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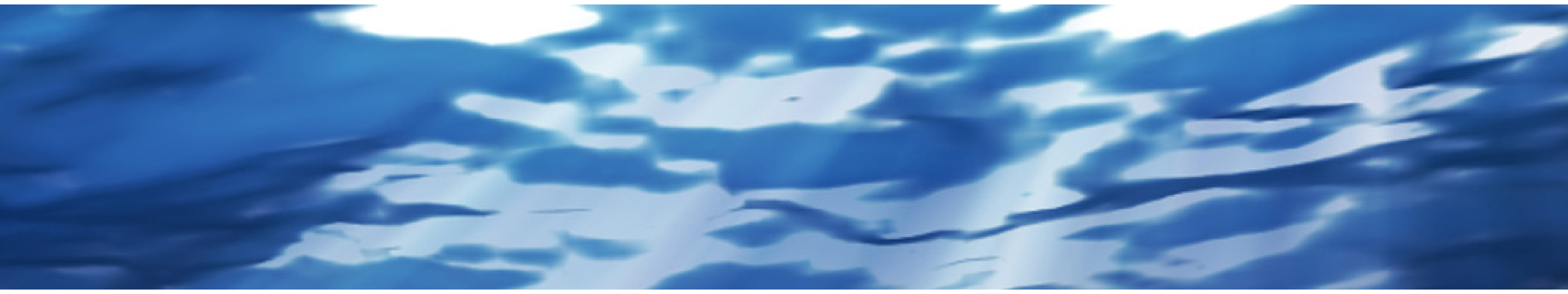

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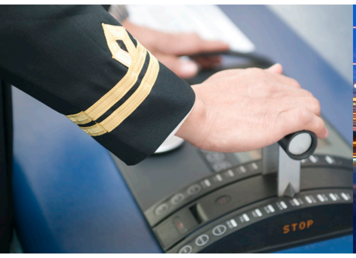
Consequences of speed reductions for ships

An impact study for shipping companies and Swedish business

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Consequences of speed reductions for ships

An impact study for shipping companies and Swedish business

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Summary

Mandatory speed reductions have been proposed by different parties within the International Maritime Organization (IMO) as a short time measure to reduce the emissions of greenhouse gases from shipping. This study assesses what consequences it can have for Swedish shipowners and the Swedish business society that relies on maritime transportation in their supply chains.

The most relevant IMO proposals for mandatory speed reductions are described in the study and from these a selected number of speed reduction proposals are analysed further.

The speed that the vessels is operating at will affect the consumption of fuel per transport work and in many cases, a lower speed will also result in a reduced greenhouse gas impact per moved amount of cargo. The effects in total savings are higher for the speed reductions close to vessels design speed and will give lower savings the more the speed is reduced.

The results show that the effects for a specific shipping company can be anything from minor towards an impact that makes the present business case unfavourable. The study cannot lay down that mandatory speed reductions will give all shipping companies severe negative effects, this as the effects will vary substantially, from positive to negative, depending on shipping segment, geographic market, modal competition and the design of the service. It is clear, though, that some shipping companies will be severely affected.

When fuel savings from speed reduction is assessed, the relation between main engine power needed for propulsion and vessel speed reduction, Power = $k*(v/v_0)^3$ is often used; where v is the reduced speed and v_0 the initial reference speed. This relation normally gives the correct correlation for smaller speed reductions but will overestimate the savings for larger speed reductions. A reason for the overestimates is that the fuel consumption in the main engines will not reach zero consumed fuel at zero speed (as the model indicates). Just the fact that the engines are running also at berth will consume fuel and, further, the engine and propulsion efficiency will decrease gradually when the system diverge from the speed for which the system is optimised for.

The calculations in the case studies and interviews performed in this study indicate that some of the logistics service designs will require a totally different one in case that the speed is required to decrease. Such effects can be that the turnaround time is not efficient for the number of trips per day, or weekly service that the service is designed for. For other cases, the speed is already at such a low level, compared to the average for the vessel size and segment, that even relatively large speed reduction requirements will not require further reductions and hence not affect the operations at all. Other setups will instead

lose competitiveness in comparison with competing road transport with an expected effect on modal shift towards road transport.

The consumption and the related greenhouse gas emissions per transported amount of cargo seem for most of the analysed cases be possible to lower with reduced speed for the speed limitations under study. However, the cost per moved amount of cargo seems to be optimised at present speed and tends to increase in case of further speed reductions. This has been assessed with simplified economical calculations for a tanker and a RoRo vessel case, respectively.

The interviews conducted among shipping companies give similar results as in the case study assessment: mandatory speed reductions will impose significant economical and logistical implications on ship-owners and their customers, especially in liner shipping.

An often-discussed issue is the possible effects of more vessels needed to be built when speed is lowered. An assessment performed for a Panamax tanker transport setup in a life cycle perspective indicates that the increased need for extra tonnage, when speed is lowered, will give a marginal effect on total greenhouse gases per transport work performed. This as the operational emissions connected to the consumption of fuel oil totally dominates the impact compared to building, mainting and scrapping a vessel.

Sammanfattning

Obligatoriska hastighetsminskningar har föreslagits av olika parter inom International Maritime Organization (IMO) som en åtgärd för att i närtid minska utsläppen av växthusgaser från sjöfarten. Denna studie bedömer vilka konsekvenser sådana regleringar kan ha för svenska redare och för det svenska samhället som förlitar sig på sjöfart i sina leveranskedjor.

De mest relevanta förslagen till IMO kring obligatoriska hastighetsminskningar beskrivs i studien och utifrån dessa analyseras ett antal scenarios för hastighetsminskning.

Den hastighet som fartygen opererar med kommer att påverka förbrukningen av bränsle per transportarbete och i många fall kommer en lägre hastighet också att resultera i en minskad klimatpåverkan per flyttad mängd last. Effekterna av de totala besparingarna är högre för hastighetsminskningarna nära fartygens konstruktionshastighet men med större fartminskningar minskar besparingar ju mer hastigheten reduceras.

Resultaten visar att effekterna för ett specifikt rederi kan vara allt från små till en påverkan som gör nuvarande upplägg olönsamma. Studien kan inte fastställa att obligatoriska hastighetsminskningar ger alla företag allvarliga negativa effekter, eftersom effekterna kommer att variera väsentligt, från positiva till negativa, beroende på sjöfartssegment, geografisk marknad, konkurrens från andra transportslag och transportupplägg. Det är dock tydligt att vissa företag kommer att drabbas hårt.

När bränslebesparingar från hastighetsminskning bedöms används ofta förhållandet mellan effekten i fartygets huvudmaskin som behövs för framdrivning och fartygshastighetsminskning med hjälp av sambandet, Power $= k * (v / v_0)^3$; där v är den reducerade hastigheten och v_0 den initiala referenshastigheten. Detta förhållande ger normalt rätt korrelation för mindre hastighetsminskningar men överskattar besparingarna för större hastighetsminskningar. Ett skäl till överskattningarna är att bränsleförbrukningen i huvudmotorerna inte når noll förbrukat bränsle med noll hastighet (som modellen indikerar). Bara det faktum att motorerna körs innebär förbrukning av bränsle och dessutom minskar motorns effektivitet och framdrivningseffektiviteten gradvis när systemet avviker från den hastighet som systemet är optimerat för.

Fallstudiernas beräkningar och intervjuer som utförts i denna studie, indikerar att en del av de logistiktjänster som erbjuds kommer att behöva designas om helt ifall fartygens fart måste reduceras. Detta på grund av effekter så som att tillgänglig tid inte möjliggör för ett effektivt antal resor per dag eller veckoservice som tjänsten är designad för inte längre kan utföras. I andra fall ligger hastigheten redan på en så låg nivå, jämfört med genomsnittet för

fartygets storlek och segment, att till och med relativt stora på hastighetsminskningar inte kommer att kräva ytterligare minskningar och följaktligen inte påverka operationerna alls. Andra upplägg förlorar konkurrenskraften i jämförelse med konkurrerande vägtransporter med en förväntad effekt att gods flyttas över till vägtransport.

Bränslekonsumtionen och de relaterade utsläppen av växthusgaser per transporterad mängd last verkar för de flesta av de analyserade fallen vara möjliga att sänka med reducerad hastighet. Kostnaden per transporterad mängd last verkar emellertid vara optimerad vid nuvarande hastighet och tenderar att öka vid ytterligare hastighetsminskningar. Detta har bedömts med förenklade ekonomiska beräkningar för ett tankfartyg respektive ett RoRo-fartyg.

Intervjuerna som genomförts bland rederier ger liknande resultat som i fallstudiebedömningen: obligatoriska hastighetsminskningar kommer att få betydande ekonomiska och logistiska konsekvenser för fartygsägarna och deras kunder, särskilt i linjesjöfart.

En ofta diskuterad fråga av de möjliga effekterna av en hastighetsbegränsning är att fler fartyg behöver byggas när hastigheten sänks. En beräkning som utförts i studien för ett Panamax tankfartyg i ett livscykelperspektiv indikerar att om antalet fartyg ökar, för att täcka en ökad efterfrågan av tonnage vid oförändrade godsvolymer när hastigheten sänks, kommer detta att ge en marginell effekt på totala växthusgaser per utfört transportarbete. Detta eftersom de operationella utsläppen kopplade till förbrukningen av bunker helt dominerar jämfört med byggande, underhåll och skrotning av ett fartyg

Table of content

Abbreviation list

EEDI, *Energy Efficiency Design Index*. The EEDI requires a minimum energy efficiency level per capacity mile (e.g. tonne mile) for different ship type and size segments. The regulation was adopted in 2011 with the adoption of amendments to MARPOL Annex VI.

EEOI, *Energy Efficiency Operational Indicator*, enables operators to measure the fuel efficiency of a ship in operation and to gauge the effect of any changes in operation, e.g. improved voyage planning or more frequent propeller cleaning, or introduction of technical measures such as waste heat recovery systems or a new propeller.

EEXI, *Energy Efficiency Existing Ship Index,* is a simplified index to be developed and defined. The metrics of EEXI should be compatible with that of EEDI, and thus attained EEDI can be used as an alternative to EEXI.

IMO, *International Maritime Organization*, is the United Nations' specialised agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.

ISWG-GHG, IMO' *Intersessional Working Group on the Reduction of Greenhouse Gas Emissions*.

MEPC, *The Marine Environment Protection Committee*, addresses environmental issues under IMO's remit.

MRV, The *EU Monitoring, Reporting and Verification,* is a mandatory EU reporting scheme for CO_2 emissions for vessels calling European ports since January 1st, 2018.

PSC, *Port State Control*, is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules.

SEEMP, *Ship Energy Efficiency Management Plan,* is an operational measure that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner. SEEMP provides an approach for shipping companies to manage ship and fleet efficiency performance over time using, for example, the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool. The guidance on the development of the SEEMP for new and existing ships incorporates best practices for fuel efficient ship operation, as well as guidelines for voluntary use of the EEOI for new and existing ships.

1 Introduction

1.1 Aim and motivation

Since the IMO decision that shipping should reduce its emissions of greenhouse gases by 50% by 2050 compared with the level of emissions in 2008, possible ways of achieving this goal have been studied. In a number of proposals for policy measures, mandatory speed limits for all vessels are described as the only measure that enables rapid reductions in greenhouse gas emissions. There is a concern that this will be counterproductive by inhibiting the necessary technological development and possibly leading to the transfer to road transport.

The aim of this pre-study is to analyse the effects of a proposed future general regulation on speed reductions for shipping. The analysis includes consequences for shipping companies and their customers (transport buyers) regarding carbon emission/climate, operational/logistical and market/cost aspects.

1.2 Scope

The study is focused on shipping activities related to Sweden and the effects of mandatory speed limits on Swedish companies. In order to cover a large part of the different kinds of ships and types of shipping that operates within, to and from Sweden, ten typical transport cases/ships were selected and quantitatively analysed with focus on the link between speed and carbon emissions. In addition, qualitative interviews were carried out with four shipping companies in order to discuss their views on the foreseen consequences on a mandatory speed reduction for them and their customers.

