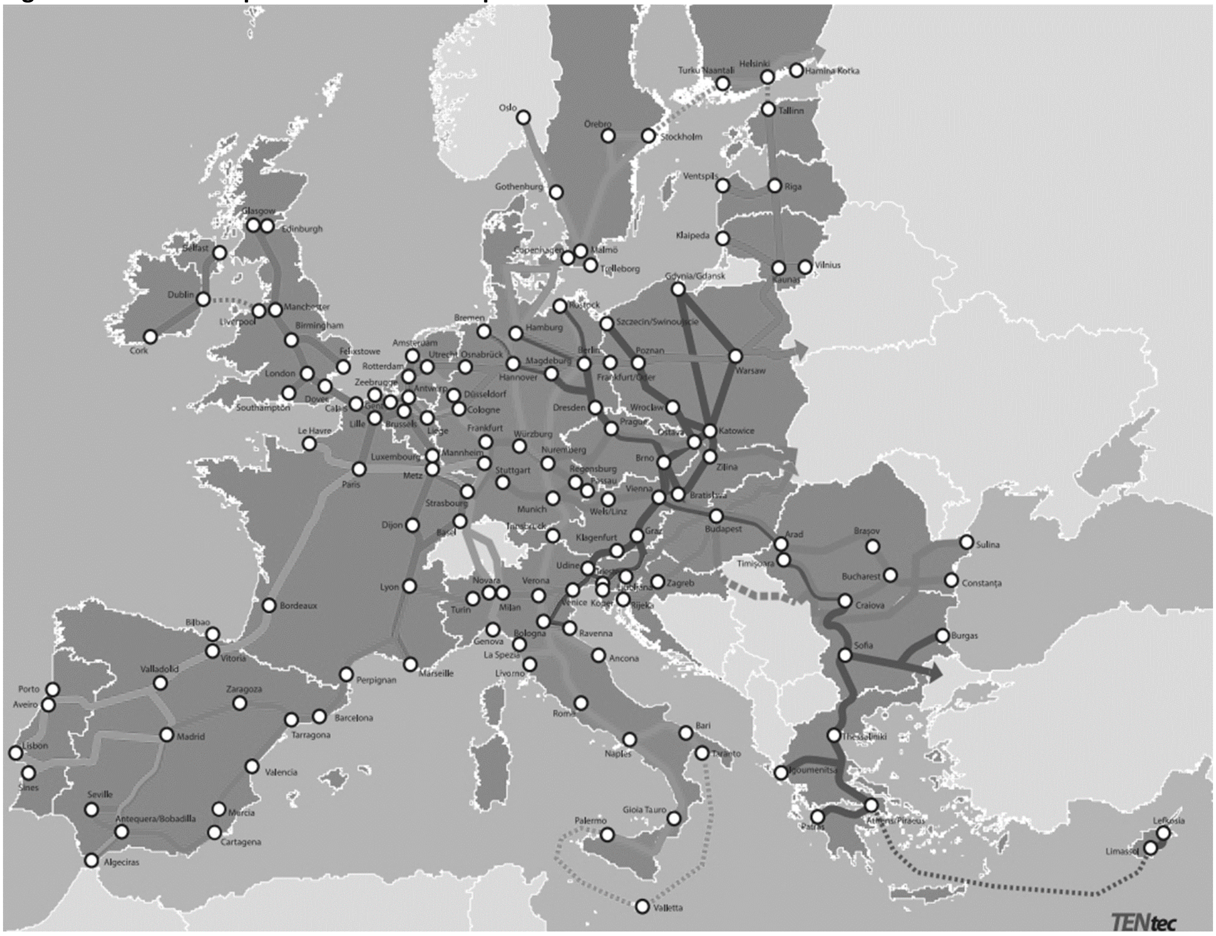
Source: own composition

Chapter 4 **COOPERATION BETWEEN SEAPORTS IN THE EUROPEAN HINTERLAND**

0 empiricalizes the concepts of the preceding chapter with a focus on the continental European hinterland. It describes the actual data available for identifying and quantifying the opportunities for cooperation in the European hinterland. The method starts from hinterland data to locate regions that are at the edge of the contested hinterland of a port region and results in a conditional system that will indicate where opportunities for cooperation are present in any given hinterland in continental Europe. The constraint of distance is reduced drastically when intermodal services become available (Guerrero, 2018). In chapter 5, these data will be used for a number of European case studies with relevant sensitivity analyses applied to the data of the cases.

The European Union has identified 9 corridors crisscrossing the EU (see Figure 14), which is known as the Trans European Network – Transport (TEN-T) (European Comission, 2017). These multimodal corridors aim at connecting the remote parts of Europe with its core thus facilitating European trade (Vanderhaegen, 2012). In this network, over 300 seaports have been identified. 104 ports (see Figure 16) are chosen as part of the core network.

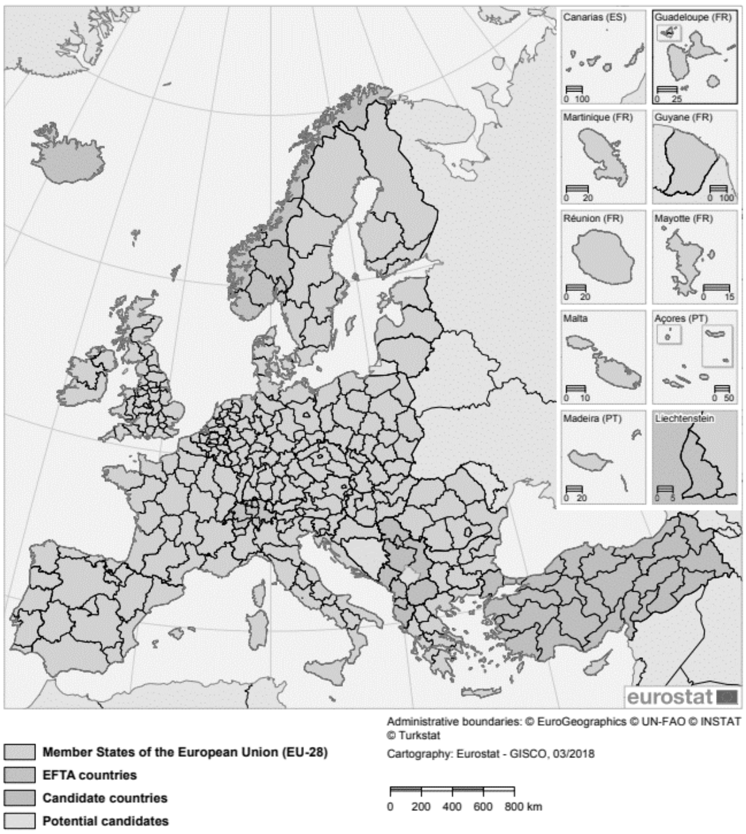
Figure 14 - Trans European Network - Transport



Source European Commission, 2013

When applied on any combination of the 104 core TEN-T port regions the following methodology will result in a list of hinterland regions where cooperation can make a difference, in decreasing order of importance. Such a list can help neighbouring PAs to prioritise their efforts and LSPs can find market opportunities. This results, as such, in a case-study (Flyvberg, 2005; Yin, 2014) of the extended European heartland, showing in which level 2 Nomenclature of Territorial Units for Statistics (NUTS2) regions (see Figure 15) cooperation offers a competitive advantage. The available data are collected on NUTS3 region (see Figure 17), but the object of analysis will be all the EU hinterland regions on NUTS2 level for two reasons. Firstly, there are 1,348 NUTS3 regions (each between 150,000 and 800,000 Inhabitants) defined by Eurostat, this makes each of them rather small in surface, population and economic and logistic capacity. This large number would result in a long list of small opportunities that would be hard to prioritise. Secondly, the NUTS3 regions that make up one NUTS2 region (each between 800,000 and 3 million inhabitants) are geographically together, making the final mile from/to the assembly point to all the local NUTS3 regions possible. With 'only' 281 NUTS2 regions the potential cooperation projects become much clearer while still keeping enough detail to be relevant. (European Commission, 2015; Eurostat, 2017d)

Figure 15 - 281 European NUTS2 regions

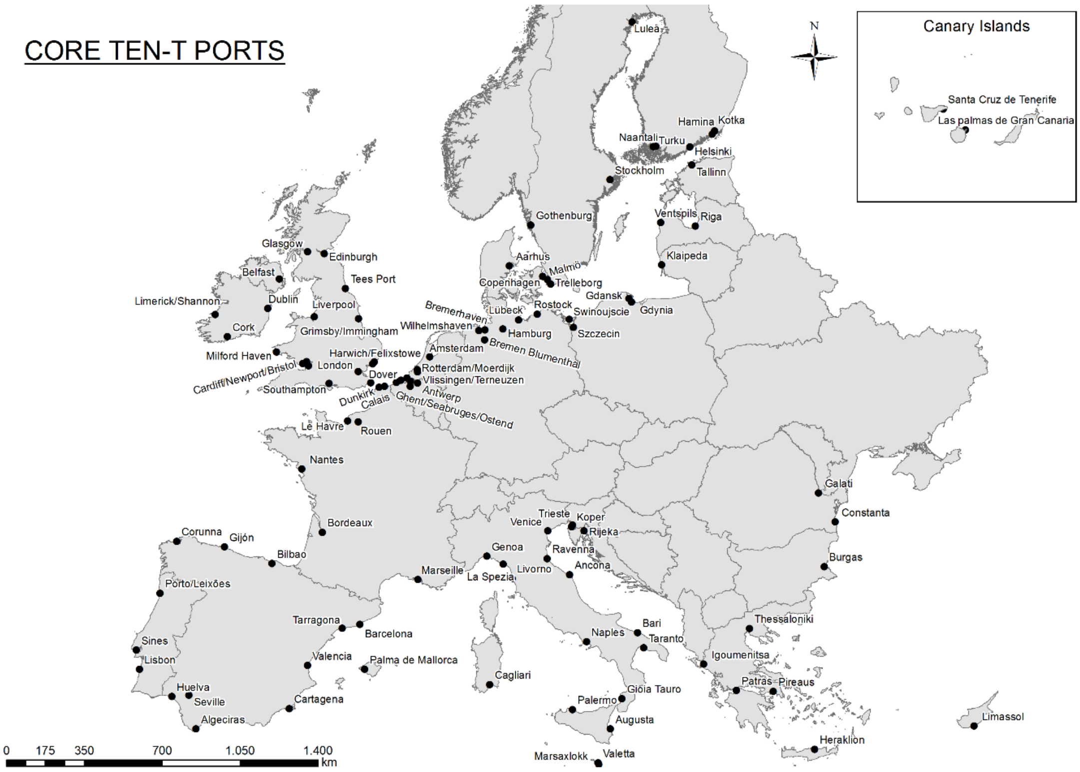


Source: Eurostat, 2018c

It can be assumed that in (or near) the centre of every NUTS2 region, a bimodal road-rail terminal is available. All that is needed is a separate railway track besides a road, a small yard area capable of holding a few hundred TEU and a reach stacker. Ideally, for every NUTS2 region an optimal rail-road bimodal terminal would be identified (see for instance Limbourg & Jourquin, 2009, 2010) but since the model handles 281 hinterland destinations and origins, this would make it unwieldy. But, NUTS2 regions are big enough to make the assumption realistic and on the other hand small enough to make any inland terminal not too far from the centre of the NUTS2 region.

The other cell of every OD pair is one of the 104 ports (list in annexe) that the EU has defined as core ports out of the 329 seaports that are part of the TEN-T network (European Commission, 2014a). Of these pairs the ones that originate or terminate on an island will have, of course, to be subtracted.

Figure 16 - 104 Core TEN-T ports



Source: own composition, based on European Commission, 2014a

The analysis is done in a static market, where costs will not be influenced by the actions of the actors. When, through bundling, two ports increase their competitiveness, it is assumed that the competing ports, that lose market share, cannot react by reducing the costs of their own hinterland connectivity. After all, the road transport market that services the hinterland of the port(s) that lose(s) market share is presumed to be already very competitive, so there is no room for service prices to drop and recover the competitiveness lost due to the modal shift realised by the cooperating ports. The only course of action open for the 'losing' ports is to also cooperate and bundle volumes to realise or increase a modal shift in their hinterland.

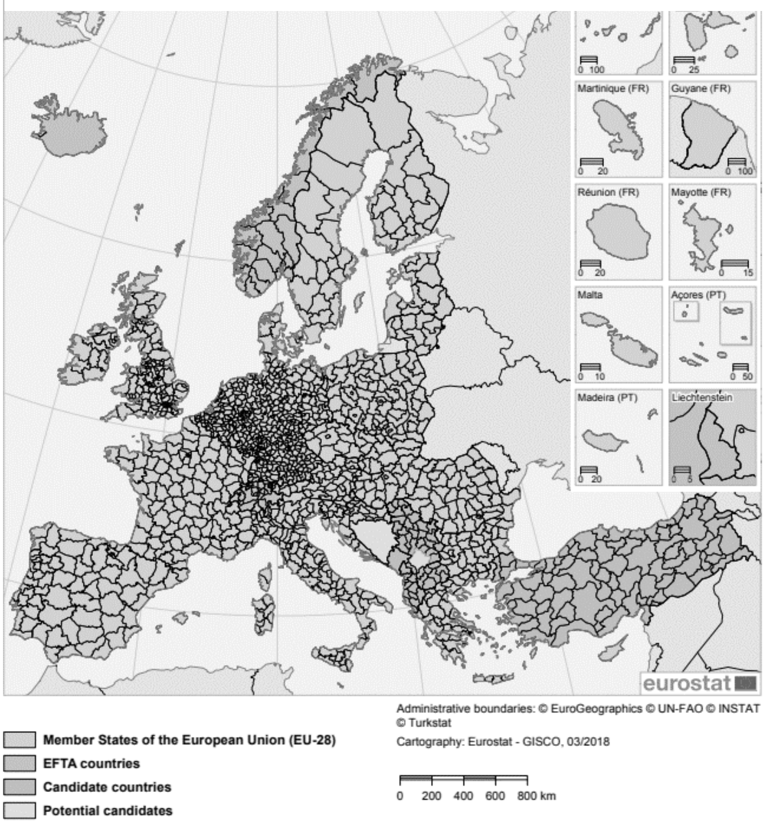
4.1 Sources of cargo flow data

The following sections will describe the available transport data for the different modes, applied to the EU. The quality but especially the wide geographic coverage of the data will define the usability of the model (Meers & Macharis, 2015).

4.1.1 Road freight data

Eurostat collects and provides OD data on NUTS3 (see Figure 17) level of road transport. The tonnes, tonnes.kilometres and vehicle kilometres are detailed by product at NST 2007 level (see Table 13) and the cargo type is given based on a list of 10 different types (see Table 11) which is close but not identical to the five cargo types used in port statistics. Interesting, but not relevant for this research, is that also the nationality of the truck is part of the database. This data is quarterly collected and parts of it are available on the Eurostat website[2] (Eurostat, 2018a). The full dataset is not publicly available but can be gotten upon request at the national statistical agency.

Figure 17 - 1 348 NUTS3 regions



Source: (Eurostat, 2018c)

The reliability of these road freight data is somewhat limited because it is collected by the Member States during a one week period based on a 5% sample where every country collects the data for its own licence plates, independent of the country where the truck in question is

[2] The data are available on the website under the references: road_go_na_ru3g and road_go_na_rl3g respectively for the unloaded and loaded cargo at NUTS3 level.

driving (European Commission & Eurostat, 2011, 2016). But, as specified in the reference manual and the pertaining EU regulation, the reliability must be, and is, commensurate with the needs of the data users (European Commission & Eurostat, 2005, 2005; Regulation (EU) No 70/2012, 2012). As can be learned from the detailed instructions and publications of the different member states, the reliability of the result is very high with a standard error, with a 95% confidence, of less than 5% in most countries. A few, smaller, countries still achieve a standard error of less than 10% (see Table 8) (European Commission & Eurostat, 2014; Eurostat, 2013).

Table 8 - Error margin with a 95% confidence

Survey	Standard error (tonnes), in %	
	2012	2013
Belgium	1.97	1.98
Bulgaria	10.37	9.24
Czech Republic	3.42	3.86
Denmark	4.55	3.90
Germany	0.83	0.83
Estonia	10.01	8.95
Ireland	3.23	3.27
Greece	11.34	14.17
Spain	2.01	1.86
France	1.43	1.37
Croatia	4.16	3.83
Italy	3.74	3.41
Cyprus	6.56	6.81
Latvia	6.59	6.84
Lithuania	2.90	2.95
Luxembourg	4.22	3.25
Hungary	2.24	2.25
Malta	n.a.	n.a.
Netherlands	1.88	1.90
Austria	2.21	2.25
Poland	2.70	2.65
Portugal	3.83	3.62
Romania	3.43	3.49
Slovenia	5.01	5.00
Slovakia	6.55	7.04
Finland	5.56	5.89
Sweden	4.67	4.99
United Kingdom	3.17	n.a.
Liechtenstein	7.65	10.68
Norway	5.69	5.26
Switzerland	5.10	5.01
FYR of Macedonia	n.a.	n.a.

Source: European Commission & Eurostat, 2014

These data are relatively up to date; the most recent available year is 2016. The dataset of 2016 uses the NUTS classification of 2013 which became officially in use in 2015. The whole dataset of 2016 lists all road transport between all 1 342 NUTS3 regions thus creating over 1,800,000 OD cells (not all them filled), every cell is further disaggregated by either the type of goods (based on the NST 2007 classifications of 20 categories of goods) or by the type of cargo, which has 10 categories that are listed in Table 11. As mentioned earlier, the data are registered by reporting country which is the nationality of the licence plate. The database lists tonnes, tonne-kilometres and vehicle kilometres. The full dataset of 2016 with detailed cargo types has an average cell value of 42,958 tonnes of cargo transported by road, with a standard deviation of 381,561 tonnes, the median is 5,876 tonnes. When looking at the largest cells it is obvious and logical that the largest cells are all recursive, i.e. they have the largest cargo flow inside their own NUTS3 region. But some of these are outliers in the sense that they are unexpected smaller NUTS3 regions that, according to the data, have large cargo movements that are out of proportion to the local economy. The most striking example is the largest cell in the set which has 82 million ton of dry bulk shipped by road inside the Greek NUTS3 region EL133 which is in NUTS2 West-Macedonia, and this is the case in the three datasets that were available for the years 2012, 2014 and 2016. The second largest cell is its neighbour EL134 with 36 million ton of dry bulk. When analysing the non-recursive flows, it becomes, not surprisingly, clear that the relations are always the biggest with the neighbouring NUTS3 region. The datasets of 2012, 2014 and 2016 are similar in their outliers and averages. An extract of the most salient data is given in Table 9. Graph 10 gives the histogram of the full dataset of 2016.

Table 9 - Road data 2012, 2014, 2016

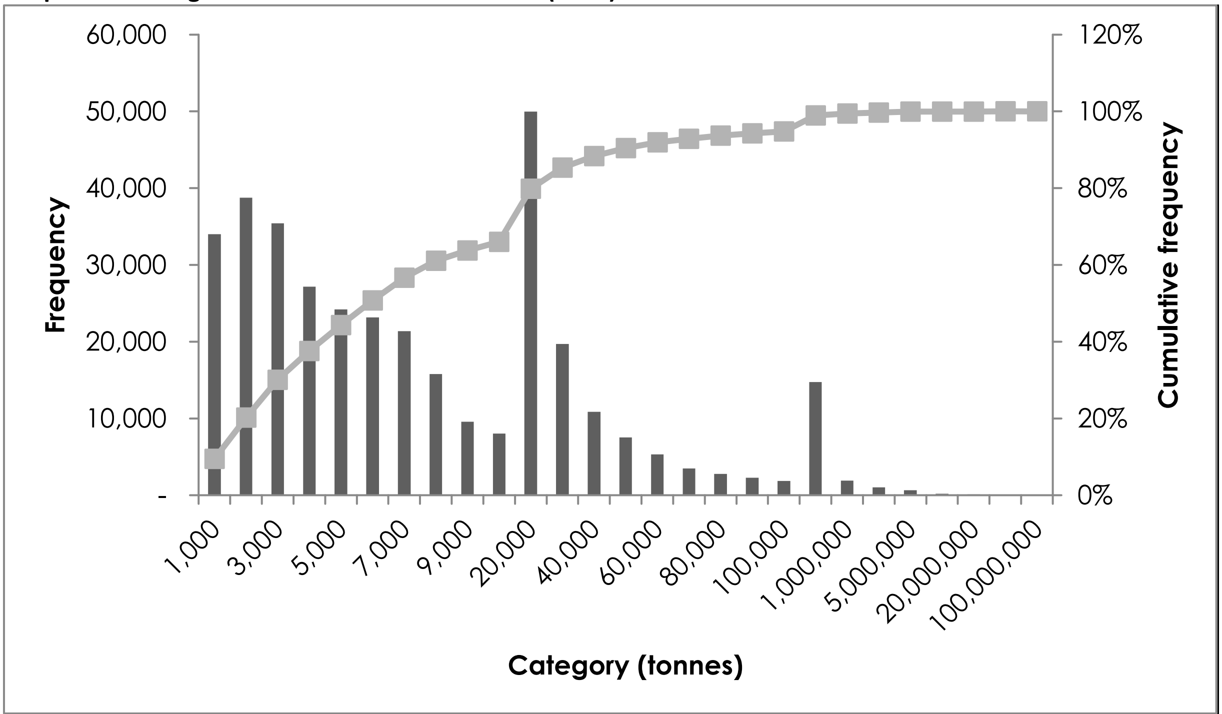
		2012	**2014**	**2016**
Mean (tonnes)		41,349	40,935	42,958
Standard deviation		420,222	388,682	381,561
Number of observations		352,989	359,896	355,991
Total tonnes		14,595,827,225	14,732,347,867	15,234,360,286
	Top 5	**Tonnes**	**Tonnes**	**Tonnes**
EL133 (531)	Dry bulk – Western Macedonia	96,580,946	82,363,480	76,203,546
EL134	Dry bulk – Western Macedonia	48,736,993	36,262,738	
FR523	Dry bulk – Eastern Bretagne		29,221,934	
ES511	Dry bulk – Barcelona	42,954,821	28,343,068	30,900,164
FR301	Dry bulk – Nord-Pas de Calais	30,171,856	27,398,287	28,221,650
ITC47	Unknown – Brescia-Lombardia	28,506,377		
DK032	Other – Southern Denmark			29,498,700
FI1B1	Dry bulk – Helsinki			27,664,573
	Other countries largest			
DE600	Containers – Hamburg	12,371,101	12,818,744	8,018,073
NL339	Containers – Groot-Rijnmond	9,871,046	6,712,208	13,235,967
BE211	Dry bulk – Antwerpen	3,388,930	4,312,814	2,297,954

BE241	Pallets – Flemish Brabant			3,798,469
	Top 5 – Non-recursive			
ITH34 - ITH35	Unknown – Veneto-Treviso>Venezia		6,763,227	
ITI44 - ITI43	Unknown – Latino>Roma	5,851,106		
IE021 - IE022	Unknown – Southern & Eastern-Dublin>Mid-East		5,778,034	7,210,089
FR302 - FR301	Dry bulk – Nord-Pas-de-Calais – Nord>Pas-de-Calais	5,525,496	5,596,283	
ITC47 - ITC46	Unknown – Brescia>Bergamo	5,262,332		
PL634 - PL633	Dry bulk – Pomoskie – Gdansk>Trojmiejski	4,185,759	4,757,882	
NO012 - NO011	Dry bulk – Akershus>Oslo		4,556,946	
UKH33 - UKH32	Dry bulk – Essex>Thurrock	4,115,641		
NO011 - NO012	Dry bulk – Oslo>Akershus			5,267,312
IE022 - IE021	Unknown – Mid-East>Southern & Eastern-Dublin			4,809,591
ITH53 - ITH54	Unknown – Reggio nell'Emilia>Modena			4,588,980
ITH35 - ITH34	Unknown – Venezia>Veneto-Treviso			4,522,254

	Other countries largest – Non-recursive			
DE600 - DE933	Dry bulk – Hamburg>Harburg	1,757,220	1,995,927	1,950,314
DE933 - DE600	Dry bulk – Harburg>Hamburg			2,491,939
NL339 - NL411	Containers – Groot-Rijnmond>West-Noord-Brabant	943,641	1,171,506	1,828,054
BE234 - BE211	Containers – Ghent>Antwerp	556,145	1,633,512	330,524
BE211 - BE213	Dry bulk-Antwerp>Turnhout			1,288,617
	Largest border crossing			
BE327 - FR301	Dry bulk – Hainaut-Tournai>Nord	2,177,426	1,885,697	1,515,211
DEA1B - NL421	Dry bulk – Kleve>Noord-Limburg			1,975,727

Source: own composition based on Eurostat, 2017a

Graph 10 – Histogram with annual road volumes (2016)



Source: own composition, based on Eurostat, 2017a

Of this massive dataset, only those cells that refer to a NUTS3 region with a core TEN-T port are needed. Therefore, a reduced dataset is extracted which contains those OD pairs where at least one of the two points has a port. This results in a dataset with over 58,000 OD pairs.

Table 10 - Road data 2014, 2016 – to/from core TEN-T ports, all cargo

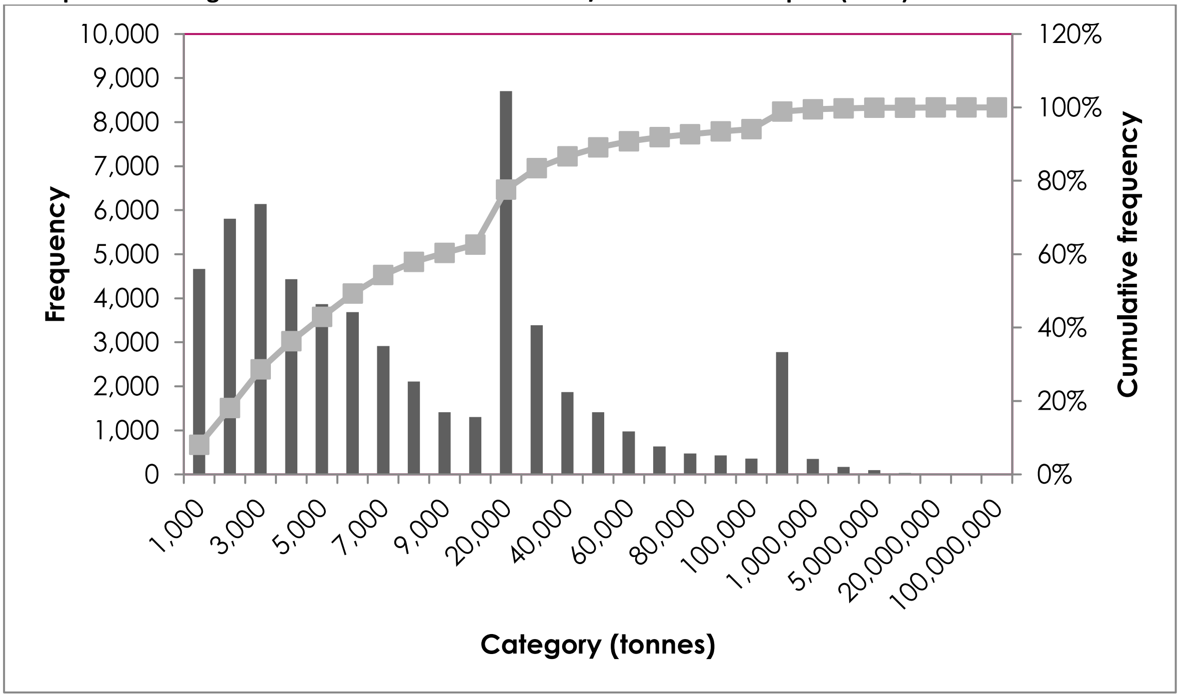
		2014	2016
Mean (tonnes)		46,383	49,772
Standard deviation		445,239	466,774
Number of observations		58,045	61,093
Total tonnes		2,692,319,472	3,040,742,135
	Top 5	**Tonnes**	**Tonnes**
ES511	Dry bulk – Barcelona	28,343,068	30,900,164
FR301	Dry bulk – Nord-Pas de Calais	27,398,287	28,221,650
FI1B1	Dry bulk – Helsinki	25,783,663	27,664,573
DK042	Unknown – Southern Denmark		26,903,050
FR612	Dry bulk – Gironde	23,132,336	
SE232	Containers – Gotland	22,101,802	
ES620	Dry bulk - Murcia		21,255,505
	Other countries largest		
DE600	Containers – Hamburg	12,818,744	8,018,073
NL339	Containers – Groot-Rijnmond	6,712,208	13,235,967
BE211	Dry bulk – Antwerpen	4,312,814	2,297,954
	Top 5 – Non-recursive		
ITH34 - ITH35	Unknown – Veneto-Treviso>Venezia	6,763,227	
ITH35 - ITH34	Unknown – Venezia> Veneto- Treviso		4,522,254
IE021 - IE022	Unknown – Southern & Eastern-Dublin>Mid-East	5,778,034	7,210,089
FR302 - FR301	Dry bulk – Nord-Pas-de-Calais – Nord>Pas-de-Calais	5,596,283	4,484,284
PL634 - PL633	Dry bulk – Pomoskie – Gdansk>Trojmiejski	4,757,882	
IE022 - IE021	Unknown – Mid-East>Dublin	3,626,040	4,809,591
FR301 - FR302	Dry bulk – Nord-Pas-de-Calais – Nord>Pas-de-Calais		4,374,362

	Other countries largest – Non-recursive		
DE600 - DE933	Dry bulk – Hamburg>Harburg	1,995,927	
DE933 - DE600	Dry bulk – Harburg>Hamburg		2,491,939
BE234 - BE211	Containers – Ghent>Antwerp	1,633,512	
BE211 - BE213	Containers – Antwerp>Turnhout		1,288,617
NL339 - NL411	Containers – Groot-Rijnmond>West-Noord-Brabant	1,171,5069	1,828,054
	Largest border crossing		
BE327 - FR301	Dry bulk – Hainaut-Tournai>Nord	1,885,697	1,515,211

Source: own composition based on Eurostat, 2017a

Quite a few cells remain unchanged. Especially the non-recursive cells were all already port oriented. Only the Norwegian region dropped out because Norway is not part of the TEN-T core port system.

