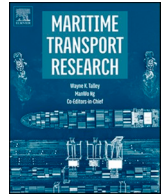




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# Modal shift ambitions of large North European ports: A contract-theory perspective on the role of port managing bodies

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## ABSTRACT

Port managing bodies (PMBs) need to respond to increased societal pressures for improving environmental performance. For many PMBs, a modal shift (MS) from road to rail and barge transport (where available) represents a strategic priority. Yet, in practice, few PMBs have set clear MS targets or have been able to achieve their MS objectives at the level of the port cluster. In this context, the extant port management literature has not yet provided actionable and generally applicable conceptual guidance for PMBs towards achieving ambitious MS goals. In this paper, we develop such guidance by following a contract theory approach to the effectiveness of MS strategies implemented by PMBs. We argue that a PMB, in its role of port cluster manager, can facilitate a MS through strategically deploying governance mechanisms based on sound economic theory. Here, an arsenal of incentives and penalties can be used to push port users (PUs) towards achieving MS targets. Building upon insight from contract theory, we also assess the importance of information management as a prerequisite for a successful MS strategy. We formulate strategic directions for PMBs and identify a future research agenda that should allow improved understanding of how MS goals can be achieved in real world settings.

## 1. Introduction

The evolution towards sustainable development has been on the agenda of the port industry for some time, given increased societal pressures to operate sustainably; it has become a precondition for earning and retaining a social license to operate (Lam and Notteboom, 2014a; Kotowska and Kubowicz, 2019; Alamouh et al., 2020). Port managing bodies (PMBs) have embraced the green port concept to reduce negative environmental impacts not only at port cluster level and in maritime shipping, but also in relation to the hinterland (Hanaoka and Regmi, 2011; Alamouh et al., 2020). Most ports still rely heavily on road transport for serving the hinterland (Kotowska and Kubowicz, 2019), although this mode often has significant negative environmental impacts (ECMT, 2006). Heavy-duty vehicles contribute about a quarter of the total CO<sub>2</sub>-emissions from road transport in the European Union (EU) (European Commission, 2018) and close to 6% of total EU-emissions (Kotowska, 2016).

Port communities and actors throughout the supply chains are challenged to achieve a greener modal split in hinterland transport,

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which assumes a more prominent role for rail transport and also inland navigation in case the port has access to a system of rivers and canals. In addition to efforts to mitigate traffic congestion and reduce harmful atmospheric emissions, the modal shift (MS) from trucks to barge and rail transport has become a commonly adopted objective pursued by PMBs (Gonzalez-Aregall et al., 2018). A PMB can implement a variety of measures to influence modal choices of freight forwarders, shippers or shipping lines in inland transport, but also to facilitate MS initiatives of terminal operators and hinterland transport operators. The concepts of synchronomodality and co-modality have been strongly promoted in scientific and policy circles in the context of green hinterland transport (van Riessen et al., 2015). The MS concept remains highly relevant at present, from a seaport perspective. Indeed, the transition towards more environment-friendly transport modes often implies changes in the relative shares of trucks, trains and barges in incoming and outgoing hinterland flows of a terminal and even an entire port. Furthermore, in pursuit of the greening of hinterland transport, government agencies might establish and subsequently enforce specific performance targets in terms of MS (in addition to imposing that synchronomodality or co-modality be available as a precondition for new investments).

This paper focuses on the MS goals of seaports and the effectiveness of MS strategies. In particular, we analyze MS measures and governance mechanisms through a contract theory lens, with a particular focus on the role of PMBs in three large container ports in North-Western Europe. In spite of mounting scholarly literature on environmental performance and sustainability, scant attention has been given to conceptualizing measures at the level of PMBs that could enhance green hinterland transport (Gonzalez-Aregall et al., 2018), though the advantages of combined transport have been demonstrated extensively (International Union of Railways, 2020). The extant academic literature remains fragmented and focused on either descriptive case studies of MS measures implemented in specific ports, or on mathematical estimations of MS generation (e.g. cost and modal choice models). The individual case studies often ignore that the effectiveness of MS measures can be time and place dependent. The purpose of this paper is to provide a contract theory perspective that can provide a more actionable and generalizable conceptualization to support MS strategy formulation and in turn, to achieve MS goals in a seaport context. Contract theory provides a framework for aligning objectives of contracting parties, reducing uncertainty and stimulating cooperation and performance towards shared objectives. Furthermore, we offer new insights related to: (i) the management of complexity inherent in implementing MS measures, as identified by Gonzalez-Aregall et al. (2018); (ii) the interaction between individual MS measures and broader governance systems, as identified by Alamouh et al. (2020), and (iii) information management being a prerequisite for achieving MS goals, as highlighted by Veenstra et al. (2012) and Alamouh et al. (2020). Using a contract theory lens, our research proposes a comprehensive framework that port cluster stakeholders can use to assess *ex ante* which MS instruments should be implemented. This approach should also allow the PMB to formulate a case-specific, actionable, effective and integrated MS strategy.

The paper is structured as follows. In the literature review, we provide a comprehensive overview of MS measures with a focus on their MS related challenges. The section closes with a brief review of contract theory, the related importance of (strategic) information management, and how it relates to MS-measures implementation and can help to overcome MS challenges. In Section 3, we describe the methodology, and construct a framework to assess MS measures through a contract theory lens. Section 4 presents the current state-of-affairs on MS in the three largest container seaports in North-Western Europe. In Section 5, we discuss the research findings, and link these results with the literature review. We present policy implications and an agenda for future research. Section 6 summarizes the paper's conclusions.

## 2. Literature review on modal shift in seaports

### 2.1. Modal shift measures

Sustainability issues in ports and the transport sector more generally, have been much studied during the past two decades (Pettit, 2008; Gibbs et al., 2014; Puig et al., 2014; Acciaro et al., 2014; Kotowska, 2016). The MS-approach, limited in the present paper to the shift of moving cargo from road to rail and inland waterway (IWW) transport (Meers and Macharis, 2015), is widely considered to be a promising way of reducing CO<sub>2</sub>-emissions and adding to the economic, environmental, social and modal advantages of combined transport (Meers et al., 2017; Tao et al., 2017; International Union of Railways, 2020).

Port users (PUs) include, inter alia, shippers, shipping lines, terminal operators, forwarders and freight handlers. Many of these economic actors presently try to reduce land transport emissions and improve environmental performance (Du et al., 2019; Alamouh et al., 2020). They are viewed as co-responsible for externalities created in the hinterland (Gonzalez-Aregall et al., 2018). PMBs that focus on seaside measures in their green strategies do not necessarily pay equal attention to hinterland-related measures. For example, only 12 PMBs of the 55 member ports of the World Ports Climate Initiative (WPCI) have implemented explicit hinterland related measures, and only 76 out of 365 ports included in Gonzalez-Aregall et al., 2018 paper, have adopted green hinterland measures. Alamouh et al. (2020) identified a variety of port technical and operational measures that can decrease greenhouse gas (GHG) emissions in ports, based on a systematic review of 214 studies. Among the 7 main categories and 19 subcategories identified, MS appears as a subcategory within the main category "land transport measures".

MS strategies can target: (i) a restructuring of the hinterland transport chains through investments in rail and IWW transport, and associated inland cargo handling platforms as substitutes for road transport (Frémont and France, 2010; Monios, 2016; Tao et al., 2017; Kotowska and Kubowicz, 2019); (ii) cargo handling and intra-port transfer operations, to reduce the emissions caused by vehicles, terminal facilities and other equipment used within the port (Kotowska, 2016; Kotowska and Kubowicz, 2019); and (iii) externalities caused directly by road transport (Kotowska and Kubowicz, 2019).

Kotowska and Kubowicz (2019) identified four types of measures (i.e. regulatory, financial, technical and innovative ones) that the 11 largest PMBs in OECD member states have adopted to alleviate road transport externalities. Measures taken at the organizational

level are the most frequently used, but financial measures are also effective. For example, in US ports, financial incentives that encourage replacement of the vehicle fleet (such as the Clean Truck Program in LA/Long Beach) are widely used and have had positive outcomes. Larger ports, i.e., those with more slack-resources, are able to invest in more innovative measures. For example, Rotterdam has adopted “truck platooning”, whereby fuel consumption is reduced through distance minimization between trucks on highways (Kotowska and Kubowicz, 2019). Dedicated infrastructure is the leading measure taken to promote a MS, whereas the implementation of modal split mandates in concession contracts; targeted data gathering and processing related to the modal split; and the use of certification programs, have remained less common. The use of MS mandates in concession contracts has typically been viewed as difficult to implement, as compared to environmental regulations that are mostly based on incentivizing PUs to improve their modal split. The latter are “easier to implement and not stringent enough to antagonize customers” (Gonzalez-Aregall et al., 2018).

During the past two decades, the European Commission (EC) has developed strategies to reduce road congestion and pollution, and it has expressed a preference for greener modes (European Commission, 2001). In order to stimulate the use of IWW and rail, much effort has been directed to hinterland infrastructure development in the context of the Trans-European Transport Network (TEN-T), despite some reports on the high transport emissions of IWW (Caris et al., 2014; Rogerson et al., 2020). A mental shift will be required for port stakeholders to change existing transport practices to IWW and rail (Meers et al., 2017; Rogerson et al., 2020). A PMB can invest in intermodal rail and barge facilities<sup>1</sup>. However, continuous investment is necessary to maintain environmental superiority over other transport modes (You et al., 2010; Hanaoka and Regmi, 2011). Operational aspects (e.g. break-of-gauge in rail, draft limitations in IWW) are also important when considering transnational intermodal network operations. Integrated networks, linking different transport modes effectively via dry ports, are vital to encourage hinterland rail and barge transport (Hanaoka and Regmi, 2011; Veenstra et al., 2012).

