Why Slow-Steaming is not a Zero-Sum Game[1]

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Slow steaming, the practice of running ships slower, is the most effective short-term measure to cut down on shipping's greenhouse gas (GHG) emissions. It does not require costly retrofits or expensive visits to the shipyard. And best of all, it is effective immediately.

There are still a few traditional misconceptions around slow steaming. One of them is that slow steaming is a zero-sum game. When ships sail slower more ships are needed to carry the same amount of seaborne trade (tonne-miles) in the same amount of time. The misconception assumes that this additional capacity cancels out the initial emission benefits. However, this is not true. The emissions saved through the speed reduction still far outweigh the emissions caused by the additional ships.

In theory, the relationship between a ship's speed and its fuel consumption is a straightforward one: As a ship increases its speed, the degree of drag and water resistance its hull experiences increases exponentially. Hence, a vessel's fuel consumption (and by extension its GHG emissions) can be approximated as an exponential function of its sailing speed (Ronen, 1982).

$$GHG\ emissions\ per\ day = \ EF * F_D \left(\frac{V}{V_D}\right)^{CE} \tag{1}$$

where EF is the GHG emissions factor, and is 3.114 tonnes of GHG per ton of HFO, F_D is the daily fuel consumption at the design speed, V_D is the design speed, V is the actual speed and CE is the consumption exponent.

The literature commonly describes the consumption exponent as cubic ($CE = 3$) for diesel driven ships (Stopford, 2009, p. 234). Unfortunately, the theoretical, cubic relationship between speed and GHG emissions does not translate perfectly into practice. In reality, outside factors such as weather and hull or engine specifications play a significant role. Adland, Cariou, & Wolff (2020) therefore suggest that the relationship between speed and emissions is not perfectly cubic; instead, a consumption exponent of 1.87 should be used when the vessels speed is not close to the design speed. While this weakens the effect of speed reductions on GHG emissions, the basic principle behind slow steaming still holds.

For a typical panamax bulk carrier with a capacity of 70,000 dwt, a design speed of 14 kn and a daily fuel consumption of 30 tonnes, the formula can be written as:

$$GHG\ emissions\ per\ day = \ 3.114 * 30 * \left(\frac{V}{14}\right)^{1.87} \tag{2}$$

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[1] Draft working paper as a follow-up to the Global Maritime Forum's Annual Summit 2021 in London and as an input to the World Bank's research on energy efficiency in shipping.

Applying the formula shows that a 10 percent reduction in sailing speed would lead to a 18 percent decrease in GHG emissions. Figure 1 illustrates this relationship.

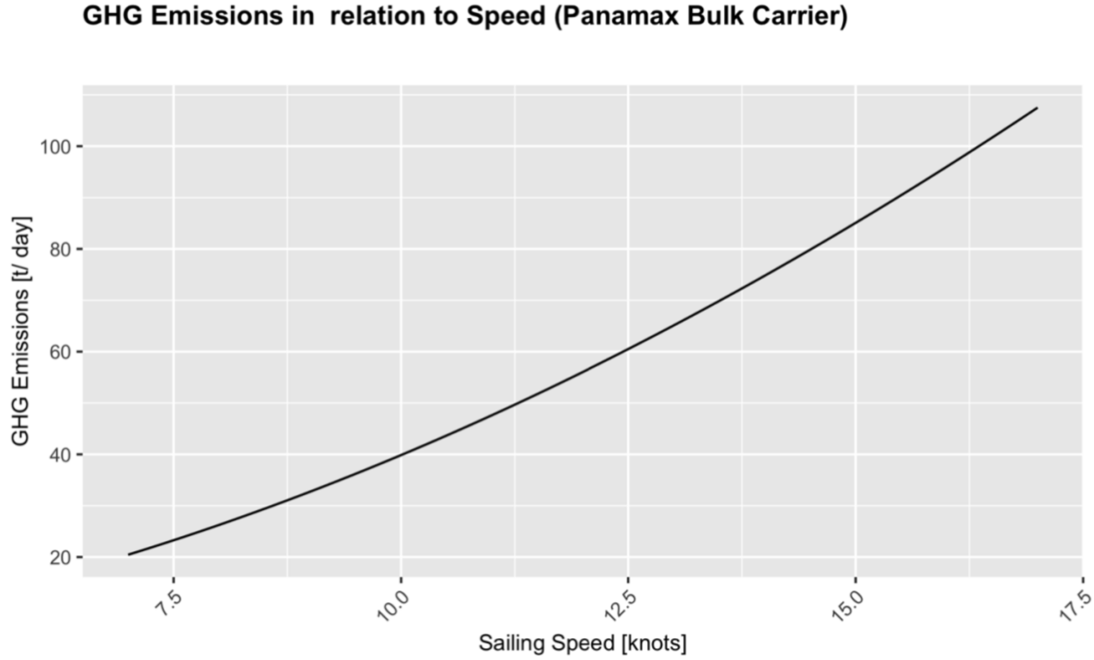

Figure 1: GHG emissions as a function of sailing speed (own illustration)

