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The Greening of Terminal Concessions in Seaports

Theo Notteboom [1,2,3,4,*] and Jasmine Siu Lee Lam [5]

1 Center for Eurasian Maritime and Inland Logistics (CEMIL), China Institute for FTZ Supply Chain, Shanghai Maritime University, Shanghai 201306, China
2 Faculty of Business and Economics, University of Antwerp, 2000 Antwerp, Belgium
3 Maritime Institute, Faculty of Law and Criminology, Ghent University, 9000 Ghent, Belgium
4 Antwerp Maritime Academy, 2030 Antwerp, Belgium
5 School of Civil and Environmental Engineering, Nanyang Technological University, Singapore 639798, Singapore; sllam@ntu.edu.sg
* Correspondence: theo.notteboom@gmail.com

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Abstract: Port authorities around the world are pursuing a greening of port management in view of safeguarding their license to operate, and increasing their economic and environmental competitiveness. This paper analyzes how port authorities, via the design and implementation of concession agreements, can contribute to a further greening of port management. The paper presents a typology of green instruments applicable to a terminal concession setting. The instruments are evaluated on overall feasibility and suitability in a concession context, but also on more specific criteria related to implementation issues, contribution to green strategies, and targets of port authorities and regulatory/enforcement aspects. The evaluation matrix is based on the output of a structured workshop with port managers and concession experts in a sample of European ports. We demonstrate that a variety of regulatory, investment, and pricing measures are available to port authorities to include green targets in terminal concession agreements. Not all instruments have the same likeliness of being embraced or implemented by port authorities, in part because of a low perceived contribution, high associated regulation costs, or simply because the port authority is unlikely to have jurisdiction in that specific area. Measures related to information reporting and some types of harm-based standards, design standards, and technology specifications are relatively easy to implement in a concession setting. The results also show that many of the measures with a higher expected contribution to innovation and environmental objectives are typically also the ones with higher regulation costs, which might post a higher complexity in terms of their implementation in a concession setting. We further argue that initiatives toward the greening of concession procedures can only reap full benefits if these actions are embedded in a chain approach toward the environment (ship, port, terminal, warehouse, and inland transport).

Keywords: ports; emissions; environmental policy; terminal; concession

1. Introduction

In many countries around the world, governments and public port authorities have retreated from port operations in the belief that enterprise-based port services and operations would allow for greater flexibility, more competition, higher efficiency in the market, and a better response to port users' demands. Many ports have adopted some sort of landlord port authority model. Under this model, the landlord port authority typically is a separate entity under public law established by a specific legislation with the capacity to conclude contracts, to enforce standards, and to make rules and regulations applicable within the port area. Port operations (especially cargo-handling) are carried out by private companies. Today, the landlord port is the dominant port model in larger and medium-sized

ports in Europe [1]. Under the landlord model, the concessioning of terminal operations to private operators has become common practice [2]. A terminal concession is a grant by a government or public port authority to a (private) terminal operator in view of providing port terminal services.

Landlord port authorities are challenged to develop effective terminal awarding procedures in view of attracting private terminal operating companies. At the same time, port authorities can use a well-designed concession policy to retain some control on the supply side of the port market and to optimize the use of scarce resources. Land for port development is scarce making the concessioning of terminals to private stevedoring companies a prime task of landlord port authorities. Key issues in the concessioning of terminals include the allocation mechanisms used for granting seaport concessions, the determination of the concession term and concessions fees, and the inclusion of special clauses (e.g., throughput guarantees) in the concession contract aimed at assuring that the terminal operator will act in the interest of the port authority and the wider community [3].

In the past decades, environmental considerations became an integral part of port planning processes and port operations across the world [4]. The design of terminal concessions provides a suitable avenue for incorporating green port management targets. We consider the inclusion of green factors when awarding terminals to private terminal operators as one of the most interesting fields of action for landlord port authorities at the terminal level. Thus, we argue that terminal concession procedures and agreements have a role to play in the greening of port management. In line with the above, this paper focuses on the following research question:

Which instruments can port authorities (PAs) use in terminal concession policy to contribute to a virtuous cycle that leads to a stronger consideration of the PA's environmental objectives by terminal operators and to a further greening of port management?

We zoom in on actions to mitigate adverse environmental effects of terminal operations, not so much on terminal construction. The paper focuses on current practices and perspectives in leading north European seaports which follow the landlord management system, i.e., Rotterdam, Antwerp, Hamburg, and Amsterdam. However, the research design and findings can also be instrumental to port authorities around the world which are considering or already actively pursuing environmental sustainability through terminal concessions. To the authors' knowledge, the investigation of greening terminal concessions has not been addressed in the literature. Thus, this study makes an original contribution to the field of green port management.

The paper is structured as follows: the first section deals with the current attention to environmental aspects in concession procedures and agreements as developed under the landlord port management system. Section 2 presents key considerations in the greening of port management based on extant literature. Next, we present a methodology in view of evaluating instruments potentially available to port authorities in a concession setting to control/reduce environmental impacts of terminals. The methodological framework includes the identification of instruments, the identification and selection of evaluation criteria, and the scoring of instruments on the proposed evaluation criteria. The results are discussed in detail in Section 5. Managerial and policy recommendations, and research limitations, as well as avenues for further studies, are presented in the final section of the paper.

2. Concession Agreements in a Landlord Port Management Setting

The granting of terminal concessions and leases in seaports is a highly complex matter guided by regulatory, economic, environmental, and technical considerations. Theys et al. reviewed all important questions related to the procedures in view of selecting the most appropriate operators for their scarce land and the conditions under which these private companies can be given the right to operate the facilities [3]. It is widely recognized that the awarding of port services to private operators has become one of the most important means for landlord port authorities to influence the prosperity of the port community [5,6].

Academic literature gives some guidance on the design of effective terminal awarding procedures and on specific key issues in concessions such as the duration of the terminal contracts [7] and the

concession fee system [8]. Notteboom et al. discuss the development of a "good practice guide" to help individual port authorities in Europe with the development of sound and effective terminal award procedures and contracts [9]. This guide also is a step forward toward providing more transparency to current industry practices and toward the acceptance by port authorities of the principles of the European Union (EU) governing concessions.