The above suggests that the academic interest in MS measures has resulted in various typologies and approaches. We contribute to this ongoing dialogue by providing a structured overview in Table 1 of MS measures available to PMBs and public agencies, including references to scholarly work that addresses specific measures. The measures presented build on the categorizations proposed by Lam and Notteboom (2014a) and Gonzalez-Aregall et al. (2018). This overview includes a multitude of positive and negative incentive-based MS measures available to PMBs.

## 2.2. MS goals and challenges in seaports

PMBs now typically aim for a higher share of rail and IWW (if feasible) in hinterland transport activities, thereby potentially adopting some of the MS measures presented in the previous section. However, these PMBs, as well as public agencies and/or private port-related companies do not necessarily set clear MS goals. Moreover, in case MS goals have been set, recent data at the EU level show that, with some exceptions, PUs typically struggles to achieve these goals (UIC/ETF, 2019). While Kotowska and Kubowicz (2019) argue that larger ports are more likely to have the means for MS generation and innovation, substantial differences among large ports can be observed in this field, as every port is confronted with unique MS challenges. In the following sections, we discuss three key challenges as identified in the extant literature.

### 2.2.1. The need for sufficient infrastructure capacity

Without dedicated lines and nodal infrastructure for alternative transport modes, any MS goal is impossible to achieve, meaning that infrastructure investment is one of the most critical MS tools available (Gonzalez-Aregall et al., 2018). Investments to develop and expand dry ports and extended gates are considered as potential tools for MS (Hanaoka and Regmi, 2011; Veenstra et al., 2012; Regmi and Hanaoka, 2013; Alamouh et al., 2020; Witte et al., 2019). However, in spite of hinterland terminal development, some of the environmental issues will merely be transferred from the seaport to the inland terminal (e.g. congestion), thereby often leading public agencies in the hinterland to introduce measures aimed at minimizing these externalities (Veenstra et al., 2012). Individual MS-enhancing measures should therefore be introduced as ingredients of a more comprehensive governance approach, which should consider not only the PMB and the actors within the port (the conventional PUs), but also those users active in the vicinity and in the hinterland.

### 2.2.2. Attention to broad port user management and coordinated regulatory initiatives

There are many societal pressures on PMBs and PUs exerted by actors operating on a broad spectrum of geographic scales, from a local to a global scale (e.g. Frémont and Franc, 2010; and Kotowska and Kubowicz, 2019). These include a range of stakeholders, especially public agencies and community groups.

In their operations, PUs can consider performance criteria such as price, lead-time performance, loss and damage, flexibility, infrastructure availability and capacity, regulation and legislation, reliability, controllability and traceability and environmental considerations (Blauwens et al., 2006; Hanaoka and Regmi, 2011; Veenstra et al., 2012; Regmi and Hanaoka, 2013; Rogerson et al., 2020). A substantial number of these PUs might disagree on any superiority of multimodal transport, based on their experience of low transport speed, low frequency of service, lack of high-quality service offerings, and more generally weak reliability (Meers et al., 2017).

Sustainable solutions for transport are usually supported by public agencies, which channel the more general societal pressures to

<sup>1</sup> Depending on the proximity to the port terminal, rail yards are considered on-dock, near-dock or off-dock.

**Table 1**

A typology of tools and MS measures per functional activity available to PMBs and/or public agencies.

PMB/PA Tools	MS Measures per port functional activity	Scientific References	Seaport cases as mentioned in literature
Pricing	Positive, bonus/malus or penalties: tariff structure, rebates on port dues, fines for non-compliance with agreements on MS, taxation or subsidization infrastructure use	Bergqvist and Egels Zandén, 2012; Veenstra et al., 2012; Van Der Horst and De Langen, 2008; Regmi and Hanaoka, 2013; Lam and Notteboom, 2014a; Kotowska, 2016; Tao et al., 2017; Kotowska and Kubowicz, 2019; Alamouch et al., 2020	Rotterdam, Laem Chabang, Antwerp, Ningbo, Long Beach, Botany, Oakland (USA), Hamburg
Monitoring and measuring	Monitoring of air quality, energy consumption, waste and transport Monitoring and analysis of policy developments Reporting: sustainability reports, CSR reports, green port guides	Lam and Notteboom, 2014a  Lam and Notteboom, 2014a; Geerts, Dooms and Stas, 2021; Geerts and Dooms, 2020; Notteboom et al., 2020	Antwerp, Rotterdam, Shanghai, Singapore  Antwerp  Antwerp, Rotterdam, Shanghai
Market access control and environmental regulation	Port policy regulations (incl. licenses, admissions and enforcement)  Concession Policy: agreements on MS (soft or hard targets)  Asset management: infrastructure and property (e.g. ensuring working conditions of vehicles) Port area management (e.g. extending terminal operation time) Transport policy from municipal, regional, national or supranational governments, including logistics policy, multimodal transport policy, port policy, investment policy, environmental policy, spatial planning policy, transport and trade facilitation policy and infrastructure policy Environmental licenses (grant and maintain) and legal standards (e.g. norms on emissions of nodes, line infrastructure, and/or vehicles) Spatial planning (planning, regulations)	Kotowska, 2016; Kotowska and Kubowicz, 2019  Veenstra et al., 2012; Lam and Notteboom, 2014a; Van den Berg and De Langen, 2014; Gonzalez-Aregall et al., 2018; Notteboom and Lam, 2018  Kotowska, 2016; Gonzalez-Aregall et al., 2018; Kotowska and Kubowicz, 2019; Alamouch et al., 2020 Blauwens et al., 2006, Kotowska and Kubowicz, 2019 Dooms and Macharis, 2003; Blauwens et al., 2006; Hanaoka and Regmi, 2011; Bergqvist and Egels-Zandén, 2012; Kotowska, 2016; Tao et al., 2017; Gonzalez-Aregall et al., 2018  Blauwens et al., 2006; You et al., 2010; Acciaro et al., 2014; Alamouch et al., 2020  Hanaoka and Regmi, 2011; Veenstra et al., 2012	Antwerp, Botany, Gdansk, Hamburg, Felixstowe, Southampton, Rotterdam, NY/NJ, Barcelona, Los Angeles/Long Beach, San Diego  Rotterdam, Antwerp, Hamburg  Rotterdam, Gothenburg  Antwerp  EU ports, Busan, Gwangyang, Incheon, Kolkata/Haldia, Laem Chabang, Mumbai, Jawaharlal Nehru, Ningbo  EU ports, Los Angeles, Long Beach, Seattle  Busan, Gwangyang, Incheon, Kolkata/Haldia, Laem Chabang, Mumbai, Jawaharlal Nehru, Rotterdam
Supporting investments	Equipment and basic infrastructure investments (rail, IWW, car parks, etc.)  Superstructure investments (e.g. crane investments for handling cargo via rail)  Inland/dry port development  Hinterland network integration (financial/operational integration) Consulting, sensitizing and provision of information and development of IT platforms that allow to do so  Stimulation of MS research and applications (e.g. funding MS research projects, drafting guidelines, etc.)	Park et al., 2007; Frémont and France, 2010; You et al., 2010; Hanaoka and Regmi, 2011; Kotowska, 2016; Tao et al., 2017; Gonzalez-Aregall et al., 2018; Kotowska and Kubowicz, 2019; Rogerson et al., 2020. Frémont and France, 2010; Kotowska, 2016; Tao et al., 2017; Kotowska and Kubowicz, 2019 Hanaoka and Regmi, 2011; Caris et al., 2014; Regmi and Hanaoka, 2015; Du et al., 2019; Wiegmans et al., 2020; Yang et al., 2021 Veenstra et al. 2012; Kotowska, 2016; Alamouch et al., 2020 Hanaoka and Regmi, 2011; Lam and Notteboom, 2014a; Regmi and Hanaoka, 2015; Kotowska, 2016; Zhang and Pel, 2016; Meers et al., 2017; Kotowska and Kubowicz, 2019; Gonzalez-Aregall et al., 2018; Alamouch et al., 2020; Rogerson et al., 2020 Blauwens et al., 2006; Veenstra et al., 2012; Acciaro et al., 2014; Rogerson et al., 2020	Los Angeles, Long Beach, Busan, Gwangyang, Incheon, Kolkata/Haldia, Laem Chabang, Mumbai, Jawaharlal Nehru, Rotterdam, Antwerp Ningbo, Valparaiso, Gothenburg  Antwerp, Rotterdam, Le Havre, Bremerhaven, Hamburg, Valparaiso, Ningbo  Busan, Gwangyang, Incheon, Kolkata/Haldia, Laem Chabang, Tianjin, Mumbai, Jawaharlal Nehru., Rotterdam/Antwerp, Shanghai (Yangtze Basin) Rotterdam, Barcelona; Le Havre; Hamburg  Antwerp, Ghent, Zeebrugge, Rotterdam, Hamburg, Shanghai, Singapore, Mumbai, Jawaharlal Nehru, Laem Chabang Auckland, Gothenburg  Rotterdam, Rijeka, Gothenburg

Source: Authors, based on literature review.