Graph 11 – Histogram with annual road volumes to/from core TEN-T port (2016)



Source: own composition based on Eurostat, 2017a

From this set, only the cargo flows that are containerisable are needed. The data are disaggregated by cargo type as shown in Table 11.

Table 11 - Types of cargo

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

Source: Eurostat, 2017a

Category 2 (Large freight containers) is collected in TEU and in tonnes. However, for this research, all cargo that can be containerised must be considered, which consists of the classes 2 to 5. The other classes are much less, if at all, suited for bundling. Categories 2, 3, 4 and 5 could all be in containers if a competitive container service would be available; thus far they have been loaded in or on trucks (often tractor and trailer type) and all could just as well be loaded in containers, or the trailers can be bundled on trains.

After extracting the OD pairs that have at least one element in a NUTS3 region with a core TEN-T port, and only those observations that concern containerisable cargo; the result is a database which consists of two subsets. One set of all the import flows originating in one of the 104 core TEN-T ports and terminating in one of the NUTS3 regions and another subset with the export cargo flows, originating in one of the NUTS3 regions and terminating in one of the core TEN-T ports. These databases have still over 30,000 observations but with a lower average and standard deviation (see Table 12).

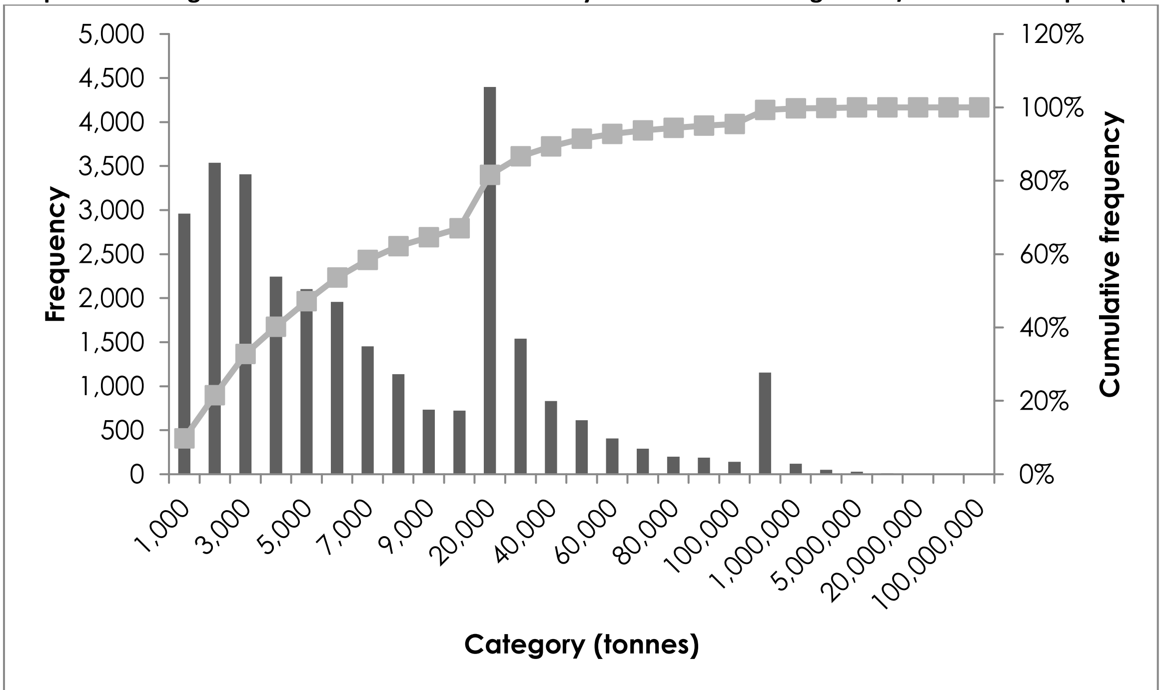
Table 12 - Road data 2014, 2016 – to/from core TEN-T ports only containerisable cargo

		2014	**2016**
Mean		31,274	35,070
Standard deviation		281,572	299,379
Number of observations		29,890	33,233
Total		934,757,365	1,165,482,942
	Top 5	**Tonnes**	**Tonnes**
SE232	Containers – Gotland	22,101,802	17,442,062
ES511	Pallets – Barcelona		19,325,467
SE224	Containers – Malmö		17,360,387
ES523	Pallets - Valencia		14,084,748
DE600	Containers – Hamburg	12,818,744	
SE110	Containers – Stockholm	11,670,399	
SE224	Containers – Skåne län (South Sweden)	11,526,855	
NL339	Containers – Groot-Rijnmond	6,712,208	13,235,967

	Other countries largest		
DE600	Containers - Hamburg	12,818,744	8,018,073
FR301	Containers – Dunkerque	7,041,702	8,125,731
BE211	Containers - Antwerpen	3,558,288	2,352,232
	Top 5 – Non-recursive		
ES522 - ES523	Containers – Castelon>Valencia	1,970,412	2,559,360
ES511 - ES512	Pallets – Barcelona >		2,502,362
ES512 - ES511	Pallets - >Barcelona		2,296,933
ES521 - ES620	Pallets - >Cartagena		2,175,006
PT16B - PT170	Containers - >Lisboa		2,086,563
BE234 - BE211	Containers – Ghent>Antwerpen	1,633,512	330,262
NL339 - NL411	Containers – Groot-Rijnmond>West-Noord-Brabant	1,171,506	1,828,054
SE232 - SE231	Containers – Gotland>Hallands	1,000,110	1,176,550
DE501 - DE502	Containers – Bremen>Bremerhaven	971,203	899,710
	Largest border crossing		
NL339 - BE211	Containers – Groot-Rijnmond>Antwerpen	404,935	542,077

Source: own composition, based on Eurostat, 2017a

Graph 12 – Histogram with annual road volumes only containerisable cargo from/to core TEN-T port (2016)



Source: own composition based on Eurostat, 2017a

Cargo composition of the road freight

Eurostat also supplies data on road freight but disaggregated along the product categories of NST 2007 (see Table 13). The NST 2007 classification has a lot of detail but only the cargo that is containerisable is of interest, which coincides mainly with the codes 04, 05, 06, 08, 11, 13, 15, 16, 17, 18, although it must be admitted that this selection is, out of necessity, slightly arbitrarily (UNECE, 2008). The type of goods transported is important for the estimation of the value of the cargo, this will be further developed in the paragraph on the value of time (VOT) and in the cases in chapter 5. The EU average of the proportions of the different containerable cargo types is shown in Table 14. The biggest categories are food, wood and its related products, chemicals and plastics. The data were only available at NUTS1 level.

Table 13 - NST 2007 first level classification

01	Products of agriculture, hunting, and forestry; fish and other fishing products
02	Coal and lignite; crude petroleum and natural gas
03	Metal ores and other mining and quarrying products; peat; uranium and thorium
04	Food products, beverages and tobacco
05	Textiles and textile products; leather and leather products
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
07	Coke and refined petroleum products
08	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel
09	Other non metallic mineral products
10	Basic metals; fabricated metal products, except machinery and equipment
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
12	Transport equipment
13	Furniture; other manufactured goods n.e.c.
14	Secondary raw materials; municipal wastes and other wastes
15	Mail, parcels
16	Equipment and material utilized in the transport of goods
17	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non market goods n.e.c.
18	Grouped goods: a mixture of types of goods which are transported together
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16
20	Other goods n.e.c.

Source: Eurostat, 2017a

Table 14 - Containerable cargo transported by road in the EU in 2016 (tonnes)

Class	Abbreviated description	Tonnes	Percentage
4	Food	1,832,650,951	37%
5	Textiles	70,794,084	1%
6	Wood	607,750,882	12%
8	Chemicals, plastics	596,891,902	12%
11	Machinery	287,716,591	6%
13	Furniture	120,801,004	2%
15	Mail	215,262,557	4%
16	Equipment	315,355,576	6%
17	Moving	164,621,467	3%
18	Mixed	805,758,374	16%

Source: own composition based on Eurostat, 2017a

4.1.2 Inland water way data

Inland water way (IWW) data are available but only at NUTS2 to NUTS2 level up to the year 2017[3]. Unfortunately, the one dataset that is disaggregated on different types of cargo is very incomplete in its geographical coverage. The other is disaggregated on products according to NST 2007 level (see Table 13) and is more comprehensive and available for the year 2016.

The data are, as mentioned above, only available at NUTS2 level but many NUTS2 regions have only one core TEN-T seaport and only flows which originate or end in a core TEN-T port are of interest so the appropriate NUTS2 region can be taken as a proxy for the port. Obviously, IWW is especially relevant for Benelux, Northern and Western-Germany and Northern France[4]. In the region relevant for IWW the ports in Belgium of Ghent and Antwerp (Waaslandhaven) share a NUTS2 region and the small port of Ostend is the same region as Zeebruges. Also, the French ports of Calais and Dunkerque are in the same NUTS2 region. Bremen and Bremerhafen share a NUTS2 region but they make up an integrated port authority. This is a very similar situation with the port of Le Havre and Rouen in France and the ports of Terneuzen and Vlissingen in the Netherlands.

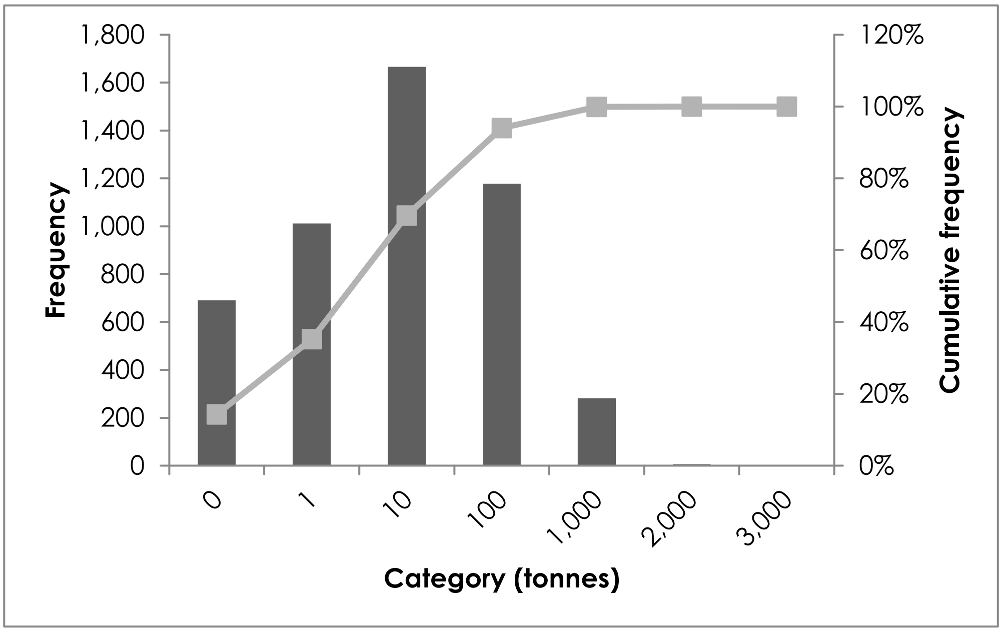
Outside the IWW region some ports in Finland, Italy, Ireland, Poland and Spain share a NUTS2 region but IWW is not relevant there anyway, so they will not appear in these IWW statistics. The TEN-T core port table gives the details in the annexe.

Thus, the full dataset of over 257,000 data points is reduced to cargo flows of containerisable products (the codes 04, 05, 06, 08, 11, 13, 15, 16, 17, 18) that originate or terminate in a NUTS2 region of one of the core TEN-T ports.

[3] The dataset with types of cargo is accessible at Eurostat under the code: iww_go_atycafl, and the one with the type of goods is available under the code: iww_go_atygofl

[4] The data at the time of writing (mid 2018) was available until 2016 and partially to 2017.

Graph 13 – Histogram with annual IWW volumes from/to core TEN-T ports only containerisable cargo (2016)



Source: own composition, based on Eurostat, 2017b

Remarkably, most of the biggest cells are non-recursive and border crossing, this confirms that IWW is especially competitive over a longer distance than road. The Eurostat data for shipment of containers by IWW has a median load of 12.5 tonne/TEU for a non-empty container (Eurostat, 2017b). This is excluding the tare weight of the container.

Table 15 - IWW data 2014, 2016 – to/from core TEN-T ports only containerisable cargo

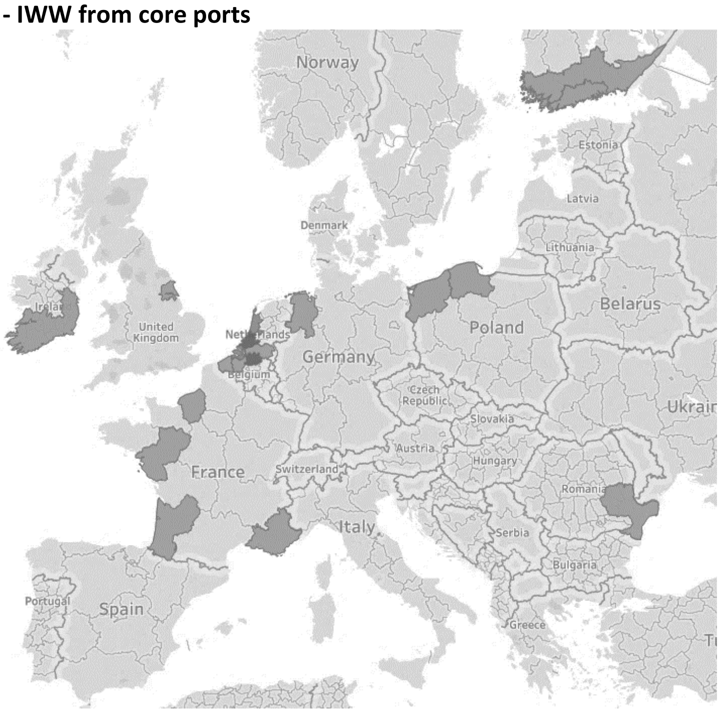
		2014	2016
Mean		31,610	35,800
Standard deviation		102,305	156,789
Number of observations		4,135	3,897
Total		131,295,000	139,523,000
	Top 5	**Tonnes**	**Tonnes**
BE 21 - BE 21	Class 16 Transport equipment – Antwerpen>Antwerpen		7,070,000
NL 33 - B 21	Class 08 Chemicals – Zuid-Holland>Antwerpen	2,413,000	2,819,000
BE 21 - NL 33	Class 08 Chemicals – Antwerpen>Zuid-Holland	1,993,000	2,388,000
BE 33 - BE 21	Class 16 Transport equipment Liege>Antwerpen		1,143,000

NL33 - DEA1	Class 04 Food products – Zuid-Holland>Dusseldorf	1,108,000	1,082,000
NL33 - DEA1	Class 08 Chemicals – Zuid-Holland>Dusseldorf	1,073,000	1,005,000
NL33 - DEB3	Class 08 Chemicals – Zuid-Holland>Rheinhessen-Pfalz	1,072,000	855,000

Source: Eurostat, 2017b

IWW is not everywhere in Europe an option to bundle cargo flows. The following maps show the NUTS2 regions that contain one or more TEN-T port and that have measurable IWW flows as collected by Eurostat (Eurostat, 2017b). The first map (Figure 18) shows the regions where IWW flows are loaded and the second one (Figure 19) where IWW flows are discharged in the respective ports. The colours indicate that the NUTS2 regions containing the ports of Rotterdam and Antwerp have IWW flows that are substantially above average.

Figure 18 - IWW from core ports



Source: own composition, based on Eurostat, 2017b

Figure 19 - IWW to core ports

Source: own composition, based on Eurostat, 2017b

However, these data must be handled with care because they include coastline cruisers that go upriver. The regions in Ireland (IE02) and UK (UKE1 and UKH3) on the maps above are actually showing flows, themselves rather small being 1,000 ton, that originate or terminate in the province of Antwerp (Belgium) (BE22) and the region of Dusseldorf (Germany) (DEA1) respectively. For the above-mentioned reasons, IWW will not be used to develop an EU wide bundling model, but for a regional approach they could be useful (for instance: Konings, van der Horst, Hutson, & Kruse (2010)).

4.1.3 Short sea shipping data

Although, conventionally, short sea shipping (SSS) is often not considered a hinterland transport mode, it can be used to replace trucks on many European connections, since most EU countries are not landlocked. In this context, SSS acts as a hinterland connection mode and can be used for bundling road cargo in a more sustainable and more economical transport mode. OD data in Europe is not available at a detailed level. Eurostat only has data[5], which describes the tonnes (without detail of type of cargo or type of goods) to/from each EU country from/to larger maritime areas (Eurostat, 2017c). This is insufficient for the purpose of this research, but the large volumes and the presence of all maritime EU countries indicate the potential of SSS for bundling.

[5] They are accessible on the Eurostat website under the code mar_sg_am_cws

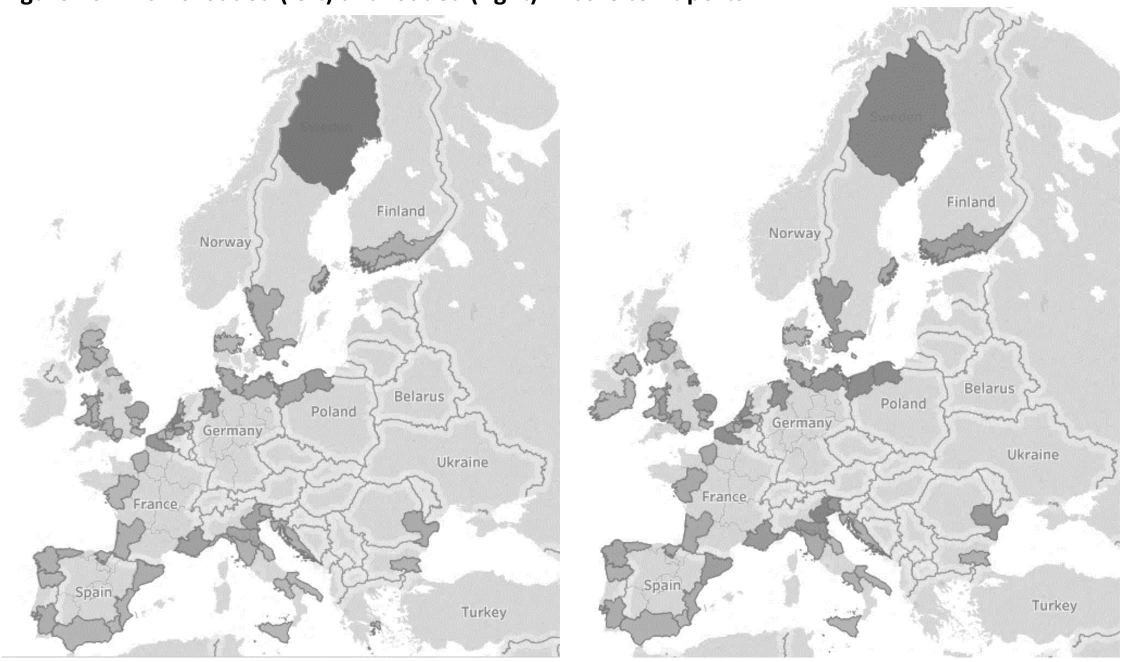
4.1.4 Rail data

Some railway data are available, but their lack of quality, detail and their partial character makes them unusable, as will be shown further. Also, it must be remembered that train weight statistics count the container in the cargo weight, which other transport modes do not. The operators even think in locomotive traction power and even include the weight of the wagons in their planning. The most recent data (in the summer of 2018) at NUTS2 level are from 2015[6]. They are collected every five years, but many countries are missing (Eurostat, 2018d). They are given at NUTS2 level but without any indication of cargo type nor the product, which makes it difficult to use them in this context. Only tonnes are given. It can readily be assumed that the biggest cargo flows are, most probably, bulk cargo. The largest flow is found in Poland (Silesia) where more than 42 million tonnes are transported inside NUTS2 region PL22. The second biggest observation is found in Germany, Braunschweig (DE91), a volume of more than 23 million is registered. The third and fourth biggest observations are between Upper Norrland (SE33) in Sweden and Nord Norge (NO07) in Norway, where the Swedish and Norwegian operators each transport slightly over 17 million tonnes. The Swedish region contains a core TEN-T port. The fifth observation is, again, in Germany where almost 14 tonnes is transported over rail inside Saksen-Anhalt (DEE0). When only the observations with precise NUTS2 references are counted, the dataset has 16,432 observation, with an average of 76,570 tonnes and a standard deviation of 550,264. Many observations have very low values which, considering that rail is mostly used for larger volumes, makes their validity doubtful. Only 10,588 observations have a value of over 1,500 tonnes, 4,914 observations rate higher that 18,000 tonnes annually, a Belgian rail operator counts on 1,500 tonnes per train (including tare and wagons), which would mean that only these last cells would represent at least one train monthly.

When a subset is extracted with origin or destination one of the NUTS2 regions that have, at least, one core ten-t port, the following pictures emerge for import and export flows. Only flows of over 46 592 tonnes annually have been withheld, this is a minimum for a weekly container train loaded at 80% ([11 tonnes cargo + 3 tonnes container] * 80 containers [TEU]/train * 80% load factor * 52 weeks).

[6] They are accessible on the Eurostat website under the code tran_r_rago

Figure 20 - Trains loaded (left) and loaded (right) in core ten-t ports



Source: own composition, based on Eurostat, 2017b

Since there is no way of knowing the type of cargo or the products covered by these data, it is difficult to know if and how they could be used for the bundling of containers.

4.2 Transport cost data

It is important to make a clear distinction between costs and prices. Prices are the result of the interaction between supply and demand and, as such, have a higher volatility than the (internal) costs that the LSP must cover. Even if costs for energy can fluctuate, the costs for labour and investments are much more stable over time. For this research it would be feasible to get prices from LSPs for the different OD pairs and transport modes, but they would present a momentary snapshot of a specific situation and would be out-of-date even after a few weeks. By working with estimated costs, the analysis has a longer lasting validity.

4.2.1 Direct cost data

Contrary to external costs (see 4.2.4) there is no generally accepted set of time and distance costs for cargo transport in Europe. Grosso (2011) made an analysis of costs and speeds of intermodal transport. The analysis compares a tractor-trailer combination with a train and a 2,000 tonnes barge and is based on average European salaries. Panteia (2017) publishes an extensive analysis of all types of road vehicles with their respective costs and with scenario's for the different services. For this research the data for truck and container chassis are used. This is part of series with a yearly update that goes as far back as 2004 (Nea, 2004). The original NEA data also have costs for rail transport where the shunting time is amortised over the hourly cost. It works with costs relevant for the Dutch trucking industry. Van Hassel et al. (2018) made a study on the greening of transport through the Rhine Alpine corridor which uses cost data for train and truck and that are based on a truck speed that increases asymptotically with the distance towards 80km/hour, it also has train costs and speeds and IWW time and distance costs (van Hassel, Vanelslander, & Doll, 2018). The seminal work of

Blauwens et al. (2016) has since its 2011 edition time and distance costs for the different transport modes. In their maritime global chain model Van Hassel et al. (2016) calculated the costs of the different hinterland transport modes.

All these different sources give, of course, different costs and have different time stamps.

Table 16 - Overview of transport costs

		Van Hassel, 2018	Van Hassel, 2016	Grosso	Panteia	Blauwens	NEA
Year of data		2015	2015	2010	2017	2011	2002
Parameter	unit	quantity					
Distance road	€/km	0.83	0.64	0.44003	0.4116	0.5	0.2742
Time road	€/h	35.4	41.79	39.72	42.2213	29.26	36.54
Distance rail	€/km	5.49	5.49	6.7			4.55
Time rail	€/h	2192	1200	210.5			751.5
Fixed cost rail	€	1950	924.58				
Distance IWW	€/km	12.05	0	6.705		5.78	5.24
Time IWW	€/h	287.55	438.17	127.5		148.57	166.2
Transshipment	€/TEU	40	40	50			
Speed road	km/h	80	80	69		65	52
Max driving time	h	4.5		4.5			
Rest time	h	0.75					
Max time	h/24h	9		9			
Speed rail	km/h	50	50	55			41.60
Speed IWW	km/h			10.5			9.22
TEU/truck		1.5	1.5				
TEU/train		70	60				
TEU/barge		200					
VOT	€/h						
Waiting time road	h		1				
Handling time road	h		0.5				
Waiting time rail	h		20				
Handling time rail	h		20				
Waiting time IWW	h		7				
Handling time IWW	h		2.5				

When all costs are put together and when an average, estimated, 2% p.a. inflation is taken into account to actualise all data to the same base year, the following table emerges. Although not exactly the same, all sources are in the same magnitude.

Table 17 - Actualised transport costs

		Van Hassel, 2018	Van Hassel, 2016	Grosso	Panteia	Blauwens	NEA
Year of data		2015	2015	2010	2017	2011	2002
Actualised costs data	2018						
Annual cost inflation	2%						
# years		3	3	8	1	7	16
Distance road	€/km	0.88	0.68	0.52	0.42	0.57	0.38
Time road	€/h	37.57	44.35	46.54	43.07	33.61	50.16
Distance rail	€/km	5.83	5.83	7.85	-	-	6.25
Time rail	€/h	2,326.17	1,273.45	246.63	-	-	1,031.65
Fixed cost rail	€	2,069.36	981.17	-	-	-	-
Distance IWW	€/km	12.79	-	7.86	-	6.64	7.19
Time IWW	€/km	305.15	464.99	149.39	-	170.66	228.16
Transshipment	€/TEU	42.45	42.45	58.58	-	-	-

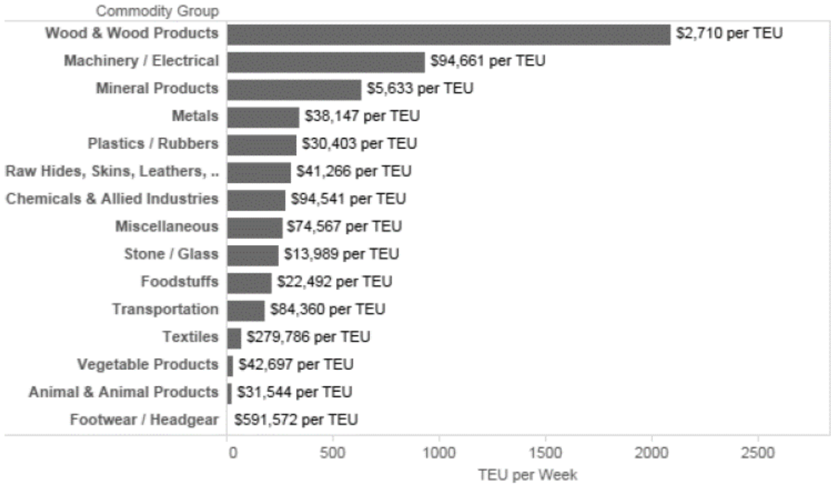
For further use in this research a rounded-off average is set, also to avoid an appearance of accuracy, influenced by the recency of each dataset.