Consider the bulk shipping segment in 2018[2]. Approximately 12,000 bulk carriers performed a combined transport work of 26,912 billion tonne-miles, sailing at an average speed of 11.4 knots (Clarksons SIN, 2022). At 196 million tonnes of GHG emissions from bulk carriers[3], this equates to an GHG efficiency of 7.29 grams of GHG emissions per tonne-mile. As sailing speed is reduced by only one knot, or 8.8 percent, tonne-mile capacity equally reduces by 8.8 percent while emissions intensity (GHG efficiency) reduces by 15.8 percent to 6.14 grams of GHG emissions per tonne-mile. This was calculated using the formula from above with the more conservative consumption exponent of 1.87.

To compensate for the loss in capacity, some additional 2,360 billion tonne-miles are required. As this tonnage can only be provided by newbuildings, the GHG emissions from the shipbuilding and scrapping process must be considered. Research by Quang, Dong, Van, & Ha (2020) suggests that newbuilding and recycling accounts for approximately 6 percent of a typical bulk carrier's lifecycle emissions. Thus, the additional required capacity, will achieve a GHG efficiency of $6.14 * (1 + 0.06) = 6.51$ grams of GHG emissions per tonne-mile.

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[2] 2018 was chosen as it represents the most recent year covered by the fourth IMO GHG study (Faber, et al., 2020)

[3] As estimated by Faber, et al. (2020) in the fourth IMO GHG study.

Table 1: Fleetwide speed reduction of one knot

	Initial	**Existing tonnage, with reduced speed**	**Additionally required tonnage**
Initial capacity (bn tonne-miles)	26,912	24,551	2,360
Initial average sailing speed (knots)	11.4	10.4	10.4
GHG efficiency (tonnes GHG/tonne-mile)	7.29	6.14	6.51
GHG emissions (million tonnes)	196.30	150.83	15.37
Total new GHG emissions (million tonnes)			166.20
Total GHG emissions improvement (%)			**(15.3%)**
Speed reduction (%)			**(8.8%)**

Assumptions: initial sailing speed (fleet average 2018): 11.4 knots; initial fleetwide GHG emissions (bulk carriers): 196.3 million tonnes; newbuilding and recycling emissions: 6 percent of lifecycle emissions; consumption exponent: 1.87

In sum, reducing the sailing speed by just one knot would yield a net GHG emissions improvement of 15.3 percent compared to the initial situation. In other words, the GHG reductions by slow steaming (45.47 million tonnes) are larger than the additional GHG emissions caused by additional capacity required (15.37 million tonnes), resulting in net GHG saving of 30.10 million tonnes. To put into perspective, these savings roughly equate to half a year's worth of GHG emissions from transatlantic flights.[4]

It must be stressed, that this simple "back-of-the-envelope“ calculation serves the purpose of illustrating the mechanics behind slow-steaming and is by no means a proper assessment of the GHG emissions savings potential of slow steaming. To obtain a reliable estimate of the effects of a fleetwide speed reduction, data would have to be analyzed on an individual ship level, taking into account the operational profile of each vessel.

Nonetheless, the above calculation undoubtedly demonstrates that slow steaming is, in fact, not a zero-sum game, but rather a highly effective, and immediate measure to reduce shipping's carbon footprint. However, its implementation will largely depend on its economic viability. In other words, how does slow steaming affect the bottom line of ship owners?

To investigate this question, assume a fictional shipowner, owning a single panamax bulk carrier (like the one in the above example) exclusively operating on a trade between the ports

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[4] 56.1 million tons of CO_2 in 2019, according to Graver, Rutherford, & Zheng (2020).

of Brisbane, Australia and Longkou, China, a rather typical voyage for this type of vessel. The voyage is 4,533 nautical miles long and takes about 17 days to complete at a speed of 11.4 knots.[5] Accounting for 4 days of laytime on each leg of the voyage, a vessel can complete a little shy of 9 round trips per year. Thus, a 70,000 dwt panamax bulk carrier would incur an annual revenue of $5.59 million at a freight rate of 10.93 $/tonne and port handling costs of $2.00/tonne.[6]

According to Stopford (2009, p. 255 ff.), a shipowner's expenses largely consist of voyage costs, operational expenses (OPEX), capital expenses (CAPEX) and depreciation. Voyage costs, variable costs which dependent on the voyage at hand, are are mainly made up of port costs[7] as well as bunker fuel costs. Table 2 shows the corresponding profit and loss statement of the exemplary shipowner.