2 Prior research relevant to speed reductions

2.1 Speed as a factor in maritime studies

Aeroplanes follow strict timetables and generally fly at a set cruise speed through air, trains align speed to timetables and the infrastructure capacity allocated well in advance, and road vehicles follow speed limits determined by infrastructure quality and traffic intensity. The speed of ships through water, however, varies widely between maritime segments and routes. The speed is subject to ship design, cost structure, customers' time demands, weather conditions and in certain fairways also to formal speed limits. There is a much wider span of speeds in comparison to the other transport modes, and business cycles and the fleet's average speed determines the total maritime transport capacity. In addition, ships are used for 20-30 years so the operations determines much of the total life cycle emissions. Particularly in comparison with road transport, with much shorter time between change of vehicles, for which the technical standard of new vehicles is more important.

Much of the scientific literature addressing ship speeds takes a shipowner perspective in minimising costs rather than maximising customer utility, although Laine and Vepsäläinen (1994) include this and Finnsgård et al. (2018 and 2020) take a shippers' perspective. Nevertheless, focusing on the transport supply side is rational when studying the tank and dry bulk segments, in which deciding the speed is a rather straightforward issue. The shipowner negotiates the terms including transport time with a single or a few customers and then the ship is operated to match the set time requirements. As comparatively cheap commodities are moved, it is often a matter of cost minimisation with rather well-defined parameters.

Liner shipping, on the other hand, is a complex compromise between different shippers' time demands. It is obvious that the cargo loaded on to a 20 000 TEU ship represents a very wide variety of transport time demands, for example between electronics with a very high capital cost and, on the other end of the scale, empty containers whose owners have low willingness to pay for fast transport. In the RoRo segment, there is a certain compromise between high-value components which are strictly timed for the next stage of a supply chain, and pulp and paper prioritising cheap before fast transport. Anyway, the segment with the widest set of customer demands to satisfy is RoPax, often referred to as ferries (Raza et al., 2019, p. 5):

> *"Travelers with cars who want to cross the water to continue driving are mixed with passengers who want to eat, shop, or just entertain themselves on board. Time-critical cargoes like vegetables, components scheduled for assembly, and e-commerce deliveries are loaded on lorries on board and mixed with less demanding goods loaded in unaccompanied semi-trailers or containers."*

"The faster the better" is often taken for granted in passenger and freight transport, but the RoPax operators also have revenues from shopping, bars and restaurants which requires that travellers have sufficient time on-board. Woxenius (2012) argues that RoPax operators also must consider turn-around times, resting times for drivers and convenient departure and arrival times. Deciding on speed in RoPax shipping is hence a complicated issue with many constraints (Raza et al., 2019).

Another example where shippers sometimes prefer slow transport is in the tanker segment when speculating in rising prices and particularly during times of over-supply of vessel capacity or scarcity of storage tanks on land when tankers are used for temporary storage.

Nevertheless, the decision on speed is in general a trade-off between time-dependent costs of crew and capital tied up in ship and cargo on one side and operational costs, mainly bunker costs, on the other side (Stopford, 2009). This means that the cost equilibrium is dynamic as interest rates and bunker costs are volatile. The speed also varies on ballast voyages depending on the business opportunities waiting. The RoPax segment is also an extreme regarding time-dependent operational costs with expensive ships and high crew costs, since bars, restaurants, shops and the cabin part require much staff.

Competition with other modes is another factor when deciding the speed. Air is the only competition for transport with other continents, but both rail and combinations of air and sea are viable options between Asia and Europe (Woxenius, 2006). Depending on geography, rail and road both compete with short sea shipping within Europe. From a Swedish horizon, shipping's market share also depends on the port selection, that is, if the maritime distance is minimised or maximised (Stelling et al., 2019). Speed is a factor in the latter case as Sweden's oblong geography implies that shipping competes head to head with road and rail transport for services such as Gothenburg-Kiel and Nynäshamn-Gdansk.

2.2 Speed reductions and fuel consumption

At certain times the shipping industry deliberately reduces the speed significantly below the vessels design speed, often referred to as slow steaming (Finnsgård et al., 2020). The stated reason is often to reduce bunker consumption and accordingly costs and emissions (Cariou, 2011 and Maloni et al., 2013) but it is often triggered by overcapacity as slow-steaming ties up ship capacity benefitting shipowners attempting to raise prices (Cariou, 2011, Ferrari et al., 2015, Finnsgård et al., 2018 and 2020).

The implementation of the Sulphur Emission Control Area (SECA) in the North Sea and Baltic Sea in 2015 triggered a certain stream of research on slow steaming as a measure to mitigate the effects of more expensive fuel (Adland et al., 2017). Raza et al. (2019) found that RoRo and RoPax operators faced particular limitations on applying slow steaming as they are subject to so many constraints.

Implications from speed reduction requirements from an operational, technical and market perspective is discussed in CE Delft, (2012) where a single speed for all vessels would have a small impact on smaller ship size categories but a large impact on large ship size categories, and that such measure would change the competitive market between ship types; *"Changing the relative performance of different ship types would render the current fleet composition less efficient"*.

Related to the model used in most of the speed-consumption studies, Psaraftis and Kontovas (2014) point out that the importance of being careful with the models used for consumption calculations and savings through speed reductions. *"Many papers that do embed ship speed in their formulation assume that daily fuel consumption is a cubic function of ship speed. The cubic approximation is reasonable for some ship types, such as tankers, bulk carriers, or ships of small size, but may not be realistic at slow or near-zero speeds and for some other ship types such as high-speed large container vessels"*.

A new study on the estimation of the fuel consumption-speed curve for ships, by analysing 16 crude oil tankers, confirm that the classical cubic law for fuel consumption is valid only near the design speed (Adland et al., 2020). However, the sensitivity with regards to sailing speed can be substantially lower at the sailing speeds actually observed. The authors conclude that the results question the economic and environmental benefits of slow-steaming and fuel levies.

3 Proposals for speed reductions forwarded within the IMO

The possibility to regulate speed for vessels during their operations is one of the possible measures in order to reach reduced fuel consumption and connected greenhouse gas emissions. Naturally this area has been subject to several proposals and discussions. In this section we have tried to summarise the essence of some of the proposals that has been forwarded to the IMO in order to regulate and cut greenhouse gas (GHG) emissions also from the existing fleet. The selection is done in order to give a basic understanding of the kinds of measures being discussed.

Speed reduction measures and regulations are discussed as both regulation of operational speed only, and regulation of operational speed with alternative compliance mechanisms. Example of a straighter speed reduction proposal is the ISWG-GHG 6/2/8 submitted by France, addressing bulk carriers and oil and chemical tankers, proposing a maximum absolute speed through water for these specific vessel segments. Other proposals are more goal-based oriented but in many cases it is expected that speed reductions will be in place in order to fulfil the goals. Examples of two such proposals are the ones from Norway (ISWG-GHG 5/4) and Japan (MEPC 74/7/2) respectively. These two proposals have similarities but also complement each other.

The proposals selected and described shall be seen as an attempt to pick the most relevant proposals submitted and is not a full description of all speed reduction proposals.

The following proposals presented to MEPC or the sub correspondence group ISWG-GHG have been selected and are described below in this section:

- ISWG-GHG 5/4 – Submitted by Norway and proposes different kinds of measures such as implementation of Energy Efficiency Design Index (EEDI) for existing ships.
- MEPC 74/7/2 – Submitted by Japan and proposes energy efficiency improvement measures for existing ships.
- ISWG-GHG 6/2/8 - Submitted by France and proposes speed regulation for bulkers and oil and chemical tankers.
- ISWG-GHG 6/2/12 – Submitted by BIMCO and proposes to regulate and limit engine power of existing ships as a means to lower speed.
- ISWG-GHG 6/2/13 – Submitted by Clean Shipping Coalition (CSC) and proposes mandatory maximum average speed limits.

The above list covers example proposals for single measures (regulating and limiting engine power for ships), goal-based approaches as well as defined speed limit proposals. It shall be noted that proposals for speed limitations have been forwarded previously to MEPC such as the Clean Shipping

Coalition's proposal MEPC 61/5/10 dated July 23rd, 2010 - *Speed Reduction – the key to the fast and efficient reduction of greenhouse gas emissions from ships.*

3.1 ISWG-GHG 5/4 - Energy efficient framework for existing and new ships

Submitted by Norway to the Intersectional meeting of the working group on reduction of GHG emissions from ships – 5th session. Dated 1st of March 2019.

The proposal presents both proposed actions for IMO to consider in order to meet the GHG targets, as well as initial estimates on the effectiveness and the potential for the proposed measures to meet the targets on GHG emissions from ships (see Table 1). The Norwegian proposal asks for measures on further improvement of the existing energy efficiency framework with a focus on EEDI and Ship Energy Efficiency Management Plan (SEEMP) and is split into several sub-measures which can be considered independently:

1. EEDI for existing ships;
2. EEDI for ships with non-conventional propulsion;
3. Consider further EEDI phases and reduction requirements; and
4. Strengthening the SEEMP including periodical surveys.

The assessed potentials of the different measures are presented in Table 1.

Table 1. The table is taken from ISWG-GHG 5/4 and shows estimates of the total contribution of measures towards the IMO 2050 ambitions. The reduction needed is the required average carbon intensity reduction of the fleet compared to 2015 in relation to the IMO ambitions. The ranges in the second column are based on a low and a high growth scenario. The total reduction column is the combined effect of all measures, including the current EEDI and SEEMP.

Generation	Reduction needed	Current SEEMP	Current EEDI	EEDI for ex. ships	Strength. SEEMP	Further EEDI Phase	Total reduction
Ships built 2000-2010	10-20%	5%		9-18%	5%		23%
Ships built 2010-2020	15-25%	5%	7-12%	4-9%	5%		24%
Ships built 2020-2030	50-70%	5%	23-32%		5%	9%	41%
Ships built 2030-2040	75-85%	5%	32%		5%	14%	47%
Ships built 2040-2050	85-95%	5%	32%		5%	14%	47%

The estimates made by Norway presented in the proposal shows that strengthening the EEDI and SEEMP framework is not enough to meet the already decided IMO GHG ambitions towards 2050 which can be seen in Figure 1. Also new and/or innovative reduction mechanisms etc is needed.

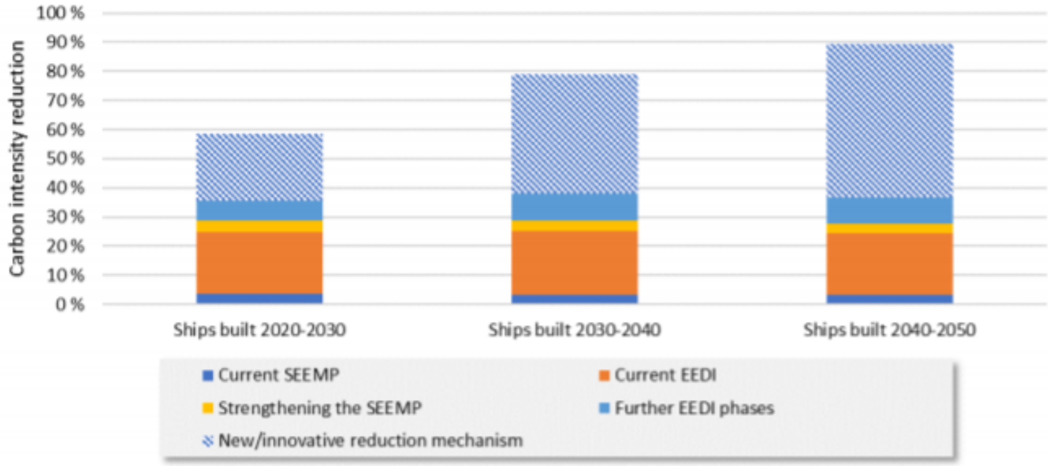

Figure 1. The figure is taken from ISWG-GHG 5/4 and shows the estimated contribution per measure towards carbon intensity reduction in 2050.

3.2 MEPC 74/7/2 - Energy efficiency measures for existing ships

Submitted by Japan to the 74th MEPC session. Dated 7nd of February 2019.

Japan has proposed regulatory measures on energy efficiency of existing ships based on existing IMO instruments.

Japan argues in the conclusion that in the current shipping market, existing ships have stronger market competitiveness than new ships, while existing ships is allowed emitting more GHG than new ships. Such a situation discourages shipowners from investing in new ships.

It is suggested that an attained EEDI or other simplified metrics could be utilised to capture efforts meeting the GHG ambitions for specific vessels. Applying the same target for all ships under each category (ship type and size) utilising a metric compatible with EEDI to secure fairness. The more effort a ship has made in attained EEDI, the less additional measures the ship should need to take. The target, or the level of energy efficiency requirement, should be decided for each category of ship.