4.2.2 Value of time (VOT)

The VOT has two large components. Firstly, there is the time cost of the vehicle. This is a cost for the operator of the vehicle, either an LSP or a cargo owner with own transport. It consists of salary costs for the driver and time costs for the investment in the vehicle. These costs are covered by the direct cost, and as such not included in the following VOT analysis. Secondly, there is the time cost of the cargo. Here, the VOT is derived from the value of the cargo. This is the VOT which is discussed in the following paragraphs. Besides VOT, there is also the value of reliability (VOR) based on the variability of the expected time. These variances can lead to a disrupted production or a dissatisfied, because not timely served, customer. The values for the VOR are in themselves not insignificant but are only a fraction of the VOT values and are therefore not taken into account in the following analysis. (Bates, 2012)

The cargo value has a very large variation. An IHS Markit study starts even with a container (TEU) filled with diamonds and a value of almost 1,2 billion USD (IHS Markit, 2017). TEU values are mostly interesting for insurers who, with the ever-increasing size of container vessel, try to estimate their increasing exposure (Cowie, 2007). Graph 14 shows the value of the cargo per TEU for the 15 most common commodities as well as their importance for maritime shipping, similar data for inland transport has not been found.

Graph 14 - Value per TEU and global weekly maritime volumes



Source: IHS Markit, 2017

The World Shipping Council reports a total value of maritime shipping containerised cargo for the EU of 1.41 trillion Euro in 60-65 million TEU, for the year 2017. Which makes an average value of 23,500 – 21,700 Euro/TEU for each loaded container (World Shipping Council, 2018). This contrast starkly with the numbers presented by O'Sullivan, who posts an average value of 80 000 USD per TEU in the 'top international ports' with figures going from 150,000 USD/TEU in Japan to 40,000 USD/TEU in Africa and the Middle-East (O'Sullivan, 2010). A more in-depth analysis can be found in the Ocean Trade database of Seabury (2018). Table 18 shows the value in US Dollar per TEU for maritime import in Benelux, France and Germany for the year 2017.

Table 19 shows the same but for exports.

Table 18 - USD per TEU imported in Benelux, France and Germany

USD per TEU	**Africa**	**Asia Pacific**	**Europe**	**Latin America**	**Middle East & South Asia**	**North America**	**All partner countries**
Capital Equipment & Machinery	160,177	64,920	71,886	60,628	51,921	81,500	68,360
Chemicals & Products	20,837	52,619	24,403	42,023	33,936	53,548	48,197
Consumer Fashion Goods	242,498	72,845	186,946	70,078	82,998	100,409	78,988
Consumer personal & household goods	58,732	30,862	26,351	43,253	25,189	50,524	30,745
High Technology	176,606	147,785	406,923	134,375	132,018	305,074	155,834
Land Vehicles & Parts	79,704	46,867	44,120	52,081	33,961	40,414	46,159
Machinery parts. Components, supplies & manufactures n.e.s.	84,953	54,335	36,368	66,817	45,052	100,735	58,448
Raw Materials, Industrial consumables & Foods	36,379	28,642	24,321	28,616	20,731	25,272	27,108
Secure or Special Handling	402,530	77,187	1,681,809	167,379	136,347	318,049	142,399
Temperature or Climate Control	16,172	37,836	56,737	17,699	23,944	33,942	21,765
All commodity groups	**41,963**	**48,435**	**27,753**	**27,559**	**34,134**	**45,404**	**43,080**

Source: Seabury, 2018

Table 19 - USD per TEU exported from Benelux, France and Germany

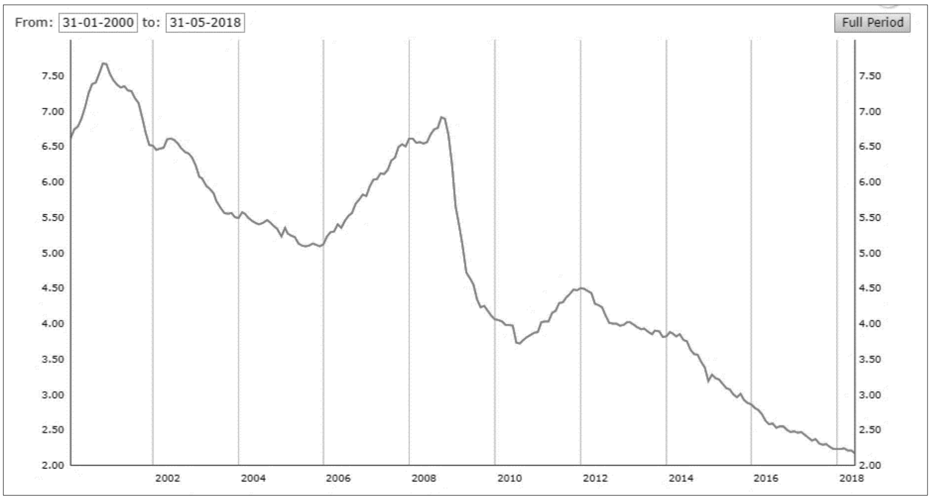
USD per TEU	**Africa**	**Asia Pacific**	**Europe**	**Latin America**	**Middle East & South Asia**	**North America**	**All partner countries**
Capital Equipment & Machinery	56,030	91,302	67,822	79,794	60,396	96,045	79,964
Chemicals & Products	45,380	65,137	29,571	46,930	39,202	70,705	55,356
Consumer Fashion Goods	116,430	269,071	207,266	158,082	165,710	154,219	171,287
Consumer personal & household goods	28,543	43,497	45,405	48,267	38,543	48,339	41,975
High Technology	158,126	333,451	128,389	293,531	181,543	882,803	343,865
Land Vehicles & Parts	30,786	62,721	51,793	57,693	39,122	55,195	51,047
Machinery parts. Components, supplies & manufactures n.e.s.	76,268	99,630	49,857	73,100	57,355	78,327	79,423
Raw Materials, Industrial consumables & Foods	20,105	21,119	20,234	21,002	18,969	25,155	21,408
Secure or Special Handling	86,230	299,071	156,564	253,252	467,338	620,044	452,732
Temperature or Climate Control	11,424	22,612	15,214	11,755	12,066	28,090	16,892
All commodity groups	**31,305**	**44,097**	**32,918**	**40,816**	**31,615**	**52,883**	**41,210**

Source: Seabury, 2018

The overall average of all countries and all commodities is a weighted average that considers the different volumes for all categories and regions. An approximative, rounded off average overall of 43,000 USD, or 35,800 EUR (at 1.2 EUR/USD at 31/12/2017) will be used in the following analysis.

The effect of time on the value of the cargo has two aspects. Firstly, there is the financing of the cargo whilst en route and secondly, there is the loss of value over time of said cargo. Additionally, there are the effects of uncertainty and flexibility, but these are much harder to quantify. They will, in any case, increase the value of time (Blauwens & Van de Voorde, 1988). The cost of financing is, of course, very much depending on the situation on the financial markets and the price of money. At the time of writing (summer 2018) with the ECB still using quantitative easing and with persisting below par inflation rates, the price of money on the European money market is historically low. Graph 15 shows the evolution of interest rates by monetary financial institutions to households and non-financial corporations for revolving loans (ECB, 2018). It is well below 2.5 % p.a. A cost of money of 2.5% will be used in the following calculations. This is consistent with a -0.325 % p.a. EURIBOR interest rate (Eurostat, 2018e).

Graph 15 - Interest rates for revolving loans in the Euro market



Source: ECB, 2018

The depreciation of the cargo over time is largely dependent on the type of goods that make up the cargo (Blauwens & Van de Voorde, 1988). Foodstuffs have a short to very short lifespan, fashion and high-end electronics depreciate still fast but slower than foodstuffs and technical components can usually be sold even after a longer period. Dry bulks like iron ore and coal have of course a nearly unlimited shelf life but since the focus is on containerisable cargo, these commodities are not relevant. The loss of value over time should be calculated differently for every commodity in Table 18 and Table 19. But since it is impossible to know which cargo flows will be bundled, an overall average needs to be used. Taking an average shelf life of 4 years, an annual depreciation of 25% seems acceptable. The value of 10% used by van Hassel et al. (2018) and based on the ASTRA model (Schade, 2005) implies a shelf life of 10 year which is unrealistic for containerisable cargo.

Combining the 25% p.a. depreciation and a 2.5% p.a. financing cost with a value per TEU of 35,800 Euro, the VOT is 26.97 Euro/day, rounded off to 27 Euro/day per TEU, making 1.12 Euro/hour.

The time spent on the way is of course a function of speed plus the time needed for the loading, unloading and bundling. Obligatory resting times for truck drivers are also calculated; every 4.5 hours a 45-minute rest is taken into account and every 9 hours an 11-hour break is counted (Regulation (EC) No 561/2006 of the European Parliament and of the Council, 2006). The above-mentioned chain model (van Hassel et al., 2016) cites a truck speed of 80 km/hour, which seems a bit optimistic in today's congestion, the other sources vary between 52 (NEA, 2004) and 69 (Grosso, 2011). An average of 65 km/hour seems realistic. For train speeds, there is much more consensus with a value of 50kms/hour, only Grosso (2011) gives 55 kms/hour. The time needed for loading, unloading and bundling is only mentioned by Van Hassel (2018) at a realistic 1.5 hour for a truck and 20 hours for a train. Important: the time for a truck while waiting to be loaded is at full cost, the driver will be standing nearby. This time for the train is important for the cargo, who is sitting idle, but the train does not have to be paid during this time.

4.2.3 Transfer and bundling costs

If containerized cargo is shipped by road straight from/to the port to/from the hinterland destination/origin, it will be loaded, for instance by a reach stacker, onto the trailer and in a similar way offloaded at the destination. This is the baseline scenario. When using a reach stacker, loading a container on a truck-trailer combination or on a train wagon has the same cost. In the hinterland, to cover the first/last mile, the container will need to be transferred to/from a train wagon from/to a road tractor-trailer combination. This is an additional cost, which is estimated at 50 Euro/TEU. This amount was fixed as a result of interviews with several terminal and rail operators and fits with the handling costs Wiegmans & Behdani (2018) have published in their overview of container handling costs in the literature (see Table 20).

Table 20 - Handling costs in an intermodal rail terminal

Source	Handling cost in scientific papers
Newman and Yano (2000)	$1–2 per container
Van Duin and Van Ham (2001)	Range: €14–68/TEU; average: €40/TEU
Arnold et al. (2004)	The relative cost of rail (compared with road) is assumed €0.65 per km and the transhipment cost is equivalent to 100 km
Bontekoning (2006)	€35 per ILU (average market price)
Jourquin and Limbourg (2007) and Limbourg and Jourquin (2009, 2010)	(Un)loading cost of €1.297/ton (an average TEU weighs about 15–16 tons)
Bhattacharya et al. (2014)	$70–100 per container
Zhang and Facanha (2014)	$40 per FEU
Source	Handling cost in grey literature
www.ectvenlo.nl (2001)	Transport (Rotterdam-Venlo) and container handling: '20 < 14.5 ton or empty €64 '20 > 14.5 ton €85 '30/40 full or empty €95 '45 full or empty €126
RECORDIT project (Black et al., 2002)	€36–60 per handling
REORIENT project (Vold, 2007)	€45 per handling
BELOGIC project (Bozuwa et al., 2011)	€40 per TEU
RIRDC (2007) reported from Victorian Department of Infrastructure (2003)	$15 per lift

Note: FEU, forty feet equivalent unit.

Source: Wiegmans & Behdani, 2018

The most important bundling cost is the assembly of the train, this cost is estimated by van Hassel et al. (2018) at 1,165.21 Euro/train. Following interviews with operators, an amount of 1,000 Euro will be used in the following calculations. This covers the direct time costs of the train and its personnel.

The additional costs for bundling can be summarized as follows: 50 Euro/TEU for one additional loading and 1,000 Euro/train fixed costs for composing the train.

4.2.4 External costs

Contrary to the disparate sources on direct costs, there is a European manual for calculation external costs which is publicly available and used by many academics and consultants. The "Update of the Handbook on External Costs of Transport", produced by Ricardo-EAE (but authored by Gibson et al. and thus quoted) and commissioned by DG Move of the European Commission has an in-depth analysis of all external costs. The use of one and unique source for all external costs has the advantage of assuring that the methodology used to calculate these costs will be standardized over the different types of costs. Combining different sources would incur the risk of adding apples to oranges. As the title implies, it is an update of an earlier study following the methodology but updating the values (Maibach, Van Essen, Doll, & Pawlowska, 2008). Mostert & Limbourg (2016) give an overview of the state of the art on external costs, starting from a distinction between marginal, average and total cost and whether the study is academic or project-oriented. Not all mentioned research covers all the different external cost types. To be applicable to the present research, external cost data must be available for the whole of the EU, cover all types of external costs and be practically usable in a project type analysis, i.e., applicable and project-based. The Ricardo-EAE publication answers to these requirements, as is shown in Table 21. The data are confirmed by a update study which is in progress (Van Essen, 2018).

Table 21 - Summary of the external cost characteristics studied in literature

Author	Air pollution	Climate change	Noise	Accidents	Congestion	Costs: Average (A) Marginal (M) Total (T)	Perspective: Academic Project-based	Objective Prescription Application Projection
Forkenbrock (1999)	X	X	X	X		A	Academic	Application
Forkenbrock (2001)	X	X	X	X		A	Academic	Application
Sansom (2001)	X	X	X		X	A, M	Project-based	Application
Mayeres (2001)	X	X		X	X	M	Project-based	Application
RECORDIT (2001)	X	X	X	X	X	M	Project-based	Application
Beuthe et al. (2002)	X	X	X	X	X	M	Academic	Application
INFRAS/IWW (2004)	X	X	X	X	X	A, M, T	Project-based	Application
CAFE (2005)	X					M	Project-based	Application
HEATCO (Odgaard et al., 2005)	X	X	X		X	A, M, T	Project-based	Prescription
ExternE (Bickel et al., 2005)	X	X		X		M	Project-based	Prescription
HEATCO (Bickel et al., 2006a, 2006b)	X	X	X		X	A	Project-based	Application
Bickel et al. - UNITE(2006c)	X	X	X			M, T	Project-based	Application
Janic (2007)	X		X	X	X	A	Academic	Projection
Janic (2008)	X		X	X	X	A	Academic	Projection
Maibach et al. (2008)	X	X	X	X	X	A, M	Project-based	Application
Van Essen et al. (2008)	X	X	X	X	X	M	Project-based	Prescription
Delucchi and McCubbin (2010)	X	X	X	X	X	M	Academic	Prescription
Macharis et al. (2010)	X	X	X	X	X	M	Academic	Application
Janic and Vleugel (2012)	X	X	X	X	X	A	Academic	Application
Michiels et al. (2012)	X					M	Academic	Application
Cravioto et al. (2013)	X	X	X	X	X	A, T	Academic	Application
Moliner et al. (2013)			X			A	Academic	Application
Pérez-Martínez and Vassallo-Magro (2013)	X	X		X		M	Academic	Application
Ricardo-AEA (2014)	X	X	X	X	X	A, M	Project-based	Application
van Lier (2014)	X	X	X	X	X	M	Academic	Prescription
Agarwal et al. (2015)	X	X			X	M	Academic	Application
Austin (2015)	X	X		X	X	A, M	Project-based	Application

Source: Mostert & Limbourg, 2016

External costs are costs that are not carried by the LSP and thus even less by his customer, the shipper (Blauwens et al., 2016). Table 22 list the sources of these extremal costs that are carried by society at large.

Table 22 - Sources of external costs

1.Congestion
2. Accidents
3. Noise
4. Air pollution
5. Climate change
6. Other environmental impacts (costs of up- and downstream processes)
7. Infrastructure wear and tear for road and rail

Source: Gibson et al., 2014

The amount of each of these external costs is dependent on time and place of occurrence. Noise pollution in a densely populated region, at night, is much more disturbing than during the day on a lonely rural country road. It is, of course, a function of the mode of transport and the size and motorisation of the vehicle. For the following calculation the comparison will be between a heavy goods vehicle (HGV) consisting of a truck tractor and a chassis for containers on one hand and an electric train locomotive capable of pulling a 700-meter cargo train, with wagons for up to 80 TEU. Although IWW will not be used in the EU-wide coverage, as discussed above, for the sake of comprehensiveness and possible regional application, the values for a 2 000-ton barge will also be included.

4.2.4.1 Congestion

Congestion is a cost that, presently, only needs to be factored in case of road haulage, it is not present in rail transport, and where it would be present the Europe wide introduction of the European Rail Traffic Management Systems (ERMTS) safety measures should result in a sharp reduction of waiting time between trains thus eliminating any congestion that might be present. IWW mostly suffers from congestion during terminal operations and occasionally at specific locks (Gibson et al., 2014). The study (also known as Ricardo-EAE) gives detailed external costs for congestions for different vehicles, regions and flow conditions.

Table 23 - Marginal congestion costs for road traffic, value 2010

Vehicle	Region	Road type	Free flow (€ct/vkm)	Near capacity (€ct/vkm)	Over capacity (€ct/vkm)
Car	Metropolitan	Motorway	0.0	26.8	61.5
		Main roads	0.9	141.3	181.3
		Other roads	2.5	159.5	242.6
	Urban	Main roads	0.6	48.7	75.8
		Other roads	2.5	139.4	230.5
	Rural	Motorway	0.0	13.4	30.8
		Main roads	0.4	18.3	60.7
		Other roads	0.2	42.0	139.2
Rigid truck	Metropolitan	Motorway	0.0	50.9	116.9
		Main roads	1.8	268.5	344.4
		Other roads	4.7	303.0	460.9
	Urban	Main roads	1.2	92.5	144.1
		Other roads	4.7	264.9	438.0
	Rural	Motorway	0.0	25.4	58.4
		Main roads	0.8	34.8	115.3
		Other roads	0.4	79.8	264.5
Articulated truck	Metropolitan	Motorway	0.0	77.6	178.4
		Main roads	2.7	409.8	525.6
		Other roads	7.2	462.5	703.5
	Urban	Main roads	1.8	141.1	219.9
		Other roads	7.2	404.4	668.6
	Rural	Motorway	0.0	38.8	89.2
		Main roads	1.2	53.1	176.0
		Other roads	0.6	121.9	403.8
Bus	Metropolitan	Motorway	0.0	66.9	153.8
		Main roads	2.3	353.3	453.1
		Other roads	6.2	398.7	606.4
	Urban	Main roads	1.6	121.7	189.6
		Other roads	6.2	348.6	576.3
	Rural	Motorway	0.0	33.5	76.9
		Main roads	1.0	45.8	151.7
		Other roads	0.5	106.0	348.1

Source: Gibson et al., 2014

Since the focus is on containers, the articulated truck data are the most relevant. As the subject is long distance, port-oriented, traffic and because an average is needed that can be applied any time of the day and all across Europe, the value for rural motorway at near capacity will be used, this is 38.8 Eurocent/vkm. This value needs to be actualised at an inflation rate of 2% p.a. resulting in a 2018 value of 45.46 Eurocent/vkm ($38.8 * 1.02^8$).

4.2.4.2 Accidents

Also, the external costs caused by accidents only apply to road transport, in the case of rail and IWW they are negligible (Gibson et al., 2014). The costs are strongly influenced by the value of statistical life which is dependent on the GDP pro capita, thus giving strongly divergent values for the different European countries (see Table 24).

Table 24 - Average social accident costs (2010)

Country	Fatality	Severe injury	Slight injury
Austria	2,395,000	327,000	25,800
Belgium	2,178,000	330,400	21,300
Bulgaria	984,000	127,900	9,800
Croatia	1,333,000	173,300	13,300
Cyprus	1,234,000	163,100	11,900
Czech Republic	1,446,000	194,300	14,100
Denmark	2,364,000	292,600	22,900
Estonia	1,163,000	155,800	11,200
Finland	2,213,000	294,300	22,000
France	2,070,000	289,200	21,600
Germany	2,220,000	307,100	24,800
Greece	1,518,000	198,400	15,100
Hungary	1,225,000	164,400	11,900
Ireland	2,412,000	305,600	23,300
Italy	1,916,000	246,200	18,800
Latvia	1,034,000	140,000	10,000
Lithuania	1,061,000	144,900	10,500
Luxembourg	3,323,000	517,700	31,200
Malta	2,122,000	269,500	20,100
Netherlands	2,388,000	316,400	25,500
Poland	1,168,000	156,700	11,300
Portugal	1,505,000	201,100	13,800
Romania	1,048,000	136,200	10,400
Slovakia	1,593,000	219,700	15,700
Slovenia	1,989,000	258,300	18,900
Spain	1,913,000	237,800	17,900
Sweden	2,240,000	328,700	23,500
Great Britain	2,170,000	280,300	22,200
EU average	**1,870,000**	**243,100**	**18,700**

Source: (Gibson et al., 2014)

This results in costs per vehicle kilometre that is different per country (see Table 25).

Table 25 - Marginal accident costs estimates Eurocent/vkm (2010)

	Car			HGV			Motorcycle		
State/Type	Motor-way	Other non-urban road	Urban road	Motor-way	Other non-urban road	Urban road	Motor-way	Other non-urban road	Urban road
Austria	0.5	0.4	0.9	5.8	1.8	3.8	0.4	5.6	12.1
Belgium	0.3	0.3	0.4	3.0	1.5	0.9	1.6	3.0	6.0
Bulgaria	0.1	0.1	0.3	0.5	0.5	1.1	0.0	0.0	0.1
Croatia	0.3	0.2	2.9	0.9	0.6	16.4	0.0	0.2	1.6
Cyprus	0.8	0.1	2.1	2.0	0.3	46.2	0.3	0.1	5.6
Czech Republic	0.1	0.2	0.2	1.1	0.6	1.0	0.0	0.2	0.2
Denmark	0.1	0.1	0.1	1.1	1.0	0.7	0.3	1.2	3.8
Estonia		0.4	0.2		0.5	0.8		0.2	0.2
Finland	0.1	0.1	0.1	0.2	0.5	0.3	0.3	1.1	2.1
France	0.1	0.2	0.2	0.4	0.5	0.7	0.9	2.3	7.8
Germany	0.2	0.4	0.6	2.4	1.3	1.5	0.6	3.3	8.5
Greece	0.2	0.2	0.2	0.9	1.3	1.3	0.1	0.1	0.4
Hungary	0.1	0.3	1.3	0.8	1.2	6.8	0.0	0.1	2.4
Ireland	0.1	0.2	0.1	1.7	1.4	0.6	0.2	0.4	0.3
Italy	0.1	0.2	0.6	2.1	1.0	4.0	0.1	0.2	1.5
Latvia		0.3	0.2		0.4	0.5		0.1	0.3
Lithuania		0.2	0.3		0.3	0.9		0.2	0.2
Luxembourg	0.9		0.1	1.8		0.1	23.8		3.5
Malta			3.6			17.3			0.7
Netherlands	0.0	0.1	0.1	0.3	2.3	1.2	0.2	4.5	11.6
Poland	0.1	0.2	0.5	0.6	0.6	1.9	0.0	0.1	0.4
Portugal	0.1	0.1	0.3	2.1	2.7	9.3	0.1	0.2	0.9
Romania	0.0	0.2	2.1	0.1	0.6	12.0	0.0	0.0	1.5
Slovakia	0.1	0.3	0.5	0.8	0.7	12.2	0.0	0.2	0.5
Slovenia	0.1	0.2	0.2	0.5	0.7	1.7	0.0	0.3	0.1
Spain	0.2	0.1	0.1	1.8	0.9	0.3	1.0	0.8	1.6
Sweden	0.3	0.3	0.3	1.2	1.0	0.9	1.0	3.4	8.1
Great Britain	0.1	0.1	0.2	0.9	0.5	0.3	0.4	1.3	2.1
EU average	**0.1**	**0.2**	**0.3**	**1.2**	**0.8**	**1.1**	**0.2**	**0.5**	**1.9**

Source: own calculations based on the accident statistics from the CARE database (average for 2005-2010)

Source: Gibson et al., 2014

The EU average for external accident cost for HGV on a motorway will be withheld for further use, but this value of 1.2 Eurocent/vkm needs also to be actualised, resulting in a 2018 value of 1.4 Eurocent/vkm.

4.2.4.3 Noise

Also, for external costs caused by noise the study calculated many scenario's (see Table 26).

Table 26 - Marginal noise costs in Eurocent/vkm (2010)

Vehicle type	Unit cost
Car	0.15
Motorcycle	0.61
LCV	0.18
Bus	0.48
HGV < 16t	0.44
HGV > 16t	0.61

Source: Gibson et al., 2014

The data for HGV >16t are relevant and the value of 0.61 Eurocent/vkm needs to be actualised to 2018, resulting in 0.71 Eurocent/vkm.

The highest value for freight trains in a rural environment are 9.97 Eurocent/vkm and are for night transport in 2010 value, actualised to 2018 this gives 11.7 Eurocent/vkm for the external noise costs freight trains. Freight trains, because they must give priority to passenger trains, are more common at night.

For IWW the external noise costs are negligible (Gibson et al., 2014).

4.2.4.4 Air pollution

The Ricardo-EAE study goes into deep detail for the different types of passengers and cargo road vehicles, summarising the many tables, the following can be concluded. An HGV with a loading capacity of 26-34 tonnes and measured when driving on a motorway, and a EURO V engine, generates an external cost of 2 Eurocent/vkm in 2010 value. Other engines can be more or less clean and will generate external costs in proportion, but a EURO V engine is realistic at the time of writing when a fast greening of the truck industry is taking place. In 2018 values this results in 2.3 Eurocent/vkm for an HGV.

For rail transport, the air pollution depends on the type of locomotive, even if it is electrical, the pollution depends on the proportion of the different types of electricity generation used. These indirect emissions are covered in the upstream/downstream other environmental impacts (see 4.2.4.6). There are non-exhaust emissions of electric freight trains that are estimated at 42.2 Eurocent/vkm (in 2010 value). Actualised this results in 49.4 Eurocent/vkm. (Gibson et al., 2014)

IWW knows a larger variety in ship sizes, and, of course, environmental economies of scale make that larger ships pollute less when expressed in tonkm. The Ricardo-EAE study does not specify container barges as a ship type, so a choice must be made between cargo type, ship size, and fuel type (see Table 27).

Table 27 - Marginal air pollution for IWW in Euro/vkm (2010)

Fuel technology	Load type	Freight capacity (tonnes)						
		Motor vessels and barges				Pushed convoys		
		250-400	400-650	650-1000	1000-3000	3000-6400	6400-12000	9600-18000
Low sulphur oil	bulk, tanker	0.9	1.4	3.5	5.9	10.4	17.3	19.6
	heavy bulk	1.0	1.6	4.0	6.9	12.2	21.2	19.0
Diesel particulate filter (DPF)	bulk, tanker	0.9	1.4	3.4	5.6	10.0	16.6	18.8
	heavy bulk	1.0	1.5	3.9	6.6	11.7	20.3	18.2
Selective catalytic reduction (SCR)	bulk, tanker	0.2	0.4	0.9	1.5	2.6	4.4	5.0
	heavy bulk	0.3	0.4	1.0	1.7	3.1	5.3	4.8
DPF+SCR	bulk, tanker	0.2	0.3	0.7	1.2	2.1	3.4	3.9
	heavy bulk	0.2	0.3	0.8	1.4	2.4	4.2	3.7
LNG	bulk, tanker	0.2	0.4	0.9	1.5	2.7	4.4	5.0
	heavy bulk	0.3	0.4	1.0	1.8	3.1	5.4	4.8
Average load factor, tonnes	bulk, tanker	158	248	608	1356	2475	6240	9009
	heavy bulk	189	297	729	1627	2970	7020	10530

Source: Gibson et al., 2014

Since SCR and LNG are not yet standard technologies due to the slow implementation of technological innovation in IWW, only the first two fuel technologies are relevant and the larger barge size of 1000-3000 tonnes is withheld. The heavy bulk category refers to ores and metals so that is irrelevant. With a 2010 value between 5.9 and 5.6 Euro/vkm an actualised average value of 6.47 Euro/vkm is valid for 2018. (Gibson et al., 2014)

4.2.4.5 Climate change

The climate change cost (in 2010 prices) for an HGV is estimated by Ricardo-EAE at 5.5 Eurocent/vkm for a EURO V vehicle with a weight of 16-32 tonnes, when rolling on a motorway. The actualised value for 2018 is equals 6.44 Eurocent/vkm.

Electric freight trains have no direct climate change costs. The indirect costs are taken into account with the upstream and downstream effects in the next paragraph.