Table 2: Impact of slow steaming on a shipowner's P&L

	Initial	**Slow steaming**	**Abs. change**	**% change**
Speed (knots)	11.40	10.40	(1.0)	(9%)
Freight Rates ($/tonne)	11.00	11.00		
Port costs ($/tonne)	(2.00)	(2.00)		
Voyages per year	8.87	8.24	(0.6)	(7%)
Voyage revenue (bn USD)	5,589,999	5,188,155	(401,844)	(7%)
Consumption (tonnes/day)	18.00	15.16	(2.84)	(16%)
VLSFO consumption (million tonnes)	5,292	4,535	(758)	(14%)
Bunker costs (USD)	(3,175,372)	(2,720,868)	454,503	(14%)
Voyage costs (bn USD)	(3,175,372)	(2,720,868)	454,503	(14%)
Voyage income (bn USD)	2,414,627	2,467,286	52,659	2%
Fixed cost (Depreciation, OPEX, CAPEX)	(1,000,000)	(1,000,000)		
Net income	1,414,627	1,467,286	52,659	4%

Assume that the shipowner now decides to reduce the vessel's sailing speed by one knot. Not surprisingly, the same ship can complete less voyages in the same year, which leads to a $401,844 (7 percent) loss in revenue. Meanwhile, owing to the exponential relationship between speed and consumption, bunker costs decrease by $454,503 (14 percent), resulting in a net benefit of $52,659 for the shipowner. Non-voyage related expenses, such as OPEX,

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[5] This calculation assumes that the ship makes laden voyages from Brisbane, Australia and Longkou, China and returns empty (in ballast condition). Further, it is assumed that the sailing speed is the same for laden and ballast voyages.

[6] Average 2020 freight rate between Brisbane, Australia and Longkou, China according to (Clarksons SIN, 2022).

[7] For simplicity, port costs, quoted in $/tonne, are deducted from the freight rate to calculate the voyage revenue. It covers cargo handling, towage and pilotage and is assumed to be $2/tonne per ton of cargo in this example.

CAPEX and depreciation are not dependent on sailing speed, thus remain constant. The savings generated by the speed reduction clearly outweigh the lost revenue.

Figure 2 is a visual representation of the above example. As the ship's sailing speed is reduced, cost savings increase exponentially, and loss of revenue increases linearly. It becomes apparent, that the shipowner should reduce the vessel's speed to 9.6 knots to optimize bottom line results.

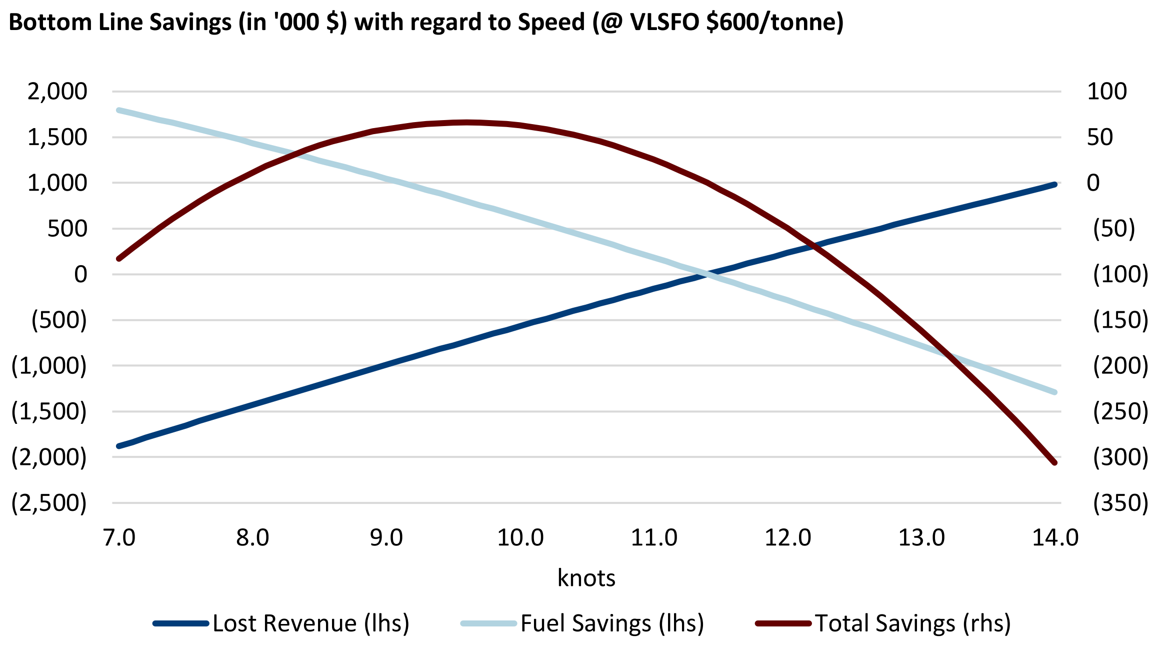

Figure 2: Impact of sailing speed on shipowner's bottom line

The example shows that the impact of a speed reduction on the profit and loss statement is largely depended on the following factors:

