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Increased energy efficiency in short sea shipping through decreased time in port

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ABSTRACT

According to a range of assessments, there exists a large cost-effective potential to increase energy efficiency in shipping through reduced speed at sea enabled by shorter time in port. This means that the energy needed can be reduced whilst maintaining the same transport service. However, the fact that a large cost-effective potential has been identified that is not being harnessed by decision-makers in practice suggests that there is more to this potential to understand. In this paper, the possibilities for increasing energy efficiency by reducing waiting time in port are explored and problematised through a case study of a short sea bulk shipping company transporting dry bulk goods mainly in the North and Baltic seas. Operational data from two ships in the company's fleet for one year showed that the ships spent more than 40% of their time in ports and that half of the time in port was not productive. The two most important reasons for the large share of unproductive time were that ports were closed on nights and weekends and that ships arrived too early before the stevedores were ready to load or unload the cargo. Reducing all of the unproductive time may be difficult, but the results also show that even a conservative estimate of one to four hours of reduced time per port call would lead to a reduction in energy use of 2–8%. From in-depth interviews with employees of the shipping company, ports and ship agencies, a complex picture is painted when attempting to understand how this potential arises. Aspects such as a lack of effective ship-shore-port communication, little time for ship operators, an absence of means for accurately predicting energy use of voyages as a function of speed, perceived risk of arriving too late, and relationships with third-party technical management may all play a role.

1. Introduction

Shipping contributes to a growing share of global CO_2 emissions. In a report to the International Maritime Organization (IMO), Buhaug et al. (2009) estimated that these emissions were approximately 3% of global emissions in 2007 and that emissions may double or even triple by 2050 in a business-as-usual scenario. Increased energy efficiency[1] through better operational practices, new technologies and improved logistic systems have been noted as key strategies in abating CO_2

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[1] Energy efficiency in shipping is often defined as energy used per transported goods and distance, e.g., kg of fuel per tonne cargo and nautical mile. A related figure is CO_2 efficiency, which is defined as grams of CO_2 emissions per tonne cargo and nautical mile.

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emissions from shipping. Buhaug et al. (2009) argued that CO_2 efficiency in shipping could increase by 25–75 per cent, with the largest share of the measures directed toward increased energy efficiency. It has also been noted that this potential should be attainable at little cost. Eide et al. (2011), for example, found that an increase in CO_2 efficiency of more than 33% by 2030 could be achievable by implementing measures with a marginal cost below zero. Hoffmann et al. (2012) showed that improving efficiency by more than 50% by 2030 could be possible at zero *net* costs for society; i.e., savings accrued through cost-effective measures pay for measures that involve a higher cost. These findings suggest that, similar to other sectors, there exists a so-called energy efficiency gap in shipping; a gap between what is actually achieved and what appears to be economically optimal (Johnson and Andersson, 2011; Rehmatulla and Smith, 2012; MaddoxConsulting, 2012; Acciaro et al., 2013; Jafarzadeh and Utne, 2014; Balland et al., 2014).

Speed reduction due to increased port efficiency[2] is one of the measures—explored in academic literature and in reports to political bodies—deemed to contribute to large reductions in emissions at limited costs. Lavon and Shneerson (1981) were among the first to discuss this in the wake of the oil crises of the 1970s. More recently, Faber et al. (2009) estimated that up to 10% improvement in energy efficiency could be feasible. Bazari and Longva (2011) determined that the potential ranged from approximately 10 to 20%, depending on ship size and type. Although Eide et al. (2011) do not disclose details of costs and savings in their assessment of the potential for increased energy efficiency in shipping, speed reduction due to increased port efficiency is among the measures with the greatest total savings potential, as well as one of the most cost-efficient. However, following Shove (1998, p. 1110), who argued that "technical potential which cannot be realised for a range of perfectly explicable sociotechnical reasons is not really technical potential, or at least it is not technical potential which is of any relevance in the race to reduce CO_2 emissions", an important gap exists in understanding this measure *in terms of* its apparent high cost-effectiveness. The fact that a large cost-effective potential has been identified but is not being harnessed by decision-makers in practice suggests that there is more to this potential to understand.

The purpose of this paper is to explore the possibilities of reducing speed at sea by decreasing unproductive waiting time in port, and how this can affect a ship's energy needs. A study of a short sea dry bulk shipping company that mainly operates in the Sulphur Emission Control Area (SECA) in the North and Baltic Seas is presented and discussed. The study originates from an action research project aiming at understanding and improving shipping company practices in terms of working to increase energy efficiency (Johnson, 2013; Johnson et al., 2014). In this study, additional quantitative data from the shipping companies' operations was gathered and was complemented with a range of interviews.

We believe that a case study examining how a short sea bulk shipping company could improve energy efficiency through addressing port efficiency could be interesting for a number of reasons. First, the main portion of research on ports and logistics has used quantitative methods, while qualitative and interpretative research has been called for to generate a better understanding of empirical phenomena (Woo et al., 2011). Paixão and Marlow (2003) argue that most research conducted on port performance is based on quantitative methods and focuses mainly on container terminals, while bulk cargo ports have rarely been investigated. Case studies are less prevalent in logistics research in general and have been recommended to bring in new perspectives (Näslund, 2002; Ellram, 1996). Second, in addition to the CO_2 discussion, shipping companies operating in Northern Europe are subject to more strict environmental requirements in terms of sulphur content in fuel, which is expected to lead to less environmental impact but also to increased costs (Bengtsson et al., 2014). An on-going discussion amongst researchers, policy-makers and industry concerns to what extent these additional costs will drive goods from sea- to land-based transportation (Notteboom et al., 2010; Holmgren et al., 2014). Speed reduction due to increased port efficiency may also be a way to alleviate such a development. The aim of this paper, however, is not to generalise across all shipping sectors, or even all short sea shipping companies in Northern Europe, but to initiate a discussion on how shipping companies could achieve reduced time in port and use that time to decrease speed and increase energy efficiency.