A typical terminal awarding procedure consists of maximum four phases (see also [3,5]): the pre-bidding phase, the optional qualification phase, the selection phase, and the post-bidding phase. In the pre-bidding phase, the port authority makes the necessary preparations for the awarding taking into account prevailing regulatory conditions. This includes decisions on criteria related to the qualification and selection of candidates and the desirable concession duration. In the optional qualification phase, the number of potential candidates is narrowed down using thresholds in terms of, e.g., financial strength or experience. In the awarding phase, the eligible candidates are screened, bids are evaluated, and the most appropriate candidate is selected. In the post-bidding phase, a legally binding concession agreement is signed with the selected candidate, and the company's performance is monitored during the contract term. If necessary, correcting measures are taken and disputes are settled.

A survey commissioned by the European Sea Ports Organization (ESPO) and including 43 recent terminal awarding cases across Europe showed that environmental issues do not play an important role in terminal awarding processes across European ports [10]. In the qualification stage, port authorities set minimum standards or thresholds with regards to the financial strength and experience in terminal handling as eligibility criteria for potential candidates. Environmental performance is never considered as a factor in the qualification phase of a terminal awarding process. In about 70% of European terminal projects, candidates who make it to the selection stage have to present studies of environmental and territorial impact covering aspects such as the impact of the terminal operations on the environment and the alternatives to eliminate, reduce, or mitigate certain effects [11]. While this proves that port authorities are interested in the environmental strategy of the candidates, it remains remarkable that environmental criteria are rarely included in the final selection round. Port authorities also rarely consider the inclusion of green performance elements in the post-bidding phase, particularly when drafting the concession agreement. While environmental clauses appear in 85% of all recent terminal contracts, in most cases, the clauses simply stipulate that the terminal operator will have to comply with local, national, and supranational environmental legislation. In about 30% of these cases, the environmental clauses refer to the compulsory use of some sort of environmental management reporting system, while stipulations on emission levels are included in 18% of the contracts. About 9% of the contracts refer to specific technical equipment to be used to limit emissions (for example, cold ironing/on-shore power for vessels at berth, or the use of electric/hybrid yard equipment). About one-fourth of all contracts combine several of the above environmental clauses. Occasionally, European ports include clauses on existing or future contamination of the terminal site.

The results above demonstrate that there is room for a further "greening" of terminal awarding procedures in each of the four phases of a concession procedure. In line with the central research question, we provide a more structured analysis of the range of instruments available to landlord port authorities to support a shift to "greener" terminal concessions. In order to do so, we first discuss key considerations in the debate on the "greening" of port management.

3. Key Considerations in the Greening of Port Management

The greening of port management is attracting growing attention in academic circles. Doerr provided an overview of policies and strategies for sustainable ports across the world [12]. Focusing on container terminal operators' firm performance, Lun proposed the elements of green management practices and analyzed their business impact for the case of Hutchison Port Holding [13]. Acciaro et al. defined a set of quantitative objectives to evaluate the success of innovations with respect to environmental sustainability at seaports [14]. In business practice, the growing green reflex is mirrored in the

many green initiatives of individual ports and the coordinated actions of the wider port community, as exemplified in Europe by the EcoPorts foundation (embedded in ESPO). Puig et al. provided a good overview of current environmental issues in seaports and the overall performance of European ports in terms of environmental management [15]. Their study is partly based on the ESPO/EcoPorts Port Environmental Reviews which show that the prioritization of environmental effects of port activities and development changed over time.

More specifically, terminal activities are prime sources of the environmental impact of seaports which can be summarized into several categories, namely, (1) port construction-related pollution; (2) air emissions of ships at berth and terminal handling equipment (such as cranes and yard equipment); (3) noise associated with cargo handling operations; and (4) the environmental effects and potential congestion associated with landside operations of barges, rail, and trucks. Environmental impacts occur at all stages of a terminal's life cycle, i.e., port planning, terminal construction, terminal operation, terminal expansion, or terminal closure/termination.

Firstly, the development of new terminals is associated with adverse effects on the environment. The United National Economic and Social Commission for Asia and the Pacific (UNESCAP) identified nine groups of environmental facets in port development and construction including water quality, coastal hydrology, bottom contamination, marine and coastal ecology, air quality, noise and vibration, waste management, visual intrusion, and socio-cultural impacts (e.g., relocation of villages) [16]. Therefore, Gupta et al. highlighted the need for an environmental management plan which facilitates proper monitoring and control of pollution in port construction projects [4].

Secondly, emission is a major area of study in terminals' environmental performance. Bailey and Solomon provided an overview of air pollution sources at ports [17]. These include marine vessels, trucks, locomotives, and cargo handling equipment. The negative environmental health impacts and the associated preventive measures were highlighted. Other studies focused on conducting case studies of individual ports' emission levels. Giuliano and O'Brien performed an assessment of port-related truck emissions at the ports of Los Angeles and Long Beach in relation to a state regulation to reduce air pollution [18]. There is another study on the port of Los Angeles in view of the port's legislated emission reduction targets [19]. The life-cycle emissions between diesel and electric yard tractors were compared. Villalba and Gemechu estimated the greenhouse gas (GHG) emission of the port of Barcelona in view of proposing policy recommendations to mitigate sea-based and land-based pollution at the port [20]. Berechman and Tseng analyzed the annual ship and truck emissions of the port of Kaohsiung, and estimated the environmental costs accordingly [21]. In Gibbs et al.'s research on the major United Kingdom (UK) ports, shipping's GHG emissions were revealed to be much higher than those generated by port activities [22]. Thus, they claimed that ports may make an impact by reducing shipping emissions. As for Tzannatos, the study targeted differently from the above papers to measure the air pollution from coastal passenger ships and cruise ships at the port of Piraeus, whereby drawing policy implications with regards to an EU Directive [23].

Thirdly, port authorities show increasing concerns about the impacts of noise pollution and air emissions on the sustainable functioning of the port. These types of pollution clearly affect the health of people working or living around ports [15]. As such, limiting air and noise pollution is not only an environmental goal of port authorities. It has also become a clear mission in the context of corporate social responsibility (CSR) and stakeholder relations management in port areas [24,25].