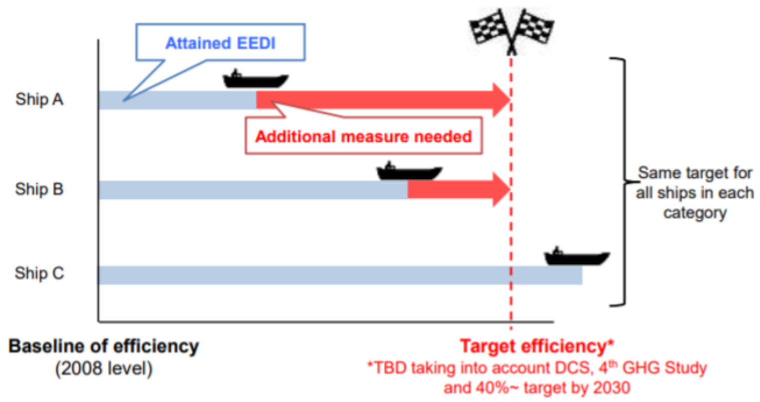

Figure 2. The figure, taken from 4.2 MEPC 74/7/2, shows the principle for how additional measures might be needed for existing ships to meet the target efficiency for the ship type and size bin.

First, existing ships shall calculate their energy efficiency performance, using a simplified index to be developed and defined as Energy Efficiency Existing Ship Index (EEXI). The metrics of EEXI should be compatible with that of EEDI, and thus attained EEDI can be used as an alternative to EEXI. A specific calculation method of EEXI should be further developed and stipulated in guidelines to be developed by the IMO. Then, each ship shall improve its energy efficiency performance to meet the mandatory requirement (required EEXI) to be set by IMO under MARPOL Annex VI. Each ship can choose suitable measures for itself, such as shaft/engine power limit to the optimum level, fuel change, energy saving device, retrofitting and/or any other options, see Figure 2 and Figure 3.

The levels of the required EEXI will be decided by IMO for each category (ship type and ship size), considering sufficient data on technical feasibility and future projection of entire fleet as of 2030 in order to contribute to the 2030 target set out in the GHG Strategy.

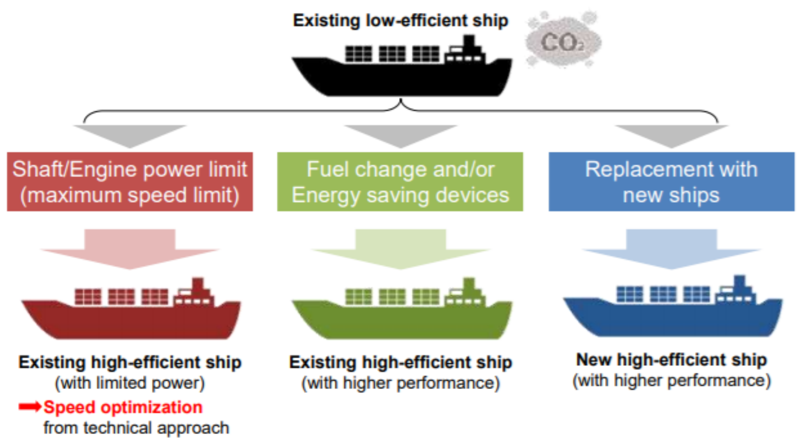

Figure 3. The figure, taken from MEPC 74/7/2, shows examples of how an existing ship not yet meeting supposed energy efficiency can chose different approaches to comply.

3.3 ISWG-GHG 6/2/8 - Speed regulation for bulkers, oil and chemical tankers

Submitted by France to the Intersectional meeting of the working group on reduction of GHG emissions from ships – 6th session. Dated 27th of September 2019

France proposes speed regulations as an additional measure for specific vessel segments, in complement to a goal-based regulation. The objective of this additional measure is to avoid a speed increase in fleet segments that are highly sensitive to economic fluctuations, the bulk carriers, oil and chemical tankers.

While supporting adoption of global goal-based measures for the entire fleet (stated in ISWG-GHG 6/2/7), France proposes an additional specific speed regulation for the sectors of bulkers and oil and chemical tankers for the years 2023 to 2025. During this period, the maximum absolute speed through the water should be limited to 10.5 knots for bulkers and to 11 knots for oil and chemical tankers.

France argues that:

> *"speed regulation is not applicable in the long run, since it does not reward technological innovation, especially in the field of energy efficiency and transition to carbon-neutral modes of propulsion, which are integral for achieving the medium and long-term objectives of the strategy. Thus, it is an excellent transitory and early measure, but it can only be provisional."*

Further, this speed regulation is suggested to be limited in time as well as limited to the specific ship types.

Some exemptions from the regulation are suggested: Already zero carbon emitting ships, and those, which already comply with the 2025 EEDI standards of their category, would be exempted from the speed regulation.

The total numbers of ships affected, according to the GISIS database, are: 11,901 for bulkers and 14,883 for oil and chemical tankers. For these two categories together, the GHG reduction is estimated to be around 10%.[1]

AIS data of the ship must include the ship's current speed through water. Furthermore, France states that port State control (PSC) tools can be put in place to punish and discourage non-compliance. In addition to fines, PSC could either arrest the ship for several weeks/months to discourage non-compliance or enforce de-prioritised access to port or port services preventing the discharge of cargo and cancelling the commercial gain of sailing over the speed limit.

3.4 ISWG-GHG 6/2/12 - Power regulation of existing ships, inducing lower speed

Submitted by BIMCO to the Intersectional meeting of the working group on reduction of GHG emissions from ships – 6th session. Dated 27th of September 2019

BIMCO presents a way to establish power limit curves based on the average performance of each ship type trading at target operational speeds for the past years. Establishing such limitation in relation to assumed performance of average ships at set target speeds per ship type bridges proposals to limit speed with other proposals. The proposal provides a conceptual proposal for achieving the perceived emissions reductions of speed limits by regulating the propulsion power of existing ships, as a proxy for emissions. See Figure 4.

[1] Not clearly specified if the 10% saving relates to the saving in relation to all vessel categories or just the tank and bulk categories.

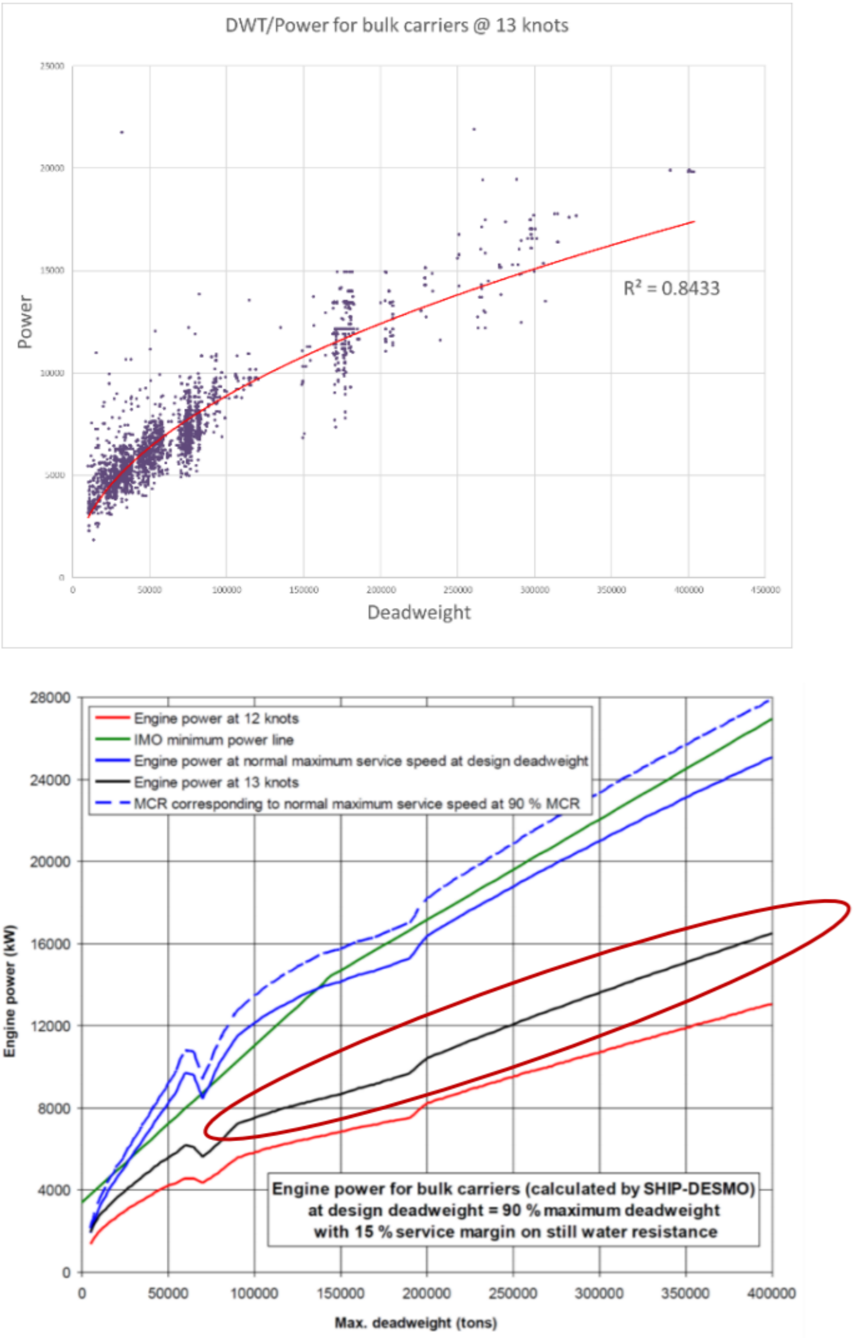

Figure 4. The figure, taken from ISWG-GHG 6/2/12, comparing the Deadweight/Power at 13 knots regression curve, with the result of generic computer model for bulk carriers' power at 13 knots versus deadweight.

BIMCO suggests a mechanism for bridging focus on speed with focus on power using an average operational speed for each ship type as the basis, hereafter referred to as a target speed.

The power limit would be derived from the performance in real weather and sea conditions of an average ship built in the decade prior to entry into force of the EEDI regulation in 2013 sailing at a target speed. The target speed would be agreed for each ship type in question, considering the average trading speeds for each ship type over the last years.

The application of a regulatory requirement to limit a ship's power under normal operating conditions could be universal within each applicable ship type. The reason is that finding a proper interface with EEDI certified ships may be difficult and, even more so, because ships have been built for different EEDI phases. Applying across the board eliminates such discussions and EEDI certified ships should anyhow be advantaged by a better efficiency in the first place.

The main policy decisions to be made are setting of target speeds for each applicable ship type, at which the resulting power limit curves should be established. The setting of target speeds as the policy decision is also sending a political signal that shipping addresses speed, as called for by some stakeholders.

3.5 ISWG-GHG 6/2/13 – Mandatory maximum average speed limits

Submitted by Clean Shipping Coalition (CSC) to the Intersectional meeting of the working group on reduction of GHG emissions from ships – 6th session. Dated 27th of September 2019

CSC believes that a higher level of ambition is needed to meet the goal "as a matter of urgency" to phase out GHG emissions from the shipping industry. To meet such ambitions, IMO should anticipate a target of at least 70% reduction of carbon intensity by 2030 compared to 2008 levels, and full decarbonisation by 2050 at the latest.

The proposal introduces the concept of mandatory maximum operational speeds, per ship type and size, for ships engaged in international voyages. The proposal suggests that mandatory speed limits could come into effect in 2021/2022. Maximum operational speeds could be capped at the level of the baseline in the first year of implementation, and then progressively reduced in the period up to 2030. The levels and timing could be determined by IMO in order to give the industry fair warning and time to adjust. The maximum speeds should be set at the levels that will help the sector to meet the 2030 carbon intensity target of -40% below 2008 levels, while taking into account operational safety, the optimum speed principle. CSC believes that a higher level of ambition, than the IMO targets agreed on, is needed to meet the goal "as a matter of urgency" to phase out GHG emissions from the shipping industry.

The approach involves exempting some ships and setting the maximum average ship speeds per annum differentiated by ship type and size. In the first instance this could involve capping speeds at the level of the baseline, with subsequent reductions designed to help IMO meet its 2030 carbon intensity target while avoiding any negative impacts.