The paper is constructed as follows: Section 2 provides a theoretical overview of short sea shipping, energy efficiency, ship speed, and port efficiency. Section 3 discusses methodological issues. Section 4 contains the empirical outcome of the case study, both from the interviews and from the quantitative data, while Section 5 explores the potential for increased energy efficiency for the studied short sea shipping company. Section 6 problematises this potential. A discussion of the method and results in relation to previous and future research are included in Section 7, followed by conclusions in Section 8.

2. Short sea shipping, port operations and energy efficiency

Short sea shipping (SSS) can be defined as the movement of cargo and passengers by sea between ports that does not involve an ocean crossing. Short sea shipping currently accounts for nearly 40% of all cargo moved in Europe, and the volumes have increased over the years while the market share has been stable (EC, 2012). In 2012, total short sea shipping in the EU-28 accounted for close to 1.8 billion tonnes of freight and represented 60 per cent of the EU-28 maritime transport of goods (Eurostat, 2014). Bulk shipping is the distribution of unpacked or large parcels of raw material and bulk cargo, and can be divided into *liquid bulk*, such as crude oil, and *dry bulk*, such as grains, coal and ore. The former accounted for nearly half (46%) of total short sea shipping of goods to and from the EU-28. Dry bulk is the second largest type of cargo with 20 per cent. Bulk shipping is thus a very important part of European waterborne transportation.

[2] Increased port efficiency relates to reduced turnaround time in this paper. Energy used in ports, both in ship auxiliary engines to produce electricity for the ship (so-called "cold ironing") and in port operations, is outside the scope of this study. The role of ports in this context has been explored recently by, e.g., Acciaro et al. (2014) and Gibbs et al. (2014).

Traditionally, maritime transport services have been divided into three major modes: *liner shipping*, *tramp shipping* and *industrial shipping*. Liner shipping provides regular services between specified ports according to timetables and usually carries cargo for a number of cargo owners, while tramp shipping is irregular in time and space (UNCTAD, 2004). In industrial shipping, the cargo owner or shipper controls the vessels (Christiansen et al., 2004).

All three shipping modes and all types of contracting practices are represented in bulk shipping (Pirrong, 1993). Types of contracting practices include *the voyage charter* (short-term negotiated spot contract of a particular cargo between a load port and discharge port), *the time charter* (the cargo owner obtains the services of a ship for a specific period of time and pays for the fuel the vessel consumes, port charges, and a daily hire to the ship owner while the owner still manages the vessel), and *the contract of affreightment* (often relatively long-term contracts where the ship owner agrees to carry cargo within a specific period of time on a specified route, which can include several vessels).

The vessels used for short sea trades are often smaller versions of deep sea trade vessels (Stopford, 2009). Many dry bulk carriers can carry different types of cargo on different voyages. A ballast leg[3] to manoeuvre a ship into position for the next port of loading is very common in bulk shipping due to the global geographical distribution of production and consumption regions. Furthermore, some of the common bulk commodities, e.g., grains, are affected by seasonal demand fluctuations. All these factors place great demands on the ship operator in a shipping company to find profitable combinations of assignments. The principal role of the *ship operator* is to plan the voyage of the ship, as well as to appoint and instruct port agents and stevedores on a daily basis. The *port agent* is responsible for handling shipments and cargo at ports on behalf of shipping companies. Consequently, good knowledge of the market has traditionally been required among short sea shipping companies, as well as organisational skills such as flexible positioning of vessels, minimisation of ballast legs and avoiding being caught in ports over weekends or holidays (Tinsley, 1984).

There are many possible key performance indicators for assessing port efficiency (UNCTAD, 1976; Marlow and Paixão Casaca, 2003). A suitable indicator from a shipping company perspective in the context of energy efficiency is *waiting time in port,* defined as unproductive time for the vessel in port. In addition to cargo handling activities, a port call consists of activities such as administrative procedures, preparation for loading/unloading, and pilotage, which occupies a great share of a ship's time in ports. Low port efficiency has been highlighted as a major hindrance to the development of short sea shipping (Ng, 2009). This can imply additional inventory costs for cargo owners, lower earning capacity for ports and increased operational costs for transport operators (Marlow and Paixão Casaca, 2003).

A useful starting point for discussing energy efficiency is the division of energy efficiency measures in shipping introduced by Eide et al. (2011): *technical, alternative fuels and/or power sources*, *operational,* and *structural measures.* Speed reduction due to port efficiency, the focus in this paper, is by this definition a structural measure, characterised by two or more counterparts in shipping working together to increase efficiency and/or to reduce emissions. In this study, counterparts include the shipping company (both crew and onshore management), port managements, the stevedores and the port agents. Structural measures are believed to have significant potential to increase energy efficiency, but are difficult to implement (Eide et al., 2011). Because the relationship between ship speed and fuel consumption per time unit is exponential (often simplified as proportional to speed to the third power), a certain reduction in speed involves an even greater change in fuel consumption. Assuming constant transportation work, decreased speed can be made possible through either an *increased fleet size* or by *reduced time in port.* Concurrently, an increased fleet size or reduced time in port enables *more transportation work* if speed is kept constant.

In autumn 2008, the worldwide financial crisis and subsequent economic downturn caused a diminishing demand for transportation; in combination with the arrival of many new-built vessels from the shipyards, there was a great level of excess capacity in the world's fleets (UNCTAD, 2011). As a consequence, the shipping companies decreased speed to save bunker fuel costs and decrease the excess capacity by tying up existing capacity (Styhre, 2010). Speed reduction has attracted attention historically (Lowe, 1891). It also became common after the oil crisis of the 1970s as a means of reducing fuel costs and idle tonnage, where it received attention from researchers studying commercial aspects (Artz, 1975; Ronen, 1982), as well as technical aspects (Rein, 1980).