reduce negative environmental impacts (European Commission, 2001; Dooms et al., 2013; Tao et al., 2017). Policy makers at various levels have been aware of the increasingly urgent problems related to road transport (European Commission, 2001a; Blauwens et al., 2006; Hanaoka and Regmi, 2011). In the EU, initiatives such as Marco-Polo, the Trans-European Transport Network (TEN-T) and Motorways of the Sea (MoS), have supported MS and the need to improve the efficiency of intermodal logistics operations (Veenstra et al., 2012; Acciaro et al., 2014; Rogerson et al., 2020). The EU White Paper on transport determined MS targets that would entail a shift of 30% from road transport exceeding distances of 300 km, towards either rail or IWW transport by 2030, and a shift of at least 50% by 2050 (European Commission, 2011, Meers et al., 2017). Governments can resort to direct subsidies for MS generation. The effects of subsidies are, however, usually only short term and therefore insignificant in the long term (see also Section 2.2.2). Effective longer-term strategies require policy packages that include financial, technological, operational and managerial measures (Regmi and Hanaoka, 2013; Tao et al., 2017). The potential impact of policy measures in the realm of: (1) increasing road transport costs through taxation; (2) decreasing costs related to intermodal transport in terms of lead-times; and (3) deregulating rail transport, were studied by Blauwens et al. (2006). These three types of measures can all have MS effects in their own right, but synergies arise when policy initiatives are combined (see also You et al., 2010). However, policies may vary to a great extent depending upon the level of government involved, and coordination among various levels – federal, regional, municipal, etc. – is therefore essential (Hanaoka and Regmi, 2011).

Community groups, which represent another channel to voice societal concerns, consist of media, NGOs as well as trade associations (ECMT, 2006; Frémont and France, 2010; Gonzalez-Aregall et al., 2018). Pressures from community groups do not only occur in the vicinity of seaport activities, but can also arise in the realm of hinterland development or integration with inland ports. Even though the latter typically have a smaller economic scale than seaports, their environmental impacts on the surrounding region are often perceived as particularly high. As a result, the development of inland ports in urban regions has often been strongly contested (Dooms et al., 2013).

### 2.2.3. Technology and information management

If a PMB wishes to influence the (environmental) performance of maritime-transport related hinterland chains, every node within such chains must be willing to measure – and report on – its (environmental) performance. However, lack of information-sharing between stakeholders has been a challenge for intermodal transport, in addition to equipment mismatches (and more broadly, imperfect interconnectivity and interoperability), unsatisfactory options to consolidate goods and lack of flexibility and reliability (Hanaoka and Regmi, 2011; Regmi and Hanaoka, 2013; Meers et al., 2017; Monios and Bergqvist, 2017; Gonzalez-Aregall et al., 2018; Rogerson et al., 2020). On the positive side, the need to correctly inform transport mode-choice decision makers on the availability of intermodal services has been encouraged (Meers et al., 2017; Rogerson et al., 2020). Improvements in information sharing, leading to lower costs of intermodal options, have been heralded as a vital MS measure (Zhang and Pel, 2016; Gonzalez-Aregall et al., 2018).

## 2.3. Contract theory and MS measures and schemes

After establishing MS goals, a number of PMBs have introduced individual measures and more overarching governance approaches to influence the behavior of PUs, in the hope this would help achieve their MS targets. Specific MS targets are difficult to include in contracts with PUs, given the complexity in terms of infrastructure requirements, PU management and coordination with regulatory initiatives, and the information level required to impose reasonable (and feasible) demands on PUs (Gonzalez-Aregall et al., 2018) as well as the competition-related ‘sensitivity’ of the issue (ECMT, 2006; Rogerson et al., 2020). In technical terms, transaction costs (TCs), which can be simply defined as contractual friction, may be particularly high in contract negotiations between PMBs and PUs on MS targets because of bounded rationality and bounded reliability challenges. In order to align the objectives of contracting parties in the context of MS, agreements or contracts must provide for adequate governance.

Contract theory, based on both modern Transaction Cost Economics (TCE) and broader analysis of ‘incomplete contracting’, offers a framework that allows selecting an optimal governance approach, i.e. one minimizing TCs as compared to feasible real world alternatives. Such approach should include measures that affect the involved parties’ behavior towards common goal achievement. Here, the relevant parties’ objectives are aligned, order is infused, conflict mitigated, and mutual gains realized (Commons, 1932; Nordberg and Verbeke, 1999). As noted by Schmidt (2017, p. 489): “Contract theory analyzes the optimal design of incentive schemes (“contracts”) that induce the involved parties to behave more efficiently”, see also Hart (1995), Hart and Holmström (1987), and Hart and Moore (2008). Applying theoretical lenses in transport and logistics research is common practice (Stock, 1997). TCE and broader contract theory have been previously applied in port economics research, e.g. by Zhang (1996), Van der Horst and de Langen (2008), Haezendonck et al. (2014), and Van der Horst et al. (2019).

The seminal work of Williamson (1996) identifies the following four assumptions underlying contract theory:

- **Bounded rationality.** Economic actors aim – via the governance design of contracts – to reduce challenges resulting from uncertainty about the future. These problems stem from imperfect information and limited information processing capacity within their organisations.
- **Bounded reliability.** Economic actors also aim – again via the governance design of contracts – to reduce challenges in the realm of unreliability. These problems stem from self-interest as well as from changes in preferences over time, and from identity-related disagreements. The governance design of necessarily incomplete contracts thereby attaches substantial importance to *ex post* governance.

- *Asset specificity.* Irreversible investments and investments with weak alternative deployment potential, foreseen to be made by one party in a contract, will always lead to the requirement imposed on the other party, of incorporating some type of safeguards and credible commitments. Such ‘hostages’ are required to protect the highly asset-specific investments.
- *Economic feasibility.* When a party in the negotiation process wields some form of regulatory power in the broadest sense, then such power must be exercised with critical attention to the economic consequences for the other party, and thus also to the economic feasibility of the proposed contract, vis-à-vis the situation without exercise of regulatory power. If the contract terms proposed by the party with regulatory power are unacceptable to the supposedly weaker party, the latter might just ‘walk away’, especially if regulatory power can only be exercised within a narrow industry setting or limited geographic space and alternative contracting options are available to the weaker party outside of this industry setting or geographic space. “Resource dependency therefore does not come as a “surprise” to unwitting victims” (Williamson, 1996, p. 45), even if this resource reflects regulatory power.

Modern contract theory, building upon these four assumptions, suggests that two parties –with one of them potentially having regulatory powers– can reach agreements that include regulatory constraints on the other party, but subject to the condition that these contracts create value for both parties involved, i.e. provide a governance framework that allows the “mutuality of advantage” to materialize (Buchanan, 2001).

### 3. Research methodology

#### 3.1. Research steps and components

In the remainder of the paper, we apply the major assumptions of contract theory to the PMB-PU relationship in the context of MS policy implementation. We argue that contract theory provides an actionable and generalizable conceptualization to support effective MS strategy formulation and implementation by providing a framework for aligning objectives of contracting parties, reducing uncertainty and stimulating cooperation and performance towards shared objectives. The research methodology consists of three components and we used triangulation of various data sources to increase the reliability of our results.

First, we performed a literature review on MS implementation, using the contract theory lens to observe a range of MS measures and to assess TCE challenges in their implementation.

Second, desk research was performed to analyze the current policies and MS achievements in the three largest container seaports in North-Western Europe (i.e. Rotterdam, Antwerp and Hamburg), in order to understand MS strategies in real-world settings. Here, we adopted the case study method, because case studies are an adequate methodology for investigating the ‘why?’ in contemporary phenomena (Yin, 2009). We limited our scope to these three large European seaports and their hinterland container traffic, given that large PMBs: (1) typically have better data available to researchers, and (2) are more likely to command adequate resources for both MS generation and innovation in governance, which in turn allow efficient monitoring (Kotowska and Kubowicz, 2019). In the financial year 2019, the turnover of the three PMBs amounted to 706.6 million euro for Rotterdam, 400.3 million euro for Antwerp and 225.8 million euro for Hamburg. The ports’ primary revenue streams are associated with land/concession fees and port dues (including marine charges and cargo dues).

Third, during the months of February and March 2020, we held four preparatory semi-structured discussions of about 2 hours each with 4 senior members of a large European PMB (each of them domain experts on hinterland transport and port area development). At least three members of the research team were present during the various preparatory meetings, in order to take detailed notes and to ensure access to a full spectrum of academic knowledge on port functioning at the meetings. The meetings were not formally recorded in order to allow for uninhibited expression of opinions and viewpoints. The following aspects were discussed: (i) the general contract-theory based framework to assess MS measures based on contract theory insights; (ii) the broader governance options within which MS measures could be embedded and the implications thereof for the relationship between PMBs and PUs; and (iii) perspectives on the prioritization of specific MS measures. This was followed by a larger online<sup>2</sup> focus group session of 2.5 hours, which included 11 senior port managers with expertise on PU behavior, concession agreements, and the operational and economic aspects of hinterland transport modes. This session was organized in April 2020 and four members of the research team were present; this session was recorded and revisited by multiple members of the research team. The aim of the focus group was to achieve further validation of our conceptual framework and to gather practical information on how to achieve the PMB’s MS targets.