The initial impact assessment annexed to this submission is conducted in accordance with the procedure set out in MEPC.1/Circ.885 and concludes that the proposal would have a significant positive impact on both the reduction of GHG emissions and transport costs. Where potential negative impacts have been identified, the assessment concludes that they can be mitigated by careful design of the measure.

The proposal discusses two main regulatory pathways to implement a system affecting operational ship speeds:

1. Regulation of operational speed only
2. Regulation of operational speed with alternative compliance mechanisms - This is more of a goal-based approach to regulating shipping emissions and provides flexibility to shipowners/operators to choose their preferred method of compliance with the set goal.

A decision also needs to be taken as to whether the regulation is going to apply to maximum absolute speeds or maximum average speeds:

1. Maximum absolute speed - ships are required to keep their maximum operational speed at any point in time below a predefined value similar to road speed limits.
2. Maximum average speed - ships are required to keep their average operational speed below a predefined maximum value either per voyage (i.e. between consecutive port calls) or per year (i.e. over the course of a calendar year).

By regulating maximum average speed on an annual basis, individual ships could vary their speed over the course of a calendar year while remaining below a predefined maximum value (while this is the approach proposed, CSC remains open to the consideration of a maximum absolute speed regulation if the shipping industry so prefers).

Maximum average speed should also be further refined by determining baseline speeds for different ship types and sizes and applying a percentage (%) reduction to each. This would also affect which segments of the industry would require additional ships, if any, to offset increased voyage times.

4 Scenarios and case study descriptions in calculations

As described in section *3. Proposals for speed reductions forwarded within the IMO*, different proposals for speed reductions exists. A study of consequences for each of them would not be feasible within the scope of this project. Therefore, an assessment was made by the project team in order to find out which scenarios that would give most value being studied.

Some proposals that connect to speed reduction are more related to goal-based requirements, some proposals direct towards energy/power limitations on-board. The choice was however made to primarily analyse speed reductions constructed as a speed average per vessel type and size in the calculations for different vessels. The same choice was made regarding the interviews with shipping companies, but the respondents were also asked questions for the case of a maximum absolute speed for any given moment.

The levels of speed reductions were chosen like earlier levels being analysed in studies such as CE Delft (2012, 2017 and 2019). The CE Delft 2012 study analysed the scenarios with three different regulated slow steaming speeds: a speed limit that leads to a 25%, 20% or 15% speed reduction related to the ships' 2007 average speed. The CE Delft 2017 study worked with the speed reduction scenarios 10%, 20% and 30% speed reduction respectively in relation to 2012 years average vessel speed.

Within several of the later reports assessing potential for slower speed among existing vessels both data and analyses from the Third IMO Greenhouse Gas Study 2014 (IMO 2015) have been used. That is also the reason for us to use data from this comprehensive and well cited report for example about average vessel speed per vessel segment and vessel size bins. The IMO has decided and started the work of updating the study. The work is initiated and IMO communicates related to that:

> *"the Fourth IMO GHG Study, which will include, inter alia, an inventory of global emissions of GHG emissions from international shipping from 2012 to 2018, estimates of carbon intensity of the global fleet on the same period and also in 2008 (the baseline year for the levels of ambition identified in the Initial Strategy), and scenarios for future international shipping emissions in the period 2018-2050. It is intended that the work could start in Autumn 2019 for submission of the final report of the Study to MEPC 76 in Autumn 2020"* From: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx

4.1 Selected speed restriction scenarios

For each of the ten selected vessel cases, estimates have been calculated on ships' energy consumption for the following four scenarios:

1. Vessel sailing at the specific design speed.

2. Sailing at estimated average speed for the specific vessel during 2018 based on Monitoring, Reporting and Verification (MRV) data.
3. Sailing at the vessel's type and size average speed during 2012 based average for that vessel type and size bin on a global basis.
4. Sailing at 80% of the vessel's type and size average speed during 2012 based average for that vessel type and size bin on a global basis

The speed restriction scenarios analysed are scenario three and four, while scenario one and two are included as benchmarks. In addition, during the interviews the respondents have also been asked for feedback on the case that the restricted speed was an absolute speed restriction and not an average speed restriction. Similar to the strict speed restrictions for vehicles. This has additionally been applied for both scenario three and four.

As shown in section 3. Proposals for speed reductions, there are different proposals being presented to IMO and discussed over the years where speed reductions on different levels are being suggested. The case of capping the average speed at a specific year's average or at a lower level (-20%) is therefore seen as scenarios in line with what is being discussed.

4.2 Selection of transport cases to be analysed

The aim is to describe consequences for different Swedish business sectors in case speed limitations for ships are being introduced. In order to cover important domestic and international sea transportation a wide range of typically important ship categories was selected. The selection aimed at not just covering important routes and trade lanes, but also to represent well-known routes in the transport industry to make it easier to relate to the results. In total ten vessels with corresponding transport cases were selected, and the sectors covered were RoRo, RoPax, container, car carrier, chemical/product tanker and general cargo/bulk vessels. For each vessel and their related routes, different data such as ship parameters and performance data have been collected and these data have been used to analyse the specific operations further.

4.3 Case study calculation methodology

The estimations of average operating speed during 2018 for the vessels studied are based on the MRV data available (EMSA 2020). Average speed is calculated based on the reported *Calculated distance* divided with *Total time spent at sea*. Vessel speed is being measured either in relation to the ground (speed over ground) or the surrounding water (speed over water). The easisest way to monitor and follow up is speed over ground which also is the speed related to in this report. The difference is not so significant for shipping on open seas, but of course decisive for maritime transport on rivers.

Estimated bunker consumption has been calculated firstly for the vessels' design speeds where it has been assumed that 85% of installed main engine capacity is used. Specific fuel consumption for the engine has been taken from IVL (2004). The consumption in auxiliary engines has been calculated based on Lloyd's List Intelligence (2019) methodology.

The fuel consumption has been assumed to vary with the vessels speed variation according to the same principles and calculation methodology as being used in the *Third IMO GHG study 2014* (IMO 2015). This in line with the assumption that main engine power varies with the relation Power=k*$(v/v_0)^3$, where v is the speed and v_0 is the reference speed.

CO_2-emissions have been calculated based on common emission factors for bunker fuels but, similar to most studies, only end of pipe emissions are considered.

4.4 Case studies – analysed parameters and estimated data

For each vessel studied, vessel parameters such as length, design speed, installed main and auxiliary engine capacity, gross tonnage, deadweight, cargo and, if applicable, passenger carrying capacity etc. were taken from SeaWeb (2020).

For each vessel and transport case, the average speed that the vessel sailed during 2018 was also calculated based on the data published in the EU MRV report (EMSA, 2020), monitoring all vessels calling European ports. In order to get a validation of the reported/calculated speed, a check of vessels' actual speed at some time spots has been made which showed good correlation with the calculated average speed based on MRV data. The average speed for the specific vessel has thereafter been compared with the different selected scenarios for speed reduction for the vessel type and size category. Some vessels are for different reasons not included in the MRV reporting of 2018, such as Visborg that was not yet introduced on the service at that time. For this vessel the average speed has been estimated by sample speed taken from Marine Traffic which reports speed curves for the latest days based on AIS data. The sample speed has been collected during December 2019 to February 2020.

These reported and calculated speeds as well as vessel parameters can be seen in Figure 5 and Table 2 below for all the vessels included in the study. Each case vessel and the specific route they are engaged in are also described more in detail below.

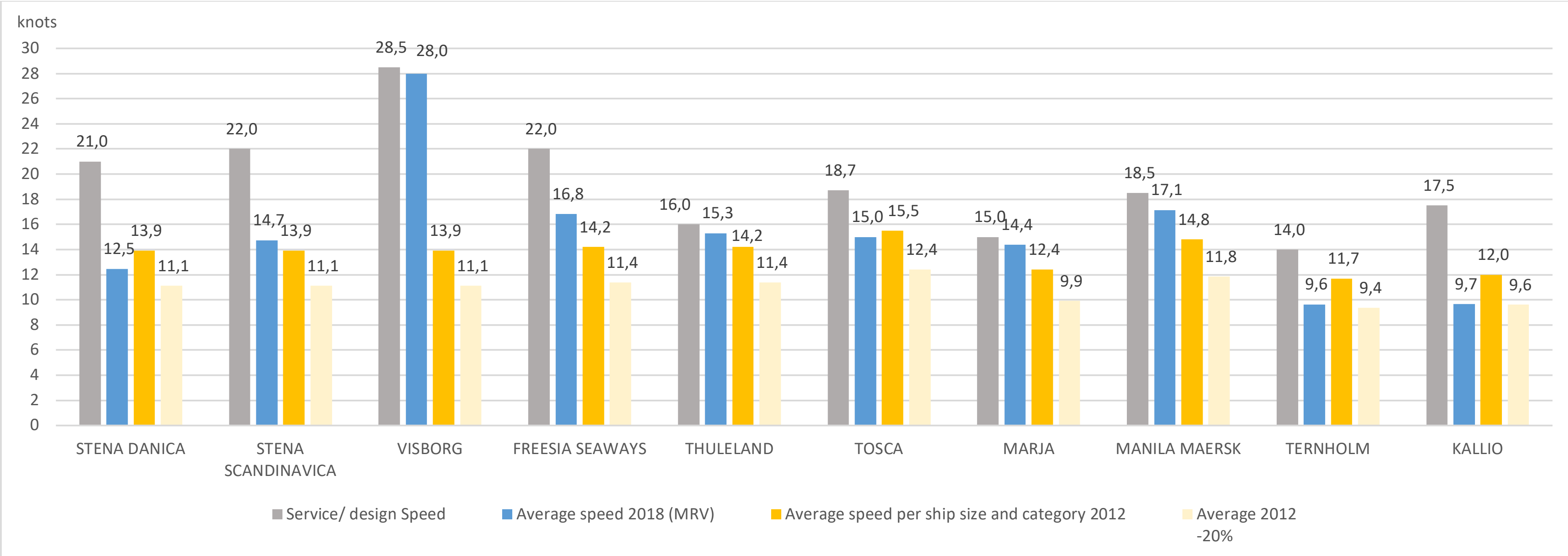

Figure 5. The graph shows a compilation of the different vessel speeds used as a basis in the case studies for each of the 10 vessels. The service speed is the speed for which the vessel is designed being able to steam while using a relatively high amount of installed main engine capacity (often 85%). The listed MRV average speed is a speed calculated based on the mandatory reporting of all vessels calling a European port during 2018 (EMSA 2020) and represents an average speed for which the vessel was speeding during 2018. The Average speed per ship size and category 2012 is the average speed for the vessel's type and size bin according to the Third IMO Greenhouse Gas Study 2014 (IMO, 2015). The speed shown as Avg. 2012 -20% correspond to 80% of the previously stated speed.

Table 2. Overview of vessel data for the ships includeed in the cases (1-10) and the routes for whhich they are engaged.