The average speed of the world fleet depends foremost on the state of the market and bunker price (Faber et al., 2012). There is thus a risk that ships will speed up again and that energy consumption will increase when freight rates and inventory costs rise in times of prosperity. In fact, as shipping companies procure more energy-efficient ships and operate them in a more energy-efficient manner, they could choose to operate them at a faster speeds (Smith, 2012). As a result, slow steaming can only remain sustainable if bunker prices are high or if powerful market-based solutions such as tax levies are implemented (Corbett et al., 2009; Cariou, 2011). Another possible solution is speed reductions enforced through speed limits (Lindstad et al., 2011; Faber et al., 2012).

3. Methodological Considerations

According to Näslund (2002), real-world logistic problems are ill-structured and messy, and qualitative studies may serve a particular role in this respect. In the face of such messiness, there is a need for methodological plurality and modesty (Law, 2004). The problem outlined in the introduction also connects to regional and international policy efforts to abate the cli-

[3] A voyage with no cargo on-board.

mate impact of the shipping sector. Economic, social and environmental aspects of sustainability all come into play. To provide meaningful reflection to practitioners and policy-makers in dealing with such problems, Clark and Dickson (2003) argue that it is important to carry out research in collaboration with practitioners. Following such arguments, this study is based on both quantitative and qualitative data taken from a practical situation in a shipping company, guided by the need to explore the problem: is there a potential for increased energy efficiency due to increased port efficiency, and can we understand it?

Two sources of quantitative data were collected from the shipping company, *Voyage Reports* and *Statement of Facts*. These documents were gathered for two ships, Ship A and Ship B, for one year of operation (in 2011).

- Voyage Reports contain data on all port calls and voyages. Voyage Reports are Excel sheets in a format standardised by the shipping company that are filled out by a ship's crew and sent from the ship to the shipping company's operational department. These reports contain data on speed and fuel consumption, time in port, time carrying pilot, and time at sea, including ballast legs (voyage without cargo on-board) and laden legs (voyage with cargo on-board).
- Statement of Facts are produced by each port and contain information on activities carried out in port, such as volumes loaded/unloaded, type of cargo, arrival and departure times, cargo handling time, breaks, clearance inward and outward, etc. The ports send these documents to the shipping companies' operational departments. The details of what facts are reported varied among ports, as ports used their own format. In all cases, these documents were sent as scanned copies of the original paper documents.

Our method of using Voyage Reports and Statement of Facts in combination with interviews was established together with the shipping company. The interviews, combined with the quantitative analysis of the Statement of Facts, were used to quantify waiting times in ports and develop likely scenarios for how many hours each port call could be reduced. The Voyage Reports were further used for calculating reductions in energy for the different scenarios.

In addition, seven interviews were carried out with one senior onshore manager, two ship operators and one captain at the shipping company, one port manager and two port agents. Based on a literature review and pre-understanding from previous projects (Johnson et al., 2014), guidelines for semi-structured interviews were composed. The interviews were taped, transcribed and coded (Charmaz, 2006, pp. 42–73), and summarised in themes that could provide further understanding. The themes overlap to some extent, perhaps a sign of the "messiness" and complexity of the problem.

To calculate the potential for increased energy efficiency due to speed reductions enabled through decreased time in port, algorithms were developed based on operational and design specifications for the ships. This enabled an estimation of energy use as a function of speed for each ship (see Appendix). A MATLAB script[4] was developed to analyse all Excel documents and to calculate energy requirements for the original speed and the decreased speed for all voyages the ships carried out in 2011, the only exception being when the speed was already so low that any further decrease would increase the fuel consumption per nautical mile (the most energy efficient speed is 9.5 knots for Ship A and 8 knots for Ship B, see Fig. 4). The Voyage Reports also contained, as described above, the fuel consumption measured by the crew. For consistency, the theoretical consumption was used (which was calibrated using the operational data measured by the crew, as explained in the Appendix).

4. Speed reduction and time in port from a shipping company perspective

The shipping company in this study operates dry bulk ships primarily in Northern Europe, with 20–25 ships in traffic in 2011. These were mainly on time-charter contracts with third-party ship technical management and ship's crew. The sizes of Ships A and Ship B were both approximately 5000 GT—as were the rest of the ships in their fleet—and carried a broad range of bulk cargo including steel coils, pulpwood, steel scrap, crushed granite, asphalt granulate, timber, sawn timber and wheat.

With few exceptions, the voyages were less than 4 days, as seen in Fig. 1. Both vessels were on a combination of long-term and short-term contracts of affreightment and voyage charter. A Bunker Adjustment Factor (BAF) was included in some of the contracts. The shipping company could thus transfer additional costs related to price increases of the bunker to the cargo owner when a BAF was included.

Fig. 2 shows the time that the two ships spent in different operational modes, based on data from the Voyage Reports. The modes are defined as time in port, time at sea (for laden legs and ballast legs) and time approaching or leaving the port. Approximately 50 per cent of the total time for the two ships was spent in ports and fairways in 2011.

4.1. Lessons from the interviews

The interviews with a senior onshore manager, ship operators and a captain at the shipping company, a port manager and two port agents are summarised below. In the first subsection, respondents quantified the potential for reduced waiting time in ports, followed by three main areas concerning time in port and speed reduction: market conditions, organisational and technical prerequisites for slow steaming, and communication between actors.

[4] MATLAB is a high-level language and interactive environment for numerical computation, visualisation, and programming.

