Original Article

Slow steaming impacts on ocean carriers and shippers

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Abstract Ocean container carriers have implemented slow steaming (reduced vessel speeds) in recent years to improve fuel efficiency and lower greenhouse gas emissions. However, many shippers oppose the practice due to increased pipeline inventory associated with longer transit times. Given this conflict, this article seeks to quantify the costs and benefits of slow steaming relative to carriers and shippers. We simulate a high volume Asia-North America container trade lane to estimate slow steaming impacts under different vessel speeds, volumes and fuel prices. Under current conditions, the results justify slow steaming practices, revealing *extra slow steaming* as the most beneficial vessel speed with a 20 per cent reduction in total costs and a 43 per cent reduction in carbon dioxide emissions. Extra slow steaming is also optimal for future volumes and a wide range of fuel prices. Furthermore, the results detail carrier and shipper cost trade-offs, thus offering practical evidence and transparency to the industry on how to create financial equity in facilitating contractual-based agreements for vessel speed standards.

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Introduction

Ocean transport contracts often refer to 'utmost dispatch', urging carriers to pursue speeds as fast as reasonably possible (Alvarez *et al*, 2010). In recent years however, 'slow steaming' (that is, slower vessel speeds) has become commonplace in order to improve vessel fuel efficiency (Cameron, 2010; Johnson, 2010a; Leach, 2010a). Considering that larger vessels may consume several hundred tons of fuel per day at US$700+ per metric ton (MT) (at the time of writing), the resulting cost savings can be significant. It is estimated that slow steaming can save carriers $3 billion in fuel annually (Page, 2011). Additional slow steaming benefits include reduced greenhouse gas (GHG) emissions, absorption of excess fleet capacity and increased schedule reliability.

Although carriers have identified slow steaming as a win for all stakeholders (Barnard, 2010c), shippers are expressing concerns (Dupin, 2011b). Shippers can benefit from slow steaming through reduced supply chain carbon footprint, but longer transit times will increase pipeline inventory costs (Bonney and Leach, 2010; Dupin, 2011b; Page, 2011). Also, even though carriers contend that slower vessels can improve schedule reliability and subsequently lower safety stock needs, speed is often more important than reliability for ocean shipping (Saldanha *et al*, 2009).

Acceptance of slow steaming as industry standard will ultimately require a reasonable balance of benefits across carriers and shippers established during service contract negotiations. Yet shippers have asserted that slow steaming benefits are highly one-sided to ocean carriers who have not contractually shared the financial gains (Gallagher, 2010). Therefore, it is important to quantify the benefits across carriers and shippers to lend transparency to this conflict. We thus present our primary research questions:

RQ1: What are the expected changes in costs across stakeholders from slow steaming and, relatedly, is slow steaming beneficial from an overall (cross-stakeholder) standpoint?

RQ2: How do slow steaming benefits change with expected future container volumes and potential volatility in fuel prices?

RQ3: With unbalanced costs and benefits across carriers and shippers, what incentives could make slow steaming more acceptable to shippers?

RQ4: What are the environmental impacts of slow steaming and how might these benefits further influence slow steaming adoption?

We address these questions through simulation of container flows to/from Asia through the Port of Los Angeles under different vessel speeds, volumes and fuel prices. The results clarify slow steaming costs and benefits across stakeholders, thus supporting insight for how shippers and carriers might reach equitable contractual agreement on a path forward for vessel speed standards. In the next section, we review industry literature to explain the advantages and shortcomings of slow steaming in practice. We also survey related academic literature to validate the research gap to be addressed in the article. We then describe the modeling approach and subsequently present the results to offer insight to the industry on how to overcome perceived inequities in slow steaming benefits.

Slow Steaming in Practice

'Full' speed for a container ship might typically be 24 knots (generally 85–90 per cent of engine capacity) (Bonney, 2010a). Reducing vessel speed to 21 knots represents 'slow' steaming with 18 knots defined as 'extra slow' and 15 knots as 'super slow' (Bonney and Leach, 2010). Slower speeds generally improve vessel *fuel efficiency* (Rosenthal, 2010), allowing carriers to save on bunker (that is, marine fuel), a volatile and expensive cost item. Fuel can exceed half of overall operating costs for container ships (Notteboom, 2006), and consequently, changes in fuel prices will have significant impacts on per TEU transport costs (Notteboom and Vernimme, 2009). As bunker prices have increased considerably in recent years (Notteboom and Vernimme, 2009; Bonney and Leach, 2010), slow steaming has become more appealing to carriers. At $500 per ton fuel prices, carriers can save 5–7 per cent on costs (Bonney, 2010b), which might represent $250 000 on one voyage (White, 2010) and $15–$20 million annually for one Asia-Europe lane (Bonney and Leach, 2010). Given thin profit margins in the industry (Notteboom, 2006; Notteboom and Rodrigue, 2009), carriers infer that slow steaming is becoming the new norm (Barnard, 2010b; Bonney and Leach, 2010).

As a second slow steaming benefit, reduced fuel consumption directly corresponds with lower levels of GHG *emissions*, namely CO_2. By consuming 265 million tons of fuel annually (Psaraftis and Kontovas, 2009), ocean shipping produces 840 million tons of CO_2 (Psaraftis and Kontovas, 2009), which represents 3 per cent of all global GHG emissions (Cameron, 2010). As a result, ocean transport is equivalent to the sixth largest polluting country in the world (Eide *et al*, 2009) and the annual GHG emissions of Germany. Container ships specifically emit more GHGs than most other ocean vessel classes (Corbett *et al*, 2009), generating 270 million tons per year (Psaraftis and Kontovas, 2009). The International Maritime Organization (2009) alarmingly predicts that ocean vessel emissions will surge by 2–3 times current levels by 2050 as international trade increases. Despite other emission-reduction options like hull design changes, routing, propeller polishing and kite systems (Eide *et al*, 2009; Notteboom and Vernimme, 2009), slow steaming represents an immediate approach for carriers to improve their environmental impacts (Eide *et al*, 2009; Rosenthal, 2010).

Slow steaming also enables carriers to absorb excess *fleet capacity* during periods of slack demand. Throughout 2009 and 2010, ocean carriers took delivery of vessels ordered before the economic downturn, nearly doubling available capacity (Council of Supply Chain Management Professionals, 2011). However, approximately 5 per cent of the world container fleet is now idle due to weak demand (Leach, 2012). Since slower vessel speeds essentially reduce capacity on a service string, carriers can deploy excess vessels to the string to maintain capacity under slow steaming rather than 'laying up' $100+ million dollar ships (Leach, 2008; Johnson, 2010b). For instance, it is estimated that super slow steaming could absorb 4 per cent of the available fleet (Barnard, 2010a, b).