Case	Name of Ship	Shipping company	Customers (examples)	Ship type	Size category	Units	Description	Built	DWT	GT	Service/ design Speed	Average speed 2018 (MRV)	Average speed per ship size and category 2012	*Reduction related to actual speed 2018*	Average 2012 -20%	*Reduction related to actual speed 2018*
											[knots]	[knots]	[knots]	*[knots]*	[knots]	*[knots]*
1	STENA DANICA	Stena Line	DHL/SCHENKER / etc.	Ferry – ro-pax	2,000–+	gt	Gothenburg - Fredrikshamn	1983	2 950	29 289	21.0	**12.5**	**13.9**	*1.4*	**11.1**	- *1.3*
2	STENA SCANDINAVICA	Stena Line	DHL/SCHENKER / etc.	Ferry – ro-pax	2,000–+	gt	Gothenburg - Kiel	2003	11 078	57 639	22.0	**14.7**	**13.9**	- *0.8*	**11.1**	- *3.6*
3	VISBORG	Destination Gotland	Various	Ferry – ro-pax	2,000–+	gt	Swedish mainland - Gotland	2018	4 636	32 447	28.5	**28.0**	**13.9**	- *14.1*	**11.1**	- *16.9*
4	FREESIA SEAWAYS	DFDS	Volvo	Ro-ro	5,000–+	dwt	Gothenburg–Brevik–Ghent	2005	14 330	37 939	22.0	**16.8**	**14.2**	- *2.6*	**11.4**	- *5.5*
5	THULELAND	SOL Lines	Stora Enso	Ro-ro	5,000–+	dwt	Oulu - Kemi - Pietarsaari - Lübeck - Antwerp - Zeebrugge - Tilbury -	2006	15 960	23 128	16.0	**15.3**	**14.2**	- *1.1*	**11.4**	- *3.9*
6	TOSCA	Wallenius Wilhelmsen	Volvo	Vehicle	4,000–+	vehicle	Car- and roro carrier on world wide trade	2013	22 585	61 106	18.7	**15.0**	**15.5**	*0.5*	**12.4**	- *2.6*
7	MARJA	CMA CGM (Unifeeder)	Biltema	Container	0–999	TEU	Feeder rotation: Gdansk - Gdynia - Gävle - Norrköping	1995	5 216	3 999	15.0	**14.4**	**12.4**	- *2.0*	**9.9**	- *4.4*
8	MANILA MAERSK	Maersk Line	Volvo	Container	14,500–+	TEU	AE5 rotation: Gothenburg - Aarhus - Bremerhaven - Wilhelmshafen - Port Tangier - Singapore - Shanghai - Dalian - Xinggang - Busan - Ningbo	2018	190 326	214 286	18.5	**17.1**	**14.8**	- *2.3*	**11.8**	- *5.3*
9	TERNHOLM	Terntank	Preem	Chemical tanker	10,000–19,999	dwt	Various routes for example: Gothenburg - Gävle	2005	14 825	9 993	14.0	**9.6**	**11.7**	*2.1*	**9.4**	- *0.3*
10	KALLIO	A to B @ C / ESL Shipping	Various	General cargo	10,000–+	dwt	Spot market transportation of bulk (grain, sand, pulp etc.)	2006	21 353	16 690	17.5	**9.7**	**12.0**	*2.3*	**9.6**	- *0.1*
	Based on:			*3rd IMO GHG Study*			*Public information such as schedules etc.*	*SeaWeb*				*MRV Reporting*	*3rd IMO GHG Study*			

4.4.1 Case 1, RoPax ferry between Sweden and Denmark

M/S Stena Danica is owned and operated by Stena Line, and engaged on a ferry link between Gothenburg and Frederikshavn. The total number of roundtrips at the Gothenburg Frederikshavn relation during 2018 was approximately 1 700 (Trafikanalys, 2019) including all three vessels engaged on the route. The crossing time is down to 3 hours and 15 minutes for the fastest trips (Stena Line, 2020).

In relation to the Third IMO Greenhous gas study, the ship is categorised as a Ferry – RoPax with a GT (Gross tonnage) over 2 000.

Figure 6. M/S Stena Danica. Photo from Stena Line

Customers using the service are all kind of forwarders, road hauliers and passengers travelling with or without cars, buses etc. Cargo accounts for an important part of total turnover and the goods reflects the intra-European trade and is normally moved in lorries and semi-trailers.

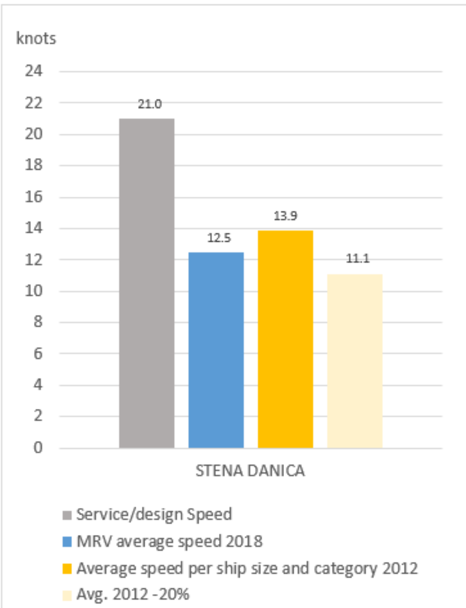

Figure 7 The design speed of Stena Danica is reported to be 21 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 12.5 knots during 2018. The corresponding average speed for the vessel category, Ferry – RoPax with a GT (Gross tonnage) over 2 000 was during 2012 13.9 knots. A 20% reduction on that 2012 average would be a speed of 11.1 knots.

4.4.2 Case 2, Ropax ferry between Sweden and Germany

M/S Stena Scandinavica is owned and operated by Stena Line on a RoRo- and ferry link between Gothenburg and Kiel. In relation to the Third IMO Greenhous gas study, the ship is categorised as a Ferry – RoPax with a GT (Gross tonnage) over 2 000.

During 2018, in total approximately 500 roundtrips was done by the two vessels engaged in this service.

Customers using the service are all kind of cargo owners and passengers travelling with or without cars, buses etc. Cargo stands for an important part of the total turnaround and semi-trailer trucks are important part of the goods flow.

Figure 8. M/S Stena Scandinavica. Photo Stena Line.

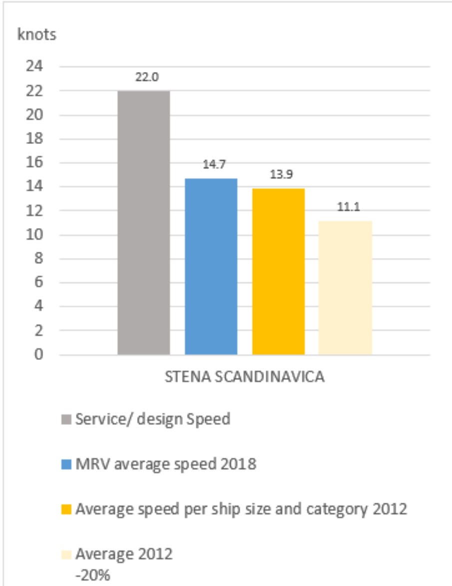

Figure 9. The design speed of Stena Scandinavica is reported to be 22 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 14.7 knots during 2018. The corresponding average speed for the vessel category, Ferry – RoPax with a GT (Gross tonnage) over 2 000 was during 2012 13.9 knots. A 20% reduction on that 2012 average would be a speed of 11.1 knots.

4.4.3 Case 3, RoPax ferry between Swedish mainland and Gotland

The RoPax vessel M/S Visborg is operated by Destination Gotland and engaged in the traffic between Gotland and the Swedish mainland. In relation to the Third IMO Greenhous gas study, the ship is categorised as a Ferry – RoPax with a GT (Gross tonnage) over 2 000.

The service performs annually some 1 500 roundtrips between Gotland and the Swedish mainland in which several vessels are engaged.

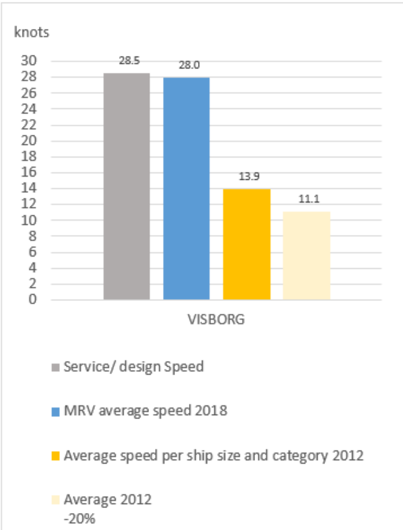

Figure 10. The design speed of Visborg is reported to be 28.5 knots (SeaWeb, 2020) and according to Marine Traffic statistics (2020) the vessel had an average speed at sea of 28 knots during 2018. The corresponding average speed for the vessel category, Ferry – RoPax with a GT (Gross tonnage) over 2 000 was during 2012 13.9 knots. A 20% reduction on that 2012 average would be a speed of 11.1 knots.

4.4.4 Case 4, RoRo traffic between Sweden and the European continent

M/S Freesia Seaways is owned and operated by DFDS on a RoRo service between Gothenburg–Brevik–Ghent and similar rotations.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a RoRo vessel of 5,000 dwt and above.

Cargo owners sending their goods on the service are among others the automotive industry such as Volvo cars and Volvo Group.

Figure 11. M/S Freesia Seaways. Photo K Jivén.

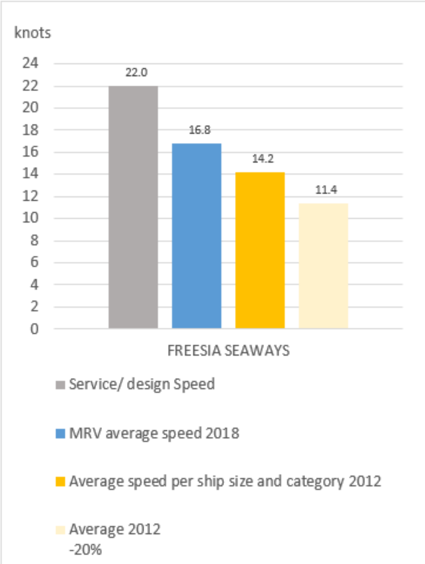

Figure 12. The design speed of Freesia Seaways is reported to be 22 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 16.8 knots during 2018. The corresponding average speed for the vessel category, RoRo with a dwt (deadweight) over 5 000 was during 2012 14.2 knots. A 20% reduction on that 2012 average would be a speed of 11.4 knots.

4.4.5 Case 5, RoRo transport in liner traffic of mainly wood products from north of Sweden to the European continent

M/S Thuleland is owned and operated by SOL Lines and operates to a large extent for the paper manufacturer Stora Enso. The routing goes from north of the Baltic Sea towards the European continent. For example, on the following port rotation: Oulu - Kemi - Pietarsaari - Lübeck - Antwerp - Zeebrugge - Tilbury – Zeebrugge.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a RoRo vessel of 5,000 dwt and above.

Figure 13. M/S Thuleland. Photo: SOL Lines.

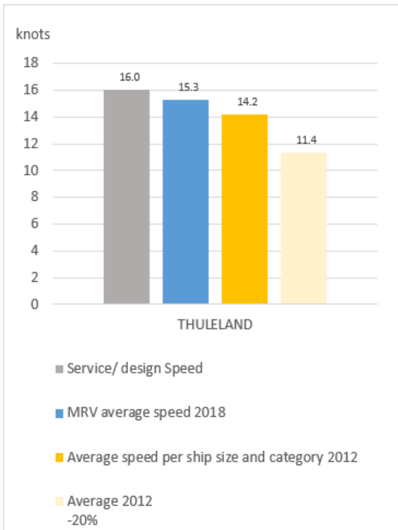

Figure 14. The design speed of Thuleland is reported to be 16 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 15.3 knots during 2018. The corresponding average speed for the vessel category, RoRo with a dwt (deadweight) over 5 000 was during 2012 14.2 knots. A 20% reduction on that 2012 average would be a speed of 11.4 knots.

4.4.6 Case 6 , Car carrier between Sweden and worldwide destinations

M/S Tosca is owned by Wallenius and operated by Wallenius Wilhelmsen. The vessel has been chosen as an example of a car carrier operating in a global network. Typically, this kind of vessels and service call Gothenburg, Wallhamn, Södertälje and Malmö.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a Vehicle vessel with a capacity of carrying over 4 000 vehicles (standard cars).

The vessel transports all kind of rolling goods such as cars, trucks, dumpsters, oversized shipments. Important customers are predominantly in the automotive industry.

Figure 15. M/S Tosca. Photo: Wallenius Lines.

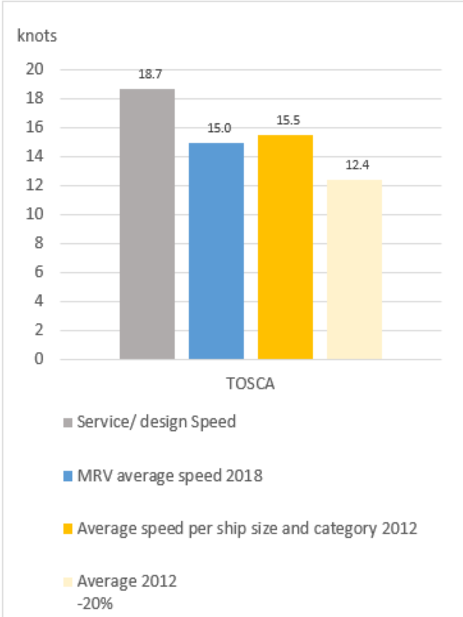

Figure 16. The design speed of Tosca is reported to be 18.7 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 15.0 knots during 2018. The corresponding average speed for the vessel category, Vehicle with a capacity for 4 000-+ vehicles was during 2012 15.5 knots. A 20% reduction on that 2012 average would be a speed of 12.4 knots.