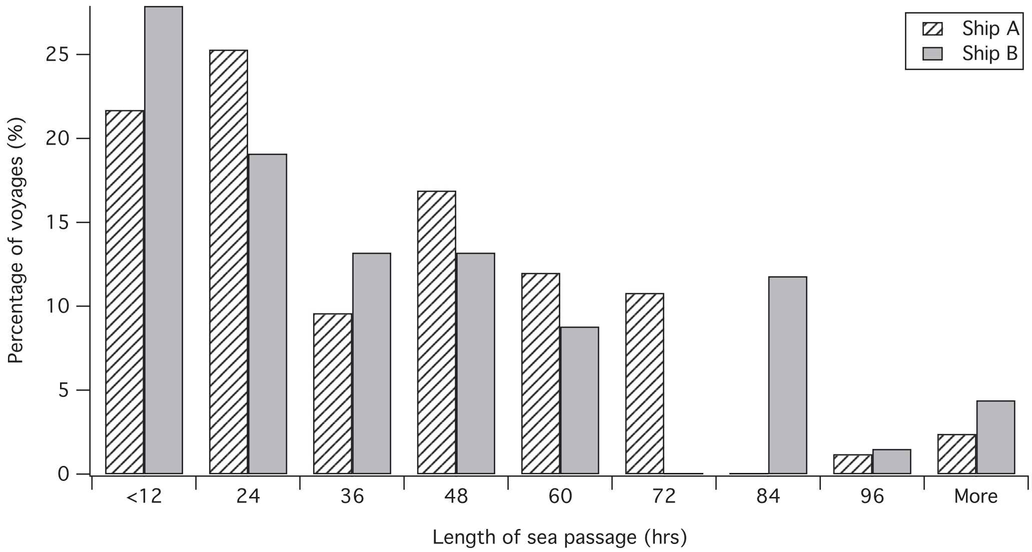

Fig. 1. Distribution of sea transit time for the two ships based on Voyage Reports for 2011.

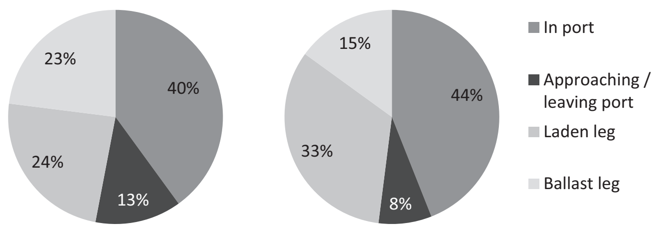

Fig. 2. Operational profile of Ship A (left) and Ship B (right).

4.1.1. Unproductive waiting time in ports

Respondents at the shipping company estimated that time savings in ports to range from 1 to 4 h (see also Johnson et al., 2014, p. 323). Stated reasons for longer turnaround time in ports than necessary include waiting for pilot, the port's opening hours, waiting for cargo to reach the quay, congestion, and low productivity. Bad weather conditions were also mentioned as an important reason for delays because some bulk cargo cannot be loaded and unloaded when there is rain or snow, which is common in Northern Europe during autumn and winter.

Most respondents stated longer opening hours in port as the central issue to reduce the turnaround time and for better voyage planning. The vast majority of bulk ports in the Northern Europe are closed on nights and at weekends, which can result in a substantially prolonged turnaround time if the vessel is not loaded before closing time. Many ports offer overtime for a higher fee, but this is often based on voluntary action from stevedores and cannot be guaranteed in advance by port management.

4.1.2. Market conditions and the ability to plan voyages better

The poor market conditions since 2008 have led to a larger share of spot contracts and fewer long-term contracts. As a consequence, ship operators need to redirect vessels to new ports with very short notice more often, which has affected the entire fleet. One interviewed ship operator explained:

> When you have a liner service, you can plan. However, [on the spot market] we change the routes all the time, and often we are very much in a hurry.

Furthermore, the shipping company's fleet had been reduced from 35 ships in 2009 down to 20–25 ships in operation in 2011. The larger fleet in 2009 covered the same geographical area as in 2011, which means it was much easier to combine vessels and cargo in planning because the average distance between an available vessel and contracted cargo was shorter. Consequently, long ballast legs could be avoided more often. There were on-going efforts to find more regular cargo and to move toward more fixed routes within the shipping company. According to an operator, another advantage of calling the same ports on a regular service is increased port efficiency when the crew becomes more acquainted with the stevedore and the procedures in the port, and the stevedore becomes more familiar with the loading and unloading of the vessel.

Each ship operator in the shipping company was responsible for several ships. One of them claimed that with more time it would be possible to plan better and calculate the saving potential for lower speeds and later arrival.

> I could [then] compare when planning a trip and compare with the exact same voyage I had done before, and gone through how the ship has performed: what had happened on the way, etc. Now, I can get a call saying you need to go to [a specific port]. Ok, then I send the ship there, and I don't have time to calculate exactly when it needs to be there.

4.1.3. Prerequisites for slow steaming

There was no clear consensus amongst ship crew and ship operators about what would be the most energy-efficient speed for the individual ships. Without knowledge or tools to establish this, determining the most commercially sound speed is difficult. However, speed and fuel consumption tables for all ships were under development. One captain stated that the voyage instructions were not always clear and that they also may not be efficient from an economic point of view.

> The slowest possible [speed] does not always mean the lowest fuel consumption per day. The main engine fuel consumption per day is what the operators are looking at. For example, they are not considering the fact that the main engine needs full speed one hour per day to be clean.

A ship operator highlighted the lack of incentives for reducing speed when the ship is managed by a third party because lower speeds can involve increased maintenance costs, which are carried by the third party management company and not by the shipping company.

Moreover, several respondents stated that there may be operational reasons for allowing extra time when approaching a port. Late arrival can have severe consequences such as high costs for waiting stevedores and delays that affect the next voyage, or several days of unemployment for the vessel if a laycan[5] for a voyage is missed. The latter is explained by an onshore manager:

> If the ship has a laycan to meet and there might be bad weather on the way or ice, the best alternative is to proceed at a higher speed than would be necessary. Saving 1 tonne of bunker or USD 750 is very low priority if I have a voyage at stake. If I miss the voyage I will lose a few days before I can get a voyage and earn some money. If the wait is three days, I have lost 3 × €4000 or €12,000. Compare this to the USD 750.