#### 3.2. A contract theory approach to MS measures and broader MS governance

Initiating change towards achieving MS goals, in a manner that infuses order, avoids conflict and allows win-win scenarios to unfold for both the PMB and the PU, can be achieved in accordance with contract theory principles. Our intention is to construct a generalizable governance framework for MS-related contracting for the PMB, whereby the following questions can be answered:

- 1 Which types of MS measures can be made attractive to both the PMB and the PUs, and included in their contracts, according to contract theory?

<sup>2</sup> Due to COVID-19 restrictions the focus group was organized online instead of face-to-face.

**Table 2**  
Questions for the PMB.

<b>PMB1</b>	<b>(Enforceability)</b> What is the <i>enforceability</i> in terms of achieving a higher usage of environment- friendly transport modes? This is a classic problem in environmental economics, whereby for example tolls (a price imposed on the polluter) can lead to a direct increase of income for the regulator, but where the envisioned MS impact remains insignificant.
<b>PMB2</b>	<b>(Administrative costs)</b> Each new governance system will, in order to meet MS goals, go hand in hand with <i>administrative costs</i> for the PMB that can vary in size. Cheaper systems are usually the ones that can be routinised, function quasi-automatically if properly designed, and do not require constant discretionary intervention by the PMB. More expensive systems can have the advantage that more precise targeting is made possible. One high-cost case would entail every substantial volume of goods, e.g., container flows that could reasonably be shifted to more environment-friendly modes, becoming subject to a dialogue with individual PUs. On an aggregate level, the port's overall modal split goals could thereby be achieved.
<b>PMB3</b>	<b>(Implementation difficulties)</b> What are, in addition to the administrative costs, <i>the expected difficulties associated with implementation</i> ? The PMB will, for instance, be confronted with decisions from large international shipping lines that pursue technically sophisticated supply chain strategies, including choices of transport modes, upon which the PMB has little or no impact. Furthermore, supranational and foreign government policies should be considered, as well as the potential market-disrupting effects of each measure considered.

Source: Authors.

- 2 How should MS measures be included in contractual agreements, so as to represent an attractive governance approach for both parties?
- 3 Which contextual factors can influence the attractiveness of the approach pursued in the realm of real-world settings, thereby affecting subsequent, actual MS achievements?

Building upon the four basic assumptions of Williamson (1996), and related insight from contracting theory, we formulated a general, actionable approach in the form of a 'questions-driven' analysis of potential MS measures. We view satisfactory responses to these questions as instrumental to achieving overall MS success.

We consider the case of two relevant parties negotiating contracts. The first party wields regulatory power, and it therefore has the status of "regulatory party" (in our case, this is the PMB<sup>3</sup>). We refer to the second party with whom a contract must be negotiated, as the "contracting party" (in our case, this is a PU). We define contracts in the broadest sense, including all formal and informal agreements and relations established between a PMB and the variety of PU groups present within a port area. The PMB should evaluate each potential measure based on its potential impact on MS goal achievement, before seriously considering this measure. Only those measures with high potential effectiveness should be selected. There are three questions a PMB should answer to assess the expected effectiveness towards achieving MS goals (Table 2).

Should the direct attractiveness for the PMB, based on the responses to the questions PMB1-PMB3, be considered 'low', then this can be an initial criterion for excluding potential MS measures. Subsequently, the high-potential measures should be assessed as to their feasibility and attractiveness from the vantage point of the relevant contracting party (PUs). PMBs should consider the following questions in terms of how they think PUs will respond to these measures, thereby affecting their feasibility and subsequently orchestrate a structured dialogue with the PUs. A first question's score (PU1: see Table 3) on potential PU exit is used as a second criterion to exclude potential MS measures that would indeed trigger such exits. From a conceptual point of view, a PMB can assess each high-potential MS measure using the following ten questions derived from modern contract theory, and which could be viewed as critical to efficient governance. Table 3 provides a list of questions that allow checking whether basic challenges of 'incomplete contracting', as they might affect PUs, have been (or can be) adequately addressed.

After a structured dialogue with PUs on possible MS measures, the PMB can estimate an *overall attractiveness score* (including both the level of attractiveness and feasibility) for each potential measure. We note that through this general CT-based approach, specific attention must be given by the PMB to the idiosyncrasies of different PU groups, as their motives for MS will differ depending on their characteristics. For example, attractiveness scores for MS measures will likely differ between shipping lines, freight forwarders, trucking companies, etc. and might even differ among companies belonging to the same PU group. However, the value of the framework lies in the general applicability of the CT-based principles across the diversity of PU groups, providing an actionable framework for PMBs. Ideally, a high attractiveness of a proposed MS measure from the PMB's view, based on the answers to the three questions most relevant to them, would be combined with attractive contracting features from the vantage point of the PUs. Such attractiveness would be determined by the answers to the ten questions relevant to their contracting preferences. Dual attractiveness would appear to be a precondition for an effective MS strategy.

Based on the literature review, review of case studies, and interaction with port experts, we also developed three stylized governance approaches to MS, each characterized by specific incentive properties in contracts, see Table 4.

Within each of these three systems, PMBs and PUs must reflect on the answers to the ten questions, to the extent that information and expertise to make *ex ante* assessments of both effectiveness and impact are available. Such assessments can then lead to an attractiveness score for each measure, with the most promising measures selected. State-of-the-art information management can contribute significantly to reaching MS goals, both in the *ex ante* assessment stage, and in the *ex post* implementation, monitoring and evaluation stage.

<sup>3</sup> We note that other regulatory parties such as governments, or hinterland actors such as railway organizations, are also competent authorities for the implementation of MS measures. However, for this research, we focus on the case of large seaports, where the PMB is the relevant organization. We therefore posit that the PMB is not "the" regulatory party for MS generation, but can be the relevant actor to direct the network's behavior (Coeck et al., 2006).

**Table 3**

Key contract-theory-based questions about likely PU-responses for proposed MS measures.

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PU1	<p><b>Exit:</b> Can implementing the proposed MS measure lead to the unintended exit of PUs, whom the PMB would like to retain (current PUs) or to the non-entry of new PUs (in this instance, exit and non-entry may imply entry in another location)?</p> <p>▷ If a substitute contractual agreement could in principle be negotiated by PUs with another PMB, any regulatory clause imposed by the latter that could trigger exit or non-entry of the targeted PUs, should be anticipated and reflected upon by the PMB holding regulatory power.</p>
PU2	<p><b>Competitive disadvantage:</b> Can implementing the proposed MS measure lead to a competitive disadvantage for the PUs subjected to it, vis-à-vis their competitors in other ports?</p> <p>▷ A level-playing-field vis-à-vis (external) competitors must be safeguarded.</p>
PU3	<p><b>Unequal Treatment:</b> Can implementing the proposed MS measure lead to a problem of unequal treatment of the PUs targeted, vis-à-vis other companies operating in the port or in its vicinity?</p> <p>▷ Equal contract treatment or compensation of all PUs must be guaranteed.</p>
PU4	<p><b>(Un)predictability of supply chain impact:</b> Will implementing the proposed MS measure be accompanied by new uncertainties for the PUs targeted, in terms of impacts on costs and on the quality of their activities, and on the supply chain within which they function?</p> <p>▷ Regulations imposed on PUs must minimize uncertainties that could affect the production processes of the targeted PUs and their supply chain partners.</p>
PU5	<p><b>Asset Specificity:</b> Can implementing the proposed MS measure produce negative effects on the present and future levels of irreversible or difficult to redeploy, transaction-specific investments made by the PUs (or the productivity thereof), for instance difficult-to-redeploy superstructure and logistics systems that are fully integrated with the local port infrastructure?</p> <p>▷ The targeted PUs, as contracting partners, will require contractual commitments from the PMB to lower uncertainty if they are contractually bound to make more highly asset-specific investments, for example investments associated with site specificity, physical asset specificity, human asset specificity, dedicated assets and time specificity.</p>
PU6	<p><b>Legal Stability and Certainty:</b> Can implementing the proposed MS measure generate problems related to the absence of legal stability and certainty, whereby the PMB as one contracting party could over time, unilaterally impose more stringent regulations (or additional regulations) on the PUs?</p> <p>▷ Legal stability and certainty should be offered to PUs as contracting parties, so as to avoid “obsolescent bargain” challenges.</p>
PU7	<p><b>Absence of Reciprocity:</b> Can implementing the proposed MS measure lead to perceived problems of absence of reciprocity, i.e., a lack of credible commitments by the PMB to compensate for the irreversible investments demanded from – and committed to – the PUs as contracting partners?</p> <p>▷ Reciprocity in credible commitments is needed when irreversible investments are involved, for efficient contracting to materialize. Such reciprocity includes commitments by the PMB wielding regulatory power.</p>
PU8	<p><b>Ex Post Governance:</b> Can implementing the proposed MS measure lead to problems related to insufficient transparency, as well as ambiguous and suspect measurements and evaluations of performance achieved, thereby potentially resulting in gaming behavior?</p> <p>▷ Ex post governance must include mutually accepted and transparent avenues to measure and assess the performance of each contracting party, thereby preventing one party from engaging in opportunistic or otherwise unreliable behavior, inconsistent with the spirit of the contractual agreement.</p>
PU9	<p><b>Mutual Dependence:</b> If implementing a proposed MS measure is likely to increase bilateral dependency between the PMB and the affected PUs over time (the Williamsonian ‘fundamental transformation’), have ex post governance mechanisms (such as bilateral dialogue) then been foreseen to address evolving challenges, e.g., in the realm of unpredictable exogenous events that could affect contract execution?</p> <p>▷ Realized impacts of any MS measure depend both on the efforts made by each party and on the evolution of exogenous variables. Performance thresholds to be achieved over time must be established in the contract ex ante, but ex post governance mechanisms must also be foreseen for the parties to address failures to meet these thresholds or success in having met them (‘what’s next?’)</p>
PU10	<p><b>Unintended or unexpected negative externalities:</b> Could implementing the proposed MS measure potentially lead to material, unintended and unexpected negative impacts on the contracting parties, and to negative externalities beyond the contracting parties?</p> <p>▷ The contracting parties should establish a monitoring function to identify unintended negative effects quickly; to map their evolution; and where relevant, to engage in a dialogue with other actors who might be negatively affected.</p>

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Source: Authors.