Fourthly, regarding landside operations connecting inland transport, environmental impacts caused by intermodal connections and congestion lead to adverse effects such as air pollution. Depending on modal choices and the associated cost and transit time requirements from shippers, such environmental effects vary and can be mitigated [26].

Given the potential environmental impacts of terminal development and operations, port authorities or any other managing body of a seaport are challenged to avoid and or reduce effects through a range of green management instruments. We define a green management instrument as a tool used by port authorities to implement their environmental policies. Lam and Notteboom [27]

classified such instruments in four distinctive groups: (1) penalty and incentive pricing; (2) monitoring and measuring; (3) market access control; and (4) environmental standard regulation. In the next section, we present the methodology deployed in this paper, mainly by linking the range of green management instruments available to port authorities to terminal concessions.

4. Methodology

4.1. Research Design and Selection of a Seaport Sample

We argue that a well-designed concession policy should also incorporate green port management targets. A variety of regulatory, investment, and pricing instruments are or should be available to port authorities to include these targets in terminal concession procedures and agreements. To develop a more structured analysis of the possibilities and limitations in this area and to answer the research question formulated in the introduction, we deploy the following research design:

- Step 1: Identification of instruments potentially available to port authorities to control/reduce environmental impacts of terminals;
- Step 2: Identification and selection of evaluation criteria;
- Step 3: Scoring of instruments on evaluation criteria.

The extant literature is used in Steps 1 and 2 of the proposed methodology and further enriched with insights obtained from experts from academia and from a sample of four European seaports. The empirical application in Step 3 also focuses on the same set of four ports.

A workshop was held with participation of four environmental specialists from the port authorities of Rotterdam, Antwerp, Hamburg, and Amsterdam and two academic experts in the field of environmental studies. All workshop participants have at least 10 years of experience in environmental aspects of seaports. On the educational front, they all possess a relevant master's degree and/or doctoral degree. The four senior representatives of the mentioned port authorities actively contribute(d) to the environmental policy of their respective ports, including the drafting of periodical sustainability reports, the design and implementation of environmental instruments, and the participation to inter-port environmental initiatives such as the Environmental Ship Index of the International Association of Ports and Harbors (IAPH) and various initiatives developed in Europe under the umbrella of EcoPorts. They also have a thorough knowledge of the concessioning policy and procedures in their respective ports. The workshop approach was chosen given the fact that the use of green instruments in a concession context is still in its infancy; thus, no data on experiences with the use of instruments could be collected.

The selection of the four ports was inspired by the following three considerations: firstly, it concerns the four largest ports in Europe in volume terms. Total cargo throughput in 2017 amounted to 467 million tons in Rotterdam, 224 million tons in Antwerp, 136 million tons in Hamburg, and 99 million tons in Amsterdam. Rotterdam, Antwerp, and Hamburg also form the top three European container ports with volumes of 13.7, 10.5, and 8.8 million TEU (twenty-foot equivalent unit) respectively in 2017. Secondly, these four ports are managed by typical landlord port authorities under the Hanseatic tradition. In the Hanseatic tradition, the local government/municipality has a strong influence in port governance, while, in the more Latin tradition, mostly found in Mediterranean countries, the central government plays a more prominent role. This distinction is important as overall Hanseatic port authorities have the most autonomy in setting the rules and regulations on land ownership and the contracting out of port land [28]. Furthermore, Hanseatic ports typically have quite some autonomy and leverage in developing and implementing green port policy.

Thirdly, the four ports are at the forefront of the greening of ports. They recognized quite early the necessity to carefully consider environmental issues in their strategic planning and behavior, and to communicate actively with the entire range of stakeholders. They were also very instrumental in enhancing cooperation among European ports on environmental matters. For example, the four

ports played a key role in the establishment of the Ecoports foundation which is aimed at exchanging environmental best practices among European ports and also at developing standards in environmental monitoring and reporting in ports. Together with the port authorities of Le Havre and Bremen, the four ports were among the early adopters of the Environmental Ship Index. Shipping companies can register their ships for this index on a website. On the basis of the data entered, such as fuel consumption and emissions, each ship is a given a score from 0 to 100 (from highly polluting to emission-free). The ports themselves decide what advantages to offer participating ships. The four ports have a clear mission to rank among the most sustainable ports in Europe. The port of Amsterdam developed an ambitious environmental policy plan, "Sustainability: Boldness, Action, and Resolve", as a basis for the sustainability theme of the Port Vision 2008–2020 with concrete measures linked to set objectives. The port of Rotterdam designs and implements a set of policies organized in cooperation with local authorities. One of these is the Rotterdam Climate Initiative which aims to halve the CO_2 emissions of the Rotterdam agglomeration in 2025 compared to 1990. The port of Rotterdam adheres to this general policy and acts mainly in the field of sustainable transport and sustainable energy port. Moreover, the port plan, "Vision 2030", of the Rotterdam Port Authority contains a lot of references to its environmental objectives and policy. Also, the Antwerp Port Authority has a strong focus on key themes such as sustainability and the 3P principle (people, planet, and prosperity). In view of further developing and implementing the sustainability idea, the Antwerp Port Authority in collaboration with VOKA (Chamber of Commerce), the port community association Alfaport, and the Left Bank Development Corporation publishes a so-called "sustainability report" every two years. The first report was published in February 2012. A more detailed discussion on the environmental policy of Antwerp and Rotterdam is presented in Lam and Notteboom [27]. Hamburg developed an extensive environmental program to promote green, sustainable port operations. For example, the Hamburg Port Authority (HPA) is using sulfur-free fuel for its own fleet of ships, equipped public mooring spaces for barges and ferries with a land power connection, and has a strong focus on a greener modal split via the use of rail and, to a lesser extent, barge transport. Hamburg's "Eco Partnership" program is an initiative by the city of Hamburg and private businesses that aims at promoting sustainable management, with a specific focus on container terminals.

4.2. Identification of Instruments

We start the analysis by listing the range of instruments presented by the Office of Technology Assessment [29]. These instruments relate to broad environmental policies governments might develop and are not specifically port-related. The instruments are grouped into two categories: instruments that directly limit environmental impacts and instruments that do not.