4.4.7 Case 7, Container feeder between Swedish ports and the European continent

As an example of container feeders operating between Swedish ports in the Baltic Sea and the European continent, the container vessel Marja has been selected. Marja operates at present on the rotation Gdansk - Gdynia - Gävle – Norrköping.

Marja is operated by Unifeeder and is used in the shipping company CMA CGM's global network.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a Container ship with a capacity of carrying 0–999 TEU (Twenty-foot equivalent unit)

The cargo moved in containers reflects the Swedish trans-ocean trade with imported consumer products, exported products from the basic industry and, in both directions, machinery and components for the next step of the supply chains. In addition, some intra-European trade is moved in containers over rather long distances.

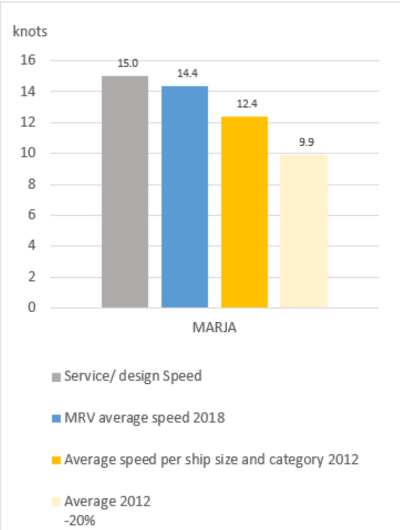

Figure 17. The design speed of Marja is reported to be 15 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 14.4 knots during 2018. The corresponding average speed for the vessel category, Container with a capacity of 0 – 999 TEU was during 2012 12.4 knots. A 20% reduction on that 2012 average would be a speed of 9.9 knots.

4.4.8 Case 8, Direct calls with container vessels between Gothenburg and the Far East

As an example of direct deep-sea container traffic between Sweden and the Far East, the Maersk Line vessel Manila Maersk was chosen. The vessel represents the largest container vessels and is at present engaged in the AE5 service calling Gothenburg - Aarhus - Bremerhaven - Wilhelmshafen - Port Tangier - Singapore - Shanghai - Dalian - Xinggang - Busan and Ningbo.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a Container ship with a capacity of carrying more than 14 500 TEU (Twenty-foot equivalent unit). The cargo composition is similar to the feeder traffic.

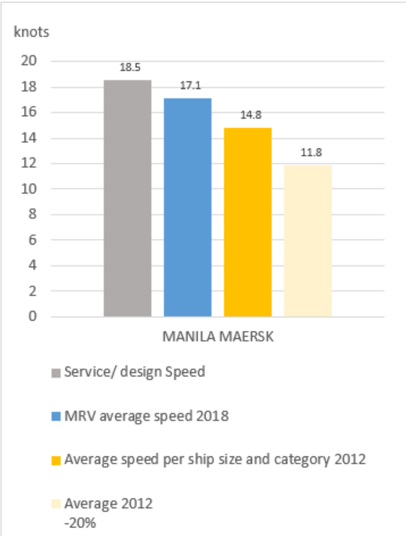

Figure 18. The design speed of Manila Maersk is reported to be 18.1 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 17.1 knots during 2018. The corresponding average speed for the vessel category, Container with a capacity of 14 500 – + TEU was during 2012 14.8 knots. A 20% reduction on that 2012 average would be a speed of 11.8 knots.

4.4.9 Case 9, Product tanker with regional distribution

Terntank owns and operates the chemical/product tanker M/T Ternholm which operates mainly between refineries on the Swedish West Coast (Gothenburg/Brofjorden) and different sites in the region such as terminals in Sweden, Norway, Finland etc.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a Chemical tanker with a capacity of 10 000–19 999 dwt and, accordingly, it moves chemicals but is also capable of moving oil products.

Figure 19. M/T Ternholm. Photo: K. Jivén.

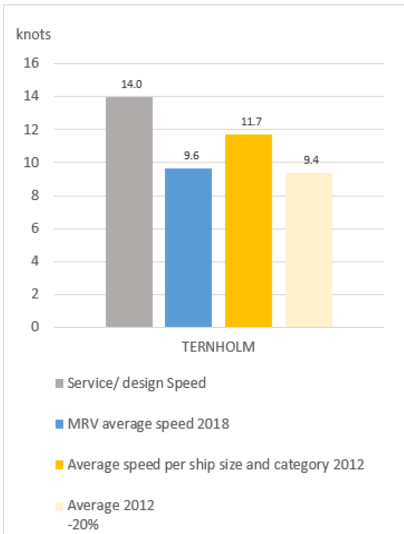

Figure 20. The design speed of Ternholm is reported to be 14 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 9.6 knots during 2018. The corresponding average speed for the vessel category, Chemical tanker with a deadweight of 10,000–19,999 was during 2012 11.7 knots. A 20% reduction on that 2012 average would be a speed of 9.4 knots.

4.4.10 Case 10 Bulk transportation in North Sea and Baltic region

The general cargo vessel M/S Kallio is owned and operated by ESL Shipping. The vessel has been chosen to represent a vessel carrying bulk such as grain, sand, wood operating in the region of the North Sea and Baltic Sea.

In relation to the Third IMO Greenhous gas study, the ship is categorised as a General cargo ship with a capacity over 10,000 dwt.

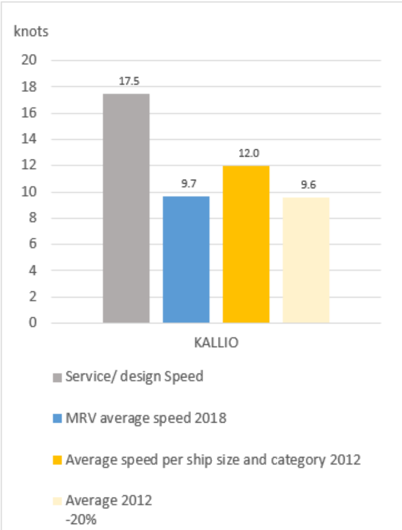

Figure 21. The design speed of Kallio is reported to be 17.5 knots (SeaWeb, 2020) and according to MRV (EMSA, 2020) statistics the vessel had an average speed at sea of 9.7 knots during 2018. The corresponding average speed for the vessel category, General cargo with a deadweight over 10 000 was during 2012 12.0 knots. A 20% reduction on that 2012 average would be a speed of 9.6 knots.

5 Case study results from calculations

5.1 Analysed scenarios

The ten selected vessel cases have been analysed, where estimates have been calculated on ships' energy consumption. This is described in section 4.1 but worth repeating as the results are presented in this chapter. The speed restriction scenarios analysed are scenario three and four, while scenario one and two are included as benchmarks for comparative reasons. The **four scenarios** are the following:

1. Vessel sailing at the specific vessels' design speed.
2. Sailing at estimated average speed for the specific vessel during 2018 based on Monitoring, Reporting and Verification (MRV) data.
3. Sailing at the vessel's type and size average speed during 2012 based average for that vessel type and size bin on a global basis.
4. Sailing at 80% of the vessel's type and size average speed during 2012 based average for that vessel type and size bin on a global.

5.2 Speed and consumption

For each of the ten cases all the scenarios have been assessed and compared. The results are shown in Figure 21 below, as an overview of theoretical consumption estimations depending on which speed the vessels would operate at.

Here are some comments to each case:

Case 1. Stena Danica. The vessel already operates at a speed lower than the 2012 average for the vessel type and size. Hence there is not a large impact on fuel savings or logistics in scenarios 3 and 4. A strict speed limit is likely to be problematic for this comparatively short route with rather long distances in fairways with low speed restrictions compensated by faster sailing at open sea.

Case 2. Stena Scandinavica. There is no large difference between vessel speed and average speed for 2012 for the vessel type and size. Some energy savings can be expected in scenarios 3 and 4.

Case 3. Visborg. This service is operating at a speed which is considerably higher than the average for the segment. Therefore, both CO_2 savings as well as logistical implications would be significant if the speed restrictions according to scenario 3 and 4 would be implemented.

Case 4. Freesia Seaways. The RoRo service, in which Freesia Seaways is engaged, is operating at approximately 15% respectively 30% higher speed than restricted scenario 3 and 4. There will probably also be a potential of CO_2 savings in case the speed would be decreased. The ship has 15% of the sailing time in canal/ fairways with low speed restrictions compensated by faster sailing at open sea.

Case 5. Thuleland. This is a vessel designed with focus on low energy consumption and with corresponding lower design speed than many other RoRo vessels. The average speed during 2018 of approximately 15 knots is still higher than the average for the vessel type and size for 2012. The theoretical CO_2 savings seems to be relatively high if scenario 4 is implemented. However, analysing real consumption data for this vessel indicates small or negligible CO_2 savings going from 14 down to 11 knots.

Case 6. Tosca. This car carrier has been operated at a slightly lower average speed during 2018 than the average for the segment in 2012, according to the MRV data, hence the scenario three would neither have affected the logistics nor the CO_2 performance. However, the stricter scenario 4 would probably affect both the logistics and the CO_2 performance.

Case 7. Marja. The container feeder seems to be operating at an average speed just below the design speed and both speed restriction scenario 3 and 4 would affect both logistics and the CO_2 performance.

Case 8. Manila Maersk. The vessel is operating at some 15% and 30% higher speed respectively than the average vessels of the type and size during 2012. Lowering speed from 17 knots down to 15 respectively 12 knots for scenarios 3 and 4 would therefore also affect lead time negatively and CO_2 performance positively.

Case 9. Ternholm. This vessel is operating at an average speed during 2018 that is almost at the level of scenario 4. Therefore, neither logistics nor CO_2 performance would be affected by the two scenarios.

Case 10. Kallio. This vessel is operating at an average speed during 2018 that is almost at the level of scenario 4. Therefore, neither logistics nor CO_2 performance would be affected by the two scenarios.

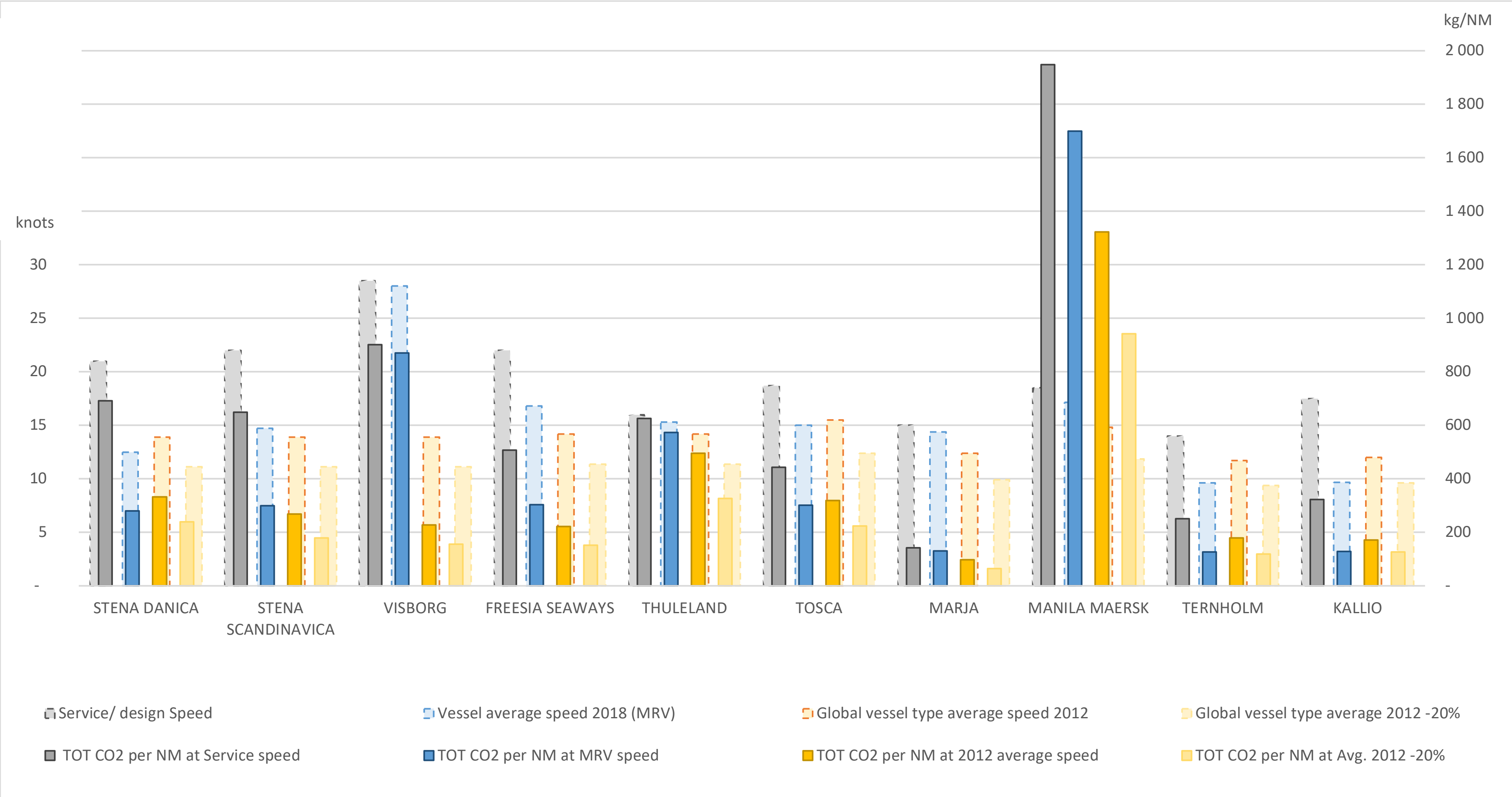

Figure 22. Result from theoretical consumption estimations depending on which speed the vessels would operate at.