The climate change cost for the relevant IWW vessels (low sulphur oil or diesel, 1,000-3,000 tonnes capacity) is 3.45 Euro/vkm in 2010 prices. This makes 4.04 Euro/vkm is 2018 prices.(Gibson et al., 2014)

4.2.4.6 Other environmental impacts

The upstream and downstream impact of an HGV is estimated at 2.4 Eurocent/vkm for a 16-32 tonnes truck driving on a motorway (see Table 28). When actualised for 2018 values this results in 2.8 Eurocent/vkm

Table 28 - Marginal external costs of up- and downstream processes for an HGV in Eurocent/vkm (2010)

Vehicle	Type	EURO-Class	Urban	Rural	Motorways	Average
			(€ct/vkm)	(€ct/vkm)	(€ct/vkm)	(€ct/vkm)
Truck	16-32t	EURO-0	4.6	3.6	3.2	3.7
		EURO-I	4.2	3.3	2.9	3.4
		EURO-II	4.1	3.2	2.8	3.3
		EURO-III	4.2	3.1	2.7	3.3
		EURO-IV	3.9	2.8	2.4	3.0
		EURO-V	3.9	2.8	2.4	3.0
	>32t	EURO-0	5.7	4.5	3.9	4.5
		EURO-I	5.2	4.2	3.5	4.1
		EURO-II	5.1	4.0	3.4	4.0
		EURO-III	5.2	3.9	3.2	3.9
		EURO-IV	4.8	3.5	2.9	3.6
		EURO-V	4.9	3.5	2.9	3.6

Source: Gibson et al., 2014

For an electric freight train the cost of other environmental impacts is estimated at 1.81 Euro/vkm in 2010 values (see Table 29). Actualised to 2018 values this comes to 2.12 Euro/vkm. It is based on an electricity production done with technology proportional to the European average.

Table 29 - Marginal external costs of up- and downstream processes for trains in Euro/vkm (2010)

Type of train			Unit cost
			€/ train-km
Passenger	Electric	Locomotive	0.93
		Railcar	0.74
		High-speed train	1.30
	Diesel	Locomotive	1.58
		Railcar	1.10
Freight	Electric	Locomotive	1.81
	Diesel	Locomotive	3.19

Source: Gibson et al., 2014

For IWW the relevant vessels have an external cost of 0.8 Eurocent/vkm in 2010 which, when actualised, mounts to 0.94 Eurocent/vkm (see Table 30).

Table 30 - Marginal external costs for up- and downstream processes for IWW in Eurocent/vkm (2010)

Fuel technology	Load type	Freight capacity (tonnes)						
		Motor vessels and barges				Pushed convoys		
		250-400	400-650	650-1000	1000-3000	3000-6400	6400-12000	9600-18000
Low sulphur oil	bulk, tanker	1.0	1.0	1.2	0.8	0.7	0.6	0.4
	heavy bulk	1.1	1.0	1.1	0.7	0.9	0.6	1.0
Diesel particulate filter (DPF)	bulk, tanker	1.0	1.0	1.2	0.8	0.7	0.6	0.4
	heavy bulk	1.0	1.0	1.0	0.7	0.9	0.6	1.0
Selective catalytic reduction (SCR)	bulk, tanker	0.9	0.9	1.0	0.7	0.7	0.5	0.3
	heavy bulk	0.9	0.8	0.9	0.7	0.7	0.5	0.6
DPF+SCR	bulk, tanker	0.9	0.9	1.0	0.7	0.7	0.5	0.3
	heavy bulk	0.9	0.8	0.9	0.7	0.7	0.5	0.5
Liquefied natural gas	bulk, tanker	0.8	0.8	0.9	0.6	0.6	0.4	0.3
	heavy bulk	0.8	0.8	0.8	0.6	0.6	0.5	0.5
Average load factor, tonnes	bulk, tanker	158	248	608	1356	2475	6240	9009
	heavy bulk	189	297	729	1627	2970	7020	10530

Source: Gibson et al., 2014

4.2.4.7 Wear and tear of infrastructure

Marginal infrastructure costs are regionally diverse inside the EU. Important parameters are labour costs on the one hand and density of the infrastructure on the other. For road freight transport, research has been very detailed. The Ricardo-EAE study succeeded in combining this in a table with European averages (see Table 31). Relevant and consistent with the above data is the value for HGV 18-26 tonnes, 3 axles on a motorway, when the 2.2 Eurocent/vkm is actualised to 2018 values, this results in 2.6 Eurocent/vkm

Table 31 - Marginal infrastructure costs for road traffic Eurocent/vkm (2010)

Vehicle category	All roads	Motorways	Other trunk roads	Other roads
Motorcycles and mopeds	0.2	0.1	0.1	0.3
Cars	0.5	0.2	0.3	0.8
Buses	2.0	0.8	1.4	2.7
LDV < 3.5 t	0.7	0.3	0.5	1.2
HGV 3.5 - 7.5 t, 2 axles	0.1	0.0	0.0	0.4
HGV 7.5 - 12 t, 2 axles	1.5	0.6	1.0	8.2
HGV 12 - 18 t, 2 axles	3.9	1.6	2.7	21.5
HGV 18 - 26 t, 3 axles	5.2	2.2	3.6	28.9
HGV 26 - 32 t, 4 axles	6.6	2.8	4.6	36.7
HGV 26 - 32 t, 5 axles	3.6	1.5	2.5	20.1
HGV 32 - 40 t, 5 axles	8.0	3.3	5.6	44.6
HGV 32 - 40 t, 6 axles	4.8	2.0	3.3	26.7
HGV 40 - 50 t, 8 axles	5.0	2.1	3.5	28.1
HGV 40 - 50 t, 9 axles	3.8	1.6	2.7	21.5
HGV 50 - 60 t, 8 axles	10.6	4.4	7.4	59.3
HGV 50 - 60 t, 9 axles	7.6	3.2	5.3	42.3
HGV 40 t, 8 axles	3.5	1.5	2.4	19.4
HGV 40 t, 9 axles	2.8	1.2	2.0	15.6
HGV 44 t, 5 axles	18.8	7.9	13.1	105.0
HGV 44 t, 6 axles	10.3	4.3	7.2	57.7

Source: Gibson et al., 2014

The research for rail is much more diverse and measures often costs per ton.km. Gibson et al. (2014) use a gross weight of 960 ton for a freight train. But they still are reluctant to come to an EU-wide average because of the effects mentioned at the start of this topic. They conclude a very wide range of 0.2 to 0.7 Euro/ vkm. But even this low value can be ignored for the purpose of this research because the wear and tear are, strictly speaking, not an external cost. Rail freight operators in the EU will pay a usage fee to the infrastructure owner, it can be reasonably assumed that this fee will cover the marginal wear and tear.

Marginal infrastructure costs for IWW are, just like IWW itself, not EU-wide available. Gibson et al. (2014) cite figures for France, Belgium and The Netherlands, in each case they divide the annual maintenance and operational cost of the canals and waterways in each country by the number of vehicle kilometres. In the Dutch data even the investment and land costs are amortised over 35 years and included. It is doubtful that these costs are marginal in the strict sense of the word. In the context of this research it is assumed that the maintenance costs are not driven by marginal use and as such they can be ignored, since they are not marginal.

4.2.5 Summary of costs

Table 32, below, summarises the internal and external cost of the different transport modes. The barge is incomplete but since this transport mode does not cover the whole of the EU, the analysis and comparison of the different modes is left for the reader. The costs are per vehicle, so it comes as no surprise that the larger vehicle also has the higher absolute costs. In the subsequent analysis, the economies of scale of the larger vehicle are considered. These values are confirmed by industry sources and are similar to the road and rail data used by Mostert & Limbourg (2016).

Table 32 - Summary of costs

Title	Unit	HGV	Electric freight train	Barge 1000-3000 tonnes	All
Distance costs	€/km	0.6	6	8.6	
Time costs	€/h	43	1,000	265	
Fixed costs	€/trip	0	1,000	0	
Cargo value	€/TEU				35,800
Financing cost	%/year				2.5
Depreciation of cargo	%/year				25
VOT	€/day				27
Transshipment	€/TEU				50
External costs					
Congestion	€ct/vkm	45.46	0	0	
Accidents	€ct/vkm	1.4	0	0	
Noise	€ct/vkm	0.71	11.7	0	
Air pollution	€ct/vkm	2.3	49.4	647	
Climate change	€ct/vkm	6.44	0	404	
Other	€ct/vkm	2.8	212	0.94	
Wear and tear	€ct/vkm	2.6	0	0	
Total external costs	€ct/vkm	61.71	273.1	1,051.94	

These cost data will be applied to three case studies in chapter 5. A sensitivity analysis will be applied to each case to establish the effect of variations of these cost data on the feasibility and resulting economies of the cooperative bundling projects.

Possible effects of the Paris Agreement

The abovementioned costs have, of course, an ‘expiry date’; in the near or far future they will become outdated. While under normal conditions a gradual degradation of their validity might be expected, on the one hand a possible reduction due to technological advances and on the other hand increases through a creeping inflation. However, they could change drastically in the coming years due to the effects of the Paris Agreement. In 2015 many countries, among which all EU countries, agreed to curb their carbon emission in such a way that the expected climate change would not be higher than an increase of the global average temperature of 2° Celsius. Every signature country must establish a plan, starting in 2020, describing how they will diminish the use of fossil fuels. (United Nations framework convention on climate change, 2015) By September 2019 the treaty that was signed by 195 countries, was ratified by 186 (‘United Nations Treaty Collection’, 2019)

With transport being an important producer of greenhouse gasses (GHG) and with air transport and maritime shipping being excluded from the agreement and its obligations, a big part of the reduction will have to be made in the hinterland transport. Additionally, the shift to renewable energy and zero-emission transport will require important investments using today's, fossil fuel based, technologies. All this while, at the same time, the living standards of the world's poor need to be improved. (Alfredsson et al., 2018)

Assuming that the need for transport will not change because curbing demand for transport is anathema to global trade, the change will have to come from using different technologies (like electrical vehicles or hydrogen fuel) and procedures (like bundling where possible and reducing empty returns) (Gota, Huizenga, Peet, Medimorec, & Bakker, 2019). For the cost data this will have several effects. On the one hand, the direct time costs for road transport will probably increase due to the higher investment in (more expensive) vehicles, although, as a result of economies of scale following an increase in production, the extra costs will diminish over time. Increases of labour costs, as a result of de-carbonisation, are not to be expected. On the other hand, the fuel costs are technology-dependent, electricity is, per ton.km, cheaper than diesel, biodiesel is, today, more expensive and hydrogen even more so, but with the expected increase in scale of production this difference would shrink. On the side of the external costs, the most important one (for trucks): congestion, will not change, assuming stable volumes. The external costs for climate change and air pollution would all but disappear, as would the costs related to electricity production using coal and other fossil fuels (Dejuán, Lenzen, & Cadarso, 2017); only small particles emitted by tires and brakes would remain.

It is, at the time of writing, impossible to predict the exact amount of changes in costs and since the increase in one might be offset by a decrease in another, the final count can only be guessed, but the tendencies of each cost can at least be qualified.

4.3 Distances

Eurostat provides what they call flat files, with distances between NUTS regions (Eurostat, 2018b). At the time of writing, two sets are available. One set based on 2010 NUTS definitions gives distances between NUTS1, 2, 3 regions. In this set, the distances are calculated between the gravity points based on populations. The more recent set based on 2013 NUTS definitions only gives distances between NUTS3 regions and these are based on the geographical centre. This last set contains a few striking errors. A new set is promised for July 2018 but was not available at the year end. Even if the set of 2010 uses 2010 NUTS definitions which are not the ones that are used in the road freight data of 2016, which have NUTS 2013 definitions, the fact that it uses population density to calculate the gravity points makes them a better source for the distances needed for the following calculations and as such will be used.

4.4 Assumptions and calculations

To be able to apply these data for a specific case, some assumptions and aggregations need to be made. This section describes how the above data can be used in an empirical way.

4.4.1 General assumptions

The first assumption that needs to be made is that every port can load trains. This is realistic since all it needs are rails and a reach stacker. Of course, this assumes also that all 104 core

TEN-T ports are accessible by rail but that is an already attained objective of the TEN-T project anyway (European Comission, 2017).

It is also assumed that the port equals the NUTS3 region of which the port is part, which is also realistic since NUTS3 regions are fairly small with a population between 150,000 and 800,000 (Eurostat, 2016). This means that in some cases, cargo will need to be brought to the port proper for bundling, but this would not be very different from bringing cargo from one side of the port to another.

The third assumption is that bundling will take place at the port nearest to the hinterland destination. It might be that an in-between point might be more efficient but, indeed, only if the nearest port is on a straight line between the furthest port and the hinterland, is this configuration optimal. But this means that if the sub-optimal bundling solution is already cost efficient, then the result can even be improved by further optimization.

The last/first mile in the hinterland is not counted because it does not differ between the bundled or unbundled solution. Even unimodal road cargo will have to be brought to the final destination. By counting the transfer cost, linked to the bundling, all additional costs vis-à-vis the unbundled scenario, are taken into account.

IWW is not generally considered because the aim is to cover all 104 TEN-T core ports and IWW has only a limited geographical coverage, as is already discussed above.

The fourth assumption is that the road distance is equal to the train distance; the hinterland bundling is more relevant for longer distances and for these distances, the difference between road and rail distance is relatively small.

Finally, there is the overall assumption that economic agents act rationally, the optimizing agent is the cargo owner or its representatives buying services from logistic service providers.

4.4.2 Load factors

The analysis will be done per TEU, and for this, tonnes need to be recalculated in TEU. The ports of Antwerp, Rotterdam and Hamburg respectively reported the following loads per non-empty container in 2015: 13.99 ton/TEU, 12.86 ton/TEU and 12.1 ton/TEU. These weights include an average tare weight of 2,23 ton/TEU for the container. Based on these average weights of a non-empty container, it can be presumed that 11 tonnes are equivalent to one TEU (Hafen Hamburg, 2016; Havenbedrijf Antwerpen, 2016; Port of Rotterdam, 2016). If the load factor would change, this would have an impact on the cost per ton but would only marginally influence the break-even volume between transport modes, because the effect would work in the same way on all transport modes. It would slightly improve the competitiveness of the bundled transport modes because the proportionally bigger fixed costs would be amortized over a larger volume. Also, the LSP has little to no influence on the load factor, which is mostly controlled by the shipper.

To reiterate, based on the research by Rashed (2016) it is assumed that the annual data can be used as an approximation for weekly data by simply dividing them by 52.

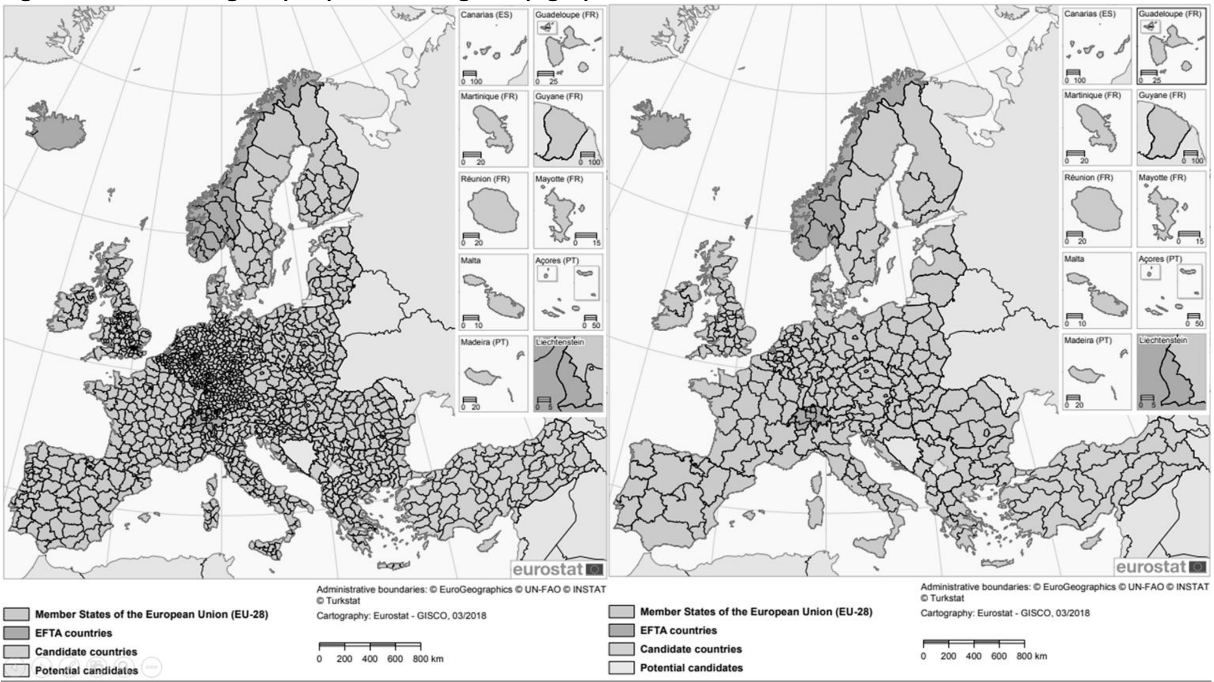
To be able to offer a competitive service in a bundled hinterland multimodal transport mode, a sufficient volume needs to be attained. To make sure the market follows the shift from road to rail, a twice-weekly service would be a minimum. The resulting average waiting time, before departure, of 1.75 days is in proportion to the average dwell time of a container. The assumption is made that a train is loaded with containers at 80% of its capacity. This assumption is based on discussions with rail operators. 100% occupation degree as an average is too optimistic. If a regular service cannot reach a sufficient average load factor the service will be discontinued. By taking a conservative minimum of 80%, the results, if positive, will leave room for improvement, the effect of which is shown in the detailed sensitivity analysis. Based on a train with 80 TEU capacity and with an 80% occupation degree, this would mean that a weekly volume of 1,408 tonnes (11 tonnes/TEU * 80 TEU/train * 2 trains/week * 80% occupation rate) each way should be attained by bundling, or 73,216 tonnes on an annual basis. Rounded off this makes 75,000 tonnes per year. Trucks, by comparison, are loaded with two TEU.

The bundling between two (or more) adjacent ports offers the additional advantage of the possibility to balance import and export flows. 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 flow (which results in empty containers going to the hinterland for loading), then the vehicle and container use can be optimized by combining the flows of the two ports.

4.4.3 Aggregating the hinterland

The available data are collected per NUTS3 region, but the object of analysis will be all the EU hinterland regions at NUTS2 level and this for two reasons. Firstly, there are 1 348 NUTS3 regions defined by Eurostat, which makes each of them rather small in surface, population and economic and logistic capacity. This large number would result in such a long list of small opportunities that it would be hard to prioritise. Secondly, the NUTS3 regions that make up one NUTS2 regions are so closely together that the organisation for final mile from/to the assembly point can be used to serve all the local NUTS3 regions. With ‘only’ 281 NUTS2 regions, the potential cooperation projects become much clearer, while still keeping the detail necessary to be useful. (Eurostat, 2016)

Figure 21 - NUTS3 region (left) - NUTS2 regions (right)



Source: Eurostat, 2018c

4.4.4 Calculation steps

When the concepts of the third chapter are applied to the data collected in the fourth chapter, a methodology for all core TEN-T ports of Europe materialises. A port authority that wants to look for opportunities by expanding its hinterland needs first, in the above-mentioned database, to look for hinterland regions that have volumes in road freight transport that are too small for bundling in a daily rail service. Following the capacity of a rail service as described above, this is a volume of less than five times weekly of 80 TEU at 80% capacity at 11 ton/TEU comes down to 183,040 tonnes annually. Rounded off this makes 185,000 tonnes annually. If this volume is not reached, then a daily rail service will not be feasible, and this hinterland will only be of marginal importance for the port. Next, for those regions that are identified, the port authority must look at the volumes that neighbouring ports transport by road to the hinterland in question. If these volumes fall below the same levels, then an opportunity for cooperation might be available. All this, of course, needs to be done twice, once for the import and once for the export flows.

Then, it needs to be verified if, by combining the volumes, sufficient volumes are reached to justify bundling. This means that the combined volume needs at least to reach a level necessary for two trains per week. This level is set at, as shown above, 75,000 tonnes annually. Ideally, between two neighbouring ports, more than one hinterland destination falls within these criteria which makes the cost of bundling lower because it will already be a bundle of several hinterland destinations.

Once the opportunities for cooperation are identified, it needs to be seen whether they are economically viable. For this, the generalised cost of bundling and rail transport should be lower than the original generalised cost for road transport. This is done by, starting from the distance between the closest port to the studied hinterland region, multiplying the distance in kilometres with the cost per kilometre of each vehicle. Based on the average speed the time is calculated which needs to be multiplied with the hourly cost as well as the VOT for the cargo.

Next, for the multimodal solution, the bundling costs are added based on the distance between the cooperating ports, the speed of train connecting them and the value of time for the cargo that will travel from the furthest port to the nearest. The fixed costs for the forming of a train need to be added.

Additionally, the potential benefits in external costs savings needs to be calculated in a similar way, by multiplying the distance with the external cost/kilometre of each vehicle. In some cases, the direct cost savings might be minimal, or even slightly negative, but the external costs savings can justify some financial support from a landlord port authority that can thus internalise a part of the external costs savings and increase the welfare of the port region.

Following the conceptual cost model of chapter 3, chapter 4 empiricalized this model for the 104 European core TEN-T ports and their connections to 281 NUTS2 hinterland regions. In the following chapter, this will be applied to three cases, which will include in every case a sensitivity analysis on the values of the data.

4.4.5 Break-even distance

The analysis in the following case studies searches where and whether a minimum volume is reached to make bundling on a given destination and distance economically viable. Bundling analysis is more often based on a search for a minimum distance with a given volume (see for instance Meers et al., 2014 and Niérat, 1997), which is an approach that is diametrical to the concept of the present research. With a given distance between two (or more) ports respectively and a chosen hinterland, the question is whether the combined road volumes can economically be bundled into a more direct, generalised and external cost-efficient rail service. The chosen cases show that the savings of external costs make up a large part of the benefits of the bundling. The VOT has an important, negative, impact on the direct cost savings, making the whole bundling operation an economically less interesting proposition. The external cost savings on the other hand make more than up for this reduction in generalised cost savings.

If, however, the values are used to define the minimum relation between the bundling distance and the hinterland of the cooperating ports, a cut-off distance can be defined where a minimum hinterland distance is calculated in relation to the bundling distance. This is the distance where the direct cost of the bundled transport mode is equal to the direct cost of the unbundled mode.

If a case is assumed where two ports A and B, each have an equal volume of 40 TEU to a given hinterland at a $distance_{hinterland}$ and the distance between the two ports is $distance_{bundling}$. The volume of the two ports combined is exactly the capacity of one bundled train, i.e. 80 TEU.

If the break-even point between bundled and unbundled scenarios is calculated, based on the EU values, the following equation (see Chapter 5 for more details) is valid:

$(Volume_A + volume_B) * [(distance_{hinterland} * kmcost^{truck} + distance_{hinterland} / speed^{truck} * timecost^{truck}) / capacity^{truck}] = [Volume_A * (distance_{bundling} * kmcost^{truck} + distance_{bundling} / speed^{truck} * timecost^{truck}) / capacity^{truck}] + [transfer\ cost] + [(volume_A+volume_B) * (distance_{hinterland} * kmcost^{rail} + distance_{hinterland}/speed^{rail} * timecost^{rail} + Train_{forming}) / capacity^{train}]$

If the given values defined in the preceding paragraphs are used, the formula becomes:

$(40TEU + 40TEU) * [(distance_{hinterland} * 0.6€/km) + (distance_{hinterland} / 65km/hour * 43€/hour)] / 2TEU / truck = [40TEU * (distance_{bundling} * 0.6€/km) + (distance_{bundling} / 65km / hour * 43€ / hour) / 2TEU / truck] + [50€/TEU] + [(40TEU + 40TEU) * (distance_{hinterland} * 6€ / km + distance_{hinterland} / 55km / hour * 1000€ / hour+1000€) / 80TEU / train]$

When this formula is solved the remaining relation is:

$(48€ / km * distance_{hinterland} + 52.92€ / km * distance_{hinterland}) / 2 = (24€ / km * distance_{bundling} + 26.46€ / km * distance_{bundling}) / 2 + 50€ + ((480€ / km * distance_{hinterland} + 18.18€ / km * distance_{hinterland} + 1000€) / 80)$

Resulting in:

$distance_{hinterland} = 0.57 * distance_{bundling} + 62.5$

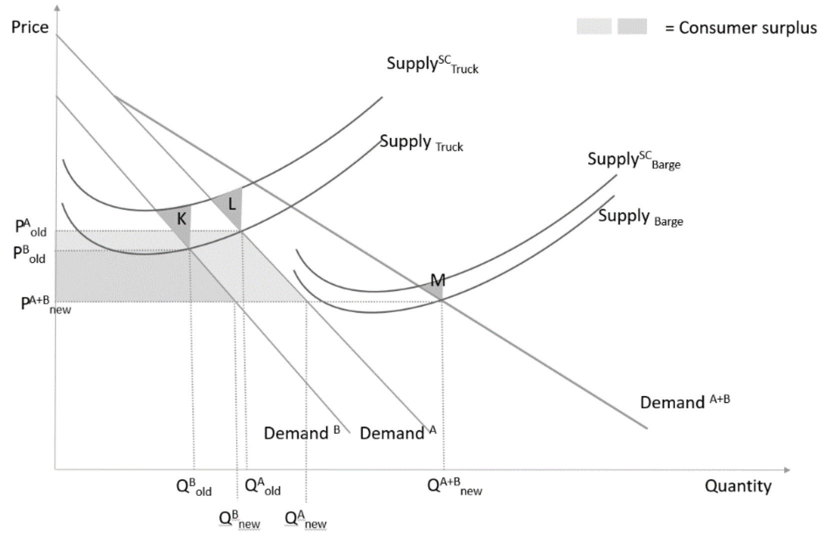
The cost per TEU.km per train being substantially lower than the cost per truck, the break-even point for bundling, when taking a train load factor of 100% and based on direct cost is only slightly higher than half the distance between the bundling seaports, with a fixed distance of 62.5 km added. Of course, if the value of time is added to the costs, the distance increases but the external costs savings always largely outweigh these. A reduced load factor of the trains will, of course, push the break-even distance further away.

Chapter 5 **CASE STUDIES**

In this chapter, three cases with potential for hinterland cooperation will be developed based on the methodology and databases as elaborated in the preceding chapters. The present volumes often already create funnel effects and it can only be expected that these volumes and the resulting congestion will increase in the next decades and influence the market shares of the most congested ports (Deutsch, 2013). When neighbouring ports both service the same hinterland, but the flows to and from each port are too small to allow for bundling, it might be possible that, by combining the flows of the two, or more, ports, volumes might be attained that suffice for a modal shift. This shift could lead to a reduction in direct cost, probably implying an increase in time spent and potentially a reduction in external costs. The cost model is static and assumes that the competing ports will not react to the bundling project. Especially the prices of road transport are under such competitive pressure that substantially reducing them is difficult. The resulting growth in consumer surplus will increase the attractiveness of the participating ports, and consequently their market share. These effects will be quantified for each of the three cases in the following pages. The result will be the monetization of the result of cooperation, in the hinterland between the respective ports, on the hinterland part of the supply chain. At the end of the chapter, the different consequences for the strategies and policies of the different port actors and authorities are discussed.

Graph 16 reiterates and summarises these concepts. The case studies each calculate the squares P_{old}^{A}, Q_{old}^{A}, P_{new}^{A+B} and P_{old}^{B}, Q_{old}^{B}, P_{new}^{A+B} as well as the external costs and the savings through bundling.

Graph 16 - Consumer surplus and external benefits of bundling



The calculations, based on the concepts developed in 3.3.1 and further, are made based on the data described in 4.1.1 and 4.2. Each case will summarise the used data. The direct, unbundled, costs per TEU for each OD pair are calculated as follows:

$Volume * [(distance_{hinterland} * kmcost^{truck}) + (distance_{hinterland} / speed^{truck} * timecost^{truck})] / capacity^{truck}$

The calculations of each port are added together resulting in the total hinterland road cost.