The list of instruments as presented by Office of Technology Assessment was further refined by taking into account the extant literature on green port management (see Section 3), particularly the toolbox presented by Lam and Notteboom [27]. Figure 1 provides an overview of the range of instruments and provides examples in a port terminal context for each sub-group. The listed instruments form the environmental toolbox with potential relevance to a concession context. Some of the instruments identified in Lam and Notteboom [27] were not included because of a complete absence of a possible link with concession procedures or agreements, or a lack of relevance to a terminal context.

INSTRUMENTS THAT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS	
Setting of fixed impact reduction targets	
Single-source instruments ("command and control")	
TO needs to comply with an emission limitation or face penalties	
Harm-based standards	Description of required end results (e.g. cap on CO2 emission of terminal)
Design standards	Description of required emission limits based on model technology
Technology specifications	Specification of the technology the TO must use to control its pollution
Bans and limitations	Ban or restrict equipment or operations that present unreasonable risks
Multi-source instruments (limits on cumulative impacts from multiple sources)	
TO has some flexibility in how it complies with specific environmental targets => change own behavior or make other entities comply on the TO's behalf	
Integrated permitting	Multiple requirements into a single permit
Tradeable emissions	Allow TOs to trade emission control repsonsibilities among themselves given an aggregate regulatory cap on emissions
Challenge regulations	TOs are given responsibility for designing and implementing a program to achieve imposed target.
INSTRUMENTS THAT DO NOT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS	
Encouragement of pollution control without setting specific emission targets	
Pollution charges	TO pays fixed amount for each unit of pollution (no ceiling)
Liability	TO pays compensation to those that are harmed by impacts
Information reporting	TO needs to report impacts publicly
Subsidies/discounts	Financial assistance or discounts to TOs as an incentive/carrot to change their behavior, or to help defray costs of mandatory standards.
Technical assistance	Knowledge support to TOs (good practice guide, training, information centre)

Figure 1. Instruments potentially available to port authorities to reduce environmental impacts of terminals (TO = terminal operator). Source: adapted and extended from Office of Technology Assessment (1995).

Extant literature offers more recent classifications of environmental instruments to promote sustainability. For example, the Science and Technology Select Committee [30] of the UK presented an overview on how different types of regulation can guide the actions of individuals and business. A distinction is made between regulation to eliminate or restrict choice of the individual or business, fiscal incentives and disincentives, and non-regulatory and non-fiscal measures (such as persuasion, use of social norms, or information provision). In later studies, this set of instruments was customized in the context of green behavior (e.g., [31–33]). While the approach of the Office of Technology Assessment on the classification of instruments differs significantly from the one used by the Science and Technology Select Committee, all instruments listed in Figure 1 could be regrouped to fit the classification of the Science and Technology Select Committee. For example, most of the "command and control" or single-source instruments in Figure 1 would classify under "regulation to eliminate or restrict choice" in the toolbox of the Science and Technology Select Committee. "Pollution charges" can be categorized as "fiscal incentives and disincentives", and the instrument "information reporting" in Figure 1 can be considered as a non-fiscal measure. However, given that the classification the Office of Technology Assessment is more explicitly guided by technology and asset deployment (i.e., two important aspects of modern ports), we consider it as a relevant and valid base for evaluating instruments in a concession context.

4.3. Identification and Selection of Evaluation Criteria

In a second step, we identify and select criteria which can be used to assess whether a specific instrument is relevant in a terminal concession setting. In order to draw up the list of criteria, we relied on some criteria used in the environmental tool methodology of the United States (US) Congress—Office of Technology Assessment [29]. However, we added additional criteria obtained from the earlier mentioned workshop with port authority representatives and experts. Through the use of an interactive setting, the list of criteria presented by the US Congress was assessed while ample room was given to introduce more port-specific evaluation criteria. This led to the identification of 11 evaluation criteria which were grouped into four categories.

Firstly, two criteria relate to the overall evaluation of a specific instrument. This includes the overall suitability of the instrument in a concession context and the overall feasibility of implementation. The overall suitability criterion refers to the extent to which the proposed instrument can be associated with one or more of the four phases of a terminal concession procedure. The overall feasibility of implementation gives an idea of the overall ease of implementation of the instrument in a concession context. These two criteria are meant to provide a high-level interpretation and evaluation of the assessed instruments.

Secondly, three evaluation criteria focus on the obstacles toward implementation of the instruments. One of these criteria identifies the phase or phases of the concession process which would allow the introduction of such an instrument. We use the four phases: pre-bidding (phase 1), pre-qualification (phase 2), selection (phase 3), and post-bidding (phase 4). Another implementation criterion assesses whether the instrument could serve as a port-wide standard for all terminal concessions or likely needs to be tailored to each separate concession case. A last criterion with regards to implementation looks at whether a specific instrument and the associated targets/objectives (e.g., a cap on annual CO_2 emission by the terminal) refer to a hard target or a soft target. A hard target embedded in a concession agreement is legally binding and will typically lead to penalties or sanctions in case the targets are not met (see also the discussion on penalty pricing in Lam and Notteboom [27]). The sanction policy can also relate to the forced implementation of measures such as the compulsory development of an environmental reporting system by the terminal operator. An alternative approach for a port authority is to implement soft targets: terminal operators are asked to show a high environmental performance, but there are no sanctions if they do not meet certain targets or reference values, or if certain measures are not implemented. For both hard and soft targets, port authorities might opt for the "carrot" approach by rewarding terminal operators which manage to perform above certain compulsory (hard) or indicative (soft) threshold values in terms of emissions or energy use. Such forms of incentive pricing can also be formalized in a concession agreement. The use of a gentle stick that allows terminal operators to enjoy the carrot can be more rewarding than a brutal one. A brutal stick can eventually discourage terminal operating firms from following the direction intended by the stick and may even push them to move in the opposite direction.