Schedule *timeliness* represents a fourth primary benefit of slow steaming. Delays in ocean shipping can arise from a broad spectrum of sources such as port congestion, terminal productivity, weather and mechanical issues (Notteboom, 2006). With limited buffer time in schedules, 'unexpected vessel waiting times in one port cascade throughout the whole loop' (Notteboom, 2006, p. 32). Reduced vessel speeds and longer transit times conceptually enable greater carrier flexibility to adjust speeds to overcome delays, allowing better schedule adherence (Barnard, 2010b; Bonney and Leach, 2010). Ocean schedule reliability is currently highly problematic with most carriers achieving only 50–60 per cent on-time arrivals (Gallagher, 2010). For shippers, better schedule reliability can reduce uncertainty and subsequent safety stock needs.

Shipper concerns

With the above benefits, carriers appear to be standing firm on slow steaming practices (Barnard, 2010c). However, shippers have voiced significant concerns over the parity of the benefits, mainly regarding longer *transit times*. First and foremost, longer transit times directly increase shipper in-transit (pipeline) inventory levels (Bonney and Leach, 2010; Dupin, 2011b). Longer transit times also extend the forecast horizon, thus likely decreasing forecast accuracy and subsequently increasing safety stock needs (Bonney and Leach, 2010; Dupin, 2011b) and making just-in-time shipment volumes more difficult to estimate (Dupin, 2011b). Similarly, longer transit times create challenges with perishable and short life cycle products (like clothing and electronics) (Page, 2011).

With these concerns, a sense of unfairness among shippers has emerged regarding a lack of transparency of both the cost impacts and implementation plan of slow steaming. A recent survey reveals that 70 per cent of shippers expect lower rates when slow steaming is used (Bonney, 2011). Yet, shippers have skeptically noted that since the onset of slow steaming, rates have not only increased but on-time reliability, touted by carriers as a slow steaming benefit, has not improved (Gallagher, 2010). Moreover, service contracts have not been adapted to address slow steaming outcomes. These challenges appear to be pervasive across the carrier base, limiting shipper power to switch carriers to share in the lower costs via reduced rates. Shippers have also criticized a lack of communication from carriers when transit times change (Dupin, 2011b). The intensity of shipper disapproval has prompted the US Federal Maritime Commission (FMC), the US regulatory body over international ocean transport, to prioritize an assessment of slow steaming to better understand the net effects on supply chains, carriers, shippers and the environment (Dupin, 2011a).

Academic Research

A growing base of academic literature has addressed elements of slow steaming, primarily focusing on carriers. Early research by Ronen (1982) identifies opportunities with optimizing ship speed to reduce fuel costs. Several researchers have since assessed tradeoffs between vessel speed and fuel savings, with some studying emissions benefits. For instance, work by Alvarez *et al* (2010) attempts to optimize fuel and ship costs with regard to vessel speed and berth availability. Notteboom and Vernimme (2009) evaluate the effects of carrier service design (that is, speed, ports called and vessels) in response to increasing fuel prices. Likewise, Zelasneya *et al* (2011) examine how fuel prices affect Asia-North America routing.

Additional works more specifically incorporate environmental impacts. For instance, Fagerholt *et al* (2010) identify substantial fuel savings and emission reductions from lower vessel speeds. Likewise, Corbett *et al* (2009) note that establishing a maximum vessel speed is not cost effective for reducing emissions but purport that adding a $60 per ton fuel tax, a controversial program (Rosenthal, 2010), will lower emissions by 20 per cent. In a similar vein, Eide *et al* (2009) compare the business cases for a variety of vessel emission reduction options, finding slow steaming to be highly beneficial.

The above literature provides strong foundations for slow steaming practices but does not usually address tradeoffs across all affected stakeholders. In work closest to our own, Cariou (2011) determines breakeven prices for fuel costs given tradeoffs with inventory and ship costs to assess the practicality of slow steaming. In addition, Lindstad *et al* (2011) model vessel and shipper pipeline inventory costs given slower vessel speeds, also depicting balances between cost and emission reductions. Still, these studies do not attempt to specifically resolve inequities between carriers and shippers. So, the business case for slow steaming and an approach for financial equity across stakeholders remain unclear.

Transit times

Shipper perceptions of unfairness relative to slow steaming are likely intensified by a reported lack of understanding over the effects of slower transit times. Specifically, previous studies have concluded that transit time reliability is important for ocean shippers (Notteboom and Rodrigue, 2009) who can significantly reduce supply chain costs by selecting faster carriers (Saldanha *et al*, 2009). However, Lu (2000, 2003) and Durvasula *et al* (2000) corroborate that shippers do not value the impact of transit times on supply chain costs. In addition, shippers have discounted the significance of transit time, perceiving performance to be relatively homogenous among carriers (Brooks, 1993) despite evidence otherwise (Saldanha *et al*, 2006).

This apparent gap between perception and reality indicates that shippers have not effectively quantified the impacts of slow steaming on supply chain costs. As such, it is unlikely that they can present a clear argument for why, as well as to what extent, carriers should financially apportion slow steaming benefits. Hence, there still remains a need to assess the specific benefits and detriments of slow steaming across involved stakeholders. Without such work, the overall business case for slow steaming is ambiguous, and an acceptable trade-off between speed and cost will be difficult to determine. We address this gap below through an extension of a simulation-based model developed by Paul and Maloni (2010).

Methodology

A simulation model of ocean shipping should incorporate the interaction of multiple operational stakeholders, including shippers, ocean carriers, inland (rail, truck) carriers and ports (port authorities, terminal operators, port labor) so as to provide reliable decision support to policy-makers. Following recent research (Luo and Grigalunas, 2003; Fan *et al*, 2009, 2010; Paul and Maloni, 2010), we apply a simulation-based optimization approach to replicate a major ocean container lane under varying vessel speeds associated with slow steaming. Specifically, the model examines container flows to/from Asia through the Port of Los Angeles, the largest North American container port. The methodology is reviewed in detail in a prior *Maritime Economics & Logistics* publication (Paul and Maloni, 2010), so we only highlight key elements below.

Designed in ProModel (2007), the simulation models vessel arrivals and departures as well as inbound and outbound container processing at the Port of Los Angeles. Port capacity is represented by critical resources including berth space, cranes and container storage space as obtained from survey data and publicly available information. We employ dynamic capacity modeling via regression-based parametric equations to reflect variable container processing times given potential delays during peak port throughput (Paul and Maloni, 2010). In other words, the simulation accounts for the phenomenon that container processing times will generally slow down when the port is busier. The simulation runs entail a full year of volume, including monthly seasonality differences.