- *Freight rate:* The freight rate determines the loss in revenue incurred by a speed reduction. Falling freight rates reduce opportunity costs and encourage slow steaming. In practice, slow steaming (and the reduction in tonne-mile capacity) would create an artificial supply shortage, which would prop up freight and voyage rates, at least in the short to medium term (Devanney, 2009). Thus, the loss in revenue would likely be less than assumed in the example calculation, thereby mitigating the loss in revenue.
- *Initial consumption:* The ship's initial consumption is crucial to determine the bunker cost savings generated by slow steaming. The example uses a figure of 18 tonnes of VLSFO per day at a speed of 11.4 knots. The higher the initial consumption, the greater the bottom line improvement.
- *VLSFO bunker price:* The example above uses a VLSFO bunker price of $600/tonne. With the advent of more expensive alternative fuels and a carbon levy, shipowners can expect this price to increase even further. Higher bunker prices will exacerbate the effect of speed reductions on the bottom line.

Figure 3 illustrates the relationship between the VLSFO bunker price and the shipowner's bottom line. While the loss incurred by the speed reduction is constant, the bunker cost savings increase with the VLSFO bunker price. Thus, the bottom line improves with the VLSFO bunker pricess.

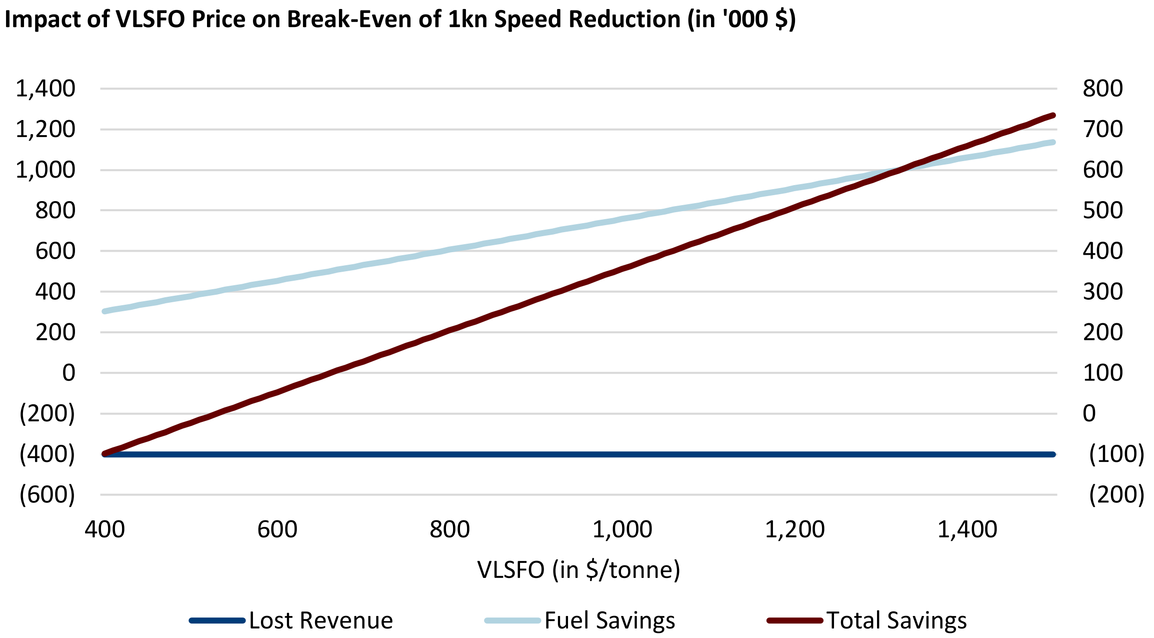

Figure 3: Breakeven of a one-knot speed reduction at different bunker prices

The case study presented above demonstrates the environmental as well as bottom line effect of speed reductions by just one knot can be quite considerable. In anticipation of rising fuel prices over the course of shipping's energy transition, this effect will only gain in significance. Yet, in practice, shipowners rarely optimize their ship's speed according to bunker prices (Adland & Haiying, 2018). Contractual limitations, such as minimum speed clauses and rigid laycan dates limit the shipowner's ability to reduce their sailing speeds when soaring bunker prices call for it. A lot must happen before shipowners can leverage the full economical and ecological potential of slow steaming. Modernizing the outdated and rigid charter party agreements into timely, flexible contracts could be a first step.

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