According to a port manager, it is uncommon that shipping companies change speed to adjust to the start time for loading or unloading:

> I know that the shipping companies call sometimes and ask if we have gangs ready. If we don't have until the following morning, they can reduce speed and adapt their arrival time. It doesn't make sense to arrive an hour early if there is no gang ready. Sometimes this happens [that they call], but not so often.

4.1.4. Communication among ship operator, ship agent and crew

The information sent from the ships and ports to the shore organisation is extensive, including noon-reports, estimated time of arrival (ETA), Voyage Reports, Statement of Facts, etc. However, the documents are only stored at the shipping company and there are no procedures established to analyse the data.[6] Respondents ashore stated that crew seldom or never received feedback, unless bunker consumption might have been too high. However, at the same time, they stressed the importance of involving the crew in the long-term work on reducing energy consumption. A captain on a time-chartered vessel replied simply:

> No comments. Never. Never.

The shipping company often has its own agent in important ports. A ship operator highlighted the importance of the ship agent as a provider of information:

> I need to know if there are other incoming ships, if there are interruptions in the cargo handling activities. I need information fast and I need it often.

In some industrial ports, the cargo owner can require that a specific agent be used. Some agents may favour a shipping company and provide information selectively. One respondent demonstrated this by describing two vessels approaching a port with temporary congestion on the quay-side: the shipping company the agent shares this information with gets the chance to speed up to arrive first in port and be served first. There are also cases where the responsible agent is physically positioned in a different location, which can make the information exchange more difficult.

4.2. Lessons from the statements of facts

Statements of Facts were studied to explore how time was spent in port. On average, Ship A spent 49.7% (17.0 h) and Ship B 56.6% (30.5 h) of its total time in port waiting for various activities to start; see Table 1. Factors not within the sphere of

[5] The term "laydays and cancelling," i.e., laycan, refers to the day when a contract can be cancelled by the charterer.

[6] Indeed, as described in the methodology section, we needed to create a tool for the purpose of this article.

Table 1
Breakdown of total time in port for Ship A and Ship B.

Category	Ship A		Ship B	
	Average waiting time per port call (h)	Percentage of total yearly port time (%)	Average waiting time per port call (h)	Percentage of total yearly port time (%)
1	7.6	22.2	9.8	18.2
2	5.9	17.1	15.1	27.9
3	1.7	5.1	2.1	3.9
4	1.1	3.3	3.4	6.4
5	0.7	2.0	0.1	0.2
Total	17.0	49.7	30.5	56.6

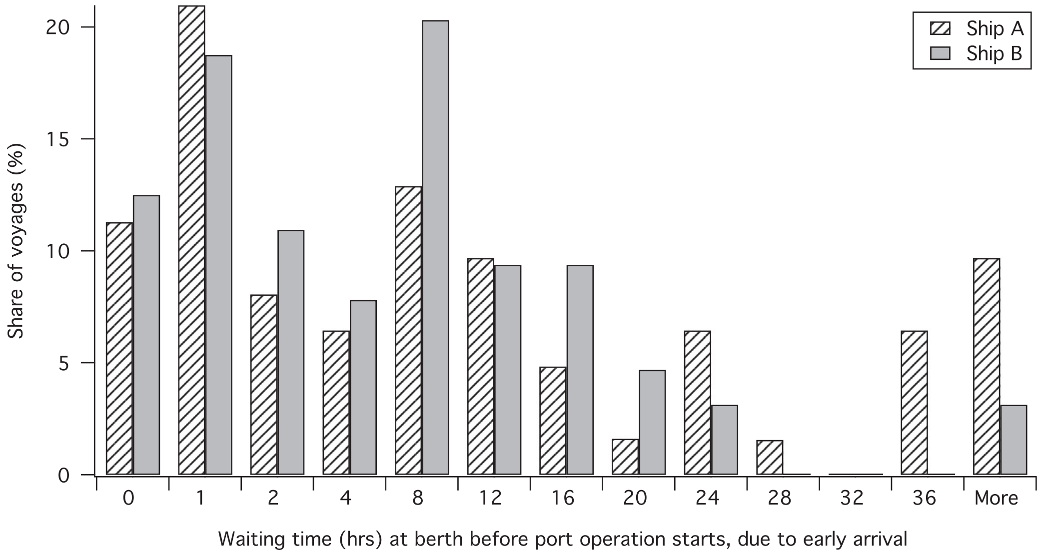

Fig. 3. Histogram of Category 2: waiting time (hours) at berth before port operation starts due to early arrival, as per cent of the total port calls.

influence for any actors are excluded from the analysis, such as waiting for unloading due to bad weather. Table 1 shows the division of waiting time in port, divided into five categories:

Category 1: Waiting time at berth when the port is closed for the night or the weekend to complete loading/unloading.
Category 2: Waiting time at berth for stevedores to start loading/unloading due to early arrival.
Category 3: Waiting time at berth or in the port area due to reasons such as congestion or clearance procedures.
Category 4: Waiting time for departure after having finished loading/unloading due to unspecified reasons.
Category 5: Waiting time for pilot, approaching or leaving the port.

In the majority of the port calls (nearly 60%), the ships enter and leave the port on the same day. For the remaining port calls, the turnaround time is often much longer because the ports are closed at night and on weekends (Category 1). The other major category (Category 2), time spent waiting at berth for stevedores to start loading/unloading due to early arrival, also varies greatly, as depicted in the histogram in Fig. 3.

The interviews indicated that there were large differences in cargo handling efficiency (time required per cargo unit) in different ports. In theory, data could also be calculated concerning cargo handling efficiency because the time for handling and cargo weight were entered into the Statement of Facts. However, there was such a large variety of goods that it was difficult to find any patterns in the performance of different ports.

5. Exploring the potential for increased energy efficiency

The analysis of the Statement of Facts showed that the average waiting times for the two ships were 17 h and 30.5 h, respectively. To calculate the potential for increased energy efficiency due to shorter turnaround time for the ships, one must determine by how many hours a port call can be reduced.