Table 1 summarizes the data sources that support realistic and accurate modeling of the vessel arrival distribution and flow of containers at the Port of Los Angeles. Following Paul and Maloni (2010), we use 2005 container volume data and vessel call information from the US Department of Transportation Maritime Administration (2005a, b). Given the economic downturn in recent

Table 1: Sources of data

Data	*Sources*
Carbon dioxide (CO_2) emissions	Function of fuel consumption (Corbett *et al*, 2009; International Maritime Organization, 2009)
Cargo value	Carrier data and Saldanha *et al* (2009)
Container volumes by origin/destination, vessel size distribution	US Department of Transportation Maritime Administration(MARAD) Waterborne Databanks (2005b), American Association of Port Authorities (2012), port-provided data
Cost of capital	Saldanha *et al* (2009)
Fuel consumption, vessel speeds	Carrier-provided information
Inland transport (rail, truck) costs, speed	Carrier-provided information (Paul and Maloni, 2010)
Ocean transport costs	Carrier-provided information, Notteboom (2006), Eide *et al* (2009), Notteboom and Vernimme (2009)
Ocean travel distances	www.mapcrow.info
Port capacity resources (berths, cranes, acreage)	Lloyd's MIU (2005); port-provided information
Port costs	Carrier-provided information (Paul and Maloni, 2010)
Port volume capacity	Survey data from ports, port-provided information (Paul and Maloni, 2010)
Vessel calls (port arrivals)	US Department of Transportation Maritime Administration (MARAD) Vessel Movement Files (2005a) and Vessel Calls Snapshot (2009)

years, 2005 data actually very closely match 2010 volumes, and we hence refer to the baseline as 2010.

The model captures stakeholder costs and vessel emissions. First, ocean *carrier costs* retain both *fuel* and *vessel* components. Daily fuel consumption is based on carrier data relative to specific vessel sizes (Figure 1) given both the actual distribution of vessels calling the Port of Los Angeles and actual maritime distances. Vessel costs cover non-fuel direct operating costs including expenses related to the vessel itself and the crew (Notteboom, 2006; Eide *et al*, 2009; Notteboom and Vernimme, 2009). Our modeling accommodates decreased vessel utilization (containers carried in a year) given lower speeds as well as carrier practices of adding vessels to service strings to maintain overall string capacity.

Shipper costs account for pipeline inventory (that is, in-transit goods not available for sale). We used a fixed 10 per cent capital rate (Saldanha *et al*, 2009) and a per-TEU cargo value of $20 000, though we vary cargo value below to reflect potential differences of distinct shippers. *Port costs* cover container loading, unloading and storage, including detention, at the Port of Los Angeles, as derived from actual cost data from container carriers (Paul and Maloni, 2010). We also captured *inland costs* in the United States based on a mix of rail and truck moves derived from historical data (Paul and Maloni, 2010). Finally, we calculate vessel CO_2 *emissions* as a direct function of fuel consumption (3.17 MT CO_2/MT fuel burned) (Corbett *et al*, 2009; International Maritime Organization, 2009) to allow consideration of the environmental effects of slow steaming.

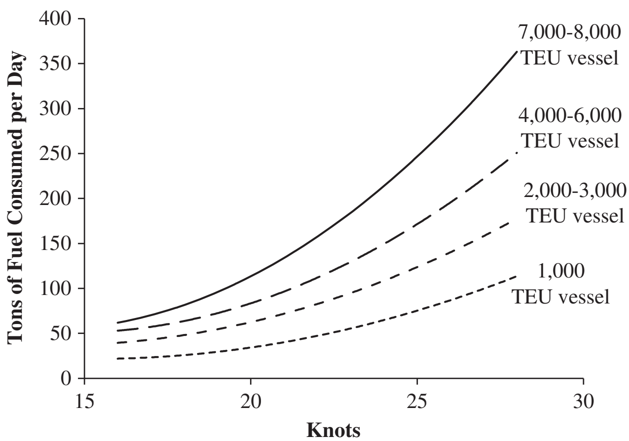

Figure 1: Container ship fuel consumption by vessel size.
Source: Ocean carrier data.

To expand the value of the model, we consider different combinations of vessel speeds, volumes and fuel prices using a factorial design. First, four vessel speeds are analyzed: full steaming (24 knots), slow steaming (21 knots), extra slow steaming (18 knots) and super slow steaming (15 knots). Actual vessel speed practices will vary within a loop with carriers generally running faster on segments with more actual loaded cargo (that is, inbound to the United States). Still, the results can represent average vessel speeds across loops and allow interpolation between speeds. We also model two levels of volume (2010 and 2015) as well as three levels of fuel prices: low ($400/MT), medium ($700/MT) and high ($1000/MT). These volume and fuel scenarios are clarified in the following discussion of the results.

Results

RQ1 – Costs and overall benefits

Figure 2 displays the results with respect to ocean carrier (fuel and vessel) and shipper (pipeline inventory) costs at 2010 volume and $700/MT fuel. Port and inland costs are not reported since the model verifies that these costs do not vary significantly with different vessel speeds. The results reveal that the combined carrier and shipper costs initially decrease appreciably as speed is lowered from full to slow then extra slow steaming. Specifically, slow steaming reduces combined overall costs by 13.0 per cent ($371 million) from full speed on the lane of study, and extra slow steaming lowers overall costs by 20.5 per cent ($585 million) from full speed. However, super slow steaming does not

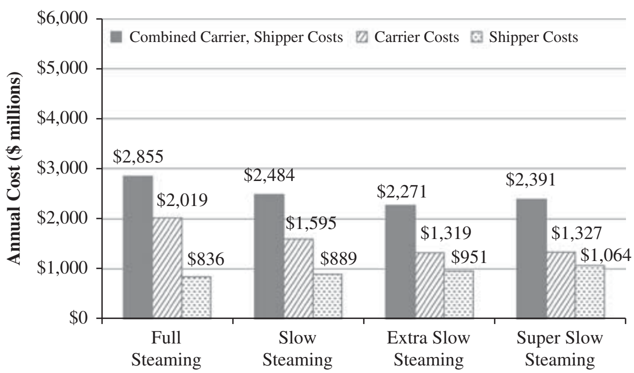

Figure 2: Annual ocean carrier and shipper costs ($ US) at different vessel speeds (2010 volume; $700/MT fuel price).

offer further improvements (16.3 per cent, $464 million reduction from full steaming) as shipper and vessel cost increases begin to outweigh fuel savings.

Figure 2 also depicts clear inequities across ocean carrier and shipper benefits, which will be discussed in detail later in response to RQ3. Despite such inequities, the results verify that slow steaming remains overall cost positive, even without considering environmental benefits. Extra slow steaming (a round trip average speed of 18 knots) appears to represent the best vessel speed. Using Response Surface Methodology, we more specifically determine that total costs are minimized at 17 knots and subsequently confirm this through additional simulation runs.

RQ2 – Volume and fuel price changes

With US container flows generally increasing at an appreciable rate (Maloni and Jackson, 2005), it is important to assess volume effects on the above results. Accordingly, we fit a trend line to 20 years of historical Port of Los Angeles container import and export volumes to extrapolate 2015 volumes (Figure 3). The year 2015 was selected based on collected capacity forecasts. It also allows for a reasonable extrapolation of TEU volumes. The *R*-squared value for this trend is highly significant at 0.90. So the forecast offers a realistic estimate of future container throughput, bearing in mind that container volume forecasts are often understated (Notteboom and Rodrigue, 2009).