5.3 Economic consequences

In order to complement the estimates on calculated fuel consumption, economical estimates for the different scenarios have been assessed for two of the cases. The reason behind is to be able to also assess how the costs per transported amount of cargo will change with reduced speed.

Cost assessments have been made for a product tanker transporting chemicals or petroleum products to a Swedish port with an empty trip back to Gothenburg and for a RoRo carrier transporting trailers and other rolling cargo in intra-European services.

Cost calculations and economics related to slow steaming is well described and analysed in the literature and the cost calculations are based on well-recognised methodologies for cost calculations described in for example Stopford (2009), Corbett (2009), Psaraftis (2014, 2016).

Cost figures for fuels and time-charter costs for the product tanker are taken from Winnes (2019). The cost structure related to the RoRo vessel is estimated in discussions with DFDS (Nordvang Kristiansen, 2020). The cost structure used in the calculations are just examples while such costs vary extensively over time.

The fuel consumption in auxiliary and main engines for the RoRo vessel, as well as auxiliary engine consumption for the product tanker, are calculated with the same principles as described in section *4.3 Case study calculation methodology*. Main engine consumption for the product tanker is from the vessel's sea trials (Lundin, 2020).

The results from the cost estimates indicate that the total cost for the speed dependent cost items seems to be at its optimum when it is close to the speed where the vessel normally operates. Also, the speed can be both increased and decreased a couple of knots without large effects. However, extensive increase or decrease in ship speed will have a significant negative effect on the costs. The result from the calculations can be seen in Figure 23 and Figure 24. The calculations should be seen as an example of how the costs, roundtrip days and consumption can vary with vessel speed and not as an optimum of the most economical speed for this specific vessel. This is for example due to the fact that calculations for the RoRo vessel have been made on speed consumption models that are likely to underestimate bunker consumption at lower speed. Despite this, these are the models most commonly used for calculations.

Please note that it is likely that the fuel consumption in main engines is under-predicted for the RoRo vessel at the lower part of the speed range, which thus explains why costs could be higher than estimated at lower speeds. The reason is that the used calculation formula assumes that the power has a cubic relation to the speed, which fits well for many vessel types close to the speed for which the vessel is optimised. The further away from that point, the less efficient other related factors will be such as the engine specific fuel consumption, the propulsion efficiency, the hull and wave resistance etc. In addition, the hull resistance will be more dominant and the wave resistance less dominant at a lower speeds.

If the speed is lowered significantly, the bunker consumption and related carbon dioxide emissions will increase per transported amount of cargo, see Figure 23. The rate of increase would be higher and higher, and when the bunker consumption is close to zero, it would approach infinity. As bunker consumption and carbon dioxide emissions on the RoRo vessel is not based on real consumption figures and instead the more common cubic relation between speed and power, the increase of consumption and emission at significantly reduced speed is not reflected in these calculations, see Figure 24.

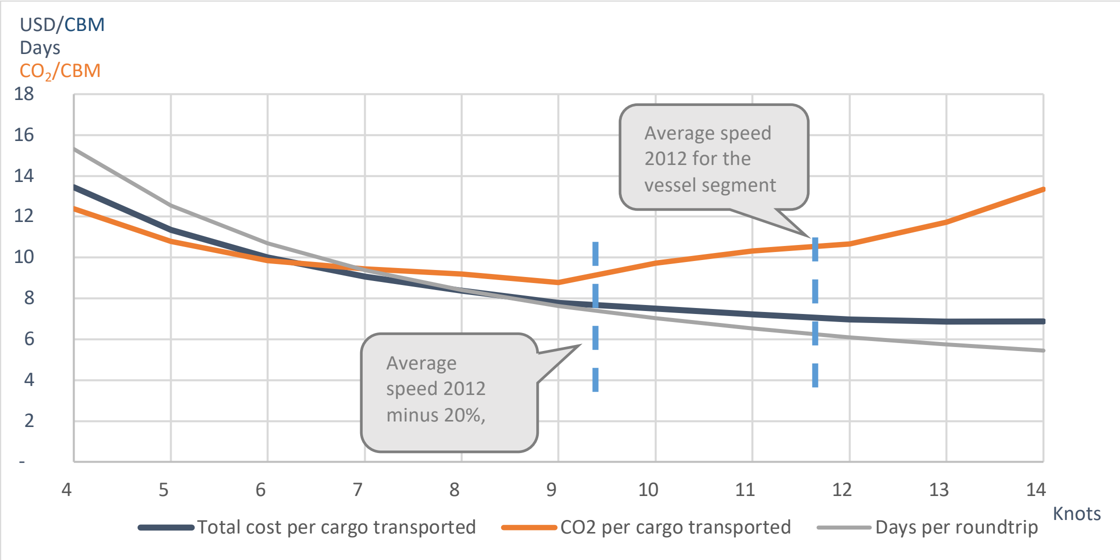

Figure 23. The graph shows calculated results for a product tanker of ~15 000 dwt. Total transportation cost seen from the shipping company perspective distributed per amount of transported cargo in cubic meter depending on the speed that the vessel is operating. In addition, also total roundtrip time (days) as well as amount of CO2 emitted per transported amount of cargo is plotted (CO2/cbm cargo). Main engine consumption is based on vessel sea trials.

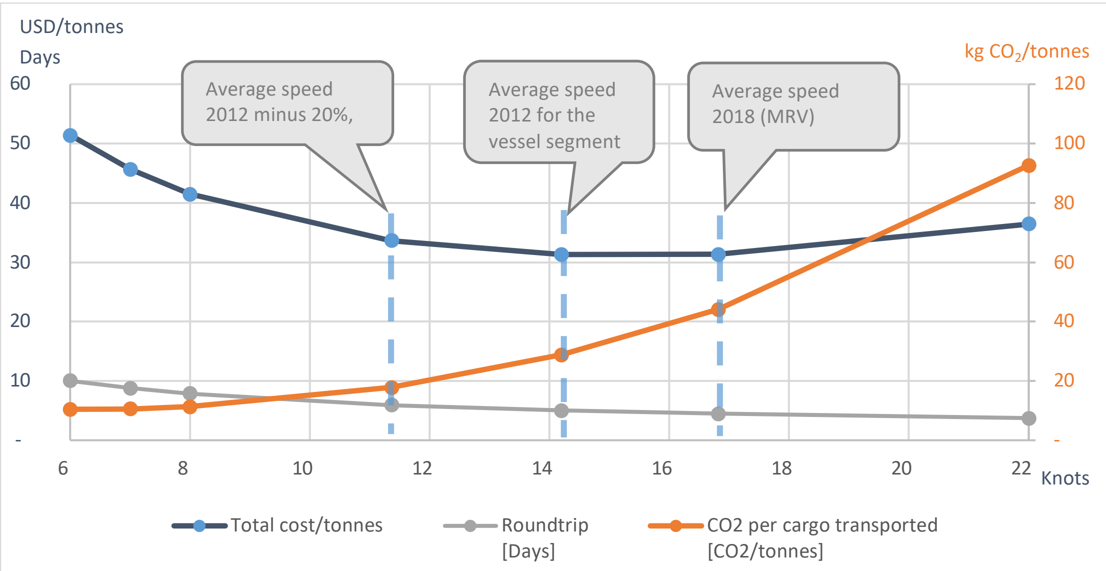

Figure 24. The graph shows calculated results for a typical roro ship with 4 500 lane meter cargo capacity. Total transportation cost seen from the shipping company perspective distributed per amount of transported cargo in tonnes depending on the speed that the vessel is operating. In addition, also total roundtrip time (days) as well as amount of CO2 emitted per transported amount of cargo is plotted (CO2/tonnes cargo). Main engine consumption due to speed is modelled with the cubic law model.

5.4 LCA perspective: the effect on GHG emissions of increased demand for ships

Common arguments for implementing speed reductions are that unused vessel capacity often can be used when each vessel is able to carry less amount of cargo per annum when the speed is lowered. An opposite argument is that the positive effects of lower energy consumption at lower speed will be lost in the trade-off when more vessels needs to be built and, at the end of the life cycle, scrapped.

In order to see how much influence the possibly increased need for additional vessels would have, a calculation has been made for a fixed amount of transport work performed. It has included the influence of CO_2 from the building, maintenance and scrapping phases for a ship during the whole life cycle, but also calculations including only operational emissions.

The functional unit for this estimate is set to the transport work of the amount of cargo that an average Panamax tanker with a deadweight of 60,000–79,999 would carry over a twenty year life cycle at an average speed for the vessel type and size. The vessel has been assumed, as a basis for the calculations, to travel at the average speed for the average amount of days at sea and in port for the vessel type, in line with the Third GHG report (IMO 2015, table 14). Calculations have thereafter been made for speeds from 5 knots up to 14 knots. When calculating port time for other speeds than the average, it has been assumed that the same amount of port time per travelled distance is needed. The number of vessels needed will thus be more than one for vessel speeds lower than the average speed, and less than one for vessel speeds exceeding the average speed. This assumes the same cargo load factor for all speeds studied.

In order to estimate the amount of CO_2 emitted from the operational phase, the stated average consumption per annum per main engine, auxiliary engines and boilers for the vessel type and size has also been used from the same source (IMO 2015, table 14). The main engine power has been assumed to vary with the relation $Power=k*(v/v_0)^3$. The consumption in auxiliary engines and boilers per hour has been assumed to be constant over the year and not dependent on speed.

Life cycle data for the construction, the maintenance and the end of life (scrapping) for a Panamax oil tanker (75,000 tonnes of dwt), has been taken from LCA calculations made by Chatzinikolaou and Ventikos (2014). It is assumed that the vessel lifetime (20 years) and that construction and maintenance will be the same regardless of the vessel's operations speed over its lifetime.

The calculation shows that the CO_2 emitted from the operational phase represents about 95% of the total life cycle CO_2-emissions for a vessel operating at the vessel type and size average speed (12.2 knots). If the vessel speed is increased to 14 knots, the operational phase will increase slightly and represent about 96% of the total. If speed is lowered as much as down to 5 knots, the part of the operational phase will decrease and represent about 88% of the total impact.

Calculations also show that even if the total amount of impact from the building/maintenance/scrapping phase will increase per unit of transport work when speed is lowered, since additional number of vessels will be needed for moving the same amount of cargo. Therefore, the decrease from the operational phase will almost totally dominate the result, see Figure 25. So even if more vessels will be needed doing the same transport work when a lower speed is used, the total life cycle emissions per produced transport work will be significantly lower when the speed is reduced in this calculation example.