Longer opening hours and more just-in-time arrivals are the two most important measures to reduce the waiting time in port. Longer *opening hours* (Category 1) is, however, a trade-union matter, and it also involves extra costs for the ports, which makes it difficult to change opening hours radically in the short term, at least for smaller ports. Fig. 3 above shows that there is a large range of waiting times due to *early arrival* (Category 2). Interviewees ashore stressed that some extra time is necessary as a buffer to reduce the risk of delays, to open hatch covers and prepare the vessel for loading or unloading, for administrative procedures, etc. However, there is a large number of port calls with a very large "buffer", which could be reduced. Furthermore, some degree of reduction in waiting time could be likely be reached for the three other categories, *waiting due to other reasons such as congestion or clearance procedures* (Category 3), *waiting after loading/unloading due to unspecified reasons* (Category 4), and *waiting for pilot* (Category 5).

Without knowledge of the quantitative analysis above, the interviewees determined the possibilities of reducing time in port by one to four hours. Given the results of the analysis, the interviewees' estimates can be considered as conservative in the sense that a much larger potential is available if all sources of waiting time are addressed. On the other hand, it is clear from the interviews that reducing time in port could not be accomplished without incurring costs, in particular with regard to open hours in port. We thus choose to remain with the estimates of the company employees, which as shown below, still implied a significant savings potential. In light of the analysis of Statements of Facts, our choice of reduction potential is within the range of what could be enabled by more just-in-time arrival. The difficulties in implementing necessary changes to reduce the turnaround time in practice are further discussed in Section 6. Three scenarios were examined:

- 1 h of reduced turnaround time;
- 2 h of reduced turnaround time; and
- 4 h of reduced turnaround time.

As described in Section 3, each actual port call in the Voyage Reports was shortened according to the three scenarios, and the corresponding sea voyage time increased equally, with the exception of the voyages with such a low speed that a further increase in energy efficiency was not possible. According to the algorithm developed (see Appendix), the most fuel-efficient speed was approximately 9.5 knots for Ship A and 8 knots for Ship B. Therefore, a reduction in speed approaching 9.5 and 8 knots, respectively, reduces the bunker consumption per nautical mile. Table 2 summarises the outcomes of the calculations.

The results of increased voyage time show that the potential for increased energy efficiency for the two ships is approximately 2–8 per cent, depending on the scenario selected. The different potentials for the two shipping services partially originate from the fact that the speed for Ship A is higher on an annual basis than that for Ship B (see Fig. 4). Additionally,

Table 2
Improvement in energy efficiency for three scenarios with 1, 2 and 4 h of increased voyage time.

Increased voyage time (h)	Ship A (%)	Ship B (%)
1	3.0	1.8
2	5.1	3.1
4	8.1	5.1

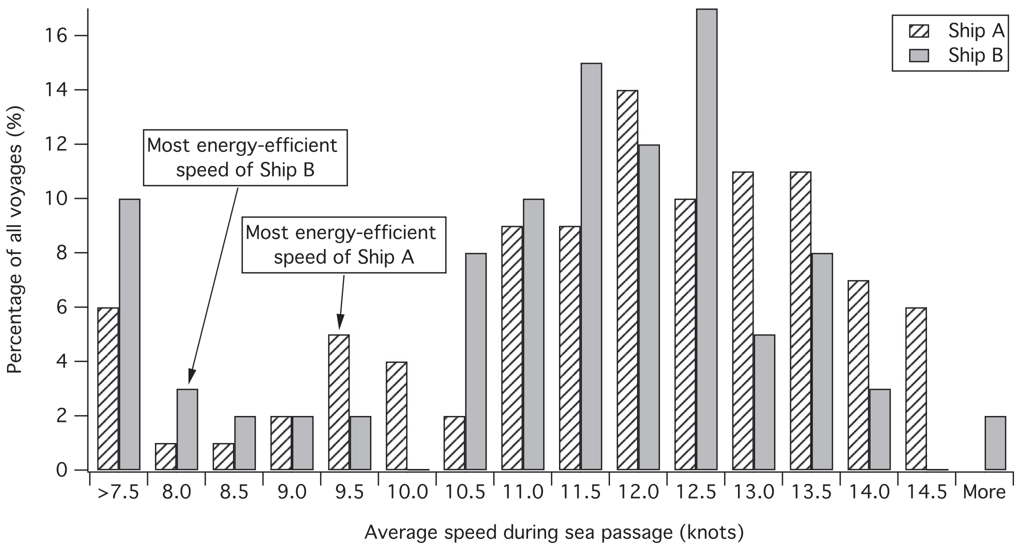

Fig. 4. Ship speed (in knots) for Ship A and Ship B and per cent of voyages operated at each speed. The theoretical, most energy-efficient speed is 9.5 knots for Ship A and 8 knots for Ship B.

the different fuel consumption algorithms indicate that Ship B consumes slightly more fuel than Ship A at the same speed. The distribution of voyage lengths is similar for the two ships, as shown in Fig. 1.

6. Problematising the gap between the theoretical potential and actual implementation

The unproductive time that ships spend in ports represents a substantial waste of resources for the shipping company. The calculated increase in energy efficiency of 2–8 per cent falls in the same range as that provided by Faber et al. (2011), but is lower than the assessments by Bazari and Longva (2011). Some areas of further interest have been revealed in this study, and in previous related work, that are key issues in understanding the potential for increased energy efficiency in shipping through increased port efficiency.