The combined ocean carrier and shipper costs for the 2015 scenario (using current fuel prices) versus that of 2010 are depicted in Figure 4. The displayed polynomial-based trends (fit via the trendline option in Microsoft Excel with all R^2 values at or exceeding 0.99) reveal that the cost reduction pattern from slower vessel speeds at 2015 volume is similar to that at 2010 volume. Slow steaming saves 12.3 per cent ($523 million) on the lane from full speed at 2015 volume. Extra slow steaming saves 18.1 per cent ($770 million), which, as occurred with

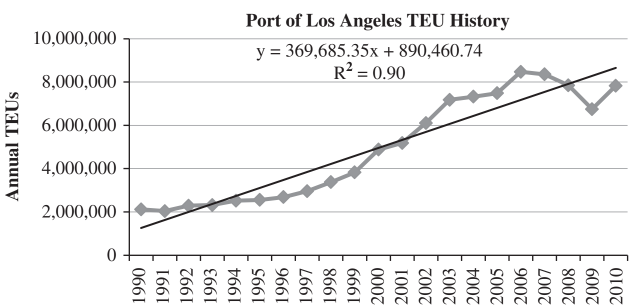

Figure 3: Port of Los Angeles TEU history with regressed trend line.
Note: 2015 volume projected as 369 685.35 × 26 (2015 is 26th year in series) + 890 469.74.

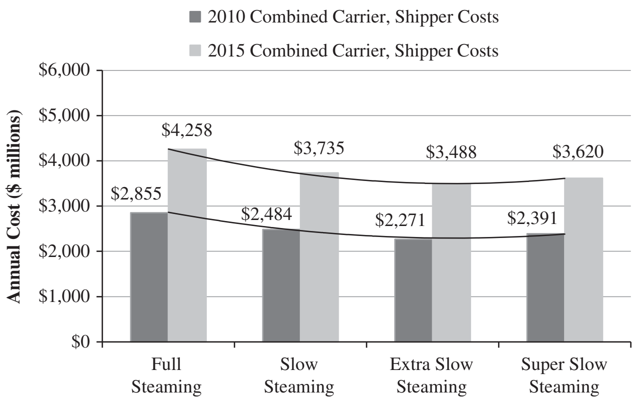

Figure 4: Combined ocean carrier and shipper costs ($ US) at different vessel speeds (2010 and 2015 volume; $700/MT fuel price).
Notes: Nonlinear trends: $122.85x^2 - 774.88x + 3516.22$, $R^2 = 0.99$ (2010); $163.73x^2 - 1034.96x + 5134.59$, $R^2 = 1.00$ (2015).

the 2010 results, again represents a stronger option that super slow steaming (15.0 per cent, $638 million savings). So, volume does not appear to change the optimal approach of targeting the extra slow steaming speed range.

Another parameter to consider is fuel price, which has arguably instigated slow steaming practices in the first place. Future prices of oil and subsequently marine fuel are extremely difficult to predict 'because a wide range of diverse, unpredictable, and sometimes unrelated phenomena impact oil and fuel markets' (Andreoli, 2011). Fuel prices have been fairly volatile over recent years (Andreoli, 2011), affected by production decisions, political unrest in oil-producing countries and rising consumption in highly populated, rapidly developing economies (Kemmsies, 2011). In the maritime industry, changes to marine fuel content standards will likely pointedly increase future prices (Johnson, 2008; Notteboom and Vernimme, 2009).

Reflecting such uncertainty, we estimate three fuel price scenarios. The above results are based on a bunker of $700 per metric ton (MT), the rounded current price (IFO 380, Los Angeles) at the time of modeling (Bunkerworld, 2012). We use this baseline as the *medium* fuel price scenario. $400/MT, which characterizes a relatively low price from the past five years (Bunkerworld, 2012), is used as the *low* price scenario to reflect an identified key slow steaming breakeven point (Barnard, 2010b; Cariou, 2011). Without reasonable knowledge of future oil prices, a $1000/MT *high* benchmark is set based on the equivalent distance from the medium scenario ($700/MT) to the lower ($400/MT) bound.

The findings from these fuel scenarios are represented in Figure 5 using 2015 volume. At full steaming, the high fuel price scenario increases combined

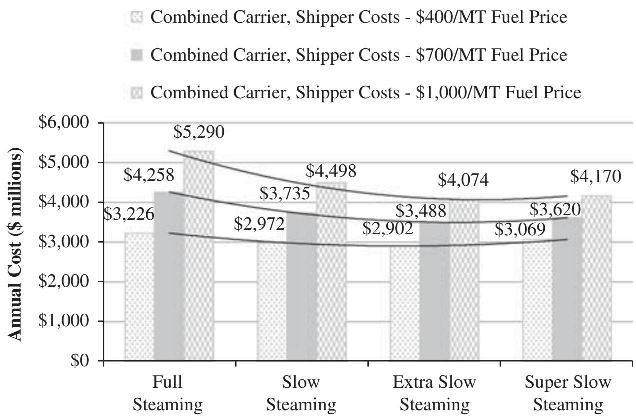

Figure 5: Combined ocean carrier and shipper costs ($ US) at different vessel speeds and fuel prices (2015 volume).
Notes: Nonlinear trends: $105.24x^2-580.27x+3703.70$, $R^2=1.00$ ($400/MT); $163.73x^2-1034.91x+5134.54$, $R^2=1.00$ ($700/MT); $222.22x^2-1489.54x+6565.38$, $R^2=1.00$ ($1,000/MT).

carrier and shipper costs by 24.2 per cent (about $1 billion). Polynomial-based trends (fit via the trendline option in Microsoft Excel with all *R*-squared values at or exceeding 0.99) show that the impacts of slower vessel speeds are stronger as fuel prices rise. As found in previous results, extra slow steaming remains optimal across all scenarios, representing the best vessel speed regardless of future volumes and fuel prices.

RQ3 – Carrier-shipper equity

Despite the clear overall gains from slow steaming, particularly extra slow speeds, inequity of financial savings across ocean carriers and shippers will limit acceptance of slow steaming implementation. Returning to Figure 2, ocean carriers solely enjoy the economic benefits of slower vessel speeds at the expense of shipper pipeline inventory increases. At the 2010 volume, medium fuel price ($700/MT) scenario for instance, carriers receive 34.7 per cent ($700 million) in savings while shippers incur 13.8 per cent ($115 million) in additional pipeline inventory costs. The latter result is energizing shipper pushback to slow steaming practices (Gallagher, 2010). Nevertheless, the model results increase shipper understanding of the specific cost effects of slow steaming to support negotiation of an amicable solution with carriers.