For the bundled mode, the cost of bringing the cargo to the bundling point, from the furthest port, needs to be added and the hinterland is connected through trains instead of trucks, resulting in the following calculations.

$$[volume_a * [(distance_{bundling} * kmcost^{truck}) + (distance_{bundling} / speed^{truck} * timecost^{truck})] / capacity^{truck}] + [transfer\ cost] + [(volume_a + volume_b) * [(distance_{hinterland} * kmcost^{rail}) + (distance_{hinterland} / speed^{rail} * timecost^{rail}) + train_{forming}] / capacity^{train}]$$

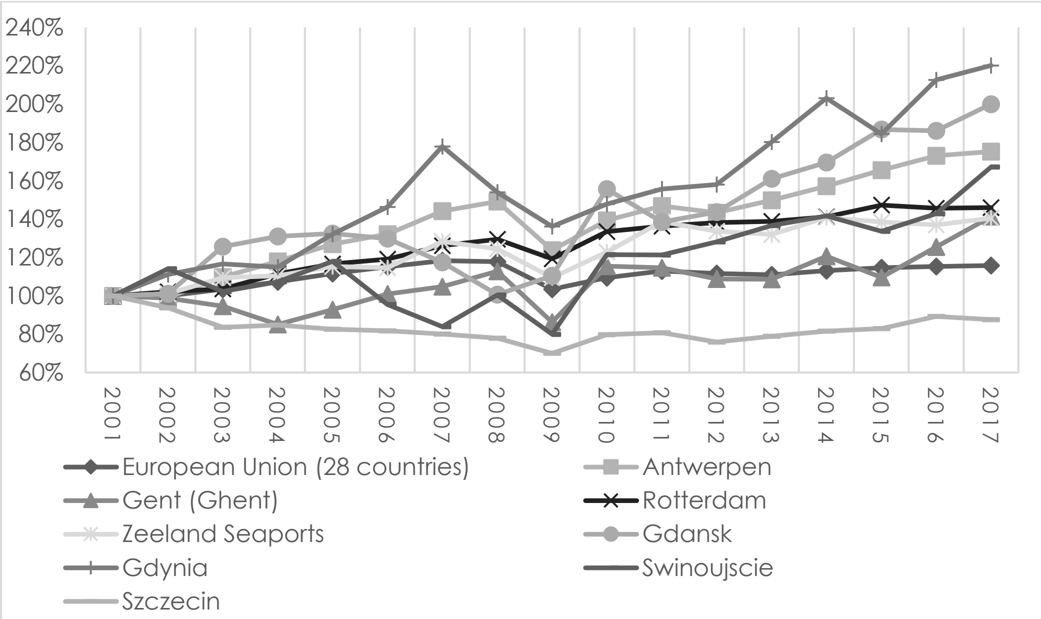
The calculations for the generalised cost, direct cost augmented with the value of time, and external costs follow the same pattern.

The first chosen case is North Sea Port: it started operations in January 2018, as a newly created cross border port, the merger of three mid-sized ports, it represents an interesting and topical example. The second case combines the hinterland flows of the two biggest European ports: Rotterdam and Antwerp are analysed. For the third case, the main Polish ports are chosen as an example of cooperation between smaller ports. Admittedly, the choice is somehow arbitrary, as any combination between any of the 104 core TEN-T ports can be calculated.

The steps followed in each case are based on the methods described in the preceding chapter. Firstly, hinterland regions where the flows are sufficient to organise a daily bundled transport service are disregarded: they do not need to cooperate with a neighbour to reach a certain volume. Next, the regions are identified where the road cargo flows of one port alone are too small to allow daily bundling but where combined cargo flows suffice for at least a two times weekly rail service. Two times weekly results in an average waiting time of 1.75 days, which should be acceptable for the shipper, as is discussed in chapter 3. Then, one promising hinterland region is chosen for a detailed analysis. This step consists of calculating the generalised cost of the road transport of one container as well as the pertaining external cost. This is followed by the calculation of the rail cost, including the cost of bundling and transshipment, and also by calculating the external cost of the rail service. Lastly, the road freight costs are compared to the multimodal solution for the total volume and the internal and external benefits are calculated. This is done for the import flows in each of the respective cases. Every case study closes with a sensitivity analysis that shows the impact of the variations of the parameters. Since the cost model is inherently linear, the variations cannot be extrapolated endlessly. They use a variation of 10% because this level is realistic in the case of transport costs; beyond this 10%, extrapolations must be done cautiously.

The cases are divergent in their evolution and in the extension of their hinterland. They have been chosen to include some mega ports, some midsized and some smaller ones. Some have only more recently become part of the European Union network; others have been part of it from the beginning. Their relative evolution is shown in Graph 17.

Graph 17 - Relative growth of port throughput (Index 100 = 2001)



Source: Eurostat, 2018a

5.1 The case of North Sea Port

The first case where the methodology will be applied is the newly created (the merger was signed on 8 December 2017) North Sea Port which, as mentioned earlier, is a merger of the Belgian/Flemish Port of Ghent with the Dutch Zeeland Seaports, which itself is a merger of the ports of Flushing (Vlissingen) and Terneuzen. By way of illustration, only the import flow towards the hinterland will be analysed. For the export flows, the analysis could be done in the same way.

Table 33 shows the growth of the throughput as well as the relative importance of the ports making up North Sea Port. From 2011 onward, the data of Terneuzen and Vlissingen (Flushing) are combined after their merger into Zeeland Seaports.

Table 33 - Throughput volumes (in thousand tonnes)

	Ghent	Terneuzen	Vlissingen	Zeeland Seaports
2001	23,863	11,171	13,117	
2002	23,556	12,123	12,430	
2003	22,569	12,261	14,331	
2004	20,302	12,319	14,517	
2005	22,133	12,746	15,248	
2006	24,107	12,035	15,803	
2007	24,988	12,786	18,392	
2008	26,912	12,105	18,114	
2009	20,579	11,173	15,407	
2010	27,572	13,725	16,099	
2011	27,343			33,694
2012	25,972			32,476
2013	25,924			32,062
2014	28,788			34,212
2015	26,143			33,642
2016	29,963			33,261
2017	33,711			34,147

Source: Eurostat, 2018a

5.1.1 Road freight volumes from North Sea Port

The following analysis will search for hinterland regions where the ports individually lack volume to organise a daily regular rail service but together, they have enough cargo to organise at least twice a week a connection per rail. Of course, whether these services are also economically viable will be calculated, as well as the savings in external costs. The Figure 22 to Figure 24 show the road freight hinterland of the different ports. Only the darker NUTS2 regions have enough volume for at least a twice weekly rail service. None of the shown regions has enough volume for a daily service from either one port. All the light-coloured regions have a volume of (a lot) less than 75,000 tonnes road freight from the port, annually.

Figure 22 - Road freight flows from Ghent, less than 185,000 tonnes annually

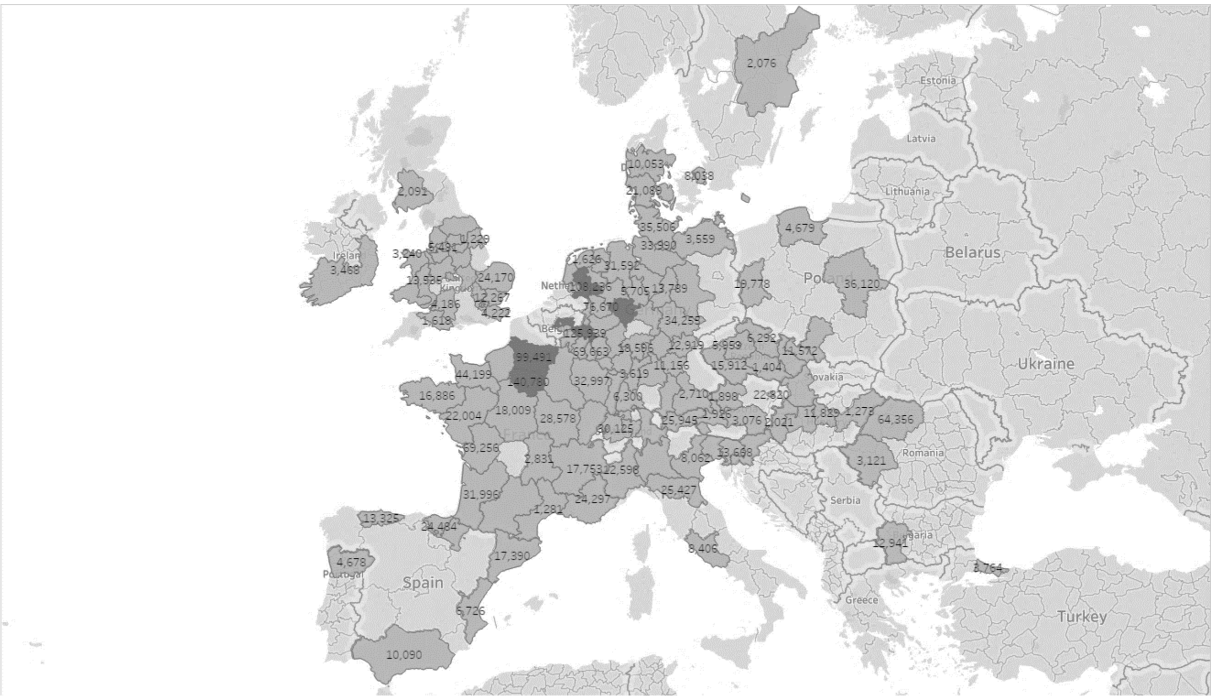


Figure 23 - Road freight flows from Terneuzen, less than 185,000 tonnes annually

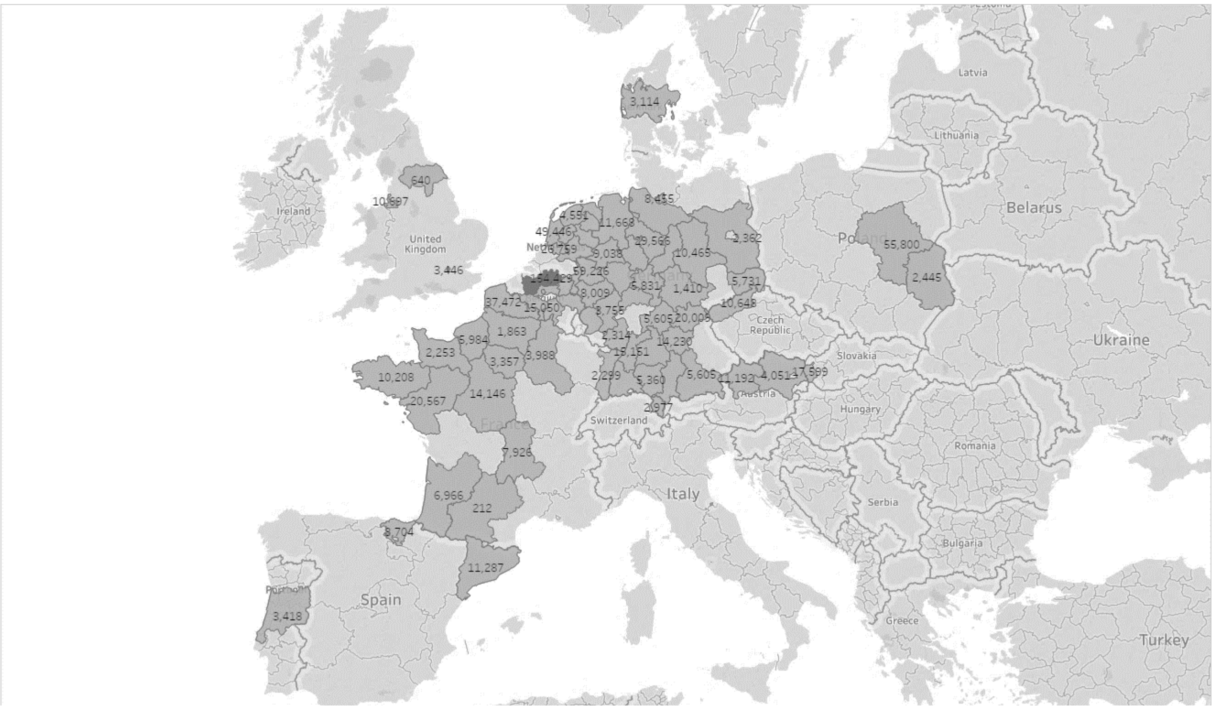


Figure 24 - Road freight flows from Vlissingen (Flushing), less than 185,000 tonnes annually

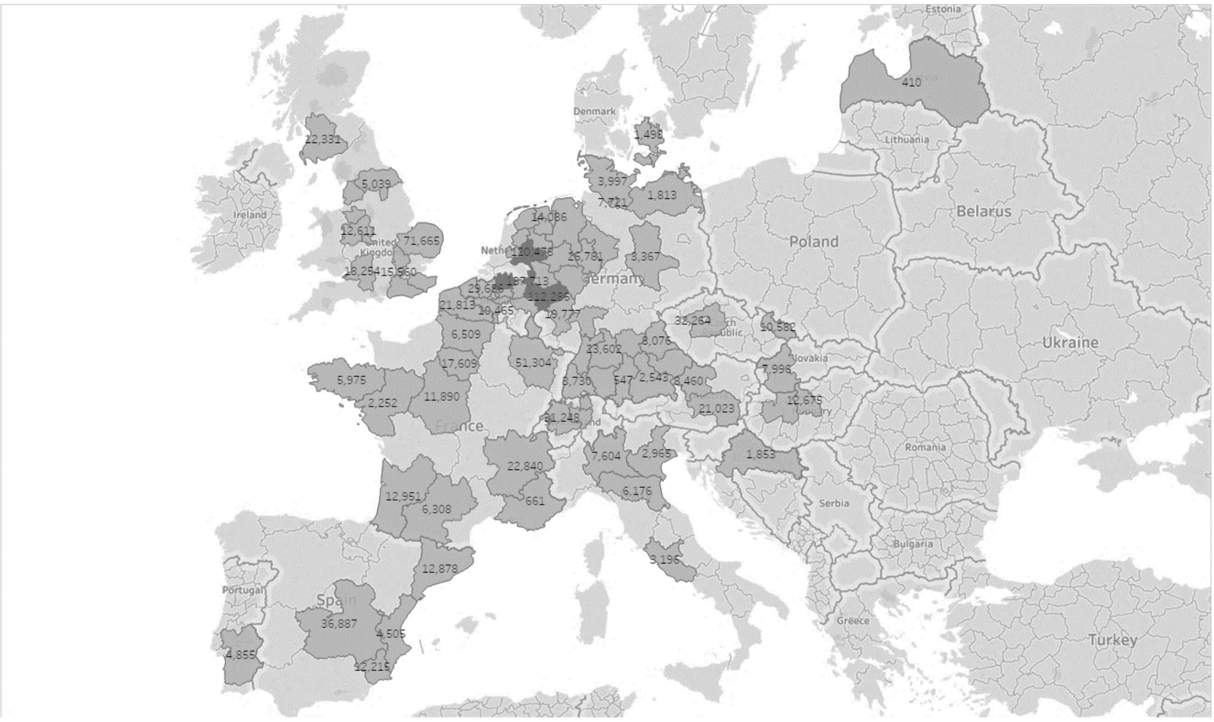
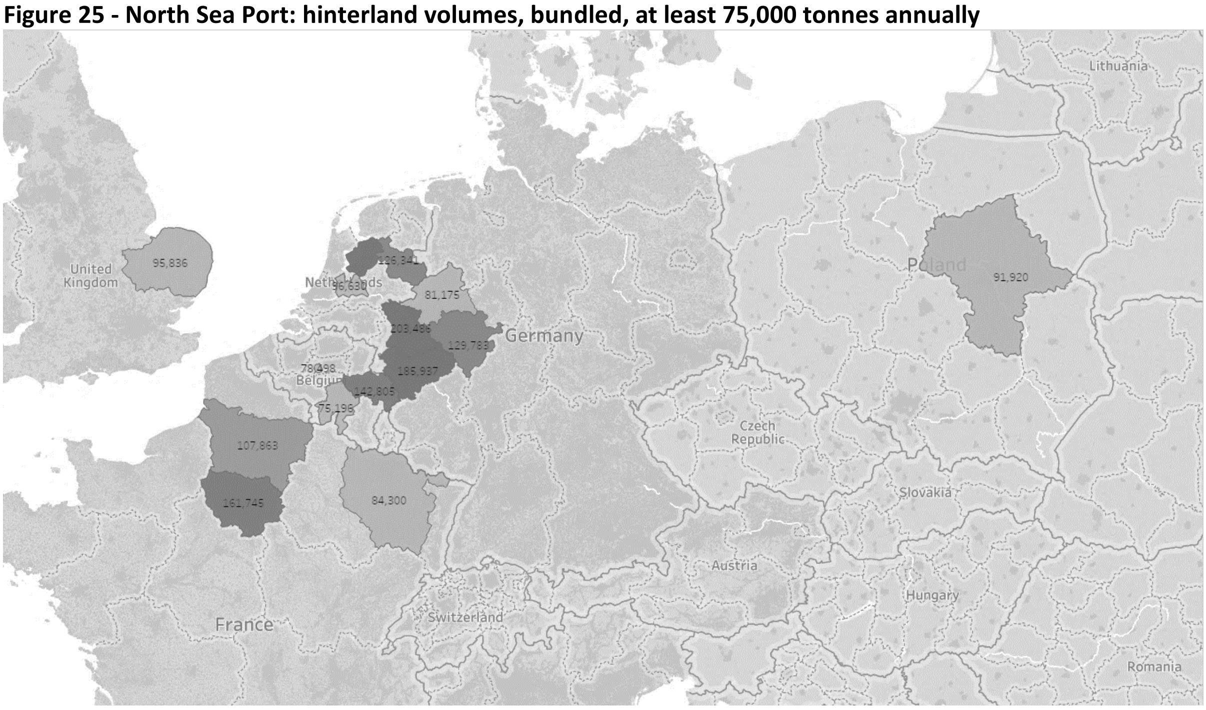


Figure 25 shows the hinterland regions for which each port, in a stand-alone scenario, does not generate enough cargo volume for bundling into a daily rail service. Together the three ports will be able to sustain at least a twice weekly rail service to the specific hinterland. In the following paragraphs, one region will be chosen to study the economic viability of the bundling service; so far only the necessary volumes have been verified.

Figure 25 - North Sea Port: hinterland volumes, bundled, at least 75,000 tonnes annually



When these graphical representations are presented in a numerical format, focusing only on those NUTS2 regions where bundling brings additional modal shift opportunities, the following Table 34 emerges (the flow with the UK is not relevant because this concerns, obviously, roro traffic).

Table 34 - Bundling opportunities in North Sea Port (tonnes annually by road)

		Ghent	Terneuzen	Vlissingen	Bundled
BE10	Region Brussels Capital	60,891	8,204	9,402	78,498
BE33	Prov. Liège	125,939	1,108	15,758	142,805
BE35	Prov. Namur	69,361	5,835		75,196
DEA1	Düsseldorf	76,670	59,226	67,590	203,486
DEA2	Köln	65,642	8,009	112,286	185,937
DEA3	Münster	20,201	9,038	51,936	81,175
DEA5	Arnsberg	97,600	8,640	23,543	129,783
FR10	Île de France	140,780	3,357	17,609	161,745
FR22	Picardie	99,491	1,863	6,509	107,863
FR41	Lorraine	32,997		51,304	84,300
NL21	Overijssel	35,811	22,726	67,804	126,341
NL22	Gelderland	108,236	81,041	120,478	309,756
NL23	Flevoland	127,159	7,676	55,292	190,127
NL31	Utrecht	13,937	26,759	55,934	96,630
NL42	Limburg (NL)	85,552	60,958	137,713	284,223
PL12	Mazowieckie	36,120	55,800		91,920
UKH1	East Anglia	24,170		71,665	95,836

For these regions, each of the port sites making up North Sea Port, does not have enough road traffic to organize a five times weekly rail service, but by bundling they reach at least enough volume to have a twice weekly service. Especially the regions in Germany (DEA1 (Düsseldorf), DEA2 (Köln), DEA3 (Münster), DEA5 (Arnsberg)) look promising because each port has an important flow but, on its own, not enough to facilitate bundling. The regions in France (FR10 (Île de France), FR22 (Picardie)) look interesting too but the port of Ghent is the dominant provider of cargo. The region in Poland (PL12 (Mazowieckie)) shows promise (even it needs only two out of the three ports) because with the eastwards-moving centre of economic gravity of Europe (J. Hintjens, Vanelslander, Van Der Horst, & Kuipers, 2015), it can be expected that it will gain importance. The longer distance will also make a positive business case more likely.

For this case study, the biggest cooperation potential (DEA1 (Düsseldorf)) will be analysed in detail. Theoretically, the bundling would take place in Terneuzen because, based on the Eurostat distance data, it is slightly closer to Düsseldorf, and it is located between the two other ports (see Table 35). But the volume from Ghent is bigger and it does makes sense, especially when the difference in distance is so small, to do the bundling at the biggest node. Theoretically, the first leg of the trip would be executed by rail, especially if at the same time other bundling flows would be combined (for example: the ones towards France, Poland or other German regions) but there is no rail connection under the river Scheldt, so for this example the first leg, towards Ghent, will be executed by road. The cargo originating in Ghent will be put directly on a train wagon.

Table 35 - Distances

Distance in km		DEA1 Dusseldorf	NL341	NL342
Ghent	BE234	267.2	37.1	66.4
Terneuzen	NL341	264.8		29.3
Vlissingen	NL342	288.4		

Source : Eurostat, 2018b

5.1.2 All road (import) from North Sea Port to NUTS2 Düsseldorf

When all the above is put together, the following costs emerge for the unimodal road scenario:

Table 36 - Costs for unimodal road transport

All road (import) towards DEA1 (Düsseldorf)										
	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours	Direct cost	VOT	External cost
Ghent	267.2	4.11	76,670	6,970	3,485	931,189	19,553	1,399,513	43,946	574,637
Terneuzen	264.8	4.07	59,226	5,384	2,692	712,864	15,005	1,072,945	33,724	439,908
Vlissingen	288.4	4.44	67,590	6,145	3,072	886,044	18,240	1,315,941	40,994	546,778
Total			**203,486**	**18,499**	**9,249**	**2,530,098**	**52,799**	**3,788,399**	**118,665**	**1,561,323**
Unit values for road transport										
Truck speed	km/hour	65								
Truck waiting time	hour/truck	1.5								
Truck direct cost (distance)	€/km	0.6								
Truck direct cost (time)	€/hour	43								
Truck external cost	€ct/km	61.7								
VOT	€/TEU.hour	1.12								

Resting times for drivers do not come into play here because the driving time is under 4.5 hours. Using the values of Table 36, the total direct cost for the whole annual volume amounts to 3,788,399 Euro, a value of time of 118,665 Euro and an external cost of 1,561,323 Euro.

5.1.3 Multimodal, road/rail from North Sea Port to NUTS2 Düsseldorf

When all the cargo for Düsseldorf is trucked from Flushing and Terneuzen to Ghent and there it is joined together on a train with the cargo already in Ghent with the same destination, then the following image emerges (see Table 37).

Table 37 - Costs for multimodal road/rail transport

Mulimodal road/rail (import) towards DEA1 (Düsseldorf)										
First leg (road)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours	Direct cost	VOT	External cost
Ghent	0	0.00	76,670	-	-	-	-	-	-	-
Terneuzen	37.1	0.57	59,226	5,384	2,692	99,876	5,575	568,846	12,529	61,634
Vlissingen	66.4	1.02	67,590	6,145	3,072	203,999	7,747	762,742	17,411	125,888
Total (first leg)			203,486	11,529	5,764	303,875	13,322	1,331,588	29,940	187,522
Second leg (rail)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Trains (number)	Train.km	Train.hours	Direct cost	VOT	External cost
Gent	267.2	4.858	203,486	18,499	289	77,232	1,693	2,156,655	516,750	210,921
Grand total								**3,488,243**	**546,690**	**398,442**
Bundling Effect								**300,157**	**- 428,025**	**1,162,881**
Unit values for rail transport										
Train speed	km/hour	55								
Train waiting time	hour/train	20								
Train direct cost (distance)	€/km	6								
Train direct cost (time)	€/hour	1000								
Train external cost	€ct/km	273.1								
Transshipment cost	€/TEU	50								

Using the unit values of Table 37 and a train forming cost of 1,000 Euro, the result is a total direct cost of 3,488,243 Euro, an increased value of time of 546,690 Euro and a substantially lower external cost of 398,442 Euro. The volume would be enough for a daily service.

This is based on a 100% shift in an all or nothing situation: since generalised costs are used, it would be, on average, suboptimal for a shipper to choose for a road solution with a higher generalised cost. In any event, for a daily service, only 185,000 tonnes annually is needed, so a shift of 90% would still allow a daily service; a lower percentage would mean that less than a daily service would be filled, or that a part of the train should be loaded with non-containerized cargo like dry or liquid bulk. This is an option train operators would be willing to use. It would even increase the loading degree of a train which is 3,000 tonnes, including tare and wagons. Train operators prefer to use the full capacity of a locomotive, which is not optimally deployed with 80 TEU and 11 tons per TEU.

5.1.4 Multimodal, road/barge from North Sea Port to NUTS2 Düsseldorf

Specifically for this case, the option of using inland waterways and barges (IWW) needs to be addressed. The ports of Ghent, Terneuzen and Vlissingen (Flushing) are seaports but are on the estuary river Scheldt (Ghent has a canal connecting it to the estuary of the river), the Western Scheldt, which is connected to the Rhine river basin where Düsseldorf is located. So, barges are a logical option if a modal shift and bundling is considered. The logical bundling point is then Terneuzen, where all ships are passing anyway, the distances or along the waterway (van Hassel et al., 2018). Barges, contrary to trains, have a much greater variety in sizes. The biggest size (ECMT class VI) can travel all the way up the Rhine to Düsseldorf and can carry up to 400 TEU. The disadvantage of such a big vessel is that, given an available volume, the frequency will be low, or a big ship will be largely empty. Two alternatives are calculated. In both cases, the first leg will be done by truck, because the starting point is a NUTS3 region of which the port is part. The cargo in question does not necessarily start from a waterside location. Thus, the cargo is trucked from somewhere in the NUTS3 region to the quay where the inland vessel is waiting. It might be the case that the container is already on a dock, in that case the cost of a modal shift will be lower than calculated and the business case more positive. In the first alternative, a barge with a capacity similar to a train, to make a comparison with the train option easy, is used. A class IV vessel can carry up to 60 TEU, when fully loaded. The results are shown in Table 38, where a small saving in direct costs is observed, that is more than lost through an increased VOT. Even the gain in external cost cannot compensate for the increased time spent on a slow vehicle. The advantage of having a smaller vessel is that there is enough cargo for a daily run.

Table 38 - Costs for multimodal road/barge transport - Class IV vessel

Truck external cost	€ct/km	61.71								
VOT	€/TEU.hour	1.12								
Mulimodal road/barge (import) towards DEA1 (Düsseldorf)										
First leg (road)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours	Direct cost	VOT	External cost
Ghent	37.1	0.57	76,670	6,970	3,485	129,293	7,217	736,389	16,219	79,787
Terneuzen	0	0.00	59,226	5,384		-	-		-	-
Vlissingen	29.3	0.45	67,590	6,145	3,072	90,018	5,993	618,950	13,470	55,550
Total (first leg)			203,486	18,499	6,557	219,311	13,210	1,355,339	29,689	135,337
Second leg (barge)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Barges (number)	Barge.km	Barge.hours	Direct cost	VOT	External cost
Terneuzen	322	32.20	203,486	18,499	308	99,276	12,086	2,121,087	814,886	1,044,328
Grand total								**3,476,427**	**844,576**	**1,179,665**
Bundling Effect								**311,973**	**- 725,911**	**381,659**
Unit values for barge transport (ECMT Class IV; 60 TEU; fully loaded)										
Barge speed	km/hour	10								
Barge waiting time	hour/barge	7								
Barge direct cost (distance)	€/km	5.47								
Barge direct cost (time)	€/hour	130.57								
Barge external cost	€ct/km	1051.94								
Transshipment cost	€/TEU	50								

In the second scenario, a class V vessel is used with a capacity of 200 TEU of which 80% is utilized. As is shown in Table 39, even with only 80% occupation degree, the business case is positive. There is a substantial saving in direct cost, that is in a large part offset by an increased VOT, but additionally there is an ever bigger saving in external costs.