The ship operators ashore need time, resources and knowledge to plan their voyages and thereby facilitate a more just-in-time arrival (Category 2). A potential for such planning is available, as shown in Fig. 3. The interviews indicated that there was little time for working pro-actively and thoroughly analysing bunker consumption for each trip to determine the most energy-efficient speed given a particular market condition and to follow up and give feedback to the crew on board. This would require time and knowledge of technical and operational aspects of shipping that the operators might not possess, e.g., ballast requirements and the effects of ice conditions on the vessel, as well as technical features of the ship engine. Such knowledge might exist among the ship crew or in the third party management company. Interviews also indicated that there may be a contradiction in incentives for the different organisations involved. For example, if slower speeds increase the demand for engine maintenance and the operating shipping company pays for fuel and the third party management company pays for maintenance and crew wages, there could be a lack of incentive for the crew to reduce speed to the most *energy* efficient speed—if they even know what speed this is. Detailed analysis of speed and consumption curves for all the shipping company's vessels had not been addressed in a systematic manner at the time of the study, though they had started to establish tables of speeds and consumption based on on-board measurements.

Furthermore, the port agent often plays an important role in informing both the ship and the ship operator ashore about the situation in port. If there are no available berths or no gangs ready to start unloading or loading the cargo, the ship should slow down. Addressing port conditions in advance would also reduce the ship's waiting time in port due to congestion (Category 3). Other identified measures to decrease waiting time per port call are smoother clearance procedures (included in Category 3) and shorter waiting time for the pilot (Category 5). The pilot often needs to be booked a few hours in advance, and many ports have little flexibility and rebooking often involves additional costs. Interestingly, there was some discrepancy between actual delays due to waiting for pilot indicated in the Statements of Facts and the respondents' interpretation of the same. Respondents in ports and in the shipping company stressed that waiting for pilot was an important source of delays. In the Statement of Facts, this represents less than 2% of the total time in port. Longer opening hours in port (Category 1) are very important to reduce the waiting time for the vessels. However, the costs associated with extra work shifts need to be less than the port's potential earnings from shorter turnaround time.

The two ships in this study spent an average of 17.0 h (Ship A) and 30.5 h (Ship B) of their total time in port waiting for various activities to start. Relative to these times, four hours of reduced waiting time seems moderate. However, in practice, harnessing a larger share of the total potential might be fraught with some difficulty. The constant repositioning of vessels and the risk of late arrival to port have led to a situation where it is difficult to optimise the speed of a particular ship. The short planning horizon implies that the vessels often arrive at port when it is closed instead of traveling at the most energy-efficient speed. The increased share of spot contracts in the last few years has reduced the planning possibilities further. As shown in Section 4.1.3, a senior manager did not agree that a more just-in-time arrival was always worth striving for due to the risk of losing future commercial opportunities.

In summary, there are many sources of unproductive time in port, and many stakeholders affect the possibility to reach the theoretical minimum waiting time in port. Their incentives, knowledge and available time to work towards this goal may vary. Developing the most effective strategy in a shipping company—that decreases the most unproductive time per effort—seems to be a complex endeavour. Further, what has been labelled "waiting time in port" in this study may not always be unproductive from the viewpoint of the ship crew, who may use the waiting time for other types of work, such as maintenance or rest. Finally, regardless of the potential for increased efficiency in port, there is always a trade-off for the shipping company between *decreased fuel costs by going slower* and *increased earnings by going faster,* i.e., to take additional contracts and carry more cargo over time.

7. Discussion and further research

The purpose of this paper is to better understand the potential for improved energy efficiency due to increased port efficiency by studying a single short sea shipping company. In a study that uses both quantitative and qualitative methods, there are many issues to explore, but this section is limited to a discussion on the relation between this study and previous research on the energy efficiency gap.

A large potential is available from just-in-time arrival practices, as well as from reforms in port productivity related to working hours. Time, tools and competence in the office and good terms of communication between the office, ship, port, port agent and third party technical management seem to be of essence. Previous literature that aims to explain the energy efficiency gap has focused largely on taxonomies of "barriers" or "drivers" (see Sorrell et al. (2004) or Thollander and Palm (2012) for comprehensive discussions). Similarly, in this study, poor market conditions, a slim organisation, lack of time, poor communication, and lack of knowledge could all be claimed to be "barriers" to increased energy efficiency (indeed, something very similar was claimed in the preceding study reported in Johnson et al. (2014)).

However, we agree with Palm and Thollander (2010) that this approach can lead to unnecessary reductionism, i.e., "the notion that there is a small class of phenomena, objects or events that drive everything else – a suggestion often linked to the belief by the analyst that he or she has understood these root phenomena." (Law, 1994, p. 12). Following Latour (2005) we suggest that the "barriers" and "drivers" that have often been the outcome of many previous studies on the energy efficiency gap could instead be the new starting point. The barriers have never explained anything; the barriers have to be explained instead, to borrow a famous phrase (Latour, 2005, p. 97). Rather than *ostensive* explanations (postulated mechanisms or principles, such as "barriers" or "drivers"), there is a need for explanations that are *performative* (Latour, 1986; Czarniawska, 2008): i.e., a focus on capturing practices rather than formulating principles. *How* are people in an organisation hindered from or driven to implement measures that increase energy efficiency? For example, how do the ship operators communicate with crew and ports? How does this affect energy efficiency? Could it be done better? How is the relationship between the shipping company and its third party technical management maintained? How could cooperation on speed reduction be achieved? And a good theory is practical, to paraphrase Kurt Lewin (1951): it solves a problem. Elizabeth Shove, who was quoted in the introduction, elucidates this notion:

> What is routinely missing [in assessments of energy efficiency potential] is any analysis of what the rest of the energy efficient utopia might look like: what new techno-economic networks do technological visions presume and what forms of social re-alignment are required along the way? More prosaically, what would everyday life be like in a world which used 50 or even 20% less energy? What organisations are involved, what sorts of companies are implied, and how are the details of energy consumption to be arranged? *In other words, there is real work to be done in articulating the features and characteristics of social worlds presupposed by proposed energy-saving scenarios.* (Shove, 1998, p. 1110, our emphasis)

Hence, the work described in this paper is far from finished. Not because it is based on a single case, but because there is much more to do with this single case. In this paper, a quantitative analysis is combined with a single round of interviews. It would have been fruitful to follow this shipping company in pursuing greater port efficiency, now that the potential for improvement and possible ways forward have been identified. Sadly, this will not be possible because the company was split and this part of its operations was sold off to another shipping company. However, the methodology developed and used in this paper to calculate the potential energy efficiency in shipping caused by reduced turnaround time, including interviews in combination with an analysis of Statements of Facts and Voyage Reports, could be used in similar research studies.