**Table 4**  
Stylized types of governance mechanisms for influencing behavior towards achieving MS goals (MS governance approaches).

Governance Approach	Incentive (Positive)	Bonus/Malus	Penalty (Negative)
Basic principles	Unilateral commitments for good performance offered by the PMB, but there is no reason why PUs would be excluded from system design, aligned with contract theory.	Mixed system with obligations imposed on the PUs, but simultaneously credible commitments from the PMB, whereby desired performance is rewarded.	Unilateral obligations imposed on PUs to steer them towards the MS goal, but even here, PUs may be included in system design, especially when there is strong divergence in PU performance because of 'initial conditions'.
In practice	Annual fixed or variable budget (fund) to reward good performers, tied to the MS goals. One potential route is that only when the port cluster as a whole achieves its MS objectives, rewards are given. Generally, this system is based on 'voluntary' participation.	Awarding a bonus to good performers and giving a malus to poor performers in terms of an agreed upon objective. Overall net costs can be zero, and the system might even be financially beneficial to the PMB, depending upon the specific implementation details.	Assigning penalties and/or increasing prices (port dues or concession rights) if the MS objectives are not met. Can be financially beneficial for the PMB, whereby the 'penalties fund' may be reinvested in additional MS measures benefiting the port community as a whole.

Source: Authors.

### 3.3. Assessing the role of information management in MS strategy

Building upon the extant scholarly literature, case studies and our focus group discussion, we identified two critical dimensions of the PMB's information management as it relates to MS measures. The horizontal dimension is intra-port focused and can be either fragmented or integrated. The vertical dimension addresses the supply chain stretching beyond the port's boundaries, and the extent of the PMB's information management across this value chain can be low or high. Fig. 1 shows that improved information management towards MS can be accomplished via these two dimensions (horizontal and vertical) and offers managerial recommendations for strategic information management.

Source: Authors

If a PMB is currently positioned in the Scenario 1a quadrant, then the recommended strategic path for this PMB with MS goals, would be to invest in broader intra-port focused instruments (moving alongside the horizontal axis to scenario 2a). Subsequently, extra-port focused instruments that improve logistics chain coordination can be made. This can occur through renegotiating contracts, e.g. taking equity shares in intermodal terminals in the hinterland, and by investing in IT platforms that allow efficient and intensive information sharing (moving on the vertical axis towards scenario 2b).

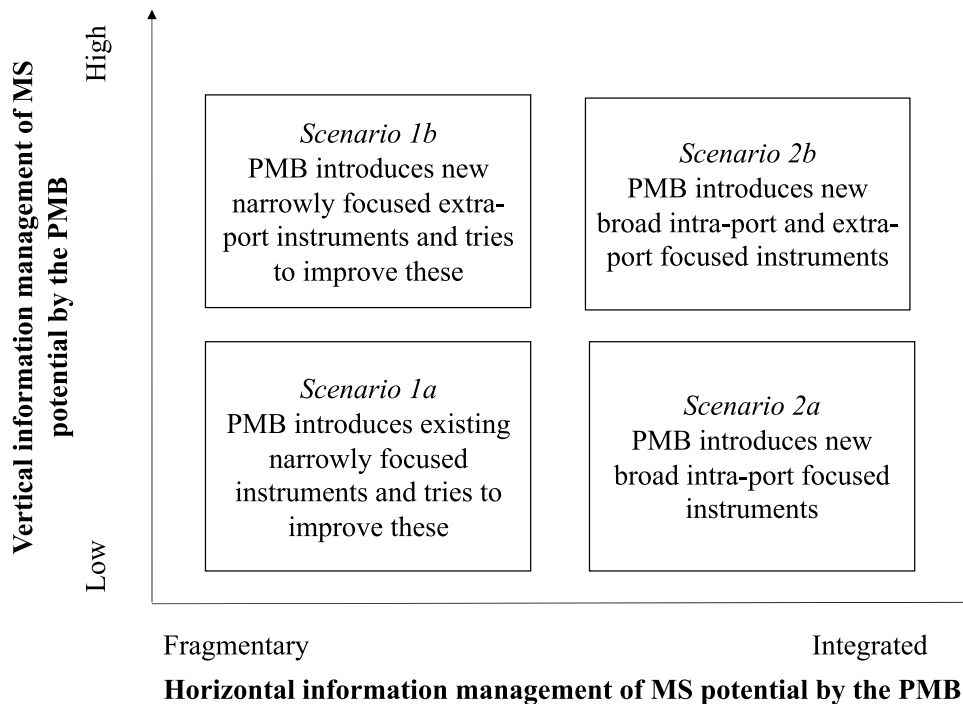


Fig. 1. Basic scenarios for MS strategy: Information Management Matrix for PMBs.

In contrast, if a PMB moves vertically from scenario 1a to 1b, the sole usage of fragmented, narrowly focused tools will likely hamper MS goal achievement. Merely attempting to move on the vertical axis to the upper left quadrant might result in vertically improved information management but fragmentation would still obstruct potential information exchange from the PMB throughout the supply chain. Reaching 1b could then trigger: (i) new intra-port focused tools and the harmonizing thereof with other instruments throughout the supply chain, for which network strengthening may be required; or (ii) divesting and moving back to scenario 1a. Another possibility is that because of contextual elements, a PMB could move to scenario 2a or 2b, e.g., if research projects funded by governments permit PMBs to obtain high quality information on the supply chain. A PMB should therefore impose on current and future PUs to provide detailed information concerning modal split, for example by redeveloping all contracts' general conditions. Such obligation could also be inserted solely in new contracts, but this could lead to the unequal treatment of current and future PUs. This further reinforces the need to answer the 10 questions in our contract theory framework, wherever a PMB is placed on the incentive-penalty spectrum, thereby enriching the discussion on potential effectiveness and impacts.

#### 4. Empirical findings

The above conceptualization presented a contract theory approach to effective MS strategy. To illustrate how such a conceptualization can be used in practice, this study focuses on the three largest container ports of Europe in volume terms, i.e. the Port of Rotterdam (PoR), the Port of Antwerp (PoA) and the Port of Hamburg (PoH). First, we look into the historic evolution in terms of modal split objectives and current strategic initiatives in these three ports. These cases provide input for uncovering which MS strategies can help to achieve MS ambitions, including the strategic information management needed to assess *ex ante* both the attractiveness and impact of these strategies and to implement the actual chosen strategies.

##### 4.1. Current MS challenges and strategic responses of the three leading European ports

###### 4.1.1. Rotterdam

While the 2030 MS targets of PoR are ambitious, the modal shares in the port of Rotterdam in 2017 show only minor changes when compared to 2005, i.e. a modest increase of the rail share at the expense of road transport. The two moderate growth scenarios (i.e., 'conservative carbon' and 'green unlimited') in the November 2019 revision of 'Port Vision 2030' of the Rotterdam Port Authority point to a growth of 25 to 40% in hinterland container volumes by 2030. To achieve the minimum MS targets, this would require a growth of 140% to 169% in rail volumes and 68% to 89% in barge volumes by 2030 compared to 2017. In the most optimistic volume scenario (i.e. 'fossil forward'), hinterland container volumes are expected to nearly double by 2030, thereby significantly raising the volume requirements for barge and rail.

The PoR focuses on cost reduction within the port area through both infrastructure and non-infrastructure solutions, which aim to improve the efficient exchange and bundling of containers and support intra-port information exchange. Examples of such initiatives are the Container Exchange Route, autonomous transport solutions, reducing bottlenecks within the port, the acquisition of Port Shuttle (an intra-port rail operator), and the OnTrack application (which offers transparency on rail transport within the port area). The PoR's commercial hinterland development as regards rail transport (down the logistics chain), focuses mainly on South-Germany and Central- and East-Europe. The Rail Incubator program supports the start of new rail transport services initiatives financially under certain conditions, in addition to giving soft incentives. Furthermore, LinkedByRail is a covenant between market actors, consultants and government, which aims to establish railway connections between the Netherlands and Poland. The commercial hinterland development with regards to IWW transport focuses nowadays more on the acquisition of controlling interests in nearby located inland container terminals (also called transferia) such as Alphen aan den Rijn, Alblasterdam and Wanssum, instead of an international acquisition path. The inland terminal strategy can be considered as a *de facto* extension of the port area in selected satellite locations in the nearby hinterland. The PoR also participates in the information platform inlandlinks.eu, a collaborative initiative of PoR and the Dutch union of inland container terminals (VITO). The port's ambition is to extend information sharing via IT platforms beyond the port area (Port of Rotterdam, 2020), indicating again a potential future strategic shift beyond the port area's boundaries. However, it seems that goals with regard to potential shifts to hinterland integration are rather limited and scattered, considering the vast hinterland of the port. In its attempts to strengthen vertical information management throughout supply chains, the port is challenged to continuously improve horizontal intra-port information management if it wants to its ambitions to end up in an unsustainable scenario where fragmented information remains scattered (versus integrated) throughout the PU landscape. The PoR agreed with its operators that on Maasvlakte 2, intermodal transport must capture at least 65% of total container transport flows to the hinterland. Rotterdam is the only documented example in Western Europe where modal split targets have been formally integrated in legally binding clauses of terminal concession contracts.