Table 39 - Costs for multimodal road/barge transport - Class V vessel

Mulimodal road/barge (import) towards DEA1 (Düsseldorf)										
First leg (road)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours	Direct cost	VOT	External cost
Ghent	37.1	0.57	76,670	6,970	3,485	129,293	7,217	736,389	16,219	79,787
Terneuzen	0	0.00	59,226	5,384		-	-		-	-
Vlissingen	29.3	0.45	67,590	6,145	3,072	90,018	5,993	618,950	13,470	55,550
Total (first leg)			203,486	18,499	6,557	219,311	13,210	1,355,339	29,689	135,337
Second leg (barge)	Distance (km)	Time (H)	Volume (tonnes)	Volume (TEU)	Barges (number)	Barge.km	Barge.hours	Direct cost	VOT	External cost
Terneuzen	322	32.20	203,486	18,499	116	37,229	4,532	1,521,195	814,886	391,623
Grand total								**2,876,534**	**844,576**	**526,960**
Bundling Effect								**911,865**	- **725,911**	**1,034,364**
Unit values for barge transport (ECMT Class V; 200 TEU; 80% loaded)										
Barge speed	km/hour	10								
Barge waiting time	hour/barge	7								
Barge direct cost (distance)	€/km	8.60								
Barge direct cost (time)	€/hour	265.00								
Barge external cost	€ct/km	1051.94								
Transshipment cost	€/TEU	50								

The disadvantage of this scenario is that there is only enough volume (when 89,9% of the cargo shifts from road to barge) for a twice weekly service, but this scenario is more convincing than a multimodal road rail/scenario with a 90% load factor.

5.1.5 Analysis and conclusion

When the above road and road/rail scenarios are compared, the savings of direct, generalised and external costs, as show in Table 40, become apparent. The benefits, or extra costs if they are negative, of the bundling of cargo streams is shown below as the effect of bundling.

Table 40 - Recapitulation of case relevant costs (in Euro)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	3,788,399	118,665	3,907,064	1,561,323	5,468,387
Multimodal rail	3,488,243	546,690	4,034,933	398,422	4,433,375
Effect of rail bundling	300,157	-428,025	-127,868	1,162,881	1,035,013
Effect of bundling on a train with load factor of 90%	539,785	-370,608	169,176	1,186,317	1,355,493
Effect of bundling on a class V barge	911,865	-725,911	185,954	1,034,364	1,220,318

Table 41 - Recapitulation of case relevant costs (In Euro per TEU)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	204.79	6.41	211.20	84.40	295.60
Multimodal rail	188.56	29.55	218.12	21.54	239.65
Effect of rail bundling	16.23	-23.14	-6.91	62.86	55.95
Effect of bundling on a train with load factor of 90%	29.18	-20.03	9.15	64.13	73.27
Effect of bundling on a class V barge	49.29	-39.24	10.05	55.91	65.97

There is a saving of the direct cost of 9% when shifting to rail, which is, unfortunately, more than lost through an increased value of time, resulting in an increased generalised cost of 3%. Of course, the value of time is dependent on the value of the cargo; it is assumed at 35,800 Euro (see paragraph 4.2.2). Any increase in value of goods would result in an increased value lost through a loss of time due to bundling. Nevertheless, at the same time, the external costs drop from 1,561,323 to a low 398,442 Euro, resulting in a total cost saving of 18.9%. This is an amount that could be used to cover, at least partly, the bundling cost thus, making the business case attractive. The external costs of trucks consist mainly of congestion cost (74%) and climate change cost (10%) (see paragraph 4.2.5); especially the former is very much time- and place-dependent and can strongly fluctuate with these conditions. The value used in these calculations is the one for a trailer-tractor combination on a rural motorway (as opposed to an urban motorway), connecting cities, at a capacity use that nears congestion (45.46 Eurocent/vkm, in 2018 values), it can be substantially higher if the road is saturated; the values are twenty times higher in the case of a truck driving through a congested, metropolitan urban region; they drop to zero in a free flow, highway scenario.

If the trains are loaded at 90% instead of 80%, the case becomes profitable even from a generalised cost point of view: there is a saving of 4.3%. The small reduction in VOT is due to the fact that since the trains are larger, less trains need to be formed and less time is lost in forming these fewer trains. The 10 percent points increase in load factor results in a 79.8% increase in direct cost savings and a 31% increase in total cost savings.

But, at the price of sacrificing frequency, a shift towards bundled transport in a class V barge is the most advantageous proposition, even with only an 80% load factor. There is a direct cost saving of 24.1%, a generalised cost saving of 4.8% and a total cost saving of 22.3%.

The effect on the different parameters on the benefits of the bundling to rail is shown in the sensitivity analysis in Table 42. Because the generalised cost benefits/costs in the base scenario are rather small, the effects of changes quickly run in impressive percentages.

Table 42 - Sensitivity analysis

Factor +10%	Effect on bundling benefits Direct cost	VOT	External costs	Generalised costs	Total costs
Truck speed	-44.6%	-1.6%		-110.2%	-13.6%
Truck waiting time	7.5%	0.3%		18.5%	2.3%
Truck direct cost (distance)	44.5%			104.5%	12.9%
Truck direct cost (time)	56.6%			132.8%	16.4%
Truck external cost			11.8%		13.3%
Train speed	42.5%	2.1%		107.0%	13.2%
Train waiting time		-9.7%		-32.5%	-4.0%
Train direct cost (distance)	-15.4%			-36.2%	-4.5%
Train direct cost (time)	-56.4%			-132.4%	-16.4%
Train external cost			-1.8%		-2.0%
VOT		10.0%		-33.5%	-4.1%
Transshipment cost	-19.2%			-45.1%	-5.6%

An increase of the truck speed by 10% will lower the benefits of the direct savings by almost 45%. With the added loss of time, of -1,6%, in the bundling scenario, the generalised cost savings are increasingly negative. Alternatively, a decrease by 10% of the truck speed would make the generalised cost benefit slightly positive with a value of 44,321 Euro. A 10% increase in the distance cost of trucks will increase the bundling benefits on the direct cost by 44.5%. The train speed but more importantly, the train waiting time, have a strong impact on the value of time. The speed increase also impacts on the direct cost but less on the VOT. Efficient train planning that would reduce the waiting time for loading, could have a positive effect on the reduction of the loss of value through time, which, unfortunately, is larger than the direct cost savings. This efficiency improvement would go a long way to reduce this loss of savings. A 10% increase on the time cost of the truck and train both have a disproportionate impact on the direct cost; those of the train are the most impactful: if used the other way around, a 10% decrease of the hourly train cost increases the direct cost benefit with 56.4% and the total cost savings with more than 16 %.

The cargo flows from the NSP to Düsseldorf differ from the European average (see Table 43). This has some impact on the value of the concerned cargo. Referring to the analysis in 4.2.2, the value of the average container will be higher because the low value goods like food and wood are replaced by a slightly above average value good: chemicals. The exact increase in value and the resulting increase in VOT cannot be calculated due to the different composition of the databases, but the VOT will be slightly higher.

Table 43 - Containerable cargo transported by road from Belgium and The Netherlands to Germany in 2016 (tonnes)

Class	Abbreviated description	Tonnes	Percentage	EU average
4	Food	10,478,987	28%	37%
5	Textiles	670,962	2%	1%
6	Wood	3,406,170	9%	12%
8	Chemicals, plastics	10,637,159	29%	12%
11	Machinery	1,589,665	4%	6%
13	Furniture	761,005	2%	2%
15	Mail	495,185	1%	4%
16	Equipment	1,684,635	5%	6%
17	Moving	183,304	0%	3%
18	Mixed	7,153,545	19%	16%

Source: own composition based on Eurostat, 2017a

The effect on market share of the cooperating ports in the service of the studied hinterland, with a direct cost saving of 9% and a negative generalised cost saving of slightly over 3%, will be positive but not consequential. With a total cost savings of almost 19%, this is still worth pursuing.

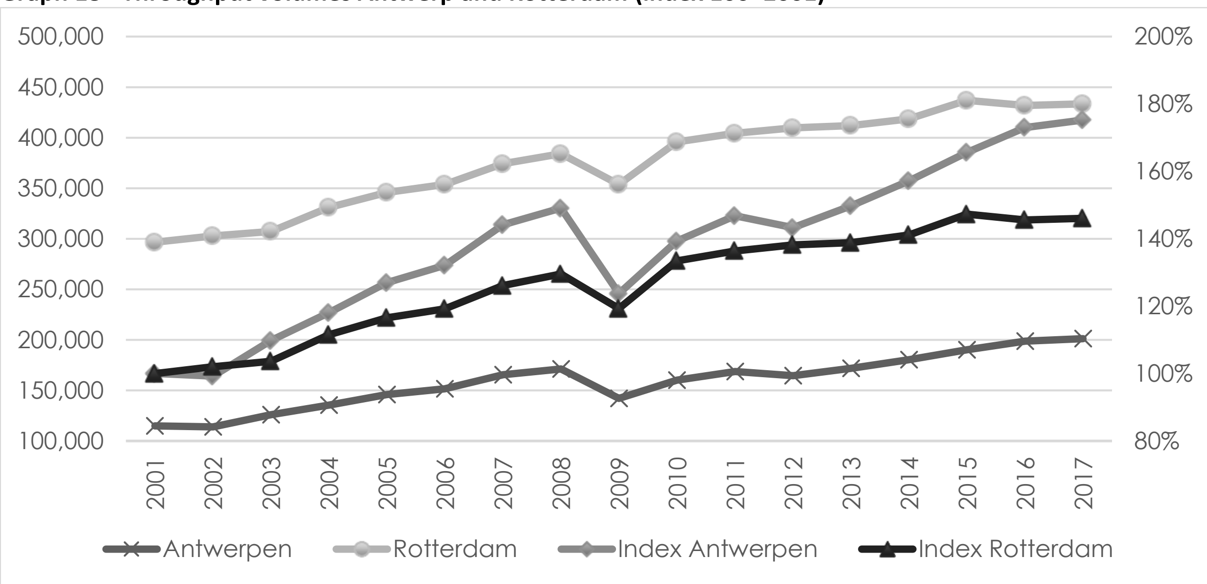
Chapter 5 concludes with a comprehensive analysis and policy implications of all three cases.

5.2 The case of Port of Antwerp and Port of Rotterdam

Port of Rotterdam and Port of Antwerp are the two biggest ports of Europe and have been competing for market share since the 19th century (Devos, Buyst, & Loyen, 2003; Paardenkooper-Suli, 2014) but at the same time they have been cooperating on a project basis. The examples, that have been mentioned before, go from the trivial: organising a bicycle race together ('World Ports Classic', 2015), over lobbying at European level for a level playing field concerning maritime emissions ('Discussie over verstrengen stikstofnormen voor schepen laait op', 2014) to (unsuccessfully) trying to acquire the inland port of Duisburg together but also, fighting the Chinese strategy that might move cargo flows to Southern or Eastern Europe, away from the Hamburg-Le Havre range ('Rotterdam: "Kansen om gezamenlijke koek groter te maken, onmiddellijk grijpen"', 2016).

They largely share a common, heavily contested, hinterland that is serviced by rail, inland waterway and a lot of road freight. Together, they form the main gateway to Europe (Vanelslander et al., 2011) and the shared hinterland reaches far into the continent. The difference in throughput volume between the ports is substantial (see Graph 18) but in added value and employment the ports are much closer; Rotterdam gets a large part of its volume from liquid bulk, whereas the biggest tankers cannot go up the river Scheldt to the port of Antwerp. This is why the two ports started a cooperation in 1969 that resulted in the opening on the 10th of May 1971 of a connecting pipeline that brings crude from Rotterdam to the petrochemical industries in Antwerp ('Rotterdam Antwerpen Pijpleiding—RAPL', 2018).

Graph 18 - Throughput volumes Antwerp and Rotterdam (index 100=2001)



Source: Eurostat, 2018a

Aggregated volumes are not necessarily indicative for the demand of hinterland connectivity of containerisable cargo, but the graph above shows the race between the two ports for growth. On the other hand, more and more cargo is handled in containers, and even bulk cargo can be part of a train towards the hinterland that carries a mixed cargo of bulk, roro and containers. This strategy is often used by rail operators to maximise the weight capacity of a train, compensating for the light weight of containers with heavier bulk cargo.

5.2.1 Road freight volumes from the ports of Rotterdam and Antwerp

The hinterland of each port serviced by road is extensive. For the port of Antwerp, two NUTS3 regions must be combined because the left bank (Waaslandhaven) lies in a different province and consequently in a different NUTS3 and even NUTS2 region: BE211 and BE236. These volumes are aggregated and BE211 is used as reference point. Again, for the sake of conciseness only the import flows will be studied, and one OD pair will be analysed in detail.

Figure 26 shows the import road flows from the port of Antwerp that did not reach 185,000 tonnes annually in 2016, thus making a five times weekly train service impossible. Whenever a daily service is not an offer, it might be worthwhile to increase the available cargo by cooperating with a neighbouring port. If a daily service can be offered in a stand-alone scenario, then cooperation becomes superfluous.

Figure 26 - Road freight flows from Antwerp, less than 185,000 tonnes annually

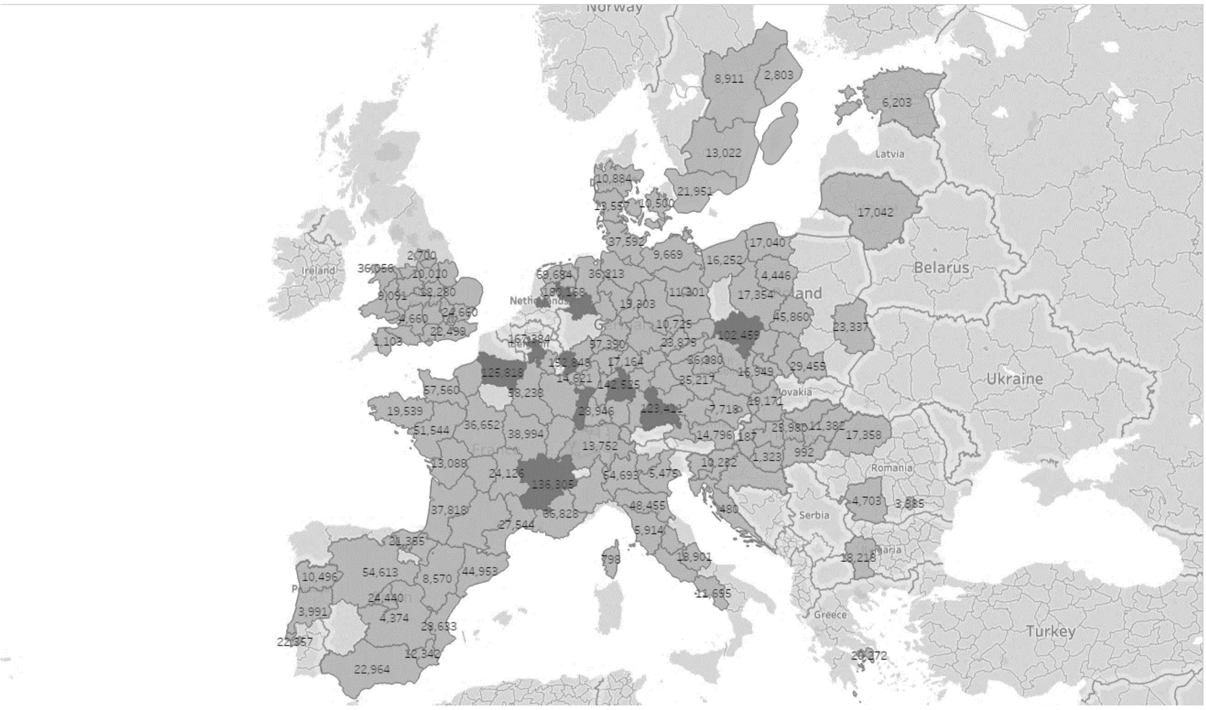
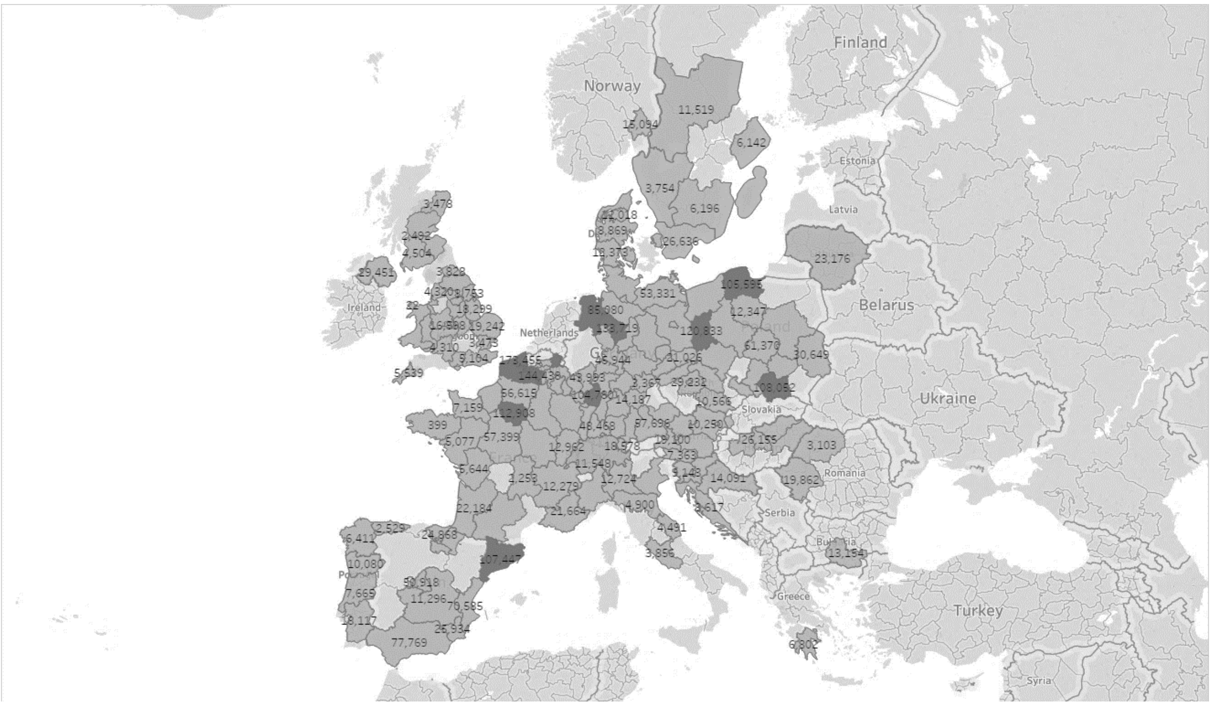


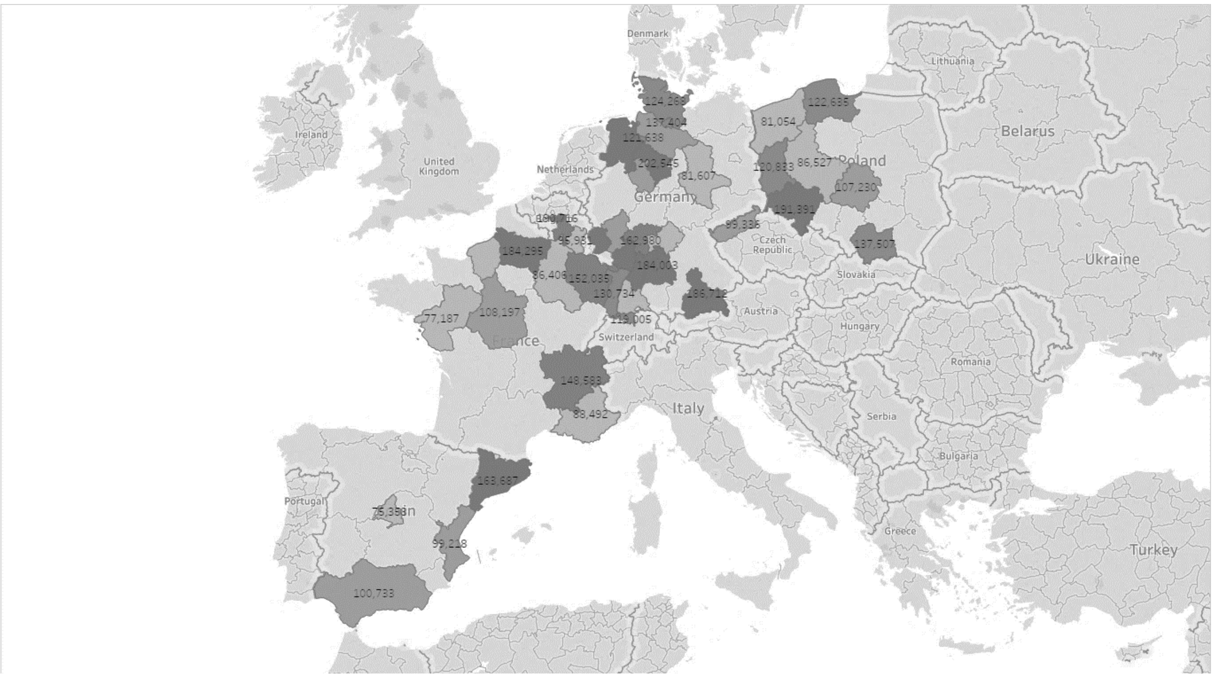
Figure 27 shows the same flows but now leaving the port of Rotterdam, NUTS339.

Figure 27 - Road freight flows from Rotterdam, less than 185,000 tonnes annually



It is immediately visible that a lot of these regions appear on both maps. When only the NUTS2 regions are withheld where one port alone does not have enough volume to facilitate a daily train service, i.e. less than 185,000 tonnes annually, but where the combined volumes are sufficient for at least a twice weekly rail freight service, i.e. more than 75,000 annually, combined, the map in Figure 28 emerges. The light colours indicate a volume for two or three services weekly, the darker ones refer to a volume sufficient for four or five weekly services.

Figure 28 - Rotterdam and Antwerp: hinterland volumes, bundled, at least 75,000 tonnes annually



It is perfectly possible that some of these regions are already serviced by a rail or barge service, but the remaining volume could be enough for additional rail or barge services. Since there is no Europe-wide database of rail and barge services, this must be researched for every NUTS2 region separately. The detailed list of all relevant NUTS2 regions can be found in Table 44. The mentioned volumes are of 'containerisable' cargo (see Table 11): large freight containers, other freight containers, pallets, and pre-slung goods.

Table 44 - Bundling opportunities for Antwerp and Rotterdam (tonnes annually by road)

		Rotterdam	Antwerp	Bundled
BE10	Region Brussels Capital	34,978	167,384	202,362
BE31	Prov.Brabant Wallon	24,398	166,318	190,716
BE34	Prov.Luxembourg(BE)	15,735	80,196	95,931
BE35	Prov.Namur	14,834	121,075	135,909
CH03	Nordwestschweiz	34,144	84,861	119,005
CZ04	Severozápad	64,959	23,730	88,688
DE11	Stuttgart	38,325	142,525	180,850
DE12	Karlsruhe	76,116	72,012	148,128
DE21	Oberbayern	57,696	123,411	181,107
DE50	Bremen	85,080	36,213	121,293
DE60	Hamburg	71,419	57,530	128,949
DE71	Darmstadt	89,129	73,851	162,980
DE92	Hannover	133,719	39,260	172,979
DE93	Lüneburg	50,921	52,589	103,510
DE94	Weser-Ems	97,496	71,042	168,538
DEA4	Detmold	49,107	52,175	101,282
DEB1	Koblenz	43,993	68,354	112,348
DEB2	Trier	31,673	152,848	184,520
DEB3	Rheinhessen-Pfalz	104,780	88,262	193,043
DEF0	Schleswig-Holstein	86,676	37,592	124,268
ES51	Cataluña	107,447	44,953	152,400
ES52	Comunidad Valenciana	70,585	28,633	99,218
ES61	Andalucía	77,769	22,964	100,733
FR21	Champagne-Ardenne	24,185	58,233	82,418
FR22	Picardie	56,615	125,818	182,432
FR23	Haute-Normandie	17,757	64,354	82,111
FR24	Centre	57,399	36,652	94,051
FR41	Lorraine	61,612	90,424	152,035
FR42	Alsace	33,206	95,229	128,435
FR71	Rhône-Alpes	12,279	136,305	148,583
FR82	Alpes-Côte d'Azur	21,664	66,828	88,492
PL11	Łódzkie	61,370	45,860	107,230
PL21	Małopolskie	108,052	29,455	137,507
PL41	Wielkopolskie	69,173	17,354	86,527
PL42	Zachodniopomorskie	64,802	16,252	81,054
PL51	Dolnośląskie	88,932	102,459	191,391
PL63	Pomorskie	105,595	17,040	122,635

One of the bigger, and at the same time further away, NUTS2 regions that shows potential is PL51 Dolnośląskie, the English name being Lower Silesia. It is situated on the western border, in the south-west of Poland and the provincial capital is Wroclaw. With an import road flow that combines to over 190,000 tonnes annually, a daily rail service could be offered if the two ports combine their cargo.

5.2.2 All road (import) from Antwerp and Rotterdam to NUTS2 Dolnośląskie

The distance to Wroclaw from Antwerp is slightly shorter than from Rotterdam but the rail connection towards Germany is better from Rotterdam. The Betuwe route is a dedicated freight rail which is shorter and has a higher capacity than the Montzen route from Antwerp. This might change when the Iron Rhine is reactivated, but this project is stuck and will, probably, not happen in the near future. The German regional and federal government, however, are now also pushing for a re-opening so it might happen sooner than expected. Anyway, it would probably be more economical to bundle in an intermediate point between the ports and Dolnośląskie, but if bundling in one port is already economically feasible than any move towards an intermediate bundling point would only be an improvement. The following analysis will, for the reasons mentioned above, use Rotterdam as a bundling point; the section from Antwerp to Rotterdam will be done by truck. Trains and even barges would be an option, but this would require an additional bundling point inside Antwerp, this would only improve the business case if the market would offer a competitive service.

Table 45 - Distances from Antwerp and Rotterdam to Dolnośląskie

Distance in km		PL51 Dolnośląskie	NL339
Antwerp	BE211	1,033.7	160.2
Rotterdam	NL339	1,054.4	

Source: Eurostat, 2018b

Using the same values for time, speed and costs as for the preceding case, the following picture emerges.

Table 46 - Cost of unimodal road transport

All road (import) towards PL51 (Dolnośląskie)	Distance (km)	Time driving (H)	Time resting (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours driving	Direct cost	VOT	External cost
Antwerpen	1033.7	15.90	12.50	102,833	9,348	4,674	4,831,749	81,346	6,396,925	314,142	2,981,672
Rotterdam	1054.4	16.22	12.50	88,932	8,085	4,042	4,262,268	71,637	5,637,748	274,569	2,630,246
Total				**191,765**	**17,433**	**8,717**	**9,094,017**	**152,983**	**12,034,672**	**588,711**	**5,611,918**
Truck speed	km/hour	65									
Truck waiting time	hour/truck	1.5									
Truck direct cost (distance)	€/km	0.6									
Truck direct cost (time)	€/hour	43									
Truck external cost	€ct/km	61.71									
VOT	€/TEU.hour	1.12									

A total direct cost of slightly over 12 million Euro, to which a value of time of almost 600,000 Euro must be added, results in a generalised cost of 12,623,383 Euro. This volume generates an external cost of more than 5.6 million Euro when all is transported by road.

5.2.3 Multimodal, road/rail from Antwerp and Rotterdam to NUTS2 Dolnośląskie

As described above, the cargo is trucked from Antwerp to Rotterdam and there it is transshipped on a train to Dolnośląskie. The resulting internal and external costs and values are shown in Table 47. A fixed cost of 1,000 Euro to form the train is included.

Table 47 - Costs of multimodal road/rail transport

Mulimodal road/rail (import) towards PL51 (Dolnośląskie)											
First leg (road)	Distance (km)	Time driving (H)	Time resting (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours driving	Direct cost	VOT	external cost
Antwerp	160.2	2.46	0.00	102,833	9,348	4,674	748,811	18,532	1,713,565	41,650	462,091
Rotterdam	0	0.00		88,932		-	-	-	-	-	-
Total (first leg)				191,765	9,348	4,674	748,811	18,532	1,713,565	41,650	462,091
Second leg (rail)	Distance (km)	Time driving (H)		Volume (tonnes)	Volume (TEU)	Trains (number)	Train.km	Train.hours	Direct cost	VOT	external cost
Rotterdam	1054.4	19.171		191,765	17,433	272	287,212	5,494	7,217,694	767,379	784,375
Grand total									**8,931,258**	**809,029**	**1,246,466**
Bundling effect									**3,103,414**	- **220,318**	**4,365,451**
Train speed	km/hour	55									
Train waiting time	hour/train	20									
Train direct cost (distance)	€/km	6									
Train direct cost (time)	€/hour	1000									
Train external cost	€ct/km	273.10									
Transshipment cost	€/TEU	50									

A total direct cost for the multi-modal solution amounts to 8.9 million Euro with an increased value of time of 809,000 Euro. The external costs drop to slightly over 1.2 million Euro

5.2.4 Analysis and conclusion

When the two scenarios are compared, the savings of direct, generalised and external costs, as show in Table 48 and Table 49, become apparent.