An obvious initial approach would be to adjust contractually fuel (that is, bunker) surcharge rates. As a point of complexity though, the cost effects of transit time changes will vary with cargo value (Saldanha *et al*, 2009). Per the explanation of shipper costs above, longer transit times increase shipper investment in pipeline inventory. Shippers with higher-value cargo will thus incur higher pipeline inventory costs than shippers of lower value cargo. So, a bunker surcharge that does not vary with cargo value will undercompensate shippers of higher-value cargo and overcompensate shippers of lower-value cargo. To address this, we consider different cargo value scenarios to allow a sensitivity analysis of shipper costs. Specifically, we use cargo value classes established by Saldanha *et al* (2009) ($6750, $32 172, $76 188, $138 797 and $220 000 per TEU), which represent 80–95 per cent of all shipment values.

Figure 6 compares incremental per shipment savings (for carriers) versus costs (for shippers) based on the five different cargo values. For low cargo value ($6750) for instance, the results reveal that the incremental pipeline inventory costs at slower vessel speeds are negligible, even in the case of super slow steaming (for example, less than $10). This infers that carriers might not offer compensation for such shipments. Shipper costs with the second lowest cargo value scenario ($32 172) are relatively low but still consequential (nearing $25 at extra slow steaming). Given that shippers have a higher bargaining power, carriers could effectively offer a portion of their per shipment savings to negate the

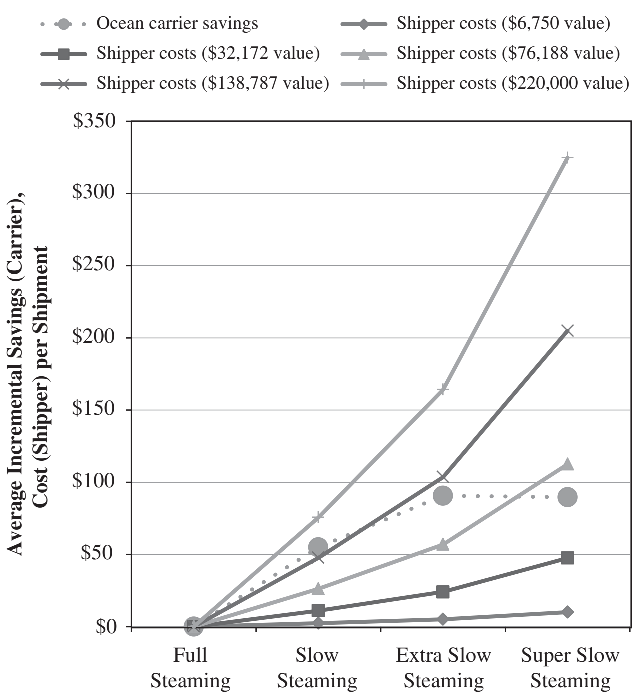

Figure 6: Per shipment carrier savings versus shipper costs ($ US) at different vessel speeds and cargo values (2010 volume).

incremental costs in such cases. For the higher cargo values, especially the \$138 787 and \$220 000 classes, carriers will not only have to cede their entire per shipment savings but actually draw from the savings from other lower-value shipments to create equity with shippers of these higher-valued cargoes. With the carrier-estimated average cargo value of \$20 000 however, such instances will likely be few in number. In addition, the results from RQ1 indicate that carriers will still retain a significant net level of savings even with compensation to shippers.

So, carriers could reach equity with shippers by employing a sliding scale bunker surcharge based on cargo value (that is, higher-value shipments receive lower bunker surcharges). Some carriers are reducing bunker surcharges to compensate for slow steaming (Leach, 2011a), but there is no indication that these adjustments uniquely reflect cargo value differences. Carriers do already tend to seek higher freight rates for higher-value cargo. Still, a cargo value-based sliding bunker would be difficult to apply given the underlying need for relative transparency of savings on behalf of carriers as well as accuracy of declared cargo values on behalf of shippers.

RQ4 – Carbon emissions benefits

Finally, we model the environmental effects of slow steaming. To do so, we approximate vessel CO_2 emissions based on a factor of 3.17 MT of emissions per MT of fuel burned (Corbett *et al*, 2009; International Maritime Organization, 2009). This accommodates varying fuel efficiencies associated with different vessel sizes (Figure 1). CO_2 emission reductions are summarized in Figure 7.

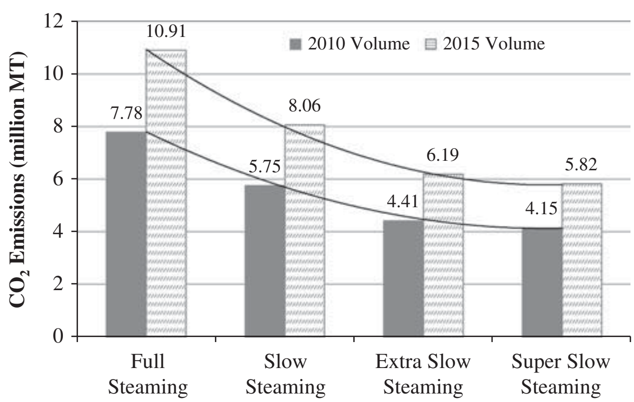

Figure 7: Annual CO_2 emissions (million MT) from vessels (2010 and 2015 volume).
Notes: Nonlinear trends: $0.44x^2-3.43x+10.79$, $R^2=1.00$ (2010); $0.62x^2-4.80x+15.12$, $R^2=1.00$ (2015).

The slopes of the fitted polynomial trends (fit via the trendline option in Microsoft Excel with all *R*-squared values at or exceeding 0.99) follow the nonlinear patterns seen previously. For 2010 volume, slow steaming lowers annual CO_2 emissions by 26.1 per cent (2.03 million MTs) from full speed on the lane of study. Extra slow steaming represents a decrease of 43.3 per cent (3.37 million MTs) from full speed, while super slow steaming adds little additional reduction (46.7 per cent, 3.63 million MTs). With many ocean carriers demonstrating commitments to improving environmental impacts (Leach, 2010b, c), these emission reductions further support the strong case for extra slow steaming established above with the prior research questions.

To allow breakeven analyses (that is, comparison of the cost to implement slow steaming-based emission reductions versus the cost of other corporate emission reduction initiatives) of the above emissions effects, Figure 8 assesses carbon reductions from slow steaming as a function of stakeholder savings by dividing cost savings (or increases for shippers) derived in RQ1 by metric ton of CO_2 emissions reduced. Eide *et al* (2009) recommend a cost (that is, negative savings) of $50 per metric ton a carrier breakeven for implementing emission reduction initiatives. In other words, they establish that carriers should expect to pay at most $50 per ton of averted emissions. The above slow steaming results fall well under this criterion, promoting slow steaming as a highly viable environmental option for carriers.