**Table 5**

MS evolution of the Port of Rotterdam (2005–2017), including MS target for 2035.

Modal Split (in%)	2005	2010	2015	2017	Target 2035
Road	60.1	56.4	53.3	58	Max. 35
Rail	9.4	10.6	10.5	12	Min. 20
IWW	30.5	33	36.2	30	Min. 45

Source: Authors, based on annual reports and sustainability reports.

**Table 6**

MS of the Port of Antwerp (2005–2018), including MS target for 2030.

Modal Split (in%)	2005	2010	2015	2018	Target 2030
Road	59	56	57	56	Max. 43
Rail	9	10	7	8	Min. 15
IWW	33	34	36	36	Min. 42

Source: Authors, based on annual reports and sustainability reports.

#### 4.1.2. Antwerp

The MS situation for inland container flows in Antwerp has seen little change in the past 15 years. IWW has gained some ground at the expense of road transport, while rail has not succeeded in increasing its inland transport share. For the Port of Antwerp, the current share of rail transport is 6.9% (450,000 TEU rail on a total hinterland traffic of 6.4 mio. TEU). The current deficit of rail in comparison to the goal of 15% share for rail, can thus be estimated at 500,000 TEU. Depending on a low or high growth scenario on the hinterland side, a total of 8.8 to 10 mio. TEU is expected by 2030, resulting in a necessary rail volume of 1.3 to 1.5 mio. TEU or a required growth in rail volumes of 190% to 235% compared to the present situation. Currently, IWW transport accounts for 36% of hinterland transport, or 2.3 mio TEU in absolute terms. In order to attain the goal for IWW transport to account for at least 42% of hinterland container traffic by 2030, the total challenge ahead is to reach 3.7 to 4.2 mio TEU, or a required growth in barge volumes of about 60% to 83%, as compared to the present situation.

The PoA has focused on managing road traffic through the truck guiding system and keeping terminals open at night<sup>4</sup> in order to lessen road congestion. Online information on roadworks and alternative routes is provided. PoA invests in projects that improve transport efficiency: seven funded initiatives have prevented 250,000 truck trips. For example, the Hakka project is a collaborative platform between carriers, whereby information is provided on empty container space for improving transport efficiency, indicating a strategic investment that improves horizontal intra-port information management. Projects promoting railway and IWW transport indicate a stronger focus on both horizontal and vertical information management. PoA is investing in cooperation among stakeholders throughout the logistics chain, and an action plan built on three pillars has been developed: (i) planning and cooperation, (ii) clustering transport volumes and (iii) digitization. The Danser group, one of Europe's largest intermodal operators, is achieving a MS in PoA by using a corridor system between Antwerp and France, as well as a hub-and-spoke system along the Brussels-Scheldt Maritime Canal. In recent years, the Liefkenshoek railway tunnel has helped to improve access for railway traffic. Railport, an initiative between the PoA and local private sector trade associations, is mandated to remove as many MS barriers as possible, underpinning the necessity for vertical information management. Railport sets up projects with rail operators to improve performance efficiency (e.g. developing a new railway link with DP World to Stuttgart), and also works on simplifying regulations, modernizing infrastructure, bundling of cargo volumes (lowering the TCs). It also launched the 'Rail Traffic System' digital pilot project, aimed at improving information exchange between terminals within the port area.

#### 4.1.3. Hamburg

PoH has a remarkably high modal split share of rail. After the fall of the Iron Curtain in the early 1990s, Hamburg seized the window of opportunity to expand its hinterland to East and Central Europe. However, the lack of adequate highway infrastructure to these regions forced the PoH to heavily rely on rail. The successful expansion of rail transport was supported by electrification and the exploitation of rail terminals, and the specific governance structure whereby the local government is the majority shareholder of the PMB and the dominant terminal operator HHLA. Both terminal operators (HHLA and Eurogate) hold substantial equity shares in railway operators (Metrans and EUROKOMBI) and rail terminals in the vast hinterland, thereby showing the strongest degree of vertical information management of the ports studied here (extra-port initiatives). The high level of vertical integration in port-hinterland relations offers cost efficiencies and commercial development opportunities thanks to the access to detailed information on cargo and market dynamics. The PoH has also invested in the digital platform EVITA/TransPORT Rail, which includes railway transport information. Two strategic measures are being implemented to achieve MS targets: (i) expansion of infrastructure, such as the completion of a new lock in Lüneburg-Scharnebeck by 2032; and (ii) digitization, covering several projects with the aim to achieve complete digital integration of inland navigation into the ports logistics system. This includes a shift to improved information management both within the port area (intra-port) and beyond the port area throughout the logistics chain. The MS targets in Table 7 seem

**Table 7**

Port of Hamburg MS (2005–2019), including MS target for 2035.

Modal Split(in%)	2005	2010	2015	2019	Target 2035
Road	68	62	55.6	51.3	Max. 53.4
Rail	30	36	42.3	46.3	Min. 42.5
IWW	2	2	2.1	2.4	Min. 4

Source: Authors, based on annual reports, sustainability reports and experts of the selected port.

<sup>4</sup> Selected container terminals on the left bank have lengthened opening hours from 5 a.m. on Monday through 5 a.m. on Saturday, since 2017. Whether this initiative can be expanded to the right bank terminals is presently being studied.

**Table 8**

Current state-of-affairs and ambitions for MS in hinterland container transport in large seaports in Northern-Western Europe.

Port		Total container volume (in TEU)	Container hinterland volume (in% of total, sea-sea transshipment deducted)	Modal split% container hinterland transport		
				Road	Rail	Barge
Rotterdam	2017	13,734,334	65.5%	56.2%	10.4%	33.4%
	Target 2035			Max. 35%	Min.20%	Min. 45%
	Necessary MS			-21.2%	+9.6%	+11.6%
Antwerp	2017	10,450,900	66%	55.1%	6.9%	38.0%
	Target 2030			Max. 43%	Min. 15%	Min. 42%
	Necessary MS			-12.1%	+8.1%	+4%
Hamburg	2017	8815,469	59.8%	55.0%*	42.5%*	2.4%*
	Target 2035			Max. 53.4%	Min. 42.5%	Min. 4%
	Necessary MS			-1.6%	N/A	+1.6%

\*Because of rounding, the sum of the PoH's modal split adds up to 99.9%. (Port of Hamburg, 2018)

Source: authors based on OSC, Drewry, Dynamar, ISL, Port of Antwerp and Port of Hamburg.

less ambitious than in Rotterdam and Antwerp. However, one has to consider that Hamburg is already operating with a very high rail share, while its less extensive inland waterway network leaves fewer opportunities to substantially increase the IWW share. [Table 8](#) contrasts the MS objectives and challenges facing the three selected ports.

In the next section, we offer a broader conceptual view, beyond these case studies, to assess specific MS measures, and the associated information management requirements. It will have become clear from the above cases that PUs are typically heavily involved in modal shift initiatives, thereby suggesting that more overarching approaches on the incentive-to-penalty spectrum would be best served by including PUs in governance design, and by approaching such governance design through a contract theory lens.

#### 4.2. Exploratory assessment of stylized MS governance approaches (incentive versus penalty), and the link with strategic information management

In [Table 9](#), we offer a first exploratory discussion of both the PMB- and PU-related contract theory questions, applied to the different stylized MS governance approaches and based on the outputs obtained from an online focus group session with senior port managers in April 2020 (see [Section 3.1](#)). The exploratory results show the assessments of the group as a whole by aggregating the tendencies and opinions expressed by individual session participants.

##### (1) PMB1: Enforceability

Enforceability issues (PMB1) for the incentive approach will not be challenging, given the voluntary nature of this approach, but the size of the incentive fund versus the cost for MS generation will be important. The fund should be sufficiently high in order both to reward adequately the efforts of PUs and to signal the MS ambitions (see also *infra*, PMB2). In the bonus/malus scenario, enforceability will likely be high, should (i) the bonus be sufficiently large and feasible, and (ii) there be an agreement on a contractual baseline performance concerning the growth rate of rail and barge share. On an annual basis, an evaluation could take place to determine which PUs have contributed positively, and which PUs have insufficiently or negatively contributed towards the baseline. In the penalty scenario, enforceability will be lower, given (i) the current balance of power of shipping lines/terminal operators versus the PMB, and (ii) external influences e.g. the current relative malfunctioning of the European rail freight industry, which is still in the midst of deregulation.