To capture the intricacies of the processes involved in improving the means with which a shipping company may address time in port and speed reduction schemes, further studies could benefit from using ethnographic-like methods (e.g., Czarniawska, 1997; Mol, 2002) or action research; the latter is a fruitful way of negotiating access (Gummesson, 2000). It is also important that such studies "follow the actors" and cross organisational boundaries (Latour, 1987; Czarniawska, 2004)—and not focus narrowly on a shipping company level, port level, or ship level. As discussed above, a whole range of organisations are involved. The incentives of people working in these different settings may or may not favour cooperation on energy efficiency.

8. Conclusions

The projected growth of greenhouse gas emissions from shipping stands in sharp contrast to the ambitions of regional bodies such as the European Union to significantly reduce emissions. Despite recent global policy instruments – the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) – emissions may double by 2050 (Bazari and Longva, 2011). The European Commission, on the other hand, has set a goal to reduce emissions from shipping by at least 40% by 2050 (EC, 2011). However, some note the need for even further reductions. Anderson and Bows (2012) argue that if the shipping sector is to hold true to its climate change rhetoric—that it should be treated as a sovereign nation—reductions of up to 80% are necessary until 2050. Increased energy efficiency is crucial for the shipping sector in meeting these goals. It may be especially important for the short sea shipping (SSS) sector because SSS is to a larger extent subject to competition from land-based transport modes. Moreover, ships operating in Sulphur Emission Control Areas (SECAs), for example, the Baltic Sea and parts of the North Sea, are subject to cost increases in bunker fuel due to regulations on the sulphur content of bunker fuel. Decreased costs for fuel can also mitigate such effects.

Previous assessments, so-called marginal abatement cost (MAC) studies, have highlighted speed reduction at sea due to decreased turnaround time in port as a measure with high potential for reducing CO_2 emissions at low cost (e.g., Eide et al., 2011; Faber et al., 2011). In this paper, this measure has been explored in a practical context, inspired by the notion that if a very "cost-effective" measure is not being implemented, the reasons for such a choice are worth investigating.

A case study of two short sea bulk shipping services has been carried out in collaboration with a short sea shipping company. The result showed that the ships spend approximately 40% of their time in ports and approximately half of that time in waiting for various processes to start. Reasons for the waiting time have been divided into five categories. These are, ranked in order of importance, waiting time due to: (1) port's open hours, (2) early arrival, (3) congestion and clearance procedures, (4) unspecific reasons and (5) waiting for pilot. Scenarios of 1, 2 and 4 h of reduced turnaround time per port call were developed from interviews with the shipping company's employees and from quantitative analysis of Statements of Facts. The scenarios can be considered conservative in the sense that the *theoretical* potential is much greater: 17 h for Ship A and 30.5 h for Ship B. Furthermore, an improved cargo handling rate, which was not addressed in this study, would allow the time in port to be further shortened. With a corresponding speed reduction at sea, the potential for increased energy efficiency for the two shipping services was between 2 and 8 per cent. This is in line with our previous assessments. The lower figure can be explained partly by the fact that the scenarios were conservative and that the ships had already reduced speed owing to poor market conditions.

The interviews indicated a need for a different approach to increase the efficiency of a port call, e.g., longer opening hours, and more time and better tools for planning the sea voyage. International policy efforts have been enacted to increase energy efficiency in how shipping companies operate ships: as of 1st of January 2013, a Ship Energy Efficiency Management Plan (SEEMP) is mandatory on-board all ships above a certain size. Speed reduction due to increased port efficiency constitutes roughly half of the total presumed effect of the SEEMP in a report to the IMO (Bazari and Longva, 2011). To what extent the SEEMP can effect such changes is still an unexplored area of research (although see Johnson et al., 2013). Increasing ports' open hours may be more of a matter of concern for local or regional policy-makers (Gilbert and Bows, 2012).

It is crucial to emphasise that it is not evident how the shipping company can in practice make use of the capacity made available by shorter turnaround time. Speed reduction is thus not an abatement measure in the usual sense. Depending on market conditions, slow steaming is not always the most profitable option. In times of prosperity, it can be more beneficial for the shipping company to keep speed high and instead increase the transport work performed. Additional policy measures could then be necessary, e.g., to raise costs for energy or to restrict speeds.

It is suggested that further research be directed toward better understanding how the potential for speed reduction due to increased port efficiency can be achieved, preferably illustrated by good examples. It is also important that such studies go beyond organisational boundaries, as many different organisations are involved in making speed reduction possible. Ethnographic studies or action research may be particularly fruitful in the sense that these can focus on actual practices: what people do, not what they say they do. In other words, such research would not study what respondents *claim* helped or hindered them in improving energy efficiency, but rather what *was done* to improve energy efficiency. Such knowledge could bring new perspectives for practitioners, academia and policy-makers.

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Appendix

Ship speed-consumption curves.

Based on experience from the research and consultancy company SSPA Sweden AB and data from the shipping company, energy consumption curves were created based on the general formula:

$$f_c = C_{vref} * \left(CPP_{corr} + (1 - CPP_{corr}) * \left(\frac{v}{v_{ref}} \right)^a \right),$$

where C_{vref} is the nominal consumption of the ship at a reference speed v_{ref} (e.g., charter-party speed), CPP_{corr} compensates for the low performance of Constant Pitch Propellers at low speeds, and the exponential a is taken as 3.8 to compensate for the speed and Froude number of the ships.

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