Shipper costs in Figure 7 furthermore offer a decision tool for shippers to set their own breakeven measures for cost-effectiveness assessment of carbon reduction projects. For instance, extra slow steaming will help shippers lower their carbon footprint if other carbon reduction project opportunities cost more than $34.23 per ton reduced (assuming no carrier financial compensation for

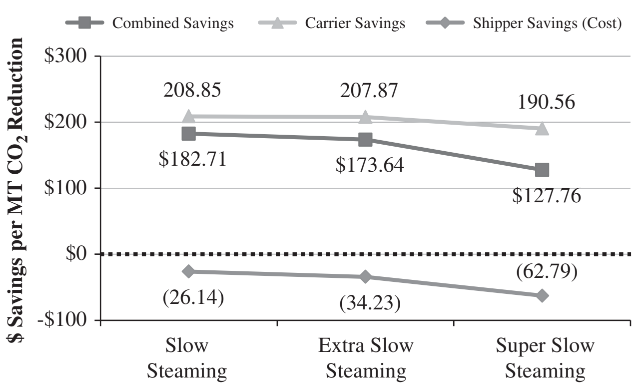

Figure 8: $US savings per metric ton of reduced CO_2 emissions (2010 volume; $700/MT fuel price).

increased pipeline inventory with slower vessel speeds). In this vein, carriers might enhance shipper acceptance of slower vessel speeds by quantifying and reporting specific carbon reduction achievements with slow steaming (Leach, 2011d). Carriers might initially target larger producers and retailers, some of which are now undertaking substantial carbon footprint reduction efforts (Rosenthal, 2008; Martin, 2009).

Conclusions

Slow steaming in the ocean container industry has the potential to significantly reduce fuel costs, lower CO_2 emissions, absorb excess fleet capacity and improve schedule reliability. With such benefits, slow steaming has become relatively common in recent years and will likely retain importance as carriers continue to face significant overcapacity and profitability issues (Edmonson, 2010; Barnard, 2011, 2012; Page, 2012). However, slower ocean transit times increase pipeline inventory. As a result, shippers are expressing significant concerns, asserting that slow steaming benefits are highly one-sided to ocean carriers who have yet to share in the financial savings via rate or bunker surcharge reductions in service contracts. The conflict appears to stem from a lack of transparency over such benefits, and limited extant research is available to provide resolution. As such, the model described in this article sought to clarify the benefits and costs of slow steaming across stakeholders as well as associated environmental impacts.

The model results purport that slow steaming is indeed beneficial from overall cost and environmental perspectives. Specifically, the findings approximate extra slow steaming as the optimal speed at which the overall net gains across stakeholders are maximized. Moreover, the results reveal that slower speeds are not always better in that vessel and pipeline inventory cost increases eventually outweigh carrier fuel savings at super slow steaming speeds. The general pattern of cost reductions were consistent across different volume levels and fuel prices, regularly identifying extra slow steaming as the best option. The study also provides insight into how to create financial equity of slow steaming benefits across carriers and shippers. The results reveal that even with passing some slow steaming cost savings to shippers (for example, via contractual rate or bunker charge reductions), particularly those with higher-value cargoes, carriers can still reduce costs. Finally, the study quantified significant CO_2 reductions derived from slow steaming, depicting breakeven costs for carriers and shippers in comparison to other emissions reduction options.

Ideally, market forces should cause slow steaming savings to be efficiently shared with customers through lower freight rates. Specifically, as carriers recognize lower costs from slow steaming, they will likely reduce freight rates to attempt to separate themselves in the market, which at the time of writing suffers from high capacity and forecasted weakening demand (Bonney, 2012). Despite recent successful carrier rate increases (Mongelluzzo, 2012), shippers will still retain negotiating power in the near-term. If carriers alienate shippers by not sharing in the financial savings of slow steaming, shippers will likely exercise their bargaining power coercively, leading carriers to cede all slow steaming savings and perhaps more via lower freight rates. So, we argue that carriers could better influence contract negotiations by proactively incorporating slow steaming benefits into rates based on detailed analyses of the financial impacts like that presented herein. Such an approach could also build goodwill and trust with shippers.

Future research

Despite the growing body of literature addressing vessel speeds and fuel efficiency, including this article, more work is urgently needed to further understand the practice of slow steaming that has now become commonplace in the industry. For instance, expanding the above analysis to multiple trade lanes would enhance the generalizability of the findings to other trades with different transit times and port capacities. Future research could also explore the impacts of slow steaming practices on perishable and short life cycle products as well as at different costs of capital wherein shipper compensation needs may be more difficult to resolve. Furthermore, the debate surrounding slow steaming could benefit from comparisons with other fuel efficiency options such as service design and larger ship sizes. A related stream of research could compare and contrast financial-based environmental incentive programs in the maritime sector, including carbon cap and trade, carbon tax, or reimbursements to carriers for increasing fuel efficiency (Tirschwell, 2011).

From an industry practice perspective, the discord created by slow steaming epitomizes challenges with the conventional nature of ocean carrier-shipper relationships. Fugate *et al* (2009) describe the potential success for collaboration in the transportation industry as weak but use qualitative evidence to demonstrate examples in motor carriage (for example, consistent routings and schedules, drop-and-hook operations, trailer standardization, dock re-design, and synchronization of production and shipping). More specifically to maritime, despite the vital role of ocean carriers within global supply chains, relationships between carriers and shippers have traditionally been characterized by complexity and a lack of transparency (Leach, 2011b). Price tends to dominate negotiations (Burnson, 2011; Leach, 2011f) with shippers framing container carriage as a commodity with significant ease of switching between carriers. Operationally, shippers may occasionally fail to deliver a container to port on time without notifying the ocean carrier, and carriers may intermittently skip a port of call or fail to load a container (Leach, 2011c, e). From a fuel perspective, ocean contracts have historically not effectively covered drastic changes in fuel prices (Johnson, 2008), and carriers have experienced difficulty in successfully recouping fuel cost increases from shippers (Johnson, 2011).

The overall cost and emissions benefits demonstrated herein implore the maritime industry to strive to overcome such conventional business practices. Some maritime industry executives are already pushing for a relational shift for shippers and carriers to maintain more collaborative mindsets to form stronger working relationships to address recurring, detrimental industry challenges like overcapacity and carrier profitability (Burnson, 2011; Leach, 2011f). However, the bulk of the academic collaboration research has focused on buyers and suppliers with minimal attention to carriers and shippers (Fugate *et al*, 2009), thus presenting a significant opportunity for future research to support collaborative carrier-shipper innovations like slow steaming. For instance, qualitative research methods such as grounded theory could lead to better understanding of managerial responses to slow steaming as well as carrier-shipper interactions in contractually negotiating a satisfactory share of slow steaming benefits. Without quantitative insight like that derived in this article combined with such proposed relational understanding, the industry will not be able to effectively operationalize slow steaming and will forego a portion of its substantial benefits.