##### (2) PMB2: Administrative costs

The potential administrative costs (PMB2) will differ in the incentive scenario between two options. Either the incentive is incorporated in the pricing structure for port dues and concessions (higher number of transactions), or a fund is established with one annual transaction for good performers. In the former case, the administrative costs will likely be higher. But in both options, relatively high administrative costs can still be expected. In the bonus/malus scenario, administrative costs are likely high at the start, because of the need for detailed, transparent and unambiguous data on which level of MS is generated by which PU. This highlights the need for a common IT platform and transparent baseline measurement. There may be a potential need for renegotiation during the initial implementation phase. Once the system is operational and stable, a lower cost can be expected, with a single annual bonus/malus transaction for each PU. The penalty scenario is expected to have low administrative costs, given that targets and quota are negotiated and formalized in the contract, thereby also leading to maximum one transaction per year (in case of a fine). Likewise, maximum

**Table 9**  
Effectiveness criteria per type of governance approach: A first exploration.

		Incentives-based system	Bonus/Malus system	Penalties-based system
PMB1	<b>Enforceability</b>	Voluntary participation.	High.	Low.
PMB2	<b>Administrative costs</b>	Relatively high.	Likely high at the start; once operational, lower cost.	Low.
PMB3	<b>Implementation difficulties</b>	Need for additional case-based research.	Limited.	Renegotiation of existing contracts needed.
PU1	<b>Exit</b>	No risk.	Medium risk.	High risk.
PU2	<b>Competitive disadvantage</b>	Need for additional research.	Need for additional research.	Need for additional research.
PU3	<b>Unequal treatment</b>	No risk.	High risk of unequal treatment between haulage types; PUs inside and outside of port; existing and new PUs.	High risk of unequal treatment between haulage types.
PU4	<b>(Un)predictability of supply chain impact</b>	No risk.	Medium risk, but need for additional research.	High risk, but need for additional research.
PU5	<b>Asset Specificity</b>	Low risk.	Average risk, but need for additional research.	High risk, but need for additional research.
PU6	<b>Legal Certainty</b>	No risk.	Negotiation with all port users is necessary.	No, but issue of renegotiating existing contracts.
PU7	<b>Absence of Reciprocity</b>	Low risk.	Medium risk.	High risk.
PU8	<b>Ex Post Governance</b>	Low risk.	Low risk.	Low risk.
PU9	<b>Mutual Dependence</b>	No risk.	No risk.	Low risk, but need for additional research.
PU10	<b>Unintended or unexpected negative externalities</b>	Need for additional research.	Need for additional research.	Need for additional research.
<p><b>Under the stylized governance approaches, the different effectiveness criteria can entail following characteristics towards (additional) information management:</b>  <b>Green:</b> (additional) horizontal or vertical information management is necessary, but limited difficulties are expected for obtaining the relevant information from PUs.  <b>Orange:</b> (additional) horizontal or vertical information management is increasingly necessary and/or more expected difficulties arise for receiving necessary information from PUs.  <b>Red:</b> (additional) horizontal or vertical information management is of utmost importance and/or a lot of expected difficulties arise related to earning necessary information from PUs.</p>				

Source: Authors, based on scholarly literature review, applied literature and focus group discussion.

annual quota, e.g. for truck traffic are easily implemented, subject to the availability of a technological solution to count the number of trucks accessing a terminal. Further, our communication with port experts revealed that between 1.25% and 2.5% of the port's income in 2019 could reasonably be dedicated to a fund associated with positive MS incentives. These percentages are aligned with those foreseen for e.g. green port dues, which can be as high as 2% of a port's income in some European ports (Geerts et al., 2017). It does remain somewhat uncertain, however, whether such pricing structures will act merely as a 'signal to the market', rather than lead to effective behavioral change. Further research is needed in terms of the appropriate size of such funds.

### (3) PMB3: Other implementation difficulties

The expected issues related to implementation (PMB3) will need individual port, case-based additional research, for instance on applicable state aid regulations (e.g., in the European Union, there is a strict framework in terms of subsidy provisions to economic operators). Current practice, guidelines and case law on state aid suggests that the incentives should be kept well under the operational cost of the hinterland transportation system (e.g. maximum 30% of operational costs should be covered). In the case of a bonus/malus system, limited issues at the judicial level are expected. In a penalty scenario, existing contracts may need to be renegotiated, but the question remains if this is achievable, considering the power balance among shipping lines, terminal operators and PMBs.

For the questions for the PUs, the following insights are provided.

## (1) PU1: Exit

There is no direct risk of potential exit of current PUs, or non-entry of new PUs in the case of a positive incentive approach. The incentive scenario is likely more attractive for well-performing users. Some risk of PU exit is expected in a bonus/malus system, with a higher risk in a penalty scenario. However, we suggest more empirical, survey-based research to understand how PU exit-risks materialize along the incentive – penalty continuum.

## (2) PU2: Competitive disadvantage

Assessing the risk of market distortions will require further research. In a related area, current incentive schemes for environment-friendly ships (such as the Environmental Ship Index or ESI) are not considered to be distorting competition either, and often are viewed as part of the PMBs' commercial autonomy in pricing (Geerts et al., 2017; De Langen and Van den Berg, 2017). Bonus/malus schemes for environment-friendly ships were not broadly implemented by ports because shipping lines allegedly provided signals that they would consider this a market distortion. However, this has not been unambiguously demonstrated. Should cargo be shifted because of a bonus-malus scheme, then competition would clearly be distorted. In case of a penalty approach, the risk is expected to be limited, given that some PMBs have already started implementation (e.g. Port of Rotterdam) and other ports may follow suit.

## (3) PU3: Unequal treatment

Based on our research, the risk of unequal PU treatment within the port and its vicinity is mainly related to container haulage types (i.e. carrier haulage, merchant haulage, but also cases where terminal operators organize the inland transport leg). In case of a positive incentive system, no risk is expected, since all users can make claims to the fund, directly or indirectly, allowing easier access to their relevant information for the PMB. Depending on the size of the incentive, there is the potential risk of preferential treatment of terminal operators and shipping lines. This could lead to increased collaboration throughout the supply chain, but it does not necessarily distort the market. All users compete for the resources present in the fund. Risk of unequal treatment between transport modes is also limited under a positive incentive scenario, because the fund makes no distinction among modes. Arguments concerning external costs are possible, as different modes generate different external costs. In case of a bonus/malus scheme, risks of unequal treatment between haulage types can exist as users that are exposed to merchant haulage will probably experience disadvantages and this would imply more intense information sharing as compared to terminal or carrier haulage where the responsibility for MS performance lies with the terminal operators (and/or the shipping lines should they have financial stakes in the terminals).

## (4) PU4: Unpredictability of supply chain impact

We expect no risk of negative impacts in a positive incentive scenario. We predict higher risks and information management difficulties in the bonus/malus and penalty schemes, although further research is necessary. Here, in-depth insights from experienced PUs are required to make an assessment, and any impacts will be highly dependent on the specific value chains considered.

## (5) PU5: Asset Specificity

Limited extra costs will be incurred in the incentive scenario, but certain PUs might experience a decrease in effectiveness and profitability in the case of MS under a bonus/malus system. We expect an increased risk of negative effects on irreversible investments in specific assets to the extent that a scheme also involves penalties, but further research is necessary.

## (6) PU6: Legal Certainty

In an incentive scenario, we expect few problems related to (the absence of) legal certainty whereby the PMB could unilaterally impose tightening of current regulations or additional regulations, although the PMB might unilaterally dissolve or phase out the fund when MS goals have been realized. In the case of a bonus/malus approach, negotiations with the current PU base is required before implementing the scheme. With the penalty approach, the only issue in terms of legal certainty relates to consistency in application, which refers to the presence of existing contracts (and the need to modify them). In new contracts, agreements are made by informed contracting parties, and therefore no problems should arise.

## (7) PU7: Absence of reciprocity

Perceived problems related to the absence of reciprocity by the PMB to accommodate the PUs will be limited in the context of incentive schemes, given that the PMB will provide the compensation, without additional earnings for the PMB. In the bonus/malus scheme, average risks can be expected, as problems may arise with PUs that make substantial efforts towards MS, but remain under the bonus threshold. This issue highlights the need for unambiguous, objective performance data. The penalty scenario entails the highest risk for the PUs, as the PMB should live up to its commitments with regards to infrastructure investments for rail and inland waterways and supporting policies, in accordance with plans and achievements of other, competing PMBs.

(8) PU8: *Ex post* Governance

Risks related to the absence of transparency and ambiguous data, after implementation, which could lead to potential ‘gaming behavior’ are limited, on the condition that a transparent, jointly managed IT platform is established. The level of risk is then limited in all scenarios.

## (9) PU9: Mutual Dependence

*Ex post* governance challenges will not arise in an incentive or a bonus/malus approach, unless related to phasing out, a dialogue is necessary. Penalty systems can expect some challenges, as concession contracts are longer-term contracts, but further research into the issue of creating mutual dependency is necessary.

## (10) PU10: Unexpected and unintended negative effects

Based on our research, this question should be the subject for further research, as it requires in-depth insight at the level of experienced PUs, whereby externalities can be highly dependent on specific value chains.

Our initial insight, especially from findings related to PMB2, PU7, PU8, PU9 and PU10, is that a transition towards common and transparent information management throughout the hinterland chain is a key element. In addition, ‘neutral’ and jointly managed IT platforms between PMBs and PUs are very likely a prerequisite to enable MS, in order for the *ex post* governance system to function on objective information and to avoid opportunistic behavior of PUs.

## 5. Discussion

We observe agreement with Rogerson et al. (2020) especially in the results related to PU1 and PU2, that MS implementation must be done in a competitive fashion. The MS measures that are considered the most attractive, and implemented through the most preferable scheme, will allow to create the necessary mental shift among PUs as identified by Meers et al. (2017) and Rogerson et al. (2020). One of our main findings is that improving information management first and foremost horizontally (intra-port) but also vertically (extra-port), can support MS generation, a finding in line with Bowersox et al. (2000), Veenstra et al. (2012), Regmi and Hanaoka (2013), Kotowska (2016), Meers et al. (2017), Monios and Bergqvist (2017), Tao et al. (2017), Gonzalez-Aregall et al. (2018) and Alamoush et al. (2020).