Thirdly, we present three criteria which relate to the expected contribution of the instrument. The expected contribution is considered at two levels: contribution to meeting environmental goals of the port authority and contribution to enhancing innovation at terminals. Innovation does not only refer to technical innovation at the level of terminal operators or their suppliers (terminal equipment manufacturers, information technology (IT) firms, construction firms, energy firms, etc.), but also to more managerial innovation that leads to a higher energy efficiency and a reduction in environmental impacts of terminal operations. Hall et al. [34] demonstrated that the actual adoption and implementation of innovations require supportive organizational and stakeholder dynamics at the level of information support, education, stakeholder forums and engagement, technology transfer programs, adoption incentives and regulations, and a variety of formal and informal institutional arrangements. At the same time, innovation is also affected by the drive for innovation in competing ports and companies, and broader regional and cross-industry innovation dynamics. Acciaro et al. [14] argued that, for innovations to stand a chance to succeed, they need to fit the demands and requirements of the actors involved and the port institutional environment in a dynamic way.

The fourth and last subset of the criteria relates to the regulatory and enforcement dimension. We identified four distinctive features that need to be considered in this context. The first one is the legal certainty provided by the instrument and its potential enforcement by the port authority. An instrument used by a port authority will partly miss its effect if it does not provide legal certainty to the terminal operator or if the enforcement of the instrument is weak. For example, a port authority which occasionally waives penalties imposed to terminal operators for not complying with specific environmental standards or targets will undermine the legal certainty and effect of that very instrument.

A second criterion relates to the likeliness that the instrument is within the regulatory jurisdiction of the port authority. Some instruments might be very effective in greening ports; however, if they are not within the jurisdiction of the port authority, the chance is very low that the port authority can actively implement and enforce such an instrument in a concession setting. However, even in case an instrument is not within the port authority's jurisdiction, it could still be integrated in the concession agreement. For example, concession agreements often include clauses that simply stipulate that the terminal operator will have to comply with local, national, and supranational environmental legislation. The third criterion refers to the extent to which the instrument guarantees equity and a "level playing field" among terminal operators. An instrument that leads to an unequal treatment of terminal operators in the same port potentially is a source of contention and conflicts between terminal operators and the port authority. A last criterion in the category of regulatory/enforcement aspects relates to the demands on and resource requirements for the port authority. Regulation becomes less effective if the regulation costs linked to implementation and/or enforcement are very high. From a pure transport economics perspective, the optimization of pollution is not its minimization. There exists an optimal level of environmental improvement beyond which the marginal costs of further emission reductions exceed the marginal benefits [35]. Regulation costs are part of these marginal costs and typically include personnel costs and investment in and maintenance of capital/technical equipment needed to implement and enforce regulation.

4.4. Scoring of Instruments on Evaluation Criteria

In a third step, the experts from the port authorities and academia were asked to give a score on each of the criteria for each instrument. In view of this step, we identified a range of concrete instruments that port authorities could possibly consider to implement in a terminal concession context. Some instruments are already implemented within or outside of terminal concessions in a number of ports. A good example is that of the modal split guarantees imposed by the Rotterdam Port Authority on the new terminals at Maasvlakte 2, i.e., Rotterdam World Gateway and APM Terminals, and embedded in the respective concession agreements [36]. It concerns a hard target linked to penalty pricing. Another example, this time not part of a specific terminal concession setting, is that of truck appointment systems which are aimed at reducing truck congestion and related pollution at terminal gates. By developing a case study on the US West Coast ports, Morais and Lord [37] argued that truck appointment systems can have varying impacts on reducing truck congestion. Giuliano and O'Brien [18] analyzed the Terminal Gate Appointment System at the ports of Los Angeles/Long Beach and concluded that the system did not result in reduced truck emissions. To our knowledge, most of the other proposed instruments were not planned or implemented in the context of terminal concessions and the associated contracts between port authorities and terminal operators.

We used a straightforward and simple scale (high–medium–low) in view of the evaluation of instruments against the criteria in the first, third, and fourth subsets. The scoring of each instrument was done after group discussions in order to be able to present one score per instrument supported by all or virtually all workshop participants. Obviously, not all experts shared the same views on the various criteria which led to discussions and opinion formation processes. In most cases, the views converged leading to scores which were widely supported by workshop participants. In some cases, however, the final scores were contested by one or two workshop participants. These somewhat "contested" scores were recorded by the workshop coordinator. Given the workshop setting, we followed a stated preference technique, not a revealed preference approach. In other words, the experts taking part in the workshop expressed how they rated the different instruments on the presented range of criteria without actually having considered or implemented many of these instruments in practice. The results of the exercise, thus, need to be interpreted as "expected" contributions of the instruments to the greening of terminal concessions and port management, not "proven" contributions.

5. Results and Discussion

5.1. Harm-Based Standards

The results based on the expert consultation in a workshop setting are presented in Figure 2. The somewhat "contested" scores on overall suitability in a concession context and overall feasibility to implement (see discussion in previous section) are highlighted with asterisks. The category of harm-based standards includes a number of measures which receive an overall positive evaluation (score "high" on the first two criteria, although there is some disagreement on the scores for some measures) are relatively easy to implement and are associated with low regulation costs: the introduction of maximum noise levels, maximum height restrictions, and visual intrusion standards. However, these three measures often go beyond the jurisdiction of port authorities (i.e., implemented and enforced by public spatial planning authorities) and are likely to add only moderately to innovation.

Imposing caps on CO_2 emissions or on energy use generally has a high expected contribution to meeting environmental goals of port authorities. Such caps are often the practical outcome of supranational and national treaties and policies dealing with emissions. Such measures are expected to have a high-to-medium effect on innovation efforts of terminal operators and suppliers. However, as this instrument typically falls outside of the jurisdiction of port authorities, it is not possible to make it a legally binding requirement as part of a concession contract between a terminal operator and the port authority.

Another instrument in the field of harm-based standards relates to the use of modal split targets in a concession agreement. Such an instrument is mostly within the jurisdiction of the port authority (see score "high" on the corresponding evaluation criterion). European ports are increasingly promoting co-modal solutions to lower the dependency on trucks in favor of intermodal solutions based on combinations between barges and truck and rail transport and trucks. For example, German ports, Hamburg and Bremerhaven, developed a strong orientation toward rail shuttles, whereas Rotterdam, Antwerp, and Amsterdam heavily rely on barges to reach water-linked hinterland regions. The increasing use of intermodal transport solutions is not only beneficial to the management of traffic flows in and around the ports. It also typically contributes to a reduction of transport-related emissions. A small number of recent terminal contracts includes modal split specifications, particularly in a container terminal context [10]. In about half of these cases, the contract elaborates on some technical specifications and compulsory investments to be done by the terminal operator in hinterland transport infrastructures on the terminal site. In only 21% of the cases, the modal split clauses explicitly impose a specific modal split on the terminal operator to be reached by a certain year (for example, 40% road, 40% barge and short-sea, and 20% rail by 2020). The modal split target is often formulated as a soft objective (an intention). Soft targets are, however, best kept outside the contractual setting, as they cannot be legally imposed on the terminal operator. The port authority can encourage terminal operators to reach the soft targets by positive pricing or awarding systems (the "carrot" approach). The setting of hard targets in the concession agreement implies a "stick" approach with binding clauses and enforcement (penalties in case of non-compliance). In following such a stick approach, port authorities often face the problem of posing credible threats [38]. For example, terminal operators confronted with "hard" modal split clauses will argue that the distribution of cargo over the various inland transport modes is largely affected by exogenous factors such as the supply chain practices of their customers, the pricing and quality of rail and barge services, and the infrastructure policy outside the port area (by government). This explains why the overall evaluation of the instrument is rated as medium. It also explains why modal split guarantees typically require the port authority to develop a range of supporting policies to facilitate the use of rail and barge (score "high" on criterion "demands on and resource requirements for PA"). The score on the criterion "equity and level playing field" is low. Modal split targets are typically included in the concession agreement of only the newest terminals; thus, the operators of the other older container terminals face less stringent conditions

when it comes to the environmental footprint of inland accessibility. Terminal operators can, however, positively influence the modal split on their terminal through pricing (for instance, a dwell-time fee system or pricing of moves to inland transport modes), actions to increase the transparency of information flows (which makes cargo bundling toward rail and barge easier), and extended gate solutions in the hinterland (see, e.g., [39,40]).

	Overall evaluation		Implementation			Contribution		Regulatory/enforcement aspects			
	Overall suitability in a concession context	Overall feasibility to implement	Phase in concession process (*)	Port-wide standard or case-by-case (per concession)	Hard target or soft target	Expected contribution to meeting environmental goals PA	Expected contribution to innovation by TO or its suppliers	Legal certainty/enforcement Measurement standards	Likeliness that instrument is within regulatory jurisdiction of PA	Equity and 'level playing field' among TOs	Demands on and resource requirements for PA
INSTRUMENTS THAT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS (single-source)											
Harm-based standards (possible combined with penalty pricing)											
Cap on total CO2 emission of terminal	medium	medium	1, 3, 4	case	hard	high	medium	medium	low	medium	medium
Cap on energy use of terminal	medium	medium	1, 3, 4	case	hard	high	high	high	low	high	medium
Maximum noise levels (in decibel)	high (*)	high (*)	1, 3, 4	port	hard	high	medium	high	low	high	low
Modal split targets (hinterland transport)	medium	medium	1, 3, 4	case	hard/soft	medium	medium	medium	high	low	high
Modal split targets (mobility of personnel)	high	medium	1, 3, 4	case	hard/soft	medium	medium	medium	medium	medium	medium
Maximum height restrictions (visual intrusion)	high (*)	high (*)	1, 4	port	hard	low	low	high	low	high	low
Color scheme cranes, equipment, warehouses (visual intrusion)	high	high	1, 4	case	hard	medium	low	high	low	medium	low
Design standards											
Targets for dewatering and water treatment facility	high	high	1, 4	port	hard	high	medium	medium	low	medium	medium
Targets with respect to green buffers around terminal	high	medium	1, 4	case	hard	medium	low	medium	medium	medium	high
Technology specifications											
Compulsory use of electric/hybrid yard equipment / coldironing for ships	high	medium	1, 4	case	hard	high	high	high	high	low	medium
Compulsory use of sprinkler system (dust emissions dry bulk)	high	high (*)	1, 4	case	hard	high	low	high	high	high	low
Insulation technology for coldstore (warehousing)	high	high (*)	1, 4	case	hard	medium	medium	high	high	medium	low
Compulsory use of noise reduction technology	high	high (*)	1, 4	case	hard	medium	medium	high	high	medium	low
Bans and limitations											
Restriction on operations during specific periods of the day/week	medium	high	1, 4	case	hard	high	medium	medium	high	medium	high
Ban on 'dirty' trucks (cf. 'clean truck program' LA)	low (*)	medium	1, 4	port	hard	medium	medium	medium	medium	high	medium
Ban on or limited use of fossil fuels to power equipment	medium	medium	1, 4	case	hard/soft	high	high	medium	high	medium	high
INSTRUMENTS THAT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS (multi-source)											
Integrated permitting											
Environmental performance criteria or an environmental track record as part of pre-qualification and/or selection stage	high	high	2	case	hard	medium	low	medium	high	high	low
Tradeable emissions											
Emission trading given an aggregate cap on emissions	low	low	-	port	hard	-	-	high	low	medium	low
Challenge regulations											
TOs are responsible to design & implement a program to achieve imposed target.	medium	medium (*)	1, 3, 4	port	hard	high	high	high	medium	medium	low
INSTRUMENTS THAT DO NOT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS											
Pollution charges	low	low	1, 4	port	-	medium	medium	medium	medium	high	high
Liability	low	low	1, 4	port	-	medium	medium	medium	low	medium	low
Information reporting	high	high	1, 4	port	-	low	low	high	high	medium	low
Subsidies/discounts	high (*)	medium (*)	1, 4	port	-	medium	medium	medium	high	medium	high
Technical assistance	medium	medium	4	port	-	low	medium	low	high	medium	high

(*) 1 = pre-bidding phase, 2 = pre-qualification, 3 = selection, 4 = post-bidding phase

Figure 2. Evaluation of the instruments potentially available to port authorities to reduce environmental impacts of terminals. Note: (*) In this case, one or two of the six workshop participants did not align with the overall score given, leaving 4 to 5 supporting the overall score. Source: authors' compilation.

5.2. Design Standards and Technology Specifications

Targets for dewatering and water treatment facilities and targets with respect to green buffers around terminals have a high-to-medium suitability and implementation potential in a concession setting. The same applies to technology specifications such as the compulsory use of electric/hybrid yard equipment, cold ironing for ships, etc. However, in quite a few cases, a number of workshop participants raised questions on the overall feasibility to implement these instruments as the concessionaire/terminal operator typically has a better knowledge on the state of technology in this area than the port authority. This information asymmetry can make a less informed port authority enforce specific technological solutions which are either not state-of-the-art, or alternatively, too advanced. All these instruments are associated with hard targets if included in the concession agreements. Measures related to technology specifications have a high likeliness to be within the

jurisdiction of the port authority and are not expected to generate issues when it comes to guaranteeing legal certainty. They have a mixed impact on the level playing field among terminal operators: the compulsory use of electric/hybrid yard equipment and cold ironing for ships might lead to significant capital investments in newer terminals which are not faced by older terminals.

5.3. Bans and Limitations

Measures that imply a ban or limitation can come in varying forms: compulsory limitation of the operating hours during specific periods of the day/week, a ban on certain type of vehicles from entering the port (e.g., on trucks that do not meet minimum emission standards), or a ban on or limited use of fossil fuels to power equipment. The overall suitability of these instruments in a concession context is considered to be medium or low. There was a general feeling among the workshop participants that these policy measures have an added value, but deserve to be implemented outside of a concession context as a part of a more general environmental strategy of the port authority or any other relevant public authority.

5.4. Integrated Permitting

Integrating permitting is a multi-source instrument that potentially directly limits environmental impacts. It is worth considering the inclusion of environmental performance criteria or an environmental track record as part of the pre-qualification and/or selection stage. The workshop participants unanimously rated such a measure as high, both in terms of suitability and feasibility for implementation. The associated costs to the port authority are low. Moreover, it provides an additional objective element to qualify and select candidates for a terminal concession. The inclusion of such a criterion in the qualification or selection stage of the awarding procedure does not, in itself, directly enhance innovation. Instead, it gives companies with a strong environmental record (partly as a result of past innovation efforts) bonus points in the qualification and selection process. By eventually selecting terminal operators with a strong environmental record, additional "green" knowledge and know-how is brought to the port which can influence the innovation potential in the wider port cluster through knowledge transfer and spill-over effects.

5.5. Tradable Emissions

A tradable emission scheme as a market-based measure could also be a policy instrument deployed by a port authority. In such an approach, an upper limit/aggregate cap of emissions generated by terminal operations should be set by the port authority or the concerned public authority. Allocation of emission allowance to individual actors, including terminal operators, could be done by auctioning. Then, individual actors who actually generate a lower level of emission than the allocated emission allowance can sell their excess emission allowance to other companies who would need to purchase more emission permits [41,42]. This emission trading scheme is also called a cap-and-trade system. The port authority is expected to be a central administration party to establish the details of tradable emissions. A key point is having an emission monitoring system that is both robust and feasible.

The experts participating at the workshop indicated that the overall suitability and feasibility of implementing emission trading within a terminal concession would be low and, if implemented, should, therefore, be best kept outside the concession policy of a port authority. Emission trading is not considered as very relevant in a concession context given that a port typically is subject to a broader (national) trading system, if applicable. The discussion on the desirability of a port-wide tradable emission scheme falls outside the scope of this paper.

5.6. Challenge Regulations

A port authority or relevant public authority could opt to impose a specific target on the terminal operator, e.g., a cap on CO_2 or energy use as presented in the harm-based standards category of

instruments. The multi-source nature of this approach lies in the responsibility of the terminal operator to design and implement a program to achieve the imposed target(s). Therefore, the terminal operator is left with a lot of freedom to decide on how to reach the targets and can communicate and discuss with the port authority about the details of the program they would like to implement. Such an approach encourages the terminal operator to embrace innovation and to meet the environmental objectives of the port authority, while the regulation costs for the port authority are expected to be small. The workshop revealed that such arrangements would not necessarily be made in the framework of concession procedures (i.e., diverging views particularly at the level of the feasibility to implement) and would most likely not be integrated as a hard target in the concession contract.

5.7. Instruments that Do Not Directly Limit Environmental Impacts

We consider four types of instruments that do not directly limit environmental impacts, but can contribute to a change in the terminal operator's behavior regarding environmental impacts: pollution charges, liability, subsidies/discounts, and technical assistance. When opting for pollution charges, the port authority or any other relevant public entity makes the terminal operator pay a fixed amount for each unit of pollution (no ceiling). Under the liability approach, the terminal operator has to financially compensate in a direct way those that are harmed by the caused environmental impacts. Both pollution charges and liability are inspired by the "polluter pays" principle which is aimed at making the party responsible for producing pollution responsible for paying for the damage done to the natural environment. Overall, pollution charges and liability are expected to have a low suitability and a low feasibility for implementation in a concession context. These two instruments are considered more appropriate as part of a broader environmental policy for the entire port (thus, not limited to terminal operators only) or even the wider industry in a (port) region.

A second instrument belonging to this group is information reporting, whereby the terminal operator is requested to provide information on the environmental impacts of its terminal activities. Such information can be extracted from a company-based environmental management and reporting system. The port authority or other relevant authority might use some of the provided data to support sustainability reporting at the level of the entire port. The workshop participants argued that the compulsory reporting of information concerning environmental impacts can easily be included in concession contracts, although its overall impact on enhancing environmental performance and innovation is expected to be rather limited.

Subsidies and discounts form a third instrument that could indirectly help limit environmental impacts of terminal operations. Forms of financial assistance or discounts to terminal operators can serve as an incentive/carrot to change their behavior, or to help defray costs of mandatory standards. When drafting terminal concessions procedures and contracts, port authorities could consider carrots (discounts) in case the terminal operator would reach certain environmental targets. Hence, instead of a penalty for under-performance, a port authority might opt for a bonus in the case of over-performance. Inclusion of such a bonus system in the concession agreement could provide more legal certainty and an additional stimulus to the terminal operator. The rate incentive can be structured as a discount, for instance, a certain percentage on the annual concession fee. However, bonuses tend to be unsustainable in the longer term because of the effect that repeating over-performance automatically develops into new perceived service standards. Alternatively, port authorities or other public entities could support certain investments that support the use of green technology or green energy on the terminal. They can also provide a financial incentive for terminal operators' investments or programs that facilitate the use of barges, rail, or clean trucks in view of reaching a greener modal split.