References

Alvarez, J.F., Longva, T. and Engebrethsen, E.S. (2010) A methodology to assess vessel berthing and speed optimization policies. *Maritime Economics & Logistics* 12(4): 327–346.

American Association of Port Authorities. (2012) Port industry statistics, http://www.aapa-ports.org/, accessed 12 August.

Andreoli, D. (2011) Andreoli on oil & fuel: The trend is not your friend. *Logistics Management*, http://www.logisticsmgmt.com/article/andreoli_on_oil_fuel_the_trend_is_not_your_friend/, accessed 1 September 2011.

Barnard, B. (2010a) Analyst warns container vessel surplus looming. *The Journal of Commerce Online*, http://www.joc.com/maritime/analyst-warns-container-vessel-surplus-looming, accessed 17 June 2011.

Barnard, B. (2010b) Extra slow steaming absorbs 100 ships. *The Journal of Commerce Online*, http://www.joc.com/maritime/extra-slow-steaming-absorbs-100-ships, accessed 18 June 2011.

Barnard, B. (2010c) Maersk says slow steaming here to stay. *The Journal of Commerce Online*, http://www.joc.com/maritime/maersk-says-slow-steaming-here-stay, accessed 17 June 2011.

Barnard, B. (2011) Alphaliner says ocean carriers face prolonged slump. *The Journal of Commerce Online*, http://www.joc.com/container-shipping/carriers-face-prolonged-slump-alphanliner-warns, accessed 29 August 2011.

Barnard, B. (2012) Alphaliner says shipping overcapacity to accelerate. *The Journal of Commerce Online*, http://www.joc.com/container-shipping/alphalier-says-container-overcapacity-accelerate-2012, accessed 10 January 2012.

Bonney, J. (2010a) Built for speed. *The Journal of Commerce Online*, http://www.joc.com/maritime/built-speed, accessed 18 June 2011.

Bonney, J. (2010b) Carriers move full speed into slow steaming. *The Journal of Commerce Online*, http://www.joc.com/maritime/carriers-move-full-speed-slow-steaming, accessed 17 June 2011.

Bonney, J. (2011) Shippers seek lower rates from slow-steaming. *The Journal of Commerce Online*, http://www.joc.com/maritime/reduce-rates-slow-steaming-savings-shippers-say, accessed 17 June 2011.

Bonney, J. (2012) Drewry forecasts rough seas for container lines. *The Journal of Commerce Online*, http://www.joc.com/maritime-news/container-lines/drewry-forecasts-rough-seas-container-lines_20121010.html, accessed 15 November 2012.

Bonney, J. and Leach, P.T. (2010) Slow boat from China. *The Journal of Commerce Online*, http://www.joc.com/maritime/slow-boat-china, accessed 25 March 2011.

Brooks, M.R. (1993) International competitiveness – Assessing and exploring competitive advantage by ocean container carriers. *Logistics and Transportation Review* 29(3): 275–293.

Bunkerworld. (2012) Bunkerworld index, http://www.bunkerworld.com/prices/#, accessed 12 March 2012.

Burnson, P. (2011) 2011 ocean shipping roundtable: Resetting strategy. *Logistics Management*, http://www.logisticsmgmt.com/article/2011_ocean_shipping_roundtable_resetting_strategy/, accessed 7 September 2011.

Cameron, L. (2010) The big money in slow shipping. *Canadian Business* 83(7): 22.

Cariou, P. (2011) Is slow steaming a sustainable mean for reducing liner shipping CO2 emissions? *Transportation Research Part D: Transport and Environment* 16(3): 260–264.

Corbett, J.J., Wang, H. and Winebrake, J.J. (2009) The effectiveness and costs of speed reductions on emissions from international shipping. *Transportation Research Part D: Transport and Environment* 14(8): 593–598.

Council of Supply Chain Management Professionals. (2011) 22nd annual state of logistics report, http://cscmp.org/securedownloads/filedownload.aspx?fn=memberonly/22sol-report.pdf, accessed 29 August 2011.

Dupin, C. (2011a) FMC plans look at slow steaming. *American Shipper*, http://www.americanshipper.com/NewWeb/news_page_SNW2.asp?news=179286, accessed 5 January 2011.

Dupin, C. (2011b) Shippers, carriers spar on slow steaming. *American Shipper*, http://www.americanshipper.com/NewWeb/news_page_SNW2.asp?news=189906, accessed 17 June 2011.

Durvasula, S., Lysonski, S. and Mehta, S.C. (2000) Business-to-business marketing: Service recovery and customer satisfaction issues with ocean shipping line. *European Journal of Marketing* 34(3/4): 433–452.

Edmonson, R.G. (2010) Lawmakers draft ocean carrier antitrust immunity bill. *The Journal of Commerce Online*, http://www.joc.com/government-regulation/lawmakers-draft-ocean-carrier-antitrust-immunity-bill, accessed 12 September 2011.

Eide, M.S., Endresen, O., Skjong, R., Longva, T. and Alvik, S. (2009) Cost-effectiveness assessment of CO2 reducing measures in shipping. *Maritime Policy & Management* 36(4): 367–384.

Fagerholt, K., Laporte, G. and Norsta, I. (2010) Reducing fuel emissions by optimizing speed on shipping routes. *Journal of the Operational Research Society* 61(3): 523–529.

Fan, L., Wilson, W. and Tolliver, D. (2009) Logistical rivalries and port competition for container flows to US markets: Impacts of changes in Canada's logistics system and expansion of the Panama Canal. *Maritime Economics & Logistics* 11(4): 327–357.

Fan, L., Wilson, W. and Tolliver, D. (2010) Optimal network flows for containerized imports to the United States. *Transportation Research Part E: Logistics and Transportation Review* 46(5): 735–749.

Fugate, B.S., Davis-Sramek, B. and Goldsby, T.J. (2009) Operational collaboration between shippers and carriers in the transportation industry. *International Journal of Logistics Management* 20(3): 425–447.

Gallagher, T.L. (2010) More ocean carriers fall behind schedule. *The Journal of Commerce Online*, http://www.joc.com/maritime/more-ocean-carriers-fall-behind-schedule, accessed 17 June 2011.

International Maritime Organization. (2009) Second IMO GHG study, http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents/GHGStudyFINAL.pdf, accessed 18 June 2011.

Johnson, E. (2008) Pump shock. *American Shipper* 50(2): 50–54.

Johnson, E. (2010a) Slow burn. *American Shipper* 52(1): 34–35.

Johnson, E. (2010b) Slow steaming changes game. *American Shipper* 52(4): 27–28.

Johnson, E. (2011) TSA defends omitting bunker from index. *American Shipper*, http://www.americanshipper.com/NewWeb/news_page_SNW2.asp?news = 201594, accessed 7 September 2011.

Kemmsies, W. (2011) Pumped up about oil prices. *American Shipper*, http://www.americanshipper.com/NewWeb/news_page_SNW2.asp?news = 187900, accessed 4 April 2011.