As identified in the literature review, as well as when applying contract theory, one of the key challenges for MS is IT and information management. While PMBs, and sometimes even PUs (such as terminal operators), do not make modal choice decisions, they can indirectly influence the related choice processes. Information-based facilitation of MS is especially challenging for goods that are transported under merchant haulage, where the final destination and intended transport mode is usually only known to freight forwarders and the owner of the goods, until the last moment (Veenstra et al., 2012). It is important that every node in the supply chain facilitates MS possibilities, in reaction to increasing stakeholder pressures from shippers or governments. Information originates with various stakeholders (shippers, shipping companies, PMBs, terminals, customs, supervisory authorities) and the level of linking these sources will determine the performance of hinterland transport, a finding aligned with Hanaoka and Regmi (2011). This will in turn affect environmental performance, leading to potential new trading partners and investors as well as higher levels of community support, as suggested by Lam and Notteboom (2014b). Furthermore, the provision of adequate information throughout the supply chain will in turn also improve synchronomodality and co-modality initiatives, improving the overall green performance of the end nodes of the supply chain as well. We thus propose that broad information sharing between parties is a crucial prerequisite for the realization of MS goals.

As we can see in the historical trajectory of the port case studies<sup>5</sup>, MS remains a challenging ambition, even for the largest seaports. As information is a prerequisite for MS realization, strategic investments are necessary for improving information management so that the PMB and its PUs move towards scenarios 2a or 2b (see Figure 1). We observe that the PoH shows the unique trait of vertical integration at the level of deep-sea terminal and hinterland rail services. Based on the path dependency of early investments in the rail network, this vertical integration allows for more efficient information sharing throughout, and thus the PoH can be situated in the upper right corner of Figure 1 (scenario 2b). Moreover, PoH differs from PoA and PoR in terms of the level of vertical integration and the difference in the PU landscape. With respect to the latter, the vast majority of PUs in Hamburg’s containerized cargo business are German<sup>6</sup>, which implies lower transaction costs in MS governance approaches than in scenarios where foreign multinationals dominate the container market within and outside of the port area (as observed in PoA and PoR). Although such vertical integration may not be feasible for other ports, it does highlight the value of lower transaction costs in potential strategic collaborations, thereby confirming the strategic value of our framework for PMBs. Given the fact that MS thinking can be applied to activities within the port (transshipment and moving of cargo within the port area), but also extends to hinterland transport, a PMB will need to cover both bases

<sup>5</sup> 2017 for PoR, 2018 for PoA and 2019 for PoH.

<sup>6</sup> In addition to terminal operator Eurogate and terminal/intermodal operator HHLA, the list of German market players also includes large logistics companies such as Deutsche Post, DB Schenker and Kühne&Nagel. Most of the inland terminals on the Rhine are also controlled by German interests (Contargo/Rhenus, Neska, etc.), see Yang et al. (2021).

should it want to realize ambitious MS goals. We agree with [Park et al. \(2007\)](#) and [You et al. \(2010\)](#) that synergies can reasonably be achieved when implementing an adequate IT platform, in combination with other policy initiatives ([Park et al., 2007](#); [You et al., 2010](#)). Yet, we suggest that if the choice between different MS measures poses a trade-off for a PMB, investing in an IT platform that would at minimum integrate information flows horizontally, should be favored.

## 6. Conclusion

Given the broad societal preferences in favor of more sustainable transport, PMBs are implementing a variety of measures as part of their green port strategies. As ports are responsible for large hinterland transport flows, many PMBs and PUs are challenged to address the dominant share of road transport in their hinterland modal split and the associated negative externalities such as congestion, GHG emissions, etc. While not all ports have made explicit their specific MS goals, PMBs have been implementing a wide variety of MS measures to reduce dependency on road transport for serving the hinterland. However, MS outcomes have often been disappointing, whereas PMB goals in the MS sphere have actually become more ambitious, aligned with the evolution of societal preferences. The scholarly literature suggests three main challenges to achieving a MS in practice: building sufficient infrastructure capacity; paying adequate attention to broad port-user management; and coordinated regulatory initiatives, and technology and information management.

We used contract theory as the basis for an actionable and generalizable conceptualization to support effective MS strategy formulation and implementation. We provided a framework for aligning objectives of contracting parties, reducing uncertainty and stimulating cooperation and joint action towards achieving shared objectives. In particular, the conceptualization can help PMBs to identify which MS measures should be considered more attractive by PMBs as well as PUs, taking into account the potential MS impact of these measures. We recommended that PMBs would construct an Assessment Matrix to map and prioritize measures in MS strategy implementation. Importantly, through the utilization of ten insights derived from modern contract theory, a PMB can affect the positioning of MS measures in the matrix through deploying specific incentives, penalties and bonus/malus systems. By choosing the governance structure with the comparatively lowest transaction costs, PMBs can improve the odds of achieving their MS goals. This study thus contributes to extant literature on MS by presenting a new conceptualization based on contract theory. Our framework can be deployed to evaluate why PMBs fail or succeed in realizing their MS goals when implementing specific MS measures and programs.

We also found –in accordance with a large body of prior literature on reducing bounded rationality challenges and irrespective of the content of individual contracts– that effective information management is a prerequisite for achieving MS goals and that large seaports are investing in their information processing capacity to improve green performance in hinterland transport. Building upon such overarching capacity, larger PMBs can then use their ownership or control of sites located close to deep water to demand from PUs more detailed modal split data and environmental impact information. This type of information is typically included in the PUs' business plans when applying for port leases and permits. Both vertical as horizontal information management are key elements to create an efficient governance system for achieving MS goals. Empirical evidence presented in this paper suggests that considerable progress has been made in the three largest seaports of Europe in establishing overarching IT systems to support improved information management for MS initiatives. Unfortunately, many PMBs are presently still characterized by fragmented information management. This refers to the compartmentalized distribution of critical information among a large number of organization members and functions, and possibly even external port stakeholders, without the organizational capability for proper aggregation, whether laterally or vertically. In such cases, our tentative recommendation is to invest first in overarching mechanisms that will improve lateral information sharing within the port cluster. Only subsequently should investments be made in new, vertically oriented, information gathering and processing instruments.

The findings presented for Rotterdam, Antwerp and Hamburg may not provide generalizable conclusions for the port sector in its entirety but hopefully offer useful insight on how to approach the MS challenge through a contract theory lens. In addition to taking on board transaction cost economizing considerations, related to contract theory, future research should also focus on how differences in the relative power between PMBs and PUs shape the feasibility and outcomes of specific MS measures and broader MS-related governance systems. As to the contract theory elements themselves, there is room for exploring further the usefulness of taking into account the following dimensions in MS-related governance, when negotiating new measures with PUs: the potential competitive disadvantage vis-à-vis users in other ports created when (re)negotiating agreements; the likely impacts of incentives, penalties and bonus/malus schemes on the cost and quality of PU activities and the related supply chains; the magnitude of negative effects on investments in specific assets and the productivity thereof; problems related to *ex post* bilateral dialogue in the case of penalty schemes; and potential, unintended negative externalities. MS possibilities also change when considering various cargo flow types. Given the superior data availability for container traffic, investments in IT platforms that provide high quality information will become increasingly critical for this particular cargo flow. Additional insight can be derived from research on best practices in MS achievement, e.g., in European ports such as Koper and Gdansk, and in ports from other continents, as well as from best practices in horizontal and vertical information management, as found in the Port of Gothenburg and its broad network of hinterland rail terminals. Some vertical information management platforms have been implemented more successfully than other ones (consider for example the success of PoR's PortBase versus PoA's Nxtport). Multiple case studies on the (relative) success of such platforms will bring additional insight, for example on the reasons for differences in port user willingness to share sensitive user data on joint platforms. The scope of this paper was limited to the development of a generalizable, yet actionable framework for PMBs to assess MS measures' attractiveness according to the characteristics of their users. Future research should focus on the application of the framework to specific PMB-PU relationships through the development of in-depth case studies that recognize the idiosyncrasies of specific PU types, and even differences within PU types (e.g., large, multinational enterprises - MNEs versus small and medium-sized enterprises - SMEs).



The scope of this paper was limited to MS governance choices available to PMBs. Other stakeholders can also deploy MS instruments that can result in positive contributions to MS: government agencies via port policy regulations; transport companies via corporate investments in environment-friendly transport modes; and manufacturers and large-scale logistics services providers via vertical supply chain integration strategies. We think that PMBs have an active role to play in reaching MS targets, but do not claim that their initiatives (even those undertaken jointly with others) are necessarily superior to the MS toolbox that other stakeholders can deploy. We recommend further research on other organisations than the PMB implementing MS measures. Here, the analysis of synergies arising from MS measures introduced by different stakeholders, deserves special attention. Finally, increased MS efforts might earn diminishing returns, whereby the additional effort required to improve further the modal split becomes disproportionately large as compared to actual gains. Unfortunately, a precise cost-benefit calculus in this realm is difficult to make *ex ante*. Further research should therefore focus more on the comparatively most efficient bundles of MS measures from a contracting perspective, rather than on trying to achieve unrealistic, 'maximum' MS levels.

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