Table 48 - Recapitulation of case relevant costs (in Euro)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	12,034,672	588,711	12,623,383	5,611,918	18,235,301
Multimodal	8,931,258	809,029	9,740,287	1,246,466	10,986,753
Effect of bundling	3,103,414	-220,318	2,883,096	4,364,452	7,248,547

Table 49 - Recapitulation of case relevant costs (In Euro per TEU)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	690.34	33.77	724.11	321.91	1046.02
Multimodal	512.32	46.41	558.73	71.50	630.23
Effect of bundling	178.02	-12.64	165.38	250.36	415.79

This case study is distinctive in its longer distance. This has an important impact for the all-road option because the driving time is long enough to require application of the daily required resting time, making the resting time almost as long as the driving time. This has no impact on the direct cost but increases the VOT of the all-road option. The longer distance, obviously, makes the recuperation of the bundling cost through a less costly transport mode, easier. The direct cost of the road-only solution is 34.7% higher than the multi-modal solution, making a difference of 178 Euro per TEU. The increased value of time of 37% diminishes the benefit partially but the generalized cost saving is still 23%, or 165 Euro per TEU. But there is a massive saving in external cost of more than 4 million Euro. The road only alternative generates an external cost that is almost five times as high as the multimodal one, the external cost savings amounts to 250 Euro per TEU. Similar to the before-mentioned case, the external costs of trucks consist mainly of congestion cost (74%) and climate change cost (10%) (see paragraph 4.2.5); especially the former is very much time- and place-dependent and can strongly fluctuate with these conditions. The value used is the one for a trailer-tractor combination on a rural motorway at a capacity use that nears congestion (45.46 Eurocent/vkm, in 2018 values), it can be substantially higher if the road is saturated: the values are twenty times higher in a metropolitan urban region. But they drop to zero in a free-flow, highway scenario.

Table 50 describes the sensitivity of the cost savings resulting from the bundling to changes in the different parameters.

Table 50 - Sensitivity analysis

	Effect on bundling benefits				
Factor +10%	**Direct cost**	**VOT**	**External costs**	**Generalised costs**	**Total costs**
Truck speed	-19.0%	-5.1%		-24.6%	-8.2%
Truck waiting time	1.0%	0.3%		1.3%	0.4%
Truck direct cost (distance)	18.8%			23.3%	7.7%
Truck direct cost (time)	21.7%			26.9%	8.9%
Truck external cost			11.9%		8.0%
Train speed	18.9%	7.1%		25.1%	8.3%
Train waiting time		-8.1%		-1.9%	-0.6%
Train direct cost (distance)	-6.9%			-8.5%	-2.8%
Train direct cost (time)	-21.9%			-27.1%	-9.0%
Train external cost			-1.9%		-1.3%
VOT		-10.0%		-2.4%	-0.8%
Transshipment cost	-1.8%			-2.2%	-0.7%

An increase in truck speed by 10% would impact on the advantages of the direct cost savings with a reduction by 19%; the generalised cost savings, including the time lost through bundling, would drop even more, by almost 25%. But the opposite is also true: if the truck speed would decrease (through congestion), consequently, the effect would be strongly positive on the direct and generalised cost savings through bundling. An increase in truck cost per kilometre or per hour would also disproportionally impact on the direct cost and generalised cost effects of bundling. The same, but in the opposite direction, does apply to effects of changes in the speed of the train. Train waiting time (because it is proportionally more important) has a substantially bigger effect than truck waiting time. The train distance cost has more impact than that of a truck, but the opposite applies to time costs. The overall effect of a 10% change of the transshipment cost (at 50 Euro per TEU) is smaller but not negligible at almost 2% change of the generalised cost.

The composition of the average container has, also in this case, a value different from the European average. Not surprisingly, the class 8 products are, here too, much more prominent, with a drop in the cheaper classes like food and wood. The value of the container will be higher than the calculated average European value and the resulting value of time too.

Table 51 - Containerable cargo transported by road from Belgium and The Netherlands to Poland in 2016 (tonnes)

Class	Abbreviated description	Tonnes	Percentage	EU average
4	Food	1,129,390	31%	37%
5	Textiles	99,013	3%	1%
6	Wood	273,853	7%	12%
8	Chemicals, plastics	1,214,438	33%	12%
11	Machinery	206,754	6%	6%
13	Furniture	142,178	4%	2%
15	Mail	80,640	2%	4%
16	Equipment	124,200	3%	6%
17	Moving	0	0%	3%
18	Mixed	412,463	11%	16%

Source: own composition based on Eurostat, 2017a

The resulting VOT will, therefore, be slightly higher too but a quantified analysis is not possible due to the incompatibility of the databases.

Similarly to the other case studies, a winner takes all approach is used to calculate the modal shift. Why would a shipper pay a higher generalised cost if a cheaper alternative is available? In the present case, a shift of 97% is needed to reach the volume necessary for a daily service. If this percentage is not met, two alternatives are possible. Either the rail operator completes the train capacity with non-containerized cargo, or, alternatively, the frequency is reduced to four or three times weekly.

With a 34.7% saving of the direct cost, the savings are substantial, as well as those of the generalised cost and total cost, this would have an impact on the market share against the competing ports in Northern Europe. In chapter 3 is described how this impact could be calculated.

As mentioned higher, chapter 5 will conclude with a comprehensive analysis and policy implications of all three cases.

5.3 The case of the port of Gdansk, the port of Gdynia, and the ports of Szczecin and Swinoujscie

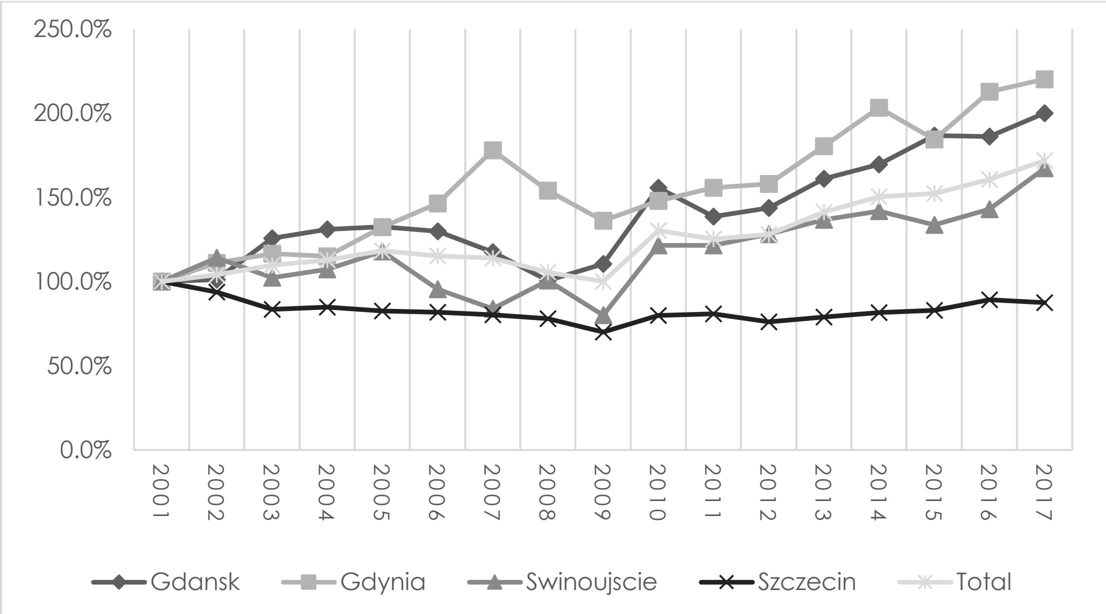
These Polish ports are atypical in the sense that they are still in a process of integration into the transport network of the European Union. When Poland was part of the Warsaw Pact, the transport infrastructure was geared towards the USSR. The integration in the EU network results in the port of Gdansk having one of the highest growth rates of all EU ports and contains the fastest growing terminal of Poland with a hinterland connectivity which is mainly road-based (Aronietis, Pauwels, et al., 2011). The ports share, pairwise, a NUTS3 region. The ports of Szczecin and Swinoujscie share not only a NUTS3 region: PL424, but also a port authority: "The Szczecin and Swinoujscie Seaports Authority". The ports of Gdansk and Gdynia, each having a completely different history, are managed by separate port authorities: the "Port of Gdynia Authority" and the "Port of Gdansk Authority". They are both located in NUTS3: PL634. The throughput, as recorded by Eurostat, has grown for most ports, albeit it not for all ports at the same rate. But with growth rates from 2001 to 2017 of 220% for Gdynia, 200% for Gdansk and 167% for Swinoujscie, they far outpace the European average of 116%. Only Szczecin stays behind with only 88% throughput growth in 2017, compared to 2001 (see Graph 19).

Table 52 - Throughput volumes (in thousand tonnes)

	Gdansk	Gdynia	Swinoujscie	Szczecin	Total
2001	16,971	8,348	8,798	9,988	44,105
2002	17,166	9,274	10,041	9,363	45,844
2003	21,323	9,733	8,997	8,345	48,398
2004	22,238	9,599	9,442	8,466	49,745
2005	22,478	11,038	10,373	8,246	52,135
2006	22,034	12,218	8,393	8,159	50,804
2007	19,944	14,849	7,385	8,008	50,186
2008	17,072	12,860	8,843	7,787	46,562
2009	18,758	11,361	7,038	6,992	44,149
2010	26,421	12,346	10,683	7,969	57,419
2011	23,513	12,992	10,680	8,064	55,249
2012	24,379	13,187	11,280	7,590	56,436
2013	27,335	15,051	12,024	7,886	62,296
2014	28,771	16,961	12,468	8,156	66,356
2015	31,685	15,391	11,759	8,276	67,111
2016	31,566	17,751	12,572	8,911	70,800
2017	33,940	18,378	14,709	8,743	75,770

Source: Eurostat, 2018a

Graph 19 - Relative port throughput growth (2001=index 100)

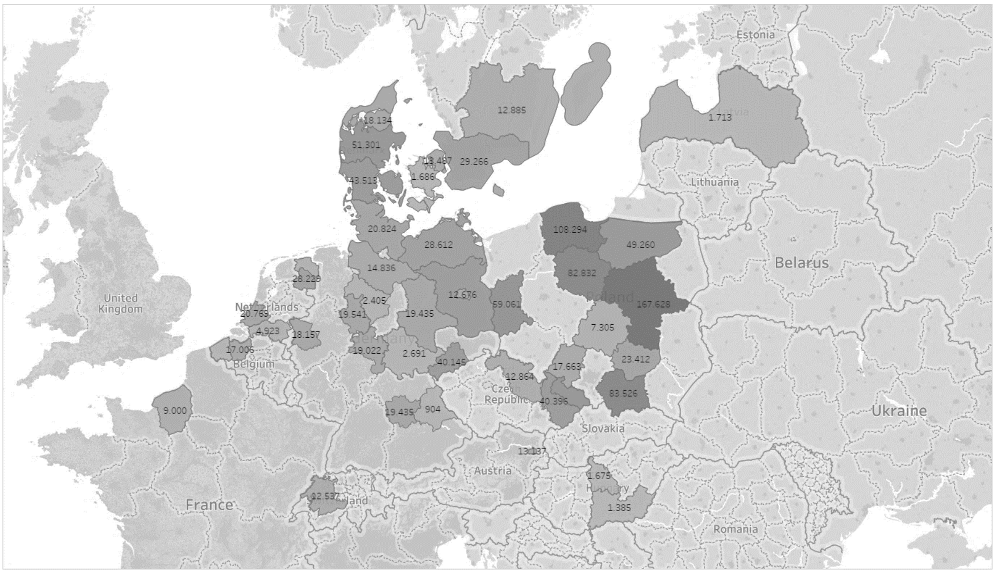


Source: Eurostat, 2018a

5.3.1 Road freight volumes from the port of Gdansk, the port of Gdynia, and the ports of Szczecin and Swinoujscie

As can be seen in Figure 29, Swinoujscie and Szczecin's hinterland is rather limited, some cargo flows reach out further into Europe, but the volumes are small once the region is not adjacent to the port.

Figure 29 - Road freight flows from Swinoujscie and Szczecin, less than 185,000 tonnes annually



The hinterland of Gdansk and Gdynia, even if the port of Gdansk is the biggest regional port, is even less extensive, but more concentrated (Figure 30).

Figure 30 - Road freight flows from Gdansk and Gdynia road freight, less than 185,000 tonnes annually

Figure 31 shows which NUTS2 regions have road freight volumes where the four ports separately do not have enough volume to organise at least 5 train services weekly but together they can facilitate at least two weekly services.

Figure 31 - Polish ports: hinterland volumes, bundled, at least 75,000 tonnes annually

The same information, but in table format can be found in Table 53.

Table 53 - Bundled road freight volumes

		Gdansk/Gdynia	Swinoujscie/Sczcecin	Bundled
		PL634	PL424	
Malopolskie	PL21	76,660	83,526	160,186
Swietokryskie	PL33	102,822	23,412	126,234
Lubuskie	PL43	17,975	59,061	77,036
Sydsverige	SE22	56,907	29,266	86,173
Grand Total		**254,363**	**195,265**	**449,628**

The distance between these regions are shown in Table 54.

Table 54 - Distances from Polish ports

Distance in km		Gdansk/Gdynia	Swinoujscie/Sczcecin
		PL634	PL424
Malopolskie	PL21	697.3	662.5
Swietokryskie	PL33	581	642
Lubuskie	PL43	373.5	109.3
Sydsverige	SE22	2213.62	338.1
Swinoujscie/Sczcecin	PL424	315.6	

Source: Eurostat, 2018b

The distance, cited by Eurostat, from Gdansk to Sydsverige (capital Malmö), is probably erroneous when compared with the distance from Swinoujscie. From Gdansk to Sydsverige the distance cannot be longer than the distance from Swinoujscie plus the distance from Swinoujscie to Gdansk. In any case, the bundling from Poland to Sweden in rail does not make sense because it is serviced by roro across the Baltic Sea. The Eurostat road freight data are, most probably, trucks that use roro services.

5.3.2 All road (import) from the Polish ports to NUTS21 Malopolskie

Volume- and distance-wise, the service to Malopolskie looks the most promising for bundling. Again, the port closest to the hinterland region will be used as bundling point, but simply looking at the map an intermediate point in the triangle between the two port regions and Malopolskie could result in an even more positive business case. Table 55 summarises the costs for a road freight solution: with a distance of almost 700 km, the external costs is over 45% of the direct cost. The value of time is relatively low due to the high efficiency of road transport.

Table 55 - Cost of unimodal road transport

All road (import) towards PL21 (Malopolskie)											
	Distance (km)	Time driving (H)	Time resting (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours driving	Direct cost	VOT	External cost
Gdansk/Gdynia	697.3	10.73	11.75	76,660	6,969	3,485	2,429,774	42,608	3,290,006	187,782	1,499,413
Swinoujscie/Sczcecin	662.5	10.19	11.75	83,526	7,593	3,797	2,515,272	44,391	3,417,995	200,032	1,552,174
Total				**160,186**	14,562	**7,281**	**4,945,045**	**86,999**	**6,708,001**	**387,813**	**3,051,587**
Truck speed	km/hour	65									
Truck waiting time	hour/truck	1.5									
Truck direct cost (distance)	€/km	0.6									
Truck direct cost (time)	€/hour	43									
Truck external cost	€ct/km	61.71									
VOT	€/TEU.hour	1.12									

The legally obligatory resting time presents a conundrum, the driver is supposed to rest 11 hours after a 9 hour drive (with a 45 minute rest in the middle) but he can twice a week continue for one extra hour, so up to 10 hours (Regulation (EC) No 561/2006 of the European Parliament and of the Council, 2006). However, with the average speed used in the cost model, after 10 hours, the driver will be 45 minutes away from his destination in case he is coming from Gdansk/Gdynia and only 12 minutes if he comes from Swinoujscie/Sczcecin. So, it is hard to predict whether the driver will obey the law and take an 11-hour rest less than an hour away from his objective, or whether he will simply drive on. This has a big impact on the rest times and the VOT. In case of breaking the law, the rest times drop from 11.75 to 0.75 and the VOT drops from 387,813 to 207,804. But, counting on a respect for the law, the higher VOT is used in this analysis.

5.3.3 Multimodal, road/rail from the Polish ports to NUTS2 Malopolskie

When the costs of the multimodal solution are calculated it becomes apparent that the relatively long distance between the port regions creates a high bundling cost. The increase in value of time, mainly caused by the waiting time of the train during the bundling operation, reduces the direct cost savings. Still, the savings in external costs could, if they could be internalised, make bundling an interesting proposition.

Table 56 - Cost of multimodal road/rail transport

Mulimodal road/rail (import) towards PL21 (Malopolskie)											
First leg (road)	Distance (km)	Time driving (H)	Time resting (H)	Volume (tonnes)	Volume (TEU)	Trucks (number)	Truck.km	Truck.hours driving	Direct cost	VOT	external cost
Gdansk/Gdynia	315.6	4.86	0.75	76,660	6,969	3,485	1,099,723	22,146	1,960,550	55,646	678,639
Swinoujscie/Sczcecin	0	0.00		83,526		-	-	-	-	-	-
Total (first leg)				160,186	14,562	3,485	1,099,723	22,146	1,960,550	55,646	678,639
Second leg (rail)	Distance (km)	Time driving (H)		Volume (tonnes)	Volume (TEU)	Trains (number)	Train.km	Train.hours	Direct cost	VOT	external cost
Swinoujscie/Sczcecin	662.5	10.95		160,186	14,562	228	150,743	2,719	3,623,620	506,487	411,680
Grand total									**5,584,170**	**562,133**	**1,090,319**
Bunding effect									**1,123,831**	- **174,319**	**1,961,269**
Train speed	km/hour	60.5									
Train waiting time	hour/train	20									
Train direct cost (distance)	€/km	6									
Train direct cost (time)	€/hour	1000									
Train external cost	€ct/km	273.1									
Transshipment cost	€/TEU	50									

5.3.4 Analysis and conclusion

The bundling of hinterland cargo flows from the four Polish ports to Malopolskie does result in a direct cost saving of almost 17%, equivalent to 77 Euro/TEU and, losing some of the benefit due to an increase of VOT of 45%, a lower generalised cost saving of 14,2% (an equivalent of saving of 65 Euro per TEU). The external costs savings amount to almost 135 Euro per TEU. The details are given in Table 57 and Table 58.

Table 57 - Recapitulation of case relevant costs (in Euro)

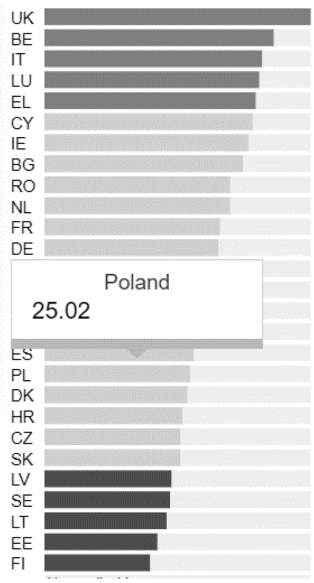
	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	6,708,001	387,813	7,095,814	3,051,587	10,147,402
Multimodal	5,584,170	562,133	6,146,302	1,090,319	7,236,621
Effect of bundling	1,123,831	-174,319	949,512	1,961,268	2,910,781

Table 58 - Recapitulation of case relevant costs (in Euro per TEU)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	460.65	26.63	487.28	209.56	696.84
Multimodal	383.48	38.60	422.08	74.87	496.95
Effect of bundling	77.18	-11.97	65.20	134.68	199.89

In this case study, even more than in the preceding cases, the total cost savings through bundling are largely made in the external costs. These costs, as mentioned earlier, consist mainly of congestion cost (74%) and climate change cost (10%) (see paragraph 4.2.5); especially the former is very much time- and place-dependant and as such changes in the where and when the truck is driving, could have a strong effect on the total cost savings of bundling. Even congestion in Poland is less critical than in Western-Europe (see Figure 32), it will probably increase over time.

Figure 32 - Hours spent in congestion (2017)



Source: European Commission, 2018

Because of the relatively small effect of bundling on cost savings the results are very sensitive to changes in the parameters. If the truck speed increases by 10% the direct cost savings of bundling, decrease by 26.4% to a direct cost effect of bundling of 10.0%. The total cost savings, mainly driven by (unchanging) external cost saving, would drop by 49.1%. Inversely, if the truck speed would decrease by 10% the effects of bundling on the direct costs become more positive with a value of 1,157,316 Euro, or 16.4%. An increase by 10% of the speed of the train increases direct cost savings by 28.5% to 1,123,83 which is a saving of 16.8% against the direct cost of the unbundled mode. Changes in the direct train time cost have the biggest effect with a leverage factor of more than twenty times those on the direct cost savings, every change of 1% changes the benefits of bundling with almost 3.4% on the direct costs, 6.0% on the generalised costs and 1.21% on the total costs. Table 59 describes the sensitivity of the cost savings resulting from the bundling to changes in the different parameters.

Table 59 - Sensitivity analysis

	Effect on bundling benefits				
Factor +10%	**Direct cost**	**VOT**	**External costs**	**Generalised costs**	**Total costs**
Truck speed	-26.4%	3.2%		-49.1%	-9.9%
Truck waiting time	2.8%	-0.3%		5.2%	1.0%
Truck direct cost (distance)	26.4%			46.5%	9.4%
Truck direct cost (time)	31.9%			56.2%	11.3%
Truck external cost			12.1%		9.7%
Train speed	28.5%	-4.7%		53.8%	10.9%
Train waiting time		8.6%		-6.6%	-1.3%
Train direct cost (distance)	-10.3%			-18.2%	-3.7%
Train direct cost (time)	-33.9%			-59.8%	-12.1%
Train external cost			-2.1%		-1.7%
VOT		10.0%		-7.6%	-1.5%
Transshipment cost	-4.0%	0.0%	0.0%	-7.0%	-1.4%

In the case of the Polish ports, the large distance between the port regions, in relation to the distance to the hinterland region, makes a bundling project an intuitively doubtful proposition, but the detailed analysis shows that, given enough cargo follows the modal shift, a direct cost saving of 13% can be made. If 94% of all available road cargo shifts to rail the volume suffices for a twice weekly service. A lower frequency loses its commercial appeal, but rail operators can use non-containerized cargo to complete a possible lack of container cargo. Alternatively, if the external costs savings could be used to subsidize the bundling operation, the lower direct cost would increase the attractiveness of the bundled services and result in a higher degree of modal shift.

This case is different since the cargo does not cross a border; the average container value of goods transported over the road inside Poland is shown in Table 60. The cargo differs from the European average by having a higher proportion of low value goods like food and wood. This is compensated by the unknown group of mixed goods. But it can be presumed that the average value will be lower than the average EU value, and, consequently also the VOT will be slightly lower.

Table 60 - Containerable cargo transported by road inside Poland in 2016 (tonnes)

Class	Abbreviated description	Tonnes	Percentage	EU average
4	Food	110,096,361	40%	37%
5	Textiles	2,066,040	1%	1%
6	Wood	54,353,686	20%	12%
8	Chemicals, plastics	38,914,325	14%	12%
11	Machinery	12,289,322	4%	6%
13	Furniture	11,637,228	4%	2%
15	Mail	14,558,876	5%	4%
16	Equipment	14,060,468	5%	6%
17	Moving	2,183,394	1%	3%
18	Mixed	13,769,530	5%	16%

Source: own composition based on Eurostat, 2017a

Even when looking for a mid-way bundling point, the bundling cost would barely decrease but simply be more equitably shared between the two port regions. Additionally, the time costs consist mainly of labour costs and the used values are European averages. The Polish the labour costs being lower than the EU average (see Table 61) and in the case of road transport the labour cost is relatively more important than for rail, so the bundling to rail would be less beneficial than calculated due to the lower labour costs.

Table 61 - Compensation of employees per hour worked (Euro/hour)

	European Union 28 countries	European Union 15 countries (1995-2004)	Poland
2000	16.0	19.7	3.5
2005	18.4	22.3	4.2
2010	20.5	24.6	5.7
2015	23.0	27.7	6.3
2016	22.8	27.4	6.3
2017	23.1	27.5	6.9
2018	23.6	28.0	:

Source: Eurostat, 2019

5.4 Overarching analysis of the case studies and conclusions

The cases show the importance of the relation between the distance between the cooperating ports on the one hand and the hinterland on the other. The case of the Polish ports shows that, because the distance to be covered for the bundling is almost half the distance to the hinterland, the bundling detour results in a slight increase in direct cost that can only be rectified if the trains are loaded at 95% instead of 80%. Still, even then the direct cost savings is (almost) lost through the increase in the VOT of the time needed for bundling. Only the benefits of external costs savings make the bundling an economically viable solution if these external benefits can be internalised.

Two important parameters can turn a negative business case positive. The first one is the load factor of the train: an increase has an important effect on the direct cost. The second aspect that makes the bundling an interesting proposition, is the saving on external costs; if these can be internalised, even only partially, the benefits turn very quickly positive even over longer bundling distances. Even in the case of Antwerp and Rotterdam, where the bundling towards Krakow results in a saving of generalised cost, shows that the external benefits greatly outweigh the direct cost savings. To make this business case enticing, any incentive policy that, even partially, allows for internalization of the external benefits, will motivate operators to offer competitive bundled services.

The market, being only interested in generalised cost savings, might not be sufficiently motivated to offer bundling services if the generalised cost savings are only relatively minimal. Cargo owners, who will want to minimize their logistics costs, will in the first order look at the direct cost savings; if these are present, they will look at the value of time, which is related to the value of their goods and the importance of factors like reliability and punctuality. If they are not convinced that the direct savings will not be more than lost through an increase in time, they will not be willing to use multimodal transport services.

But, even if not all available road cargo will make the modal shift, then still all is not lost. First, a smaller shift can be absorbed by having a lower frequency, while still having the same savings. Secondly, the cost-model ignores the increased attractiveness of the participating ports. This should result in an increased cargo volume travelling through the ports to the studied hinterland (or vice-versa). Lastly, as already mentioned, trains can be completed with wagons carrying break-bulk, liquid bulk or dry bulk. The power of the locomotive, with a strength of 3,000 tonnes, is after all capable of pulling much more than 80 TEU at 11 ton/TEU.

The internalization of external benefits can be the capstone of the hinterland strategy of cooperating ports. Ports can suffer from a lack of support from their surrounding population: they are often perceived as causes of congestion. If they want to increase their throughput, and the regional welfare and value added, a program that encourages a modal shift will diminish the opposition from the local residents to port expansion. As is shown in the cases, even a marginally negative bundling project becomes positive if the external benefits are considered.

5.5 Strategy and policy implications

The concepts of chapter 3 and the cost model described in chapter 4, resulting in its application in the present chapter, suggests some important conclusions for the different port operators. Case-by-case savings in direct costs, generalised costs and external costs might be possible. The different actors have different interest in the gains that might be made by bundling. These benefits must therefore be studied with the different viewpoints in mind.

A comprehensive incentive policy should eventually motivate the cargo owners to use multimodal transport to the hinterland that the ports want to add to their serviced region by cooperating with neighbouring ports. By lobbying with the regional, national and supranational legislative bodies, the ports should push for a transport pricing system for external costs that assures a level playing field. The money thus collected should, partly, be used to reward the users of multimodal transport for their effort by compensating them, even partially, for the bundling costs. Public port authorities are organisations that have potentially access to the knowledge of the cargo flows, the different actors and the incentive to develop a fair and efficient distribution system for the (partial) internalization of the external benefits. The PA can incentivize the cargo owner by compensating his loss of time and the LSP to offer a competitive multimodal service on specific destinations. Even a partial use of the external benefits can make a cooperation project, where the bundling benefits on direct costs are relatively small, into a tempting proposition for the cargo owner, by reducing its generalised costs, and for the service provider by creating a new market with sufficient volume and profitability.

5.5.1 Implications for LSPs and shippers

LSPs such as rail operators, barge operators or multimodal operators but also shipping lines that want to reinforce their position in carrier haulage, can benefit from the developed cost model to find market opportunities. By identifying road cargo flows in neighbouring ports, they can combine these flows into a bundled cargo mode and benefit from direct cost savings.

Shippers, if their negotiation position is strong enough would then be able to, at least partially, share in these cost savings. They are, at the same time, the actor that carries the increased VOT. So, if their share of the direct cost savings is not sufficient to compensate for an increased VOT, then they will resist the bundling of their cargo.