Leach, P.T. (2008) Too much, too soon. *The Journal of Commerce Online*, http://www.joc.com/too-much-too-soon-1, accessed 17 June 2011.

Leach, P.T. (2010a) CKYH begins slow steaming eastbound Europe-Asia. *The Journal of Commerce Online*, http://www.joc.com/maritime/ckyh-begins-slow-steaming-eastbound-europe-asia, accessed 17 June 2011.

Leach, P.T. (2010b) Green NYK ship serves Hamburg. *The Journal of Commerce Online*, http://www.joc.com/maritime/green-nyk-ship-serves-hamburg, accessed 1 September 2010.

Leach, P.T. (2010c) Maersk verifying carbon emissions data. *The Journal of Commerce Online*, http://www.joc.com/maritime/maersk-verifying-carbon-emissions-data, accessed 12 September 2011.

Leach, P.T. (2011a) APL fuel surcharges to reflect slow-steaming. *The Journal of Commerce Online*, http://www.joc.com/maritime/apl-fuel-surcharges-reflect-slow-steaming, accessed 25 June 2011.

Leach, P.T. (2011b) Big shippers respond to Maersk's call for change. *The Journal of Commerce Online*, http://www.joc.com/container-shipping/big-shippers-respond-maersk's-call-change, accessed 31 August 2011.

Leach, P.T. (2011c) Carriers implementing fees for no-show, rolled shipments. *The Journal of Commerce Online*, http://www.joc.com/container-lines/carriers-implementing-mutual-fees-no-show-rolled-containers, accessed 25 June 2011.

Leach, P.T. (2011d) Hanjin introduces upgraded carbon calculator. *The Journal of Commerce Online*, http://www.joc.com/container-lines/hanjin-introduces-upgraded-carbon-calculator, accessed 1 September 2011.

Leach, P.T. (2011e) Maersk to compensate shippers for late cargo. *The Journal of Commerce Online*, http://www.joc.com/container-lines/maersk-compensate-shippers-late-asia-europe-cargo, accessed 12 September 2011.

Leach, P.T. (2011f) Time for change. *The Journal of Commerce Online*, http://www.joc.com/container-shipping/time-change, accessed 20 June 2011.

Leach, P. (2012) Maersk CEO: Ocean carriers have idled 5 per cent of fleet. *The Journal of Commerce Online*, http://www.joc.com/container-shipping/maersk-ceo-ocean-carriers-have-idled-5-percent-fleet, accessed 15 March 2012.

Lindstad, H., Asbjørnslett, B.E. and Strømman, A.H. (2011) Reductions in greenhouse gas emissions and cost by shipping at lower speeds. *Energy Policy* 39(6): 3456–3464.

Lloyd's MIU. (2005) *Containerisation International Yearbook*. London: Lloyd's MIU.

Lu, C.-S. (2000) Logistics services in Taiwanese maritime firms. *Transportation Research Part E: Logistics and Transportation Review* 36(2): 79–96.

Lu, C.-S. (2003) Market segment evaluation and international distribution centers. *Transportation Research Part E: Logistics and Transportation Review* 39(1): 49–60.

Luo, M. and Grigalunas, T.A. (2003) A spatial-economic multimodal transportation simulation model for US coastal container ports. *Maritime Economics & Logistics* 5(2): 158–178.

Maloni, M. and Jackson, E.C. (2005) North American container port capacity: An exploratory analysis. *Transportation Journal* 44(3): 1–22.

Martin, A. (2009) How green is my orange? *The New York Times*, http://www.nytimes.com/2009/01/22/business/22pepsi.html, accessed 2 September 2011.

Mongelluzzo, B. (2012) Carriers' pricing discipline paying off. *The Journal of Commerce Online*, http://www.joc.com/maritime-news/carriers-pricing-discipline-paying_20121001.html, accessed 15 November 2012.

Notteboom, T.E. (2006) The time factor in liner shipping services. *Maritime Economics & Logistics* 8(1): 19–39.

Notteboom, T.E. and Rodrigue, J.-P. (2009) The future of containerization: Perspectives from maritime and inland freight distribution. *GeoJournal* 74(1): 7–22.

Notteboom, T.E. and Vernimme, B. (2009) The effect of high fuel costs on liner service configuration in container shipping. *Journal of Transport Geography* 17(5): 325–337.

Page, P. (2011) Time, money. *The Journal of Commerce Online*, http://www.joc.com/commentary/time-money, accessed 17 June 2011.

Page, P. (2012) Operation slow-go. *The Journal of Commerce Online*, http://www.joc.com/commentary/operation-slow-go, accessed 3 February 2012.

Paul, J.A. and Maloni, M.J. (2010) Modeling the effects of port disasters. *Maritime Economics & Logistics* 12(2): 127–146.

ProModel. (2007) Decision making tools and techniques, http://www.promodel.com/, accessed 23 June 2009.

Psaraftis, H.N. and Kontovas, C.A. (2009) CO2 emission statistics for the world commercial fleet. *WMU Journal of Maritime Affairs* 8(1): 1–18.

Ronen, D. (1982) The effect of oil price on the optimal speed of ships. *The Journal of the Operational Research Society* 33(11): 1035–1040.

Rosenthal, E. (2008) Environmental cost of shipping groceries around the world. *The New York Times*, http://www.nytimes.com/2008/04/26/business/worldbusiness/26food.html, accessed 2 September 2011.

Rosenthal, E. (2010) Cargo skippers cry, 'slow speed ahead'. *International Herald Tribune*, 17 Feb: 1, 4.

Saldanha, J.P., Russell, D.M. and Tyworth, J.E. (2006) A disaggregate analysis of ocean carriers' transit time performance. *Transportation Journal* 45(2): 39–60.

Saldanha, J.P., Tyworth, J.E., Swan, P.F. and Russell, D.M. (2009) Cutting logistics costs with ocean carrier selection. *Journal of Business Logistics* 30(2): 175–195.

Tirschwell, P. (2011) Climate for change. *The Journal of Commerce Online*, http://www.joc.com/commentary/climate-change, accessed 12 August 2011.

US Department of Transportation Maritime Administration. (2005a) *Vessel Movement Files (CD ROM)*. US Department of Transportation Maritime Administration.

US Department of Transportation Maritime Administration. (2005b) *Waterborne Databanks (CD ROM)*. US Department of Transportation Maritime Administration.

US Department of Transportation Maritime Administration. (2009) *Vessel Calls Snapshot, 2008*. Washington DC: US Department of Transportation Maritime Administration.

White, R.D. (2010) Cargo ships are under new orders: Not so fast; 'Slow steaming' helps shipping lines cut fuel costs. *Los Angeles Times*, 31 July: B.1.

Zelasneya, J., Hupperta, D. and Leschine, T. (2011) The influence of oil price on maritime routing of containerized imports from China. *Maritime Economics & Logistics* 13(3): 298–318.