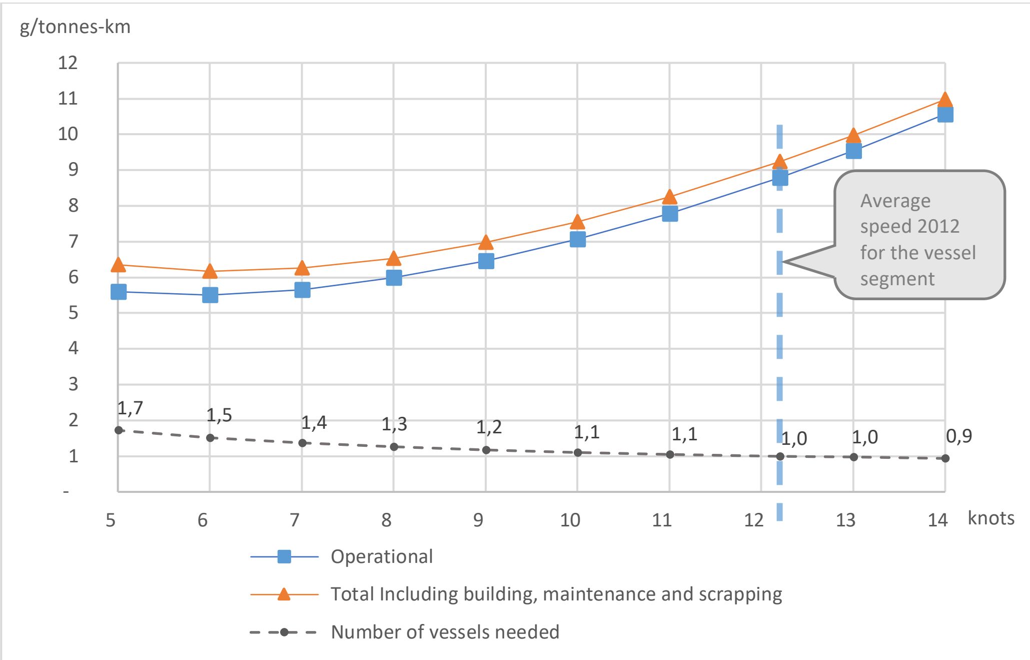

Figure 25. The graph shows the amount of carbon dioxide that is emitted from operations as well as totally including life cycle data for building/maintenance/scrapping during a 20 years life cycle. All is calculated for transport work that one Panamax oil tanker operating at the average speed of the vessel segment during 2012 (12.2 knots). Calculated for the number of vessels needed to perform the same amount of transport work at lower as well as higher speed than the average for the segment. Data is shown as gram CO_2 per transport work in tonnes-km.

6 Results from interviews

A number of in-depth interviews were conducted with representatives of shipping companies with the aim of supplementing the quantitative calculations and broaden the analysis of possible consequences of a mandatory speed reduction through regulation that this study focusses on.

6.1 Methodology

There were five representatives for four shipping companies interviewed. The aim was to include some transport buyers of shipping services as well but the outbreak of COVID-19 impeded that plan. The interviews were conducted in ZOOM or by telephone and lasted in the time span of 30-90 minutes but 45 minutes in average. All respondents had a chance to go through the text based on their interview so they could make corrections and give additional information, which four respondents did.

A semi-structed interview guide was used containing questions in the areas of:

- foreseen effects of the proposed speed reduction of 12% from the yearly average for the ship category (based on their ship selected as a case study in this study). selected for case study. Based on scenario 4.

- foreseen effects of the proposed speed reduction of 12% as an absolute limit.

-the consequences for their customers regarding logistics, modal choice, costs, production etc.

- consequences for the competition on the market.

- whether there should be any exceptions in the regulation.

- difference between new-built ships and older ones.

Also, other things that came up in the interviews the respondents considered important were discussed. An overview of the interviews is presented in Table 3.

Company	Position	Ship category	Date
SOL	Managing Director	RoRo	Feb 21 2020
DFDS	Operational director for DFDS services in Gothenburg	RoRo	Mar 3 2020
Stena Line	Technical and Operational Director (machines), Scandinavia	RoPax	Mar 12 2020
Terntank	2 persons: CEO Tärntank Ship Management AB and CEO Terntank Rederi A/S	Chemical tanker	Mar 23 2020

Table 3. Overview of respondents interviewed: shipping company, position, ship category represented and date of interview

A short description of the companies represented in the interview study is in place before the results are presented:

Terntank: Today the company operates ten chemical/product tankers (range from 10 000 DWT to 15 000 DWT). Since 2009, the headquarter of Tärntank Rederi AB is in Skagen. In June 2012 a cross border merger was completed and Tärntank Rederi AB becomes Terntank Rederi A/S.

SOL rederi: The company offers Ro-Ro line operation, transport of project cargo and general cargo, agent operations as well as commercial and technical management assignments. Together with Wallenius, SOL has formed the joint shipping company WALLENIUS SOL, that operates a line service from five ports in the Gulf of Bothnia to and from Europe / UK.

DFDS: With a fleet of Ro-Ro, RoPax, and container vessels, DFDS connects over 20 countries. DFDS offers one of Europe's most comprehensive freight shipping networks, including the North Sea, Baltic Sea, Mediterranean, and Channel shipping routes. DFDS has also eight terminals across Europe including Gothenburg (SE), Ghent (BE) and Immingham (UK).

Stena: The RoPax fleet of Stena equals to about 36 ships (own and chartered) in the North Sea, the Baltic sea and lines from Denmark, Germany, Sweden and Norway. Two of those are from Gothenburg to Frederikshavn (DK) and Kiel (GE).

6.2 The situation today

6.2.1 Speed reductions and bunker consumption

All four companies describe how they have actively worked with speed reductions, not at least from an economic perspective. The companies are finding the optimal speed. One example is given from SOL to illustrate this. If a ship that runs between Sweden and Africa, and has an optimal speed of 12 knots would go faster, more bunker is consumed. It is concluded that the cost is more important than the time saved in this case. If the ship would go slower, there would be more time charter days. Optimal speed is described as the trade-off between fixed costs, bunker consumption, charter days and the ship's performance i.e. how many trips it can do in a year (SOL). The oil price affects this. If the oil costs 250 USD/ton, then higher speed is preferred to more charter days, but with a price of 1000 USD/ton the option would be to go slower despite the increased time charter days. "Those that do not think about this, they should not be in this business" (SOL).

Another view was that speed reductions have already been implemented since the fuel prices were high some years ago and it is not feasible to reduce speed even more. So far, the perception is that speed has not increased since then, but it must be a longer period of lower prices before changes in the trading patterns and the speed can be seen (Terntank).

It is pointed out by one company (SOL) that there is an important distinction between liner traffic and time charter traffic. Most of the world fleet (tank, bulk etc.) use time charter where the owners and crew do not have the same incentive to save bunker. "It is an outdated model really because it is counterproductive to maritime environmental goals". In liner traffic, it has been a focus on speed reductions for ten years for cost reasons: to reduce bunker consumption and thus the environment impact since it is a linear connection. "It is embedded in the liner traffic" (SOL).

6.2.2 Implemented bunker saving measures

Lowering the speed to save bunker has been done by all four companies, for both economic and environmental reasons, but it is only one of many tools implemented for saving fuel. Examples of bunker-savings projects onboard include engine optimisation, using alternative fuels, better scheduling of departures etc. In the following there will be examples from each of these measures (although the companies may have implemented additional measures to those described here).

One way has been to introduce *bunker-saving projects on-board*. The RoPax operator Stena has made engine optimisation, using frequency converters and other projects on-board. This has been done since the beginning of 2000 and the company has internal goals to reduce the bunker consumption every year in a continuous improvement. The consumption has been reduced by 2.5% per year for the past 10-15 years. This includes changes in the timetable also which has affected this substantially (Stena). Are there room for more improvements? Yes, but it is mainly about new solutions in technology, but "we keep working with our energy-saving programs" (Stena).

Terntank has (like Stena) invested in systems for *optimizing the vessel´s main engine*, which is according to the company a "quite high investment cost". Now they are able to run the main engine more economically and reducing the fuel consumption up to 20% when the speed is 12 knots. The company believes that a lot of shipowners did similar investments when the SECA limit of 0.1% sulphur came in place 2015 and when the oil price was high (Terntank).

DFDS started to work with the energy consumption onboard 8-10 years ago and had a catalogue with 60-80 small possible, technical measures. It is simple: if less electricity is used on-board, less electricity is produced, and less bunker is needed. One practical example is when a ship is in port and the stevedores have a break, then the ventilation is turned off.

In the strive for reducing oil consumption, and thus the CO2 emissions, there have been programs in the shipping companies to use alternative energy sources. Stena has trials with a battery package for bow thrusters and for the auxiliary machine for on-board power utility (however not for the propulsion yet). The next step will be electricity.

Alternative fuels is another measure, but the supply of fuel is a problem for LNG (or LBG) which has made DFDS hesitant to use it in their ships. The company has 45 vessels calling 40 ports and the benefit is the flexibility that the ships can moved around depending on the demand. This would be very limited with LNG as only 2 of these ports have LNG supply. Therefore, LNG is mainly very good for a passenger vessel or for special trade, according top the company. DFDS has a diverse program for alternatives to bunker where collaborating with partners is one way ahead. Being part of various organisations in this area is another way but also to work with innovative solutions, for example, a company trying to convert nutshells to bunker oil.

Speed reduction through better *scheduling of departures* is another way to save bunker, which both Stena and DFDS mentioned. DFDS points out that the more time for the sea-crossing, the less bunker you use. Therefore, their focus has been on getting the vessel away as quickly as possible. Also changes in the departure times to get more time for the sea-crossing has been made, which has been a challenge to "sell in" to the customers (DFDS).

6.3 Effects on Operations of a mandatory speed reduction

6.3.1 The technical area: engine and bunker consumption on ships

In one proposal there is a 20% a speed reduction from the 2012 average speed per ship category. One risk is that this resulting speed limit might have negative effects on the CO_2 emissions and the engine. There is a "minimum speed" for a vessel and if the speed is lowered below that, for example at 8-11 knots, the bunker consumption will be higher due to the poorer engine efficiency and propulsion efficiency. The workload of the engine can go to a too low level causing the maintenance cost to rise and also damaging the engine. This minimum speed limit is different from ship to ship, also depending on how many engines the ship is equipped with which is based on the shipowners´ preference. DFDS has ships with one main engine.

"One big propeller, one engine, is the most economical setup you can have. That means that you also have a restriction on how slow you can go. With two engines in a vessel you can stop one engine and reduce your speed and run the other engine on the most efficient mode you have. We don´t have that option with these vessels, we have on some of our others vessels" (DFDS).

Below this breaking line, the vessel starts to consume more fuel and emit more CO_2 and produce less transport work (Terntank). The company explains that it has to do with the relationship between the length of the voyage and the speed, there is always a breaking point where fuel consumption becomes higher due to the fact that the voyage time increases more than the fuel saving. Some types of large engines also have limitations which can cause big problems, depending on which fuel are used since there are different limitations with regards to temperatures inside the engines.

"It is not so easy to just put a speed limit like you have in a car" (Terntank).

The bunker consumption cannot be assumed to go down 20% if speed is reduced by 20%. There is a breaking point for *optimal bunker consumption* (on a schedule based on the tradeoff between customer demands, the optimal crossing time, bunker consumption). If the speed is lower than this, the result may be a higher cost. This is a bit dangerous. (Stena).

DFDS emphasises a similar trade-off: "Every decision we make is a compromise of when we can get the vessel operated, the crossing time, the weather, how do we minimise our bunker consumption. This is in our DNA. If a ship is delayed with half an hour, we know that it will cost 5 tons of bunker. We work with that every day". (DFDS)

6.3.2 The traffic planning area: frequency

In order to see the consequences of a 20% speed reduction (as proposed based on a 20% reduction from the ship size average 2012), some of the companies gave real-world examples on how this would affect specific ship services.

Liner RoPax traffic

Stena is operating RoPax ferries from Gothenburg to Denmark (Frederikshavn) and Germany (Kiel). The respondent of Stena describes the difference between the two routes with differences in length and time scheduling:

"Today the speed is higher to Kiel than to Frederikshavn, because the sea journey is much longer. If speed was decreased, operationally it would be possible to turn around in Kiel, but it would be an unattractive route, especially for freight. The time of the sea journey will be too long, and the freight will be transported on land instead. That would have a negative effect on the environment. It would make a considerable difference for the freight, but also for the passengers. The departure time and the arrival time will be very different. This is super important for especially freight since for example the truck drivers must have time to collect and distribute the freight. Our focus is on the time demands around the freight and what the customers want" (Stena).

An example of this is if the ship leaves early in the morning or late in the evening, it may not be attractive for freight. The above example shows that freight transports have restrictions in time as part of a logistical chain, where pick-up times and deliveries may steer the transport choice. To Kiel, there is a viable land-based alternