



The role of port authorities in the development of LNG bunkering facilities in North European ports

Siyuan Wang · Theo Notteboom

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Abstract Liquefied natural gas (LNG) serves as an attractive fuel for ships to meet the upcoming stringent environmental regulations enacted by IMO, particularly at the level of emission control areas (ECA). The use of LNG promises a good environmental performance and a foreseeable economic viability. However, a general absence of bunkering infrastructure in seaports is a significant barrier currently preventing the breakthrough of the use of LNG as a ship fuel. Against this backdrop, we observe that public port authorities are playing a proactive role in facilitating the use of LNG as a marine fuel. The purpose of this paper was to analyze the role of port authorities in the development of LNG bunkering facilities and to investigate why and how port authorities promote this new application. A multiple-case study approach is adopted to examine the performance of eight North European port authorities in their LNG bunkering projects. The paper provides a deeper understanding of the current port practices in developing LNG bunkering facilities in North Europe and identifies the important role of the evolving port function beyond the tradition model in promoting innovations. The paper also proposes a set of port implementation policies on the facilitation and promotion of the use of LNG as a ship fuel.

Keywords Port authorities · LNG · Bunkering facilities · Multiple-case study · North Europe

S. Wang · T. Notteboom (✉)
Institute of Transport and Maritime Management Antwerp (ITMMA), University of Antwerp, Kipdorp
59, 2000 Antwerp, Belgium
e-mail: theo.notteboom@gmail.com

S. Wang
e-mail: siyuan.wang@uantwerpen.be

T. Notteboom
Transportation Management College, Dalian Maritime University, 1 Linghai Road, Dalian 116026
Liaoning, China

1 Introduction

Shipping activities and associated port operations create negative impacts on the environment especially in port areas which are usually situated within or in close proximity to urban areas. Examples of these impacts are air emissions (mainly CO₂, NO_x, SO_x, and particulate matter (PM)) from the ship's main and auxiliary engines, noise caused by cargo-loading facilities, and dust from the handling of substances such as grain, sand, and coal. At an international level, IMO has set stricter regulations under MARPOL Annex VI to reduce SO_x, NO_x and PM emissions from sea-going vessels, particularly in emission control areas (ECA). Facing the upcoming stringent environmental standards, ship operators have to look for innovative compliant solutions which could promise a good environmental performance as well as a foreseeable economic viability. Using low sulfur fuels, operating scrubbers or switching to liquefied natural gas (LNG) are the most feasible options at present. LNG is a strong option from an economic and environmental performance standpoint. LNG is a natural gas which becomes liquid at a temperature of -160 °C. Liquefied gas occupies a volume corresponding to 1/600 of the product in the gaseous state, which makes it space efficient to be stored as a bunker onboard ships. Compared to conventional ship fuels, LNG as a clean energy can reduce NO_x by up to 85–90 %, SO_x and PM by close to 100 %, and CO₂ by 15–20 % (Pitt 2010). However, as a new emerging technology, the use of LNG as a ship fuel faces several key challenges which might prevent the breakthrough of this application. According to Wang and Notteboom (2013), the current lack of LNG bunkering infrastructure and operational standards together with the intensive capital cost and the associated investment risks deter shipowners, bunkering operators, and facility investors to step forward and adopt this clean and innovative solution. The “chicken-and-egg” problem represents the current market dilemma where bunker suppliers and shipowners both follow a “wait and see” approach expecting the other party to take the initiative.

The role of government and public authorities in initiating and enhancing the large-scale adoption of new technologies, and thus breaking the market-based chicken-and-egg dilemma, is a common theme in scientific research. For example, the academic literature includes studies on the effects of government programs for renewable energy (Loiter and Norberg-Bohm 1999; Åstrand and Neij 2006) and for clean energy vehicles, like electric cars, methanol-fueled vehicles, and compressed natural gas (CNG) vehicles (Cowan and Hulten 1996; Chan and Chau 1997; Åhman 2006). Along these lines, some public authorities, like national governments or supranational bodies (e.g., EU), have started to promote the use of LNG as a ship fuel by establishing harmonized bunkering regulations/standards and financial support schemes. Moreover, we observe that public port authorities have found their responsibility to develop LNG bunkering facilities in their respective port areas. We will demonstrate that they are currently adopting a proactive role in facilitating this new application in the shipping industry.

The purpose of this paper was to explore the role of port authorities in the development of LNG bunkering facilities and to investigate why and how port authorities play a proactive role in promoting this new application. We adopt a multiple-case study approach to examine the performance and involvement of eight North European public port authorities in their LNG bunkering projects. These ports, all located in the

North Sea or Baltic Sea ECA, share a great ambition for the use of this clean fuel option due to a big pressure of the forthcoming strict ECA emission standards. The case study data for these ports are collected from two sources. The first group includes port documents such as annual reports, business plan, and archival records. The second source relies on structured interviews with senior port representatives who are in charge of the respective LNG bunkering projects in these eight ports. The paper not only provides a deeper understanding of the current development status of LNG bunkering in these eight European ports but also emphasizes that a proactive role beyond the traditional landlord model which port authorities intend to play could effectively facilitate and promote innovative technologies, like LNG. In addition, the paper also proposes a set of port implementation policies on the facilitation and promotion of the maritime use of LNG.

The paper is structured as follows: section 2 firstly presents the theoretical foundation which leads port authorities to play a proactive role in promoting the maritime use of LNG, and then identifies the research questions and outlines research design which follows a rigorous methodological path for conducting a multiple-case study. Section 3 presents an extensive cross-case study to investigate how eight North European port authorities are presently developing LNG bunkering infrastructure and also conducts a discussion on the role of the evolving port function beyond the traditional model in promoting innovations. Section 4 draws conclusions and identifies the implications for managerial practice and the contribution to scholarly knowledge and finally discusses the research limitations.

2 Methodology

2.1 Theoretical foundation on the role of port authorities in the development of LNG as a ship fuel

Why should port authorities play a proactive role in developing green innovative technologies? In this section, we present and discuss three theory-based reasons. First, the innovative technology enables ports to achieve “green and sustainable” objectives. Secondly, port authorities play an important role in their respective regional innovation system (RIS) in view of establishing social collaboration and knowledge creation and therefore to promote innovation. Finally, port authorities typically seek for meaningful extensions of their function beyond the traditional model. Promoting innovations in the port community adds to the facilitating and coordinating role of port authorities. The three theoretical bases not only provide an in-depth explanation on the concerned question but also suggest a practice guideline on how port authorities should play a proactive role in the development of LNG as a marine fuel.

2.1.1 *Green and sustainable port strategy*

Over the last decades, port authorities, as public managing bodies of the port, have been subject to port reform through privatization and corporatization schemes (Notteboom and Winkelmanns 2002; Goss 1990; Baird 2000). These port reform processes typically serve as an answer to the call for better port performance and competitiveness, e.g.,

maximizing land use and infrastructure, increasing cargo throughput and value-added creation, reducing operation cost, and strengthening hinterland connections (Kim et al. 2013). However, a new stream of port strategies has emerged aiming at enhancing the relationship with the local community by focusing on social and environmental aspects. Corporate social responsibility (CSR) in ports has drawn a lot of attention in recent years. CSR has become an integral part of port strategy definition (Dooms and Verbeke 2007; Adams et al. 2010). In addition, pursuing a sustainable development incorporating economic, social, and environmental concerns has become a key theme of contemporary port strategy (Cheon and Deakin 2010; Adams et al. 2010; Lam and Van de Voorde 2012). ESPO (2013) defined “port sustainability” as “business strategies and activities that meet the current and future needs of the port and its stakeholders, while protecting and sustaining human and natural resources.” Ports are thus challenged to simultaneously pursue economic prosperity, environmental quality, and social responsibility.

The environmental impact of port operations has attracted a rising concern due to the associated negative externalities for the local community. The motives for and drivers of environmental initiatives by ports emanate not only from the pressures of regulatory compliance and societal requirements but also from the objective of more efficient port operations and the creation of competitive advantages (Adams et al. 2010). The concept of “Green Port” emerged in line with an increasing awareness that a good environmental performance is a necessary requirement to maintain good relations with local communities as well as a source of competitive advantage (Denktas-Sakar and Karatas-Cetin 2012; Wiegmans and Geerlings 2010). According to Kim et al. (2013), a green and sustainable strategy improves port competitiveness. Moreover, any “green” strategy can be considered as an integral part of “agile” port strategies (Mangan et al. 2008; Marlow and Paixão-Casaca 2003) which requires the ability of the port to quickly adapt to and influence upcoming regulations and to respond rapidly to customer environmental demands. Therefore, the pursuit of a green and sustainable port strategy is seen as one of main ways to obtain port competitiveness, while innovative technology could provide an efficient solution to deal with some of the environmental issues faced by ports. A strong port strategy toward the promotion of innovation can contribute significantly to achieve this goal (Acciaro et al. 2013).

2.1.2 The role of port authorities in regional innovation system (RIS)

The concept of regional innovation system (RIS) was introduced in evolutionary economics. A RIS is a regional system “in which firms and other organizations are systematically engaged in interactive learning through an institutional milieu characterized by embeddedness” (Cooke et al. 1998) or “a system of innovative networks and institutions located within a certain geographic area, with regular and strong internal interacting that promotes the innovativeness of the region’s companies” (Kostiaainen 2002). Doloreux (2002) defines firms (economic agents/commercial organizations), institutions (governments, public authorities, etc.), knowledge infrastructure (e.g., science/technology parks, R&D institutions, etc.) and innovative policies as four main elements comprising a regional innovation system. Interactive and collective learning among various public and private actors is the key theme of RIS, since innovation results from a process of interactive learning (Harmaakorpi 2006). It is noted that public

authorities are crucial players who shape the environment in a way that both stimulates technical innovation and provides the normative structure (laws, rules, or standards) that promotes the stable social interactions necessary for the performance of a RIS (Doloreux 2002). The involvement of public sectors in the process of innovation could be called for in all development phases (e.g., R&D, field tests, demonstration, market introduction, and diffusion), including the funding of R&D, financial support for gaining experience and increasing the scale of production, dissemination of information, building of industrial networks, and creating standards (Åhman 2006; Freeman 1994). Innovative policy formulated by governments or other public authorities plays a crucial role in improving interactive learning and knowledge share between firms, institutions, and knowledge infrastructure in RIS (Hassink 1993).

The contribution of a port as public infrastructure to regional economic development is well recognized due to its ability to facilitate trade and maritime economic activities, generate employment, and attract investment (De Langen 2004; Bryan et al. 2006). In addition, port regionalization processes (Notteboom and Rodrigue 2005) have brought port development to a higher geographical scale, thereby increasing the functional role of the broader port area in regional development. The port authority, mostly a public managing body of the port, should be considered as a key player in its regional innovation system and in exploiting regional business opportunities through the development of an innovation network (Cahoon et al. 2013). To be a successful network leader in RIS, the port authority should be a proactive coordinating or facilitating player by establishing industrial networks, enhancing social collaboration, and improving interactive learning effects between various industry players (Chen et al. 2010).

2.1.3 The evolving function of port authority

Public port authorities traditionally can assume three typical functions, that of landlord, regulator, and operator (Baird 1995; Baltazar and Brooks 2001; De Monie 2004; Verhoeven 2010). The landlord and regulator function have become the two main functions corresponding to the general definition of the traditional “landlord port model.” In this model, the operation function in terms of cargo handling has largely been transferred to private operators (Verhoeven 2010). The “landlord model,” which has been adopted as the principal function of contemporary port authorities (Notteboom and Winkelmanns 2001a, b; Doods and Verbeke 2007), assumes a strong role of the port authority in the management, maintenance, and development of the port area, the provision of infrastructure and facilities, as well as the conception and implementation of policies and development strategies linked to the exploitation of the port area (Baird 2000; Baltazar and Brooks 2001; Van Hooydonk 2003).

Traditional “landlord” ports are confronted with an ever-changing socioeconomic environment where globalization and liberalization processes increased the power of private port actors (carriers, shippers, terminal operators, and logistics service providers). In this regard, some scholars propose a “renaissance” of the port authority (Notteboom and Winkelmanns 2001b; Verhoeven 2010), i.e., the port authority should play a more proactive role beyond the traditional function in facilitating and coordinating stakeholders in logistics networks and creating core competencies in the highly competitive market by even adopting a more entrepreneurial role (Chlomoudis et al. 2003; Comtois and Slack 2003; Notteboom and Winkelmanns 2002; Van Der Lugt and

De Langen 2007). De Langen (2004, 2007) makes a plea for a new functional role of port authorities as “cluster managers” or “community managers” to solve collective action problems in and outside the port perimeters, such as hinterland bottlenecks, training and education, ICT, marketing and promotion, as well as innovation and internationalization (economic dimension) (De Langen and Chouly 2004; Van Der Horst and De Langen 2007). Chlomoudis et al. (2003) refer to the community manager role of the port authority: “the systemic coordinator that advances and maintains good relationships with all port stakeholders, thus creating a port culture of trust.”

2.2 Research questions and case study method

The paper is mainly focused on two research questions: (1) why do port authorities play a proactive role in promoting and facilitating the use of LNG as a marine fuel? (2) How do port authorities encourage and facilitate the use of this new green technology?

According to Yin (2009), “the case study method is most likely to be appropriate for “why” and “how” research questions. The more these research questions seek to explain some present circumstances the more relevant becomes the case study method.” We adopt the case study approach to examine current port developments with respect to the use of LNG as a marine fuel. Also, the paper applies a multiple-case design (also considered “comparative studies” by Eckstein (1975)) in order to show compelling evidence making the overall study more robust (Herriott and Firestone 1983).

As Yin (2009) proposes, a multiple-case study requires five research steps: (1) the careful and thoughtful posing of research questions, (2) a thorough literature review on relevant theories or propositions, (3) the definition and selection of cases which best relate to the research questions and theories/propositions, (4) the collection and analysis of data as per each case and the completion of individual case report, and finally, (5) the presentation of cross-case conclusions and policy implications. In order to structure a good multiple-case study and to collect, present, and analyze data fairly, we strictly follow the above methodological path and present an explicit and transparent research process. The detailed research steps are illustrated in Fig. 1.

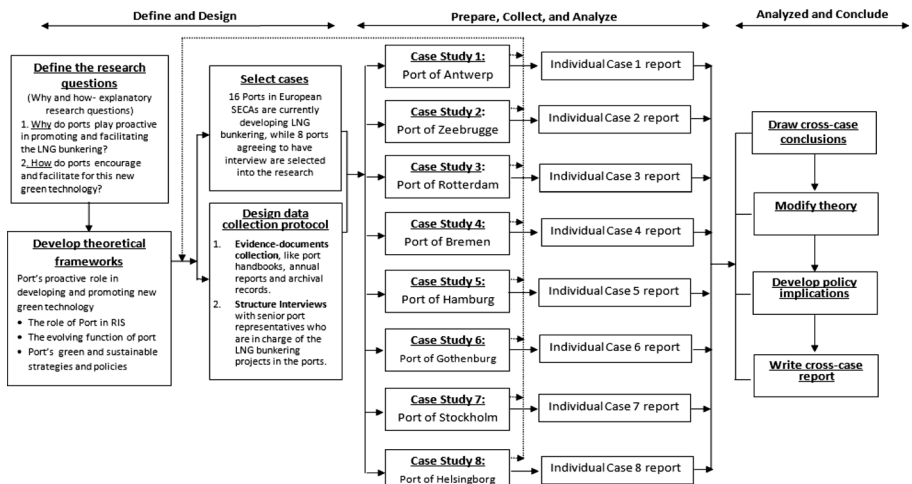


Fig. 1 Research design and methodology (multiple-case study). *Source:* own elaboration

After having defined the research questions, the next step is to look for theories or propositions which could explain why port authorities are playing or should play a proactive role in developing LNG bunkering facilities. Through an extensive literature review, we have established a theoretical foundation to support the explanation and also provide a first insight on how port authorities should develop LNG bunkering facilities. This part has been discussed in detail in the above section.

The third step is to select the most related cases. We target for the ports located within the two European ECAs (the Baltic Sea and the North Sea ECAs) since they are confronted with a high pressure to comply with the stringent emission standards in 2015. After a thorough search, there are 16 ports¹ identified in the area which are currently developing or planning to develop LNG bunkering facilities. In order to get more extensive evidence on the current level of involvement of port authorities in this new green application and to make the case study more robust, we sent interview invitations to the senior port representatives who are in charge of the respective LNG bunkering projects in these 16 ports. Eight port representatives from eight of the 16 ports agreed to participate in this study. Two ports declined the invitation to participate in the study since they had not yet developed solid plans for this new business by the time the invitations were sent (September, 2013). The rest of the five ports were finally not included in the study since we could not reach the corresponding representatives in these ports within the planned research schedule or the representatives stated they could not accept the invitation. Therefore, at last, there are eight ports selected into the case study: They are port of Antwerp (Belgium), port of Zeebrugge (Belgium), port of Rotterdam (The Netherlands), port of Bremen (Germany), port of Hamburg (Germany), port of Gothenburg (Sweden), port of Stockholm (Sweden), and port of Helsingborg (Sweden).

The fourth step includes the collection of data from the selected eight ports. The data mainly come from two sources: (1) documents like port handbooks, annual reports, and archival records and (2) information collected via structured interviews (either by face-to-face or telephone)² with the senior port representatives (see the list of interviewees in Appendix 1) who are in charge of the LNG bunkering projects. The first source of data mainly helped in collecting general information on the port, such as its geographic features, port size, institutional structure, and port environmental strategies and policies. The second type of information was collected using a questionnaire composed of questions dealing with port authorities' actions in developing and facilitating the use of LNG as a ship fuel in line with each port function (i.e., landlord, "regulator," "operator," and "community manager") identified by the literature (discussed in section 2.1.3). Each question can be regarded as a unit of analysis, and the data was collected to create individual case reports for each port authority. After completing the eight individual port reports, an extensive cross-case study among the eight ports was conducted by analyzing and comparing the collected

¹ Port of Aarhus, Port of Amsterdam, Port of Antwerp, Port of Bremen, Port of Copenhagen Malmö, Port of Dover, Port of Dunkirk, Port of Gothenburg, Port of Hamburg, Port of Helsinki, Port of Helsingborg, Port of Le Havre, Port of Rotterdam, Port of Stockholm, Port of Tallinn, and Port of Zeebrugge.

² Port of Antwerp (face-to-face interview), Port of Zeebrugge (face-to-face interview), Port of Rotterdam (telephone interview), Port of Bremen (telephone interview), Port of Hamburg (face-to-face interview), Port of Gothenburg (telephone interview), Port of Stockholm (telephone interview), and Port of Helsingborg (telephone interview).

data guided by each of unit of analysis. Section 4 presents the cross-case study in detail. The last step is to draw cross-case conclusions, to confront these conclusions with the first insights derived from theories in section 3, and to develop port implementation policies on the development of LNG as a ship fuel.

2.3 The role of port authorities in the development of LNG as a ship fuel: a first assessment

Given the above theoretical context, the reasons for port authorities to play a proactive role in the promotion of the use of LNG as a ship fuel can be summarized as follows:

- To achieve green and sustainable objectives, port authorities not only need to take a responsibility to quickly adapt to the upcoming strict emission regulations but also need to respond to the environmental needs of the port users. The promotion of LNG as a ship fuel can nicely fit in this perspective.
- Port authorities can take up the role of coordinators or facilitators in the development of a regional innovation system in view of exploiting regional business opportunities by developing an innovation network. The development of LNG as an innovative way to deal with the environmental issue could add value to this role.
- Port authorities are more and more evolving from passive landlords and “regulators” to proactive community managers. The LNG discussion offers port authorities a window of opportunity to give an additional content to their emerging role as community managers.

The literature also provides some suggestions and practical guidance on how port authorities should promote and facilitate the use of LNG as a marine fuel. Considering the current challenges faced by this new application as identified by Wang and Notteboom (2013), Table 1 provides a first assessment of possible avenues ports can follow in view of enhancing and facilitating the maritime use of LNG (see Table 1):

- First of all, port authorities could assist in realizing some basic but essential steps to make LNG bunkering feasible, including investments in LNG bunkering infrastructure (e.g., land, jetty and maritime access, etc.), the assessment of the safety risks of the use of LNG in the port environment, and the development of a set of bunkering standards and guidelines.
- Second, to solve the current chicken-and-egg market dilemma, port authorities could take initiatives to establish social collaboration and improve interactive learning with other stakeholders, such as bunkering operators, shipowners, and asset investors, to develop a financially viable business plan for building an LNG bunkering supply network.
- Third, port authorities could develop a favorable innovation policy or tool to promote the maritime use of LNG. For instance, they could launch a pilot project to gain first experience, establish financial support schemes, and/or facilitate market introduction and knowledge diffusion.

Table 1 The challenges of the use of LNG as a ship fuel and responsible parties

	Challenges	Explanation	Responsible Parties
Availability of regulatory framework	<p>Lack of regulations for gas-fueled ships</p> <p>Lack of LNG bunkering operation standards</p>	<p>Lack of international regulations or standards for design and construction of gas-fueled ships</p> <p>Standards (would be international level or regional/local level) for bunkering procedure, training, and equipment necessary to ensure safe LNG bunkering operations for gas-fueled ships via bunker vessels, trucks, onshore installations, and portable tanks</p>	<p>IMO, or other international maritime regulatory bodies (e.g., ISO and classification societies)</p> <p>International level: International maritime regulatory bodies, e.g., IMO, ISO, or other international relevant communities, e.g., SIGTTO, OCIMF, IAPH (or WPCI)</p> <p>Regional/local level: local government and <i>port authority</i></p>
Economic viability	High capital cost	Price of LNG-fueled ship is 20–25 % higher compared to an oil equivalent vessel	Naval architect, shipyard, technical tender (e.g., tank and engine manufacturer)
	Uncertainty of LNG price/LNG fuel price	Hard to accurately forecast LNG price and its associated delivery cost to ships which is included in the final LNG fuel price	Price is decide by market and delivery cost depends on bunkering facility and operation cost
Technological feasibility	Large LNG fuel tank	LNG cylindrical-shaped fuel tank is 3–4 times larger than the conventional oil system. The cargo space loss affects ship productivity and freight earnings	Technical tenders (e.g., tank and engine manufacturers)
	Retrofitting feasibility	More suitable for new-built ships. The possibility of conversion depends on case-by case study and also the retrofitting cost is higher	Naval architect, shipyard, technical tender (e.g., tank and engine manufacturer)
	Methane slip	Unburned methane (CH ₄) emitted from LNG engine (CH ₄ has higher global warming potential than CO ₂)	Technical tenders (e.g., tank and engine manufacturers)

Table 1 (continued)

Challenges	Explanation	Responsible Parties
Safety risks	No common safety risk assessment approaches and risk acceptance criteria for LNG-fueled ships and bunkering procedures	Safety risks for LNG-fueled ships: IMO, ISO, classification societies, and other responsible parties. Safety risks for LNG bunkering (hazard zone study, risk assessment): Government, maritime authority, <i>port authority</i> , etc.
Infrastructure availability	Lack of bunkering infrastructure and facilities	Bunkering infrastructure (maritime access, quay wall, jetty, and land): <i>port authority</i> Bunkering facilities: gas suppliers, bunker operators
Lack of supply chain and distribution network	No established distribution network (e.g., LNG feeder vessels or trucks) to delivery LNG to ships	Gas suppliers, bunker operators, logistic service providers (e.g., gas shipping/transport companies) and <i>port authority</i> (if applicable)
Public incentives	No well-established public incentives for this new application (subsidy, funding or taxation regime, etc.)	EU, national/local government, <i>port authority</i>
Public perception	Negative public perception of the use of LNG as a ship fuel. "Gas acceptance" by general public has not been established yet, especially for neighbors around bunkering areas	EU, national/local government, <i>port authority</i>

Source: Own elaboration based on Wang and Notteboom (2013)

- Lastly, port authorities could act as proactive community managers by sharing knowledge and skills with stakeholders, by lobbying government in view of accelerating permitting processes, and by contributing to a positive public perception in the port community on the use of LNG as a ship fuel.

In section 3, we present the detailed empirical results of the multiple-case study on the eight North European ports to examine how these port authorities are currently developing LNG bunkering facilities. These results could modify the above initial assessment and should help in developing a set of port implementation policies on the promotion of LNG as a marine fuel in the shipping industry.

3 Findings and discussion

3.1 General information of the eight ports

The selected eight ports all share the traditional “Hanseatic” culture which features the municipal governance (Verhoeven 2010). Although the eight ports enjoy the same governance culture, they vary in port size, type, institutional structure, and environmental strategies. Table 2 provides a brief overview of the eight ports (see more detail in Appendix 2). Six of the eight port authorities are public limited companies. As a result of a port reform process involving deregulation, commercialization, or corporatization, they enjoy more autonomy on managerial and regulatory issues of port development. Bremen and Helsingborg have two entities in charge of port affairs: one is the public port authority which is a department of the municipal government, mainly responsible for administrative and regulatory matters; the other is a limited port management company fully owned by the city, taking charge of development, management, and maintenance of the port area and infrastructure. The environmental performance is a key element in the strategy of the sample ports. The concepts of green, “clean,” and “sustainable” are implemented in view of upgrading the port’s social responsibility as well as gaining competitive advantage. The environmental initiatives in the field of energy efficiency can be classified into four groups: (1) developing renewable energy, like wind, solar, and biomass; (2) using onshore electricity for ships at berth and operating electric cargo handling machinery and vehicles; (3) promoting an environmental-friendly modal split in hinterland distribution by promoting railway transport and inland shipping; and (4) providing clean fuel for ships, such as low-sulfur fuel oil and LNG, to reduce air emissions. All the eight ports are developing or planning to develop LNG bunkering facilities.

3.2 The development of LNG bunkering facilities

Through an extensive review of port documents, we find that these eight ports have different conditions to develop LNG bunkering facilities. It mainly depends on whether the port already had an LNG infrastructure. Table 3 briefly lists existing and planned LNG infrastructure in each port and also the owner/operator of such facilities and the choice of bunkering solutions (see more detail in Appendix 3). Three ports have

Table 2 General information of the eight European ports

Port size and type	Port authority (institutional structure)	Port environmental strategy	Energy efficiency and air emission initiatives
Port of Antwerp (Belgium) World-class gateway port	“Hanseatic” port: an autonomous company fully owned by city	Establishing sustainability strategy	Developing renewable energy onshore electricity power and clean fuel for ships (e.g., LNG)
Port of Zeebrugge Regional port	“Hanseatic” port: an autonomous company fully owned by city	Establishing sustainability and green initiatives	Developing renewable energy onshore electricity power and clean fuel for ships (e.g., LNG)
Port of Rotterdam (The Netherlands) World-class gateway port	“Hanseatic” port: an unlisted public limited company owned by city and Dutch State	Establishing sustainability strategy and pursuing Corporate Social Responsibility (CSR)	Developing renewable energy onshore electricity power and clean fuel for ships (e.g., LNG)
Port of Bremen (Germany) World-class gateway port	“Hanseatic” port: governed by a department of the local government and a port management company owned by city	Launching a campaign of “green” port	Developing renewable energy and clean fuel for ships (e.g., LNG)
Port of Hamburg (Germany) World-class gateway port	“Hanseatic” port: an autonomous company fully owned by city	Building a “green” port and an ECO-port	Promoting modal split, developing renewable energy, onshore electricity power, and clean fuel for ships (e.g., LNG)
Port of Stockholm (Germany) Regional port	“Hanseatic” port: an autonomous company fully owned by city	Establishing environmental and social responsibilities	Developing renewable energy onshore electricity power and clean fuel for ships (e.g., LNG)
Port of Gothenburg (Sweden) Regional port	“Hanseatic” port: an autonomous company fully-owned by city	Establishing environmental and social responsibilities	Developing renewable energy, onshore electricity power, and clean fuel for ships (e.g., LNG)
Port of Helsingborg (Sweden) Smaller regional port	“Hanseatic” port: governed by a department of the local government and a port management company owned by city	Improving “green” image	Developing renewable energy onshore electricity power, electric vehicle, and clean fuel for ships (e.g., LNG)

Source: own compilation

Table 3 The development of LNG bunkering facilities in eight ports

	The existing LNG infrastructure	The planned LNG bunkering facilities	LNG bunkering facility owner/operator	Bunkering solution
Port of Antwerp	No existing LNG infrastructure	Building a bunker ship for bunkering sea-going vessels	Have chosen the strategic partner through public selection procedure to build a bunker vessel	STS and TTS
Port of Zeebrugge	Having large-scale LNG infrastructure	Building the second jetty for break-bulk activity	The second jetty is invested by PA and the existing terminal operator. The bunkering facilities will be invested by private players	STS, TTS, and LNG portable tank
Port of Rotterdam	Having large-scale LNG infrastructure	Developing LNG break-bulk terminal, and building a bunkering station for inland ships	The break-bulk terminal is invested by PA and the existing terminal owners. The bunkering facilities will be invested by private players	STS, TTS, and terminal to ships
Port of Bremen	No existing LNG infrastructure	Building a small-scale LNG facilities for the use as fuel for ships and trucks	Port management company will cooperate with the selected strategic partner to invest bunkering infrastructure. PA will order a LNG-fueled port ship	TTS and terminal to ships
Port of Hamburg	No existing LNG infrastructure	Building a small- and medium-scale LNG facilities for the use as fuel for ships and trucks	PA will cooperate with the selected strategic partner to invest bunkering infrastructure. PA will order a LNG-fueled port ship	STS and TTS
Port of Stockholm	Having medium-scale LNG infrastructure	Building the second LNG infrastructure in another port area	PA will cooperate with the selected strategic partner to invest bunkering infrastructure	STS and TTS
Port of Gothenburg	No existing LNG infrastructure	Building a medium-scale LNG infrastructure for industrial and maritime use	PA established a strategic alliance with private players to develop LNG terminal	STS and TTS
Port of Helsingborg	No existing LNG infrastructure	Building a medium-scale LNG infrastructure both for land-base demand and maritime use	PA plans to cooperate with industrial players to develop LNG bunkering facilities	STS

Source: own compilation

STS ship to ship bunkering for seagoing vessels, TTS truck to ship (TTS) bunkering for inland ships, PA port authority

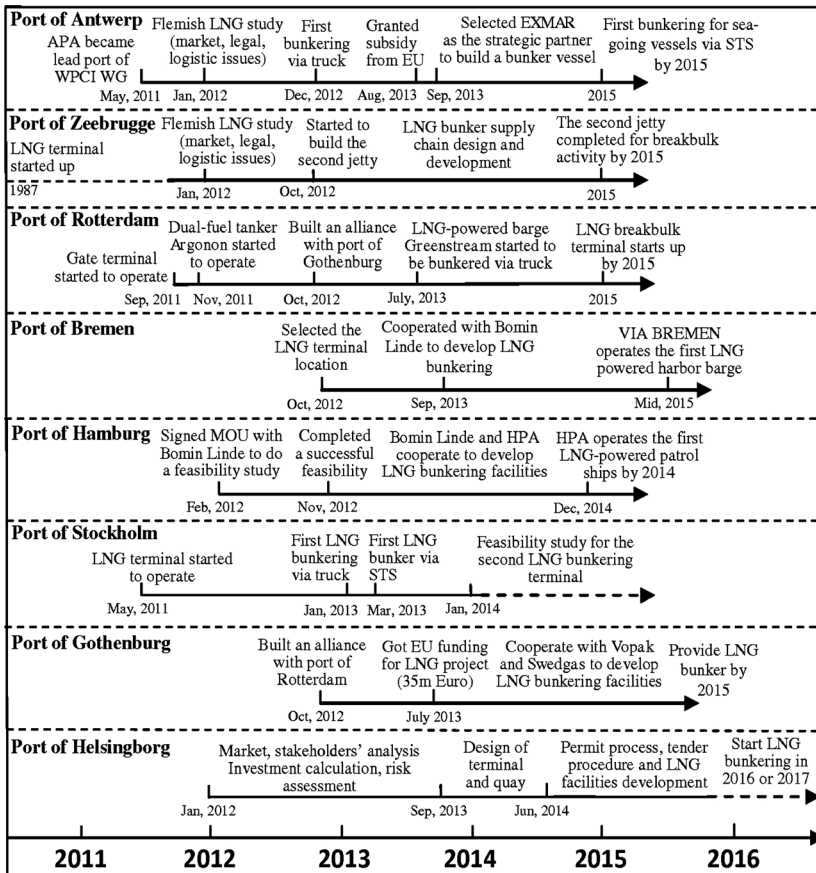
existing LNG infrastructure which could provide a favorable condition for them to develop LNG bunkering operations. The port of Zeebrugge developed one of the earliest LNG import terminal in Europe, while the LNG facilities in Rotterdam and Stockholm are rather new. The large-scale LNG terminals in Rotterdam and Zeebrugge were originally developed to satisfy land-based demand (e.g., power generation, industrial, and residential uses). From its inception, the medium-scale LNG infrastructure in Stockholm was aimed more toward LNG applications including the use of LNG as a transport fuel (i.e., for trucks and ships).

The ports of Zeebrugge and Rotterdam plan to establish LNG break-bulk activities which can not only deal with the LNG bunker demand in their own ports but could also turn the ports into hubs for LNG feeder distribution. The port of Stockholm is planning to build a second LNG terminal in another port area, thereby benefiting from the confidence and experience gained from the current LNG bunkering operations with Viking line.³ The other four ports (i.e., Hamburg, Bremen, Gothenburg, and Helsingborg) are planning to construct their first LNG storage facilities for maritime use, while most of them have not yet reached final investment decisions. The port of Antwerp chooses a rather different avenue to start up LNG bunkering operations. In a first development stage, the Antwerp Port authority together with a strategic partner plans to order a bunker vessel instead of building onshore storage facilities, since LNG can be flexibly sourced from the nearby terminals in Zeebrugge and Rotterdam.

The eight ports each have their own development plans on LNG bunkering in line with different market expectations and operational conditions. However, given the capital intensive nature of LNG technology, they all opted for cooperation schemes as a way to share risks and gain confidence for market initiatives. The eight port authorities either have found or are looking for strategic partners to develop LNG bunkering facilities together. These strategic partners are mainly private industrial players, for instance, gas suppliers, bunkering operators, or gas shipping companies, who are the key investors and operators of the LNG bunker supply chain. In order to kick-start the market and solve the chicken-and-egg problem, Antwerp took the initiative to invest in a bunker vessel together with its strategic partner. Hamburg and Bremen are aiming to become the first users of LNG bunkering facilities by owning LNG-fueled port vessels.

With respect to the choice of bunkering solutions, most of the ports favor the options of ship to ship (STS) for sea-going vessels and truck to ship (TTS) for inland/small ships. Both the bunker volume and port turnaround time play a role in deciding which option is preferred from an operational point of view. TTS operations have already been successfully tested in Rotterdam and Antwerp, and Stockholm was the first to implement STS. The STS option is a key technology for allowing a large-scale use of LNG as a ship fuel. Most ports have set targets to provide the LNG bunker supply chain for sea-going vessels by 2015 (except for the port of Helsingborg). Figure 2 depicts the timeline of the development phases for the LNG projects in each of the eight ports. The projects move at a different pace and follow a different implementation plan. Still, they

³ Viking line is a Finnish passenger ferry line. It started to operate the first LNG-fuelled passenger ferry, *Viking Grace*, from January 2013. The ship currently sails between Stockholm and Helsinki on a daily service, and it is bunkered in the port of Stockholm every day via ship to ship.



Note: APA: Antwerp port authority.
 WPCI WG: World Port Climate Initiative (WPCI) working group for standardizing the port regulations governing LNG.
 VIA BREMEN: the brand name of port management company for port of Bremen
 MOU: Memorandum of understanding
 HPA: Hamburg port authority

Fig. 2 The timeline of LNG bunkering projects in the eight ports. Source: own compilation

share a common theme aimed at developing favorable policies and incentive schemes to achieve a successful promotion of LNG as a ship fuel. The next section explores such policies in great detail.

3.3 The role of port authorities in developing LNG bunkering

In this section, we seek to explore how the eight port authorities promote the use of LNG as a marine fuel and develop bunkering facilities in full length. The following cross-case analysis is guided by the four port functions listed earlier (i.e., landlord, regulator, operator, and community manager) and is mainly based on the data collected from the structured interviews with the senior port representatives who are in charge of the LNG project in their respective ports.

3.3.1 Landlord function

The typical landlord function of port authority in the development of LNG bunkering facilities refers to the provision of land for an LNG bunkering terminal, the construction of quay walls, jetties, or other possible basic infrastructure for maritime access, and the associated development policies. The interviews revealed that most port authorities go beyond the traditional landlord function by adopting “proactive” and “cooperative” policies to speed up the development progress of this new application. These policies relate to (1) a proactive coordinating role in conducting feasibility studies on LNG bunkering in cooperation with various stakeholders (i.e., local government, competent authorities, private actors, etc.), (2) the development of a comprehensive location selection policy, (3) the forging of strategic partnerships with private industrial players and even with other ports for developing LNG bunkering infrastructure, and (4) the adoption of incentive policies to attract investments.

Table 4 uses ticked boxes on a few parameters to show the main trends on how port authority enacts its landlord function to promote the LNG maritime use (see more detail in Appendix 4). All eight port authorities play a proactive coordinating role in performing feasibility studies on LNG bunkering (e.g., technical, regulatory, and market dimensions) together with various stakeholders in order to obtain confidence among market players to kick-start the business. The selection of a location for LNG infrastructure currently is a key problem faced by the ports. The LNG bunkering facilities would be better built close to the customers (e.g., shipping lines), while considering the safety issue of handling LNG as a dangerous cargo, some ports prohibit LNG operations in populated port area. Other ports are however up against the objections from the general public on the construction of LNG facilities near residential areas. Therefore, most of the eight ports together with their strategic partners intend to conduct comprehensive studies to choose the most favorable location for LNG infrastructure by taking into account all the safety, regulatory, social, and economic factors. Since the LNG technology is capital intensive with high risks involved, cooperation is an effective way to reduce/share the uncertainties over availability of infrastructure, LNG demand and price, etc. and to help break the chicken-and-egg market dilemma. The port authorities establish two types of strategic partnerships to promote the maritime use of LNG: The development of strategic alliances with other ports in the region (e.g., the strategic alliance between the ports of Rotterdam and Gothenburg) and even cross-region (e.g., the cooperation among ports of Antwerp, Zeebrugge, and Singapore) on developing LNG infrastructure and the associated safety and technical standards. The establishment of strategic partnerships with private actors, i.e., gas facility investors, terminal operators or gas suppliers, etc., for developing LNG onshore facilities and the bunker supply chain. The port authorities choose strategic partners either via public selection procedures or through private negotiation.

When it comes to investment policy, the port authorities under consideration normally only invest in the basic port infrastructure while superstructures onshore are funded and operated by private actors. However, in the LNG case, some port authorities take the initiative of investing in bunkering facilities with private partners. For example, the port of Antwerp plans to invest in a bunker vessel together with EXMAR.⁴ Also,

⁴ EXMAR: a Belgium gas shipping company.

Table 4 The policies behind the development of LNG infrastructure in the eight ports

	Establish a feasibility study on LNG		Location selection policy		Strategic partnership			Infrastructure investment policy		
	With strategic partner	With other authorities	Close to customer	Considering related factors, economical safety, legal, logistic, etc.	With private players	With other ports in the region	With ports in other regions	Establishing PPP	Applying EU funds	Investing LNG-fueled port vessel
Port of Antwerp	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Port of Zeebrugge	✓	✓		✓	✓		✓	✓	✓	
Port of Rotterdam	✓		✓	✓	✓			✓	✓	
Port of Bremen	✓			✓	✓					✓
Port of Hamburg	✓			✓	✓					✓
Port of Stockholm		✓	✓	✓	✓				✓	
Port of Gothenburg	✓			✓	✓				✓	
Port of Helsingborg		✓		✓	✓					✓

Source: own compilation

PPP public-private partnership

some port authorities are considering public-private partnerships (PPPs) as an alternative tool to promote investments in LNG facilities (e.g., the ports of Zeebrugge and Helsingborg). Quite a few ports proactively apply for EU funds together with private partners (e.g., ports of Rotterdam, Antwerp, and Gothenburg). Hamburg and Bremen plan to invest and operate LNG-powered port vessels by themselves in order to kick-start the market development.

3.3.2 Regulator function

The traditional regulator function of port authorities is to passively apply and enforce rules and regulations set by regulatory agencies. However, as the regulations on the use of LNG as a ship fuel are absent at this moment, the development of relevant rules and standards for such new application is key for the wide diffusion of the LNG technology. Table 5 summarizes the regulatory role of the eight ports in this matter. Port authorities mainly adopt a stronger regulatory role in the following ways:

- 1) By actively assisting regulatory authorities to enforce air emission standards. Some ports even set a monitoring and measuring system to enforce regulatory compliance, e.g., the upcoming IMO strict air emission limits in ECAs.
- 2) By proactively coordinating and facilitating the development of regulations on the maritime use of LNG and by setting corresponding port bylaws. The relevant regulations and rules on LNG are presently under development in most of the eight ports. The port of Rotterdam is the first port where the LNG bunkering to inland ships is legally regulated.
- 3) By developing an LNG bunkering checklist and by evaluating risk perimeters. Seven of the eight ports participate in World Ports Climate Initiative (WPCI) working group to jointly develop an LNG bunkering checklist for all possible bunkering solutions (e.g., ship to ship, truck to ship, etc.), to evaluate risk perimeters and to raise public awareness.
- 4) By setting a differential port tariff on ships fueled by LNG or other clean fuels. The eight ports all adopt a differential port tariff on clean ships. LNG as one of the clean fuels could help shipowners to save operating costs. Six ports of the sample adopted the Environmental Ship Index (ESI), while the ports of Stockholm and Helsingborg developed their own tariff system. Moreover, the port of Stockholm developed a specific incentive regime for ship conversion to LNG.

3.3.3 Operator function

Looking at the three traditional functions of port authorities, i.e., the landlord, regulator, and operator functions, it can be concluded from the literature that, as operators, port authorities gradually moved away from providing services of cargo handling, stevedoring and bunkering, etc. These have in most cases been

Table 5 The “Regulator” function in the development of LNG

	Port of Antwerp	Port of Zeebrugge	Port of Rotterdam	Port of Bremen	Port of Hamburg	Port of Stockholm	Port of Gothenburg	Port of Helsingborg
Actively assist regulatory authorities to enforce air emission standards	Yes	Yes	Yes (setting a monitoring and measuring system)	Yes	Yes (setting a monitoring and measuring system)	Yes	Yes (setting a monitoring and measuring system)	Yes
Proactively coordinate and facilitate the development of regulation on LNG as a ship fuel and set port bylaw on LNG maritime use	Yes (The regulation is under process)	Yes (The regulation is under process)	Yes (The regulation has been developed)	Yes (The regulation is under process)	Yes (established the specific permit for LNG)	Yes (The regulation has been developed)	Yes (The regulation is under process)	Yes (The regulation is under process)
Develop LNG bunkering checklist and evaluating risk perimeters	Ports of Antwerp (the chairing port), Zeebrugge, Rotterdam, Bremen, Hamburg, Stockholm, Gothenburg, and other five port participant in an “LNG Fuelled Vessel Working Group” which is established under the auspices of the International Association of Port and Harbours (IAPH)’s World Ports Climate Initiative (WPCI). The working group is tasked for developing guidelines on safe procedures for LNG bunkering operations (bunkering checklist), evaluating the bunkering risk perimeters, and raising public awareness							Bunkering checklist and risk perimeters are under process
Differential port tariff on ships powered by LNG or other clean fuels	Adopt ESI index	Adopt ESI index	Adopt ESI index and Green Award	Adopt ESI index	Adopt ESI index	Apply differential port dues	Apply differential port dues and provide funds for ship conversion	Establish a refund system of port dues for clean ships

ESI index: Environmental Ship Index (ESI) was launched at the end of 2010 by IAPH. This international standard rewards clean sea-going ships with reductions of port dues as a method of stimulating sustainable practices in shipping

Green Award: Port of Rotterdam established the initiative for encouraging sustainable inland shipping. Inland vessels with Green Award certificates can receive a discount of 15 % on their port dues from the January 2012

Source: own compilation

privatized (Verhoeven 2010). The best strategic option for port authorities is to enact an active control and supervision of concessions to stimulate intra-port competition and market contestability as well as sustainable and efficient operations of private operators (De Monie 2004; Notteboom 2007). Thus, LNG bunkering services are supposed to be mainly operated by private actors, although at the beginning of market development, the port authorities might adopt incentive policies to promote investments in the maritime application of LNG.

3.3.4 *Community manager function*

The function of community manager assumes a coordinating role of the port authority to solve collective problems in and outside the port perimeters, for instance, marketing and promoting innovations, etc. Table 6 examines the function of port authorities as community managers in promoting LNG as a ship fuel: Marketing and promotion on the maritime use of LNG. The eight port authorities use different ways to promote and market the maritime use of LNG by organizing conferences, seminars, and workshops or by sending handbooks or arranging meetings with the interested parties. Learning and sharing knowledge and skills with port stakeholders and even other ports. The structured interviews revealed that most of the eight ports intend to enhance interactive learning and knowledge sharing with their stakeholders by establishing various workshops or stakeholder platforms or developing strategic alliances with other ports in/or across the regions. For example, port of Helsingborg collaborates with other six ports in Baltic Sea to encourage interactive learning and promote the use of LNG as a ship fuel. Also, ports of Antwerp, Zeebrugge, and Singapore build a strategic alliance across the regions to sharing knowledge and skills on the development of LNG bunkering infrastructure. Lobbying government and raising public awareness. LNG is regarded as a dangerous cargo which mostly has not been regulated for the use as a ship fuel. Some port authorities play a more proactive role in lobbying the competent governmental authorities and raising the general public awareness in order to facilitate the permitting processes.

4 Discussion

The empirical results of the above multiple-case study further demonstrate that port authorities intend to play a more proactive role beyond the traditional landlord and regulator functions in coordinating and facilitating new applications of innovative technologies, e.g., the maritime use of LNG. The proactive and cooperative are the keywords in the development process of LNG bunkering projects in these eight European ports, i.e., from establishing flexibility studies, selecting strategic partners, and developing infrastructure investment policy to conducting safety and risk analysis and guaranteeing all possible bunkering rules and standards legally recorded. It is therefore concluded that the evolving port function beyond the traditional model not only helps to

Table 6 “Community manager” function in the development of LNG

	Port of Antwerp	Port of Zeebrugge	Port of Rotterdam	Port of Bremen	Port of Hamburg	Port of Stockholm	Port of Gothenburg	Port of Helsingborg
Marketing and promotion on the LNG maritime use	By organizing conferences and workshops	By joining conferences and workshops and arranging individual meetings with the interested parties	By joining conferences and seminars and arranging individual meetings with the interested parties	By joining conferences and sending handbooks	By organizing workshops and organizing conference	By joining conferences and seminars	By joining conferences and talking to potential investors	By organizing conferences and talking to potential investors
Learning and sharing knowledge and skills with stakeholders and other ports	Yes (via strategic partnership and workshop)	Yes (via cooperation and workshop)	Yes (via strategic alliance, cooperation, and workshop)	Yes (via strategic partnership and workshop)	Yes (via strategic partnership and workshop)	Yes (via strategic partnership and workshop)	Yes (via strategic alliance/partnership and workshop)	Yes (via establishing strategic platform)
Lobbying government and general public for facilitating permit process and establishing public perception	Yes (started permit process and kept a good communication with general public)	Under plan	Yes (the bunkering of LNG to inland ships is legally regulated)	Under plan	Yes (started permit process and kept a good communication with general public)	Yes (kept a good communication public by various media)	Yes (started permit process, while other authorities communicate with general public)	Yes (started permit process and kept a good communication with general public)

Source: own compilation

enhance port core competences, e.g., an efficient logistical network and hinterland connections (Notteboom and Winkelmanns 2002; Van Der Lugt and De Langen 2007), but also effectively facilitates and promotes innovation, especially when innovative technologies are confronted with a market-based chicken-and-egg problem.

In respect of the emerging community manager function, the literature mainly emphasizes the role of port authorities as “systemic coordinator” in maintaining good relationships with port stakeholders (Chlomoudis et al. 2003; De Langen and Chouly 2004; Van Der Horst and De Langen 2007). However, in this paper, we observe that community manager function can also play an important role in promoting innovation. The eight ports enact their role as community manager in the LNG projects not only in advancing stakeholder relationships by launching marketing and promoting campaigns to industrial players, lobbying competent governmental authorities to accelerate permitting process, and raising general public awareness but also in facilitating and enhancing social cooperation in learning and sharing skills and knowledge among port stakeholders via strategic alliances or stakeholder platforms. It is thus indicated that strengthening social collaboration and communication for promoting innovation in the port could add an additional content to this emerging role of community manager. Moreover, the community manager function also captures the essential role of port authorities in their regional innovation system (RIS). Therefore, enhancing such function could extend the role of port in its RIS.

In addition, the case of LNG points to broader geographical innovation networks involving more than one port authority: for instance, the intra-regional cooperation between seven ports in the Baltic Sea (port of Helsingborg is the leading port), the inter-regional collaboration between the ports of Rotterdam and Gothenburg, and the international strategic alliance among the ports of Antwerp, Zeebrugge, and Singapore. The examples therefore indicate that port authorities do not need to establish innovation networks only confined to their port perimeters but can widen cooperation platforms to a rather broad range, e.g., intra- and inter-regional or even across the world. It is believed that a wide innovation network can accelerate knowledge diffusion and market introduction of new technologies in a large context.

5 Conclusions and research implications

5.1 Implications for managerial practice

It is acknowledged that the stringent ship emission regulations under IMO’s MARPOL Annex VI are a main driver for considering LNG as a ship fuel. In order to achieve a green and sustainable philosophy, port authorities not only find their responsibility to quickly adapt to the upcoming strict emission regulations but also intend to rapidly respond to the customers’ environmental needs for gaining competitive advantages.

The detailed discussion on the current port practice of the concerned eight ports in promoting the maritime use of LNG makes it possible to further develop a set of port implementation policies. These policies listed below are proposed by considering not only the initial more theoretical assessment presented in section 2.3 but also the empirical evidence observed by the case study:

- 1) *Cooperative development policy*: Port authorities should establish various forms of cooperation with stakeholders in or outside of the port perimeter (such as industrial players, governmental authorities, research centers, and other ports in the region and even cross-region). The cooperation can focus on the development of LNG port infrastructure (e.g., location selection), the assessment of the safety risks of the use of LNG in the port environment, and the development of a set of bunkering standards or guidelines. In addition, close partnerships with industrial actors in conducting commercial feasibility studies (e.g., market demand, logistics, price, etc.) is also a key to success. It is believed that cooperation can enhance interactive learning and knowledge sharing which can reduce the market uncertainty and improve the confidence among market players.
- 2) *Financial incentive policy*: The infrastructure investment is the crucial issue in the process of developing LNG as a ship fuel. Port authorities should use various types of financial instruments to promote the market development of LNG facilities, for instance, (a) by building joint ventures or PPPs with private actors to invest in bunkering facilities; (b) by providing funding or applying for subsidies from the EU or local government to support investment; (c) by developing a differential port tariff favoring ships powered by clean fuels, like LNG (e.g., ESI and Green Award), or by providing funding for ship conversion (e.g., in port of Stockholm); and (d) if applicable, by establishing pilot projects, for example, owning LNG-powered port vessels, to kick-start LNG market development and solve the chicken-and-egg problem.
- 3) *Coordinating communication policy*: Port authorities should take a proactive coordinating role in view of maintaining a good communication within the port community regarding the development of LNG facilities, for instance, (a) by launching a promotion campaign or by organizing conferences, seminars, or workshops; (b) by building a “stakeholder platform” to share knowledge and skills among various stakeholders; and (c) by lobbying the government and raising public awareness to facilitate the permit process.

The above policies are expected to be helpful also to other ports which are planning to extrude their proactive roles in the promotion and facilitation of the use of LNG as a ship fuel.

5.2 Contribution to scholarly knowledge

The findings of the concerned multiple-case study indicate that the promotion of LNG as a ship fuel can offer port authorities a window of opportunity to give an additional content to their emerging role as coordinators or facilitators in developing an innovation network in the port community. Therefore, we conclude the following three points to

stress the role of the evolving port function beyond the traditional model in promoting innovation:

1. A more proactive role of port authorities beyond the traditional landlord and regulator functions could effectively facilitate and promote innovation.
2. The emerging function of port authorities as community manager also plays an important role in promoting innovation by enhancing social cooperation, interactive learning, and knowledge sharing in the port community. This evolving function captures and extrudes the essential role of port authorities in their regional innovation system (RIS).
3. Port authorities could establish a broad innovation network beyond their port perimeters, e.g., strengthening cooperation across regions or over the world, in order to accelerate knowledge diffusion and market introduction of new technologies in a global context.

5.3 Limitations

The multiple-case study in this chapter includes eight ports within the two European ECAs (the Baltic Sea and the North Sea ECAs). The limited number of port samples in the confined geographic area affects the level of generalization achieved by the research. Further, the proposed set of port implementation policies which mainly reflects the current practice of the concerned eight ports may limit its application scope on the promotion of the LNG maritime use in a larger context. However, the above limitation suggests for future research which could include other ports (e.g., the eight ports are not included in this study) in the European ECAs, ports in other ECAs (e.g., Northern American ECA) and even the pioneer ports in non-ECA areas. This could supplement and enrich the above proposed port policies and then broaden their application scope to a global context.

Appendix 1: The list of Interviewees

Eight interviewees from eight North European ports are listed as below

Port authority	Contact person	Department/position
Port of Antwerp	Ms. Tessa Major	Senior Project Manager Environmental Dept
Port of Zeebrugge	Mr. Paul Schroé	Environment and zone planning
Port of Rotterdam	Ms. Ankie Janssen	Business Developer Gas and Power at Port of Rotterdam
Port of Hamburg	Mr. Hendrik Hollstein	Deputy of Environmental Strategy
Ports of Bremen	Ms. Bjela Koenig	Master Mariner and Expert for maritime sustainability
Port of Gothenburg, Sweden	Ms. Jill Soderwall	Vice President Business Area Energy and Cruise

Port authority	Contact person	Department/position
Ports of Stockholm, Sweden	Ms. Sandra Gegerfelt	Public Affairs/Development, Activity Leader
Port of Helsingborg, Sweden	Mr. Per Olof Jansson	LNG Project Leader

Appendix 2: General information of the eight European ports

	Port general information	Port authority (institutional structure)	Port environmental strategy	Energy efficiency and air emission initiatives
Port of Antwerp (Belgium)	The second largest (gateway) port in Europe with excellent hinterland connection. In 2012 about 184 million tons of various kinds of goods were handled.	Port authority was established in 1997 as an <i>autonomous company</i> fully-owned by City of Antwerp. It operates in “landlord” port model.	<i>Sustainability</i> is the unifying theme for Antwerp port where the 3 P’s (people, profit, and Planet) play a key role. The first sustainability report was published in 2010.	Wind, solar, biomass, combined heat and power (CHP), industrial residual heat, onshore electricity power for barges, LNG as a ship fuel.
Port of Zeebrugge (Belgium)	One of the fastest growing sea ports in the range of ports between Le Havre and Hamburg. In 2012, 43.8 million tons of cargo was handled. RoRo cargo, food, and LNG are the main cargo handled in the port.	Port authority (MBZ.nv) was established in 1895 as an <i>autonomous company</i> fully owned by City of Bruges. It operates in “landlord” port model.	Port of Zeebrugge focuses on <i>sustainability and green initiatives</i> . It wants to build a “clean” port where green energy could be largely used.	Wind energy, onshore electricity supply, Ecological footprint to decrease the CO ₂ emission. LNG as a ship fuel.
Port of Rotterdam (The Netherlands)	The largest (gateway) port in Europe and also the largest Logistics and industrial hub in Europe. In 2012, 442 million tons of a variety of goods were handled.	Port authority is an <i>unlisted public limited company</i> established in 2004. The city of Rotterdam holds 71 % shares and Dutch State holds 29 %. It operates in “landlord” port model.	Port of Rotterdam wants to be the leader both in efficiency and <i>sustainability</i> and seeks balance between economy, people and environment. <i>corporate social responsibility (CSR)</i> is an essential element of port culture	Wind, solar, biomass, CO ₂ capture and storage, shore-based power, electronic vehicle Rotterdam Incentive scheme for clean inland shipping, LNG as a ship. fuel.
Port of Bremen (Germany)	Port of Bremen (has two ports: Bremerhaven	The twin ports has one port authority which is a	Port of Bremen has launched a campaign	Wind, solar, ship to ship power

	Port general information	Port authority (institutional structure)	Port environmental strategy	Energy efficiency and air emission initiatives
	and Bremen port) is the 6th largest port in Europe. In 2012, the total port throughput is <i>85 million tons</i> . It becomes the crucial container port and automotive logistic hub in Europe.	<i>department of the local government of Bremen City</i> : Port management Company (Bremenports GmbH&Co.) is a limited company 100 % owned by City of Bremen. It operates in “landlord” port model.	of “ <i>green</i> ” port. It spares no efforts to protect environment for every port development and expansion planning.	and low sulfur fuel oil, LNG as a ship fuel.
Port of Hamburg (Germany)	Port of Hamburg is the third largest port and the second largest container port in Europe. In 2012, the total port throughput is <i>130.9 million tons</i> . Hamburg is Europe’s No.1 railway port.	Hamburg Port Authority is a <i>limited company fully owned by the City of Hamburg</i> . It was established under public law in 2005. It operates in “landlord” port model.	The “ <i>green</i> ” port is a declared aim of port of Hamburg. It is a founder member of <i>ECO-ports</i> , a network of 150 European ports promoting communication and the exchange of information on environmental questions.	The modal split (strengthen the railway and inland waterway shipping), wind, solar, electronic vehicle, onshore power, low sulfur fuel oil, LNG as a ship fuel.
Port of Stockholm (Sweden)	Port of Stockholm is the one of important ports in Baltic sea area. In 2012, <i>12 million passengers traveled and 8 million tons</i> of goods were shipped. The port has three port areas.	The port authority, Stockholms Hamm AB, is a <i>limited company fully-owned by City of Stockholm</i> . It has three subsidiaries which are co-owned by the local communities. The port also provides services for ferry and freight traffic.	<i>Environmental and social responsibilities</i> are a natural part of Port of Stockholm’s mandate. In 2012, port of Stockholm submitted the first sustainability report.	Wind, solar, biomass, onshore electricity power, LNG as a ship fuel.
Port of Gothenburg (Sweden)	Port of Gothenburg is the Scandinavia largest port and the 13th largest port in Europe. In 2012, the total cargo throughput is <i>40 million tons</i> .	Gothenburg Port Authority, Göteborgs Hamm AB, is a <i>company wholly owned by the City of Gothenburg</i> , founded in 2011. It operates in “landlord” port model.	Four core values the port of Gothenburg pursuers: Reliability, Innovation, Co-operation, and <i>Sustainability</i> . <i>Environmental issues</i> constitute an important foundation for the port.	Onshore power supply, rail shuttles, electronic vehicle, LBG (Liquefied biogas) /LNG as a ship fuel.
Port of Helsingborg (Sweden)	Port of Helsingborg is a small regional port but is one of the busiest ports in Baltic sea area,	The port authority is a department of city of Helsingborg. Port management company, Helsingborg Hamm AB, is	The port of Helsingborg pursues its environmental targets in order to improve “ <i>green</i> ”	The use of LNG and LBG (Liquefied biogas) as a ship Fuel, onshore power, and

Port general information	Port authority (institutional structure)	Port environmental strategy	Energy efficiency and air emission initiatives
which has extensive and diversified cargo handling facilities.	a limited company fully owned by the city founded in 1987. It still provides services for container handling and stevedoring.	<i>image</i> and corporate social responsibility to the local community.	electric vehicle.

Source: own compilation

Appendix 3: The development of LNG bunkering facilities in eight ports

	The existing LNG infrastructure	The planned LNG bunkering facilities	LNG bunkering facility owner/operator	Bunkering solution
Port of Antwerp	No existing LNG infrastructure	Building a bunker vessel with strategic partner mainly for bunkering sea-going vessels. Developing intermediary storage tank or even liquefied plant later depends on the market growth.	After public selection procedure in Sep, 2013, <u>EXMAR</u> became the strategic partner of PA to build a bunker vessel.	Ship to ship (STS) for seagoing vessels Truck to ship (TTS) for inland ships (the first operation in Dec, 2012)
Port of Zeebrugge	The LNG terminal (large-scale) in Zeebrugge started to operate in 1987, mainly for land-based demand, having three 87,000 m ³ , one 140,000 m ³ (in 2008) storage tanks and one jetty. It serves as an important gas hub in Europe.	Building the second jetty for break-bulk activity which can load LNG feeder and bunker vessels. The jetty will come into service in 2015. The LNG truck filling station up in 2010.	The existing LNG terminal operator is <u>Fluxys</u> . The second jetty is invested by PA and <u>Fluxys</u> for break-bulk purpose. The bunkering supply facilities will be invested by other private players.	STS for seagoing vessels TTS for inland ships LNG portable tank (will start from 2014)
Port of Rotterdam	The GATE LNG terminal (large-scale) started to operate in 2011, mainly dealing. It has three storage tanks (3×180,000 m ³) and two jetties.	Developing an LNG break-bulk terminal, nest to the Gate terminal where LNG can be loaded to bunker vessels and trucks for bunkering purpose. Also, building a bunkering station in another port area especially for inland ships	PA together with <u>Vopak</u> and <u>Gasunie</u> to develop LNG break-bulk terminal. PA provides basic port infrastructure, <u>Vopak</u> and <u>Gasunie</u> invest onshore facilities. The bunker supply chain will	1. STS for seagoing vessels 2. TTS for inland ships 3. Terminal to ships by loading arm for small or inland ships (still under plan)

	The existing LNG infrastructure	The planned LNG bunkering facilities	LNG bunkering facility owner/operator	Bunkering solution
		(still under plan).	be invested by private actors.	
Port of Bremen	No existing LNG infrastructure	Building a small-scale storage LNG tank in port, roughly up to 500 m^3 , mainly for the use as a fuel for maritime and land vehicles.	Port management company will cooperate with <u>Bomin Linde LNG</u> who will invest onshore facilities. The supply chain will be invested by private actors. However, PA will order a LNG-fueled harbor barge to kick-start the market demand.	The possible bunkering solutions are TTS and Terminal to Ships, while the final decision has not been made.
Port of Hamburg	No existing LNG infrastructure	Building a medium or small scale storage LNG tank in port, roughly up to $20,000\text{ m}^3$ (still under plan) particularly for supplying fuel for ships and trucks.	PA is together with <u>Bomin Linde LNG</u> , to develop LNG bunkering terminal. The bunker supply chain will be invested by private actors. However, PA will order a LNG-fueled patrol ship to kick-start the market demand.	The possible bunkering solutions are STS and TTS, while the study is still ongoing.
Port of Stockholm	LNG terminal in Stockholm (medium-scale) started to operate in 2011, having a storage tank of $20,000\text{ m}^3$ and one jetties, serving both for land-based and transport demand.	The existing LNG terminal started to provide LNG to ships as fuel in Jan, 2013. Currently, PA is looking for a new place in another port area for building the second LNG infrastructure.	The existing LNG bunkering project is developed by <u>AGA</u> (a gas supplier), <u>Viking Line</u> (a shipping line) and PA together. <u>AGA</u> is the terminal owner and bunkering operator. The second project is still under plan.	The first port in the world offered LNG to ships by STS in Mar, 2013. The solution for the second terminal is still under discussion.
Port of Gothenburg	No existing LNG infrastructure	Building a medium-scale storage LNG tank in the port, around $10\text{--}25,000\text{ m}^3$, both for industrial and maritime use.	PA established a strategic alliance with <u>Swedgas</u> and <u>Vopak</u> to develop LNG terminal. The two private companies will be the terminal owners and operators.	The port will develop STS bunkering solution, but at the beginning of the project, TTS will be used.
Port of Helsingborg	No existing LNG infrastructure	Building a medium-scale storage LNG tank in	PA plans to cooperate with other stakeholders,	<i>The port wants to develop STS</i>

The existing LNG infrastructure	The planned LNG bunkering facilities	LNG bunkering facility owner/operator	Bunkering solution
	port, around <i>15,000 m³</i> , both for land-base demand and maritime use.	like gas supplier, shipowner, etc., to develop LNG bunkering facilities together.	<i>bunkering solution, which is regarded as a flexible option.</i>

The underlined words mean private entities, such as LNG facility invest/owner/operator (like Fluxys, Vopak, Gasunie, Bomin Linde, AGA, Swedgas), gas shipping company (EXMAR), and shipping line (Viking line).
 Source: own compilation

PA port authority

Appendix 4: The policies behind the development of LNG infrastructure in the eight ports

	Establish a feasibility study on LNG	Location selection policy	Strategic partnership	Infrastructure investment policy
Port of Antwerp	Together with Flemish government and other Belgian ports (Zeebrugge, Gent) conducted a feasibility study. Also, PA plans to do a commercial study with its strategic partner later.	No onshore facility needed for bunkering sea-going ships via STS, while the location of inland barge bunker station is still under decision considering all related factors (economical, safety, logistic, etc.).	<ol style="list-style-type: none"> 1. Establishing strategic alliance with port of Rotterdam to develop port infrastructure of inland barge bunker station. 2. Cooperating with ports of Zeebrugge and Singapore on LNG infrastructure. 3. Through public selection establishing strategic partnership with <u>EXMAR</u> to build a bunker vessel. 	<ol style="list-style-type: none"> 1. Establishing public private partnership (PPP) with <u>EXMAR</u> investing in a bunker vessel. 2. Besides providing basic port infrastructure, PA got EU funding for barge bunker station which could also support private investment.
Port of Zeebrugge	Together with Flemish government and other Belgian ports (Antwerp, Gent), conducted a feasibility study, and also cooperated with other stakeholders to work on several pilot projects.	No bunkering terminal planned currently, as the bunkering operation mainly via STS by the bunker vessel loaded LNG in the second jetty.	<ol style="list-style-type: none"> 1. Establishing cooperation with ports of Zeebrugge and Singapore on the development of LNG infrastructure. 2. Together with <u>Fluxys</u> to develop the second jetty. 3. Looking for strategic partners to build bunker supply chain. 	<ol style="list-style-type: none"> 1. PA provides basic port infrastructure for the second jetty, and <u>Fluxys</u> invests others. 2. Possibly investing in bunker vessel with private actors, or providing funding for other bunkering solutions, like trucks, LNG portable tanks (still under discussion).
Port of Rotterdam	Cooperating with strategic partners to conduct a feasibility	The location of break-bulk terminal has been selected just next to the	<ol style="list-style-type: none"> 1. Establishing strategic alliance with port of 	PA invests in the LNG infrastructure but investment of onshore

	Establish a feasibility study on LNG	Location selection policy	Strategic partnership	Infrastructure investment policy
	study on the development of break-bulk terminal and inland barge bunker station.	Gate LNG terminal easily for break-bulk activities. The barge bunker station has also been chosen in the inner port area close to barge operation place.	Antwerp for inland barge bunker station. 2. Establishing strategic alliance with port of Gothenburg on LNG infrastructure. 3. Together with <u>Vopak</u> and <u>Gasunie</u> to develop LNG break-bulk terminal.	bunkering facilities mainly come from private actors, while PA got EU funds (around 74million Euro) for the LNG projects.
Port of Bremen	Port management company together with PA and other competent authorities to conduct infrastructure study, while the commercial study mainly done by private actors.	The location has been selected via working with various stakeholders, and considering maritime access, logistic, regulatory, and safety factors.	Together with strategic partner, <u>Bomin Linde LNG</u> , to develop LNG bunkering facilities.	The port provides the basic port infrastructure, while onshore facilities and supply chain will be invested by <u>Bomin Linde</u> . PA plans to invest a LNG-fueled port ship to kick start market demand.
Port of Hamburg	PA together with Linde Group conducted a comprehensive feasibility study in the early of 2012.	The location has been chosen next to the existing oil terminal, by considering safety and regulatory factors.	Together with strategic partner, <u>Bomin Linde LNG</u> , to develop LNG bunkering facilities.	PA invests the basic port infrastructure, while the onshore facility and supply chain will be invested by <u>Bomin Linde</u> . PA plans to invest a LNG-fueled port ship to kick start market demand.
Port of Stockholm	Together with other six ports in Baltic Sea (EU funded project "LNG in Baltic Sea" ²⁴) conducting feasibility studies for developing LNG bunkering infrastructure.	The location of the second LNG facility is still under decision, while to be close to the customer (e.g., ferry lines) is the key factor.	Looking for the strategic partners to develop the second LNG bunkering facility.	PA invests and provides the basic port infrastructure, while the onshore facility will be invested by private actors.
Port of Gothenburg	Cooperating with strategic partners to conduct a feasibility study on the development of bunkering terminal.	The location has been selected next to the oil terminal by considering various factors, like safety, regulatory and economic factors.	1. Establishing strategic alliance with port of Rotterdam on LNG infrastructure. 2. Together with <u>Swedgas</u> and <u>Vopak</u> to develop LNG bunkering facility.	PA provides the basic port infrastructure, other facilities are invested by <u>Swedgas</u> and <u>Vopak</u> . PA together with port of Rotterdam got 35 million euro EU funding to support investment.

	Establish a feasibility study on LNG	Location selection policy	Strategic partnership	Infrastructure investment policy
Port of Helsingborg	Playing as a leading port in EU project “LNG in Baltic Sea” with other six ports to conduct feasibility studies for developing LNG bunkering infrastructure.	Conducting location study with consultant company. The location has been decided which sits next to the oil terminal mainly considering safety concern.	Looking for the strategic partners to develop the LNG bunkering infrastructure by launching public selection procedure.	The investment decision is still under discussion, while the port possibly invest with private actors (e.g., PPP) for LNG bunkering facilities.

^a EU funded project “LNG in Baltic Sea”: There are seven partner ports joining this project: Ports of Aarhus, Helsingborg, Helsinki, Copenhagen-Malmö, Tallinn, Turku, and Stockholm. Port of Helsingborg as a leading port of this project aims to establish “stakeholder platform” among seven ports to share knowledge and skills on the development of LNG infrastructure. *Source*: own compilation

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