Both actors are only marginally interested in external costs savings. The societal benefits of these savings, as well as the increased attractiveness of the implicated ports is not against their interest, per se, but will not influence their bottom line. They might still benefit from a decrease in externalities because it would have a positive impact on their image and be part of their corporate social responsibility business strategies.

5.5.2 Implications for PAs

PAs are the prime, but not exclusive, targets for applying the developed concepts. Depending on the view the PA has of its role in the port community, different strategies and policies are possible.

The PA, and specifically in the case of a Hanseatic landlord port authority, has interests that supersede the short (or even long) term bottom-line approach of the business actors. The benefits described in the preceding chapters, like increased attractiveness of the port and reduced externalities concern the port region and all its inhabitants. As such, they can motivate a publicly-owned port authority who has to justify its operations to the population surrounding the port. At the same time, their first concern is the satisfaction of port users with the services offered by all the actors.

A strategy that asks the least, commitment-wise, from the cooperating PAs is to collect and share information from and with the interested operators and shippers about hinterland cargo flows that might benefit from a bundling operation where one port alone would not reach sufficient volumes. One problem with this approach is that companies might fear sharing information with suppliers and competitors that they consider confidential. This could lead to the conclusion that PAs need to be more involved in such a project and create and manage themselves the data platform thus becoming a data clearinghouse. As a neutral party, they could guarantee confidentiality of the data making it possible to share them in an anonymous way. In this, they could create, or support the creation, of a data sharing platform where IT facilitates the bundling of the hinterland flows.

Even more involvement would be required in a policy where the cooperating PAs finance the kick-starting of a bundled hinterland service that combines the flows from two (or more) ports. This would be a way to internalise, at least partly, the external costs savings and thus motivate LSPs and shippers to use the service and reduce their direct costs by compensating for the additional bundling cost. After a pre-defined period, the service should have attracted enough customers and cargo to become self-sufficient.

A more long-term commitment from PAs would be a continued participation in the bundling costs, straight from the PAs to the operator or shipper. This could be justified as an internalization of external benefits. As such, it should not be considered as a subsidy.

In a more atypical role for a PA, the cooperating PAs could decide to offer the bundled service themselves together and thus expand their role into that of a transport operator for specific hinterland destinations. Even if this might be anathema for many PAs, some have a more entrepreneurial view of their role.

An important part of the bundling benefits lies in the reduction of externalities. If these externalities would be internalised through changes in policy, like a consistent application of smart road pricing, then the business cases would automatically fully benefit from all advantages offered by bundling. PAs can lobby for more tools to allow the internalization of these external costs, or benefits.

5.5.3 Implications for regional governments

The economic, but also environmental, effects of ports far outreaches the control of local authorities. This makes regional governments, especially if they have more than one port in their region, also interested in the benefits of port cooperation. Extended regions can benefit from the bundling of cargo streams from or to adjacent seaports, they can enjoy a reduction of external costs and a more attractive port and more efficient hinterland connections can bring additional welfare and lower access costs to suppliers and customers overseas. Not being a part of the port ecosystem, they have more difficulty in identifying the opportunities and can only realise the promotion of bundling projects with the active cooperation of the implicated port authorities and or port communities. They can motivate the above-mentioned port actors to start projects as described in the preceding paragraphs, but they cannot force projects on unwilling PAs.

However, they can more easily create tools that allow for the internalization of external benefits. They have more power to create legal and fiscal tools that can be used to motivate shippers and LSPs to use a bundled transport mode. They could, for instance, carry a part of the transshipment and bundling costs. This should not be seen as subsidies but as a way to reward actors, partially, for reducing the costs society is covering as a result of transport activities.

5.5.4 Implications for (supra)national governments

Higher level authorities, when covering multiple ports have, of course, no interest in increasing the competitiveness of one port over another, unless the ports that lose market share are outside their purview. But they have an interest in increasing the customer surplus and reducing the externalities. As such, being far away from the operational side of ports, they can initiate legislation that allows for cooperation without running foul of competition laws. They control the means for regulating unfair competition between the different ports. Cooperation as such is not necessarily an unfair competition, especially if it increases consumer surplus.

They can also develop policies that allow the internalization of external cost reductions without these being considered subsidies. They external costs savings will be internalized automatically if legislation is enacted that internalises all external costs.

Their main preoccupation should be to guarantee a level playing field where rules apply to all ports equally.

5.5.5 Dynamic reactions to policy and strategy implementation

The present cost model is static, and many actors can take advantage of the opportunities offered by bundling the road cargo flows of neighbouring ports. However, once the advantages of bundling have been reaped it is likely that other actors will adapt their strategies. Especially when market share is gained then by definition some other party has lost market share and might not be taking this lying down.

When other competing ports have lost out through the collaboration that has strengthened their competitors and thus reduced their market share, then they might want to look for ports to start a collaboration with, too. From a larger perspective, society would again be a winner because more ports would realise a modal shift and reduced external costs. The first group of cooperating partners might lose a part of the previously gained market share, it remains to be seen, case-by-case, if enough cargo volume remains available for a shift to rail and still result in minimal frequencies. This potential partner might be available but if the losing port is on the edge of the port range, it might be difficult, even impossible, to find a neighbouring, suitable partner. The port is then boxed in, surrounded, as it were. They only option available would be to have one of the cooperating ports change its alliance. Alternatively, the port might reduce its port dues to enhance its attractiveness, but it remains doubtful that this reduction could outweigh the costs savings the cooperating ports offer.

If the losing party is an LSP, like a road haulage company that loses business to rail, it would be next to impossible to win this cargo back to road after it made a modal shift. The margins in the road haulage business being what they are, a price reduction that is economically viable would probably not suffice to result in a reverse modal shift. If a losing actor is a rail operator then there might be, either in a stand alone or in cooperation, to regain (part of) the lost market share by improving the value proposition it offers.

If the losing party is one of the cooperating ports, then the lifespan of the cooperation project will be limited unless the winning port is willing to use some of his gains to compensate the losing partner. This could mean redirecting a part of the gain to the partner.

Chapter 6 CONCLUSIONS, DISCUSSIONS AND FUTURE RESEARCH

This final chapter summarises the preceding chapters, reiterates the most important concepts and draws the conclusions. It closes with future research questions.

6.1 Research context

Surely, the key property of business economics at the beginning of the 21^{st} century is globalisation. Manufacturing and distribution networks are spread out over the globe and distances between production and consumption are almost inconsequential thanks to efficient transport networks. Seaports are important nodes in these global networks: they are crucial nodal points between markets and customers. As such, ports are also locations where value added is created and employment is provided, servicing the surrounding business as entry points of raw materials and spare parts and providing access to customers in the global market. Local, regional and national policy makers are motivated in increasing the competitiveness of their ports, thus enhancing the competitiveness of their local businesses and increasing the value added and employment created by their port system(s).

Contrary to popular belief, competition and strife are not the normal human behaviour, early man out-evolved the other apes using language and cooperation. Even if competition is an important driver of innovation and expansion of a company, in today's VUCA environment companies and other organisations use cooperation to diminish the risks associated with product and market development and to seek economies of scale and scope. If this is equitably shared with the customers and does not lead to rent seeking and collusion, cooperation can be a win-win-win, where the customer, and society at large, can be the third winning partner of a project.

One of the strategies that can be used to enhance the competitiveness of a port cluster is cooperation with its neighbours, the preceding chapters have shown how horizontal cooperation between seaports can be beneficial to regional welfare. Starting from the more general concepts on cooperation, the second chapter established a three-dimensional taxonomy to differentiate the cooperation projects of seaports. The relevant dimensions are the implicated part of the port-oriented supply chain, the objective of the cooperation and lastly, the intensity of the cooperation. The role of the tertius, as a party that is not part of the cooperation but benefits, is analysed in the difference of a top-down versus a bottom-up driven cooperation project. The port authority can be this tertius and through a judiciously established incentive policy, motivate actors in the port clusters and LSPs to bundling specific hinterland cargo flows. To be successful, a cooperation project needs to be feasible, likely and desirable.

6.2 Research question

Neighbouring ports can share a common hinterland. The introduction of the container diminished the importance of the captive hinterland while increasing the contested hinterland: using containers, cargo can more easily travel further inland, but at the same time the hinterland with neighbouring ports has an increasing overlapping region. The reach of this hinterland is one of the defining factors of the attractiveness of a port. Through cooperation, ports can extend the reach of their hinterland. At the edge, cargo flows become too thin to attract bundling services of LSPs. By combining the thin flows of two (or more) neighbouring ports, the flows can become thick enough to allow for a shift to a bundled transport mode. This can result in a lower cost of the hinterland connectivity, thus increasing the attractiveness of the cooperating ports and resulting in an increased market share.

This thesis researches the possible benefits of cooperation between neighbouring seaports and focusses on the cooperative development of the hinterland connectivity. Where can hinterland flows of neighbouring ports be bundled and thus lead to a lower direct and generalised cost? What are the external benefits of such a cooperation project?

The conceptual cost model is further developed into an empirical model incorporating all 104 core TEN-T ports and their import and export flows toward the 281 European NUTS2 regions. The empirical research question then becomes, which combination of these 104 ports can enhance the hinterland connectivity of the cooperating ports and lead to cost savings, in direct costs, generalized costs as well as external costs?

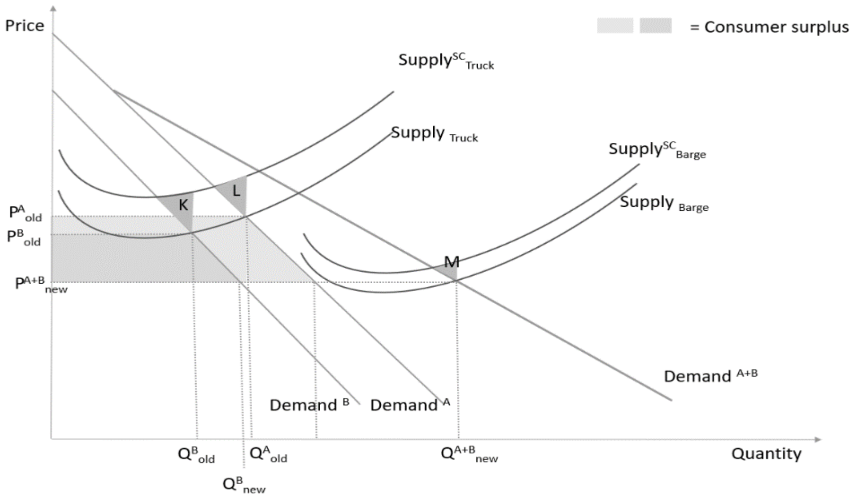
6.3 Research methodology

Using the concepts of welfare economics and consumer surplus, chapter three shows how, through bundling of hinterland cargo flows, neighbouring ports can increase their attractiveness by combining the road cargo services to the further-away hinterland destinations. Separately, the volumes are insufficient for a more efficient, bundled, transport mode, but, by merging flows of two or more neighbouring ports, a volume is reached that allows a shift towards train or barge. This reduces the direct and the external cost and using a societal cost benefit analysis it can be deduced whether the cooperation can be beneficial.

Graph 20 best summarises these concepts and shows how, through the bundling of hinterland cargo flows, two (or more) competing ports can combine hinterland flows that separately lack volume needed to fill a bundled service, thus facilitating a more cost-efficient transport mode. The consumer benefits not only from a lower price, but also the whole port region can benefit from external cost savings resulting from the modal shift.

The lower cost will also lead to an increased attractiveness of the participating ports, thus increasing their market share, resulting in an increased throughput and regional value added.

Graph 20 - Consumer surplus through bundling



This allows identifying those flows where a port alone has too small a containerisable cargo flow to allow a shift towards a rail service but where, by combining road flows of adjacent port regions, a volume can be reached which allows at least a twice-weekly rail service. The model compares the cost of the bundled and unbundled transport mode, including the VOT, to define whether such a service is economically viable. It also calculates the external costs of both modes, which results in a monetized external cost saving of a potential modal shift.

Chapter four shows how this cost benefit analysis can be empiricalized in the European hinterland. Starting from the 104 TEN-T core seaports, a cost model is developed that connects the 281 NUTS2 regions to these ports starting from the extant road cargo flows.

6.4 Results and analysis

These concepts are applied to three cases in chapter five. The newly-created North Sea Port (NSP) could combine flows to the NUTS2 region DEA1, Düsseldorf, (and several others) in its hinterland, resulting in a saving on direct cost, generalised cost (if the train has a higher load factor) and especially external costs, as is recapitulated in Table 62. The model takes the load factor of the train at 80%; with a higher load factor the benefits, obviously, increase. A 90% loading factor is needed to make the case profitable from a generalised cost viewpoint. The modal shift is analysed in a winner-takes-all strategy. Why, when using generalised costs, would a shipper choose for a transport mode with a higher generalised cost? The detailed analysis gives, nevertheless, attention to the effects of a partial modal shift. This case, with the ports being all on the same river systems with the studied hinterland region, is also analysed with an IWW option. Bundling into a large barge would decrease the frequency but increase the profitability of the business case.

Table 62 - Savings through bundling from NSP to Düsseldorf (in Euro)

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	3,788,399	118,665	3,907,064	1,561,323	5,468,387
Multimodal rail	3,488,243	546,690	4,034,933	398,422	4,433,375
Effect of rail bundling	300,157	-428,025	-127,868	1,162,881	1,035,013
Effect of bundling on a train with load factor of 90%	539,785	-370,608	169,176	1,186,317	1,355,493
Effect of bundling on a class V barge	911,865	-725,911	185,954	1,034,364	1,220,318

The second case studies the cooperation between Europe's two biggest ports, Rotterdam and Antwerp, where they can combine the flows to one of their common hinterland regions, PL51, Dolnośląskie, in South-West Poland, which has Wroclaw as regional capital.

Due to the longer distances the savings through bundling are even more obvious (see Table 63). The volumes are sufficient to allow for a daily service.

Table 63 - Savings through bundling from Antwerp and Rotterdam to Dolnośląskie

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	12,034,672	588,711	12,623,383	5,611,918	18,235,301
Multimodal	8,931,258	809,029	9,740,287	1,246,466	10,986,753
Effect of bundling	3,103,414	-220,318	2,883,096	4,364,452	7,248,547

Lastly, the third case looks at the four Polish ports of Gdansk, Gdynia, Szczecin and Swinoujscie and how the road cargo that flows towards the south, to PL21 Malopolskie, can be bundled to a rail service. Due to the large inter-port distance of 316 km compared to the hinterland distance of 697 km and 662 km, the business case for bundling is proportionately less interesting but still positive. This is shown in Table 64.

Table 64 - Savings through bundling from Polish ports to Malopolski

	Direct cost (a)	VOT (b)	Generalised cost (a)+(b)	External cost (c)	Total cost (a)+(b)+(c)
Road only	6,708,001	387,813	7,095,814	3,051,587	10,147,402
Multimodal	5,584,170	562,133	6,146,302	1,090,319	7,236,621
Effect of bundling	1,123,831	-174,319	949,512	1,961,268	2,910,781

But here too, the external cost savings make a bundling operation worthwhile, even if it is only from a welfare viewpoint.

The results of the case studies are very sensitive to the parameters used in the cost model. In all the cases, factors like vehicle speed, direct vehicle cost and loading factor have a high impact on the direct and generalised cost, in chapter 5 every case has a sensitivity analysis describing the effect of the variance of these parameters.

6.5 Conclusions

From the literature review, it can be concluded that, while generally cooperation is aimed at reducing costs, more often it aims at reducing the risk of product and market development. It is often an emerging strategy driven by pressures caused by a changing economic environment. Applied to seaports, this is apparent in the many cases expounded in the preceding chapters. Driven by competition (for instance, the ports in the Hamburg-Le Havre range, defending their primacy in the European continent against the Southern European ports), by changing geography (for instance, the port of Copenhagen-Malmö, driven by the Öresund bridge that eliminated their ferry function) or by changing economic and political conditions (for instance, the merging of ports in the Peoples Republic of China), ports cooperate in varying levels going from ad-hoc projects to full-fledged mergers.

The opportunities for cooperation between seaport authorities are spread out over the triptych but especially in the hinterland there is still room for efficiency gains. The hinterland represents the largest part of the direct and external costs, of the global supply network, thus allowing for more opportunities for cost savings. Through bundling, a modal shift can bring a lower direct cost, an increased consumer surplus and, as a result, a growth in regional welfare. At the same time, the shift towards a more sustainable transport mode results in a reduction of external costs. This results in a win-win-win for the participating port companies and authorities, but also for the port users and eventually the welfare of the port region.

The actor that gives the primary impetus for a cooperation project can come from the port community or from a higher regional or national authority. Especially Hanseatic landlord port authorities are averse for imposed cooperation, but they are motivated to enhance the competitiveness of their port cluster. This can motivate them to start bottom-up cooperation projects. Also, the proportional size of the cooperating partners is important. A substantially smaller partner can experience a project as a hostile take-over with fears of his interest being neglected. A substantially bigger partner might feel that the benefits are accruing to the smaller partner, while the bigger partner does all the heavy lifting.

When the conceptual cost model is applied to the 104 core TEN-T ports and specifically looking at the case studies, it is shown that cooperation in the hinterland connectivity can expand the hinterland of the cooperating ports. Through a bundling of smaller, further reaching, cargo flows, a volume can be attained that allows for a shift towards a bundled transport mode. There are regions where together these volumes can be reached, while at the same time the extra expenses for bundling and the increased VOT is more than compensated for by a saving in direct and generalised cost. Additionally, there is a proportionally important external cost saving that can be (partly) internalized to compensate for the bundling cost.

From the case studies, the importance of the value of time and the external costs becomes obvious. Through the sensitivity analysis, it is furthermore shown that the used values of the cost parameters have a strong influence on the feasibility of the bundling project. In the studied cases of NSP and the Polish ports, the increase in VOT, caused by the bundling, is proportionally higher than in the case of the Flemish-Dutch Delta ports. This is because in the case of the NSP, the hinterland distance is relatively low, which makes the bundling time an important factor. In the case of the Polish ports, the inter-port distance is high, proportionally to the hinterland distance making the bundling cost high. The boundaries of the sensitivity analysis, as a result of the linearity of the cost model, must be set intuitively to a realistic limit. The case of Antwerp and Rotterdam, cooperating on a longer distance towards Krakow, shows a savings in both direct and generalised cost. The bundling costs, as a result of the, relatively short, distance between the between the cooperating ports, is lower than the cost savings on the, relatively longer, hinterland leg. Nevertheless, when only using the direct costs, the ratio of the distance between the ports and the distance between the ports and the studied hinterland region does not need be very high: already at a distance of 57% of the bundling distance, increased with fixed amount 63 km, does the direct cost of the bundled mode become lower than that of the unbundled road transport.

It can be concluded, without exaggeration, that the real benefit of cooperation in the hinterland connectivity lies in the reduction of external cost, especially in port regions that already experience a lot of road congestion. In the studied cases, the external cost savings are substantially higher than the direct costs savings: they are more than three times the direct costs savings in the case of rail bundling at the NSP and 1.6 times the direct cost savings in the case of Antwerp and Rotterdam. They more than compensate for possible losses through an increased VOT. To maximise the attractiveness of a cooperation project, these external cost savings need, at least partially, to be shared with the shippers to create a win-win-win scenario.

This is where the PAs can play a role. Especially public port authorities have access, through their customers, to the necessary knowledge of the cargo flows, and can, sustained by a motivation for local welfare, be the driver of an incentive policy that functions as a conduit to internalize the external cost savings. By facilitating bundling services, they could incentivize a modal shift and reduce the bundling costs, making a bundled service more attractive. The societal cost would be negative because, if the incentive policy is properly executed, the external cost savings would be bigger than the sums used to finance the policy. By, at the same time, sustaining this policy with a chapter to disincentivize road traffic, the amounts thus collected could be used to finance this policy. This should be done on a wider regional level to avoid creating a competitive disadvantage.

A better connection to the hinterland will increase the attractiveness of the participating ports but the hinterland is only, however increasingly important, part of the global supply chain cost. The effect of a reduced hinterland cost will only substantially affect the market share of the participating ports if the cost savings is proportionally important on the total generalised supply chain cost. This is more likely for inland destinations further away from the port, and cooperation can combine smaller flows in bundles that make a modal shift economically viable. Even for nearby destinations, the proportional saving in hinterland cost can be substantial, without impacting on the market share, while still increasing the regional welfare and reducing the external cost.

Different port actors can deduce different strategies from the opportunities described in this thesis. LSPs can find market opportunities, port authorities can develop incentive policies to increase their port attractiveness while at the same time reducing external costs for the local inhabitants and higher authorities can develop incentives to reduce the external costs for a wider region.

6.6 Future research

The use of SCBA as a methodology has consequences, one of them being that it is not clear who will benefit from the cost reductions. Further study should clarify whether the cost savings will be passed on to the customer or result in a rent seeking behaviour from the service provider. The assumption that competition in the market of LSPs is sufficiently fierce to avoid such behaviour is valid in general but in some regions and transport modes, oligopolies might be present where LSPs can capture the benefits, thus diminishing the attractiveness of the bundling proposition.

The cost model developed in this thesis is static. Further research is needed to study the dynamics of the actors and the possible sequence of reactions to changes. It would be worthwhile to reflect on the reactions of the competing ports that might lose market share, although the effect on market share might be less important, as is discussed above. Inside the cooperating port regions, the transport mode that loses market share, might react by increasing its competitiveness through in increase in service level or a reduction in cost or price. Outside the cooperating ports, the competing ports, or their constituents, might react in a similar fashion. The latter would have a negative effect on the cooperating ports and diminish the beneficiary results of the cooperation. But, as already stated, without creating a cooperation between themselves, the competing ports have, probably, few degrees of freedom since their unbundled hinterland connection service providers are likely already offering a competitive product, driven as they are by intra-port competition. But, alternatively, they could be pushed into a cooperation between some of the remaining, competing ports.

The effect of an implementation of the Paris agreement on the cooperation strategies remains unclear and would need more study. They could increase the direct cost of unbundled transport, but they would probably also reduce the external costs. The net result still needs to be analysed.

The effect of cooperation on the discrete port choice is, thus far, only conceptually developed. It would be worthwhile to further analyse this at a quantitative level. The choice effects could be empiricalized for any combination of the core TEN-T ports, case-wise, but would entail the calculation of the door-to-door total generalised chain cost for all the main ports servicing a particular hinterland and competing with the cooperating ports that would be studied; this would establish a case-dependent market share price elasticity.

For more detail, the case studies did not develop the concept of balancing import and export flows. Should any case be further developed, the first step would be to examine the return flow of the land vehicles and establish whether enough cargo is available to fill the opposite direction. In some cases, it might be that one port might have an import flow that could be combined with the export flow of a neighbouring port thus maximising the use of vehicles and creating opportunities that a stand-alone port might not have due to the cost of empty return vehicles.

In conclusion, the preceding chapters have shown that cooperation between seaports can enhance the capacity to generate value added for the whole port region and reduce the external costs caused by the hinterland connectivity. To be truly attractive, an incentive policy would be required, by a Hanseatic landlord port authority or any other regional government, that would make, at least partial, the internalization of the external benefits possible. It would be worthwhile to study the design of this policy more in detail. The sources of the financing remain to be defined, as well as the necessary proportion of the external cost savings that need to be internalized.

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Annexe

MS	Port Name	Corridor
ESP	A Coruña	
DK	Aarhus	Scandinavian-Mediterranean
ESP	Algeciras	Mediiterranean / Atlantic
NL	Amsterdam	North Sea-Baltic / North Sea- Mediterranean / Rhine-Alpine
IT	Ancona	Scandinavian-Mediterranean
BE	Antwerpen	North Sea-Mediterranean / Rhine-Alpine
GR	Athens	Orient/East-Med
IT	Augusta	Scandinavian-Mediterranean
ESP	Barcelona	Mediterranean
IT	Bari	Scandinavian-Mediterranean
UK	Belfast	North Sea-Mediterranean
ESP	Bilbao	Atlantic
FR	Bordeaux	Atlantic
DE	Bremen	North Sea-Baltic / Scandinavian-Mediterranean
DE	Bremerhaven	North Sea-Baltic / Scandinavian-Mediterranean
UK	Bristol	
BU	Burgas	Orient/East-Med
IT	Cagliari	Scandinavian-Mediterranean
FR	Calais	North Sea-Mediterranean
UK	Cardiff	
ESP	Cartagena	Mediterranean
RO	Constanţa	Rhine-Danube
IRL	Cork	North Sea-Mediterranean
UK	Dover/Folkestone	
IRL	Dublin	North Sea-Mediterranean
FR	Dunkerque	North Sea-Mediterranean
UK	Edinburgh	North Sea-Mediterranean
UK	Felixstowe	North Sea-Mediterranean
FR	Fos-sur-Mer	North Sea-Mediterranean
RO	Galaţi	Rhine-Danube
PL	Gdańsk	Baltic-Adriatic
PL	Gdynia	Baltic-Adriatic
IT	Genova	Rhine-Alpine
BE	Gent	North Sea-Mediterranean / Rhine-Alpine
ESP	Gijón	
IT	Gioia Tauro	Scandinavian-Mediterranean
UK	Glasgow	North Sea-Mediterranean
SW	Göteborg	Scandinavian-Mediterranean
UK	Grimsby/Immingham	

DE	Hamburg	North Sea-Baltic / Scandinavian-Mediterranean / Orient/East-Med
SF	Hamina	Scandinavian-Mediterranean
UK	Harwich	North Sea-Mediterranean
SF	Helsinki	North Sea-Baltic / Scandinavian-Mediterranean
ESP	Huelva	
GR	Igoumenitsa	Orient/East-Med
GR	Iraklion	
LIT	Klaipėda	North Sea-Baltic
DK	København	Scandinavian-Mediterranean
SLO	Koper	Baltic-Adriatic / Mediterranean
SF	Kotka	Scandinavian-Mediterranean
IT	La Spezia	Scandinavian-Mediterranean
ESP	Las Palmas	
FR	Le Havre	Atlantic
CY	Lemesos	Orient/East-Med
IRL	Limerick / Shannon	
PT	Lisboa	Atlantic
UK	Liverpool	North Sea-Mediterranean
IT	Livorno	Scandinavian-Mediterranean
UK	London	
DE	Lübeck	Scandinavian-Mediterranean
SW	Luleå	
SW	Malmö	Scandinavian-Mediterranean
MT	Marsaxlokk	
FR	Marseille	North Sea-Mediterranean
UK	Milford Haven	
NL	Moerdijk	North Sea-Baltic / North Sea- Mediterranean
SF	Naantali	Scandinavian-Mediterranean
FR	Nantes Saint-Nazaire	
IT	Napoli	Scandinavian-Mediterranean
UK	Newport	
BE	Oostende	
IT	Palermo	Scandinavian-Mediterranean
ESP	Palma de Mallorca	
GR	Patras	Orient/East-Med
PT	Porto	Atlantic
IT	Ravenna	Baltic-Adriatic
LAT	Rīga	North Sea-Baltic
CRO	Rijeka	Mediterranean
DE	Rostock	Scandinavian-Mediterranean / Orient/East-Med
NL	Rotterdam	North Sea-Baltic / North Sea- Mediterranean / Rhine-Alpine
FR	Rouen	Atlantic
ESP	Sevilla	Mediterranean

PT	Sines	Atlantic
UK	Southampton	North Sea-Mediterranean
SW	Stockholm	Scandinavian-Mediterranean
PL	Świnoujście	Baltic-Adriatic
PL	Szczecin	Baltic-Adriatic
EST	Tallinn	North Sea-Baltic
IT	Taranto	Scandinavian-Mediterranean
ESP	Tarragona	Mediterranean
UK	Teesport	
ESP	Tenerife	
NL	Terneuzen	North Sea-Baltic / North Sea- Mediterranean / Rhine-Alpine
GR	Thessaloniki	Orient/East-Med
SW	Trelleborg	Scandinavian-Mediterranean
IT	Trieste	Baltic-Adriatic / Mediterranean
SF	Turku	Scandinavian-Mediterranean
ESP	Valencia	Mediterranean
MT	Valletta	Scandinavian-Mediterranean
IT	Venezia	Baltic-Adriatic / Mediterranean
LAT	Ventspils	North Sea-Baltic
NL	Vlissingen	North Sea-Baltic / North Sea- Mediterranean / Rhine-Alpine
DE	Wilhelmshaven	North Sea-Baltic / Scandinavian-Mediterranean
BE	Zeebrugge	North Sea-Mediterranean / Rhine-Alpine

Source : European Commission, 2014a)