A last instrument typically at the disposal of port authorities is the provision of technical assistance. Port authorities can share and support knowledge with terminal operators in many ways: the distribution of a good practice guide, the organization of training sessions, the use of information centers, the initiation and facilitation of workshops and working groups aimed at the exchange of knowledge and experiences between companies, the co-organization of international

conferences and seminars, etc. The provision of technical assistance does not necessarily have to be part of the concession setting. It is considered as one of the basic tasks of a landlord port authority. The port authority is often only one of the many sources terminal operators can consult for technical assistance in view of improving their environmental knowledge and performance. Other sources include reports published, events organized and training provided by industry organizations, supranational, national, and regional public entities, specialized consultants and knowledge developers, etc.

Figure 3 graphically presents some of the dimensions used during the evaluation of the instruments. The vertical axis shows possible combinations of scores for the overall suitability and feasibility of the instrument in a concession context. The horizontal axis combines the scores of the expected contributions of the instrument in reaching environmental targets and stimulating innovation. The measures and instruments listed in the 16 cells at the top left are the most interesting ones to be considered in a concession setting based on the workshop results: they combine a high or medium overall evaluation with a high or medium contribution. Obviously, the other dimensions, i.e., the implementation and regulatory/enforcement aspects, also need to be taken into account when considering the application of a specific instrument/tool to a real-life terminal concession case.

Expected contribution to reaching environmental objectives / *expected contribution to innovation by terminal operator or its suppliers*

Suitability in concession context/ *feasability to implement in concession context*	**High**/*High*	**High**/*Medium*	**Medium**/*High*	**Medium**/*Medium*	**High**/*Low*	**Low**/*High*	**Medium**/*Low*	**Low**/*Medium*	**Low**/*Low*
High/*High*		Max noise levels (1) Water treatment (2)		Insulation coldstore (3) Noise reduction techno. (3)	Sprinkler for bulk (3)		Color scheme (1) Integrated permitting		Max height (1) Information reporting (5)
High/*Medium*	Electric/hybrid equipment (3) Cold-irnoning (3)			Modal split personnel (1) Subsidies/discounts (5)			Green buffers (2)		
Medium/*High*		Operating hours (4)							
Medium/*Medium*	Cap on energy use (1) Use of fossil fuels (4) Challenge regulations	Cap on CO2 (1)		Modal split freight (1)				Technical assistance (5)	
High/*Low*									
Low/*High*									
Medium/*Low*									
Low/*Medium*				Clean trucks (4)					
Low/*Low*				Pollution charges (5) Liability (5)					

Figure 3. Comparison of results based on criteria groups "overall evaluation" and "contribution". Source: authors' compilation.

6. Conclusions

This paper started from the notion that a well-designed concession policy should also incorporate green port management targets. We analyzed which instruments port authorities can use in terminal concession policy to contribute to a positive virtuous cycle that leads to a stronger consideration of the PA's environmental objectives by terminal operators and to a further greening of port management. This study relied on the classification of instruments as presented by Office of Technology Assessment (1995). While we consider this classification to provide a good and valid base for evaluating instruments in a concession context, newer and more behavioral insights on instruments potentially available to reduce environmental impacts could also be used to explore a further greening of port concessions. The results show that a variety of regulatory, investment, and pricing measures are available to port authorities to include green targets in terminal concession procedures and agreements. Environmental factors are not yet widespread as criteria in bidding procedures. Port authorities should (continue to) have the possibility to work out terminal awarding procedures taking into account environmental objectives and the need for a sustainable and highly competitive port context. The results in this paper are based on the views of four large European ports which adopt a leadership role in the greening of port management. It is demonstrated that not all instruments have the same likeliness of being embraced or implemented by port authorities, in part because of a low perceived contribution, high associated regulation costs, or simply because the port authority is unlikely to have jurisdiction in that specific area.

The results of the study point to some low-hanging fruits in this regard. Measures related to information reporting and some types of harm-based standards, design standards, and technology specifications are relatively easy to implement in a concession setting. Moreover, the associated

regulation costs for the port authority are expected to be low. A stronger integration of these measures in a concession context is recommendable, even though not all these measures might reap high impacts in terms of innovation potential or expected contribution to the environmental objectives of the port authority (see Figure 3). Many of the measures with a higher expected contribution to innovation and environmental objectives are typically also the ones with higher regulation costs, which might post a higher complexity in terms of their implementation in a concession setting.

While each port is unique, there is some scope for joint action and convergence among seaports with respect to these aspects. Port authorities and terminal operators are only able to fully benefit from initiatives toward the greening of concession procedures if these actions are embedded in a chain approach toward the environment (ship, port, terminal, warehouse, and inland transport). Green concession agreements miss their effect when treated in isolation. Any green concession policy should give incentives to firms to integrate environmental issues into their management practices, while avoiding making terminal operators victim of any unfair or ineffective green policies. Eventually, such an approach will benefit both the port authority and the terminal operating companies.

The research contributes to the literature and industry practice by developing a typology of green instruments applicable to a seaport terminal concession setting. The overall feasibility and suitability of these green instruments in a concession context was evaluated. However, there is a limitation that no weights were assigned in the evaluation matrix. Yet, as a paper to propose a typology, the research objective has been met. Also, a generic approach without providing weights would lead to wider applications of the typology as port case studies in future research. For instance, weights can be assigned based on the environmental objectives of a specific port authority. Another limitation is linked to the sample of ports included in the workshop setting. The four ports considered are large ports managed by Hanseatic, and thus, rather autonomous landlord port authorities. They are considered as leading European ports when it comes to environmental management. The nature of these port authorities and their current track records in green policy imply the results of this study should be considered as relating to environment-focused, autonomous, and forward-looking ports. Port authorities with far less autonomy or weak environmental ambitions would most probably see a lower feasibility and suitability of green instruments in a concession context. Further research can shed light on the impact of port governance arrangements on the advances in green port policy and land management strategies. In sum, the green instruments would create avenues for further research in terminal concessions and port sustainable development with applications to a wider sample of ports in terms of geography, port governance, and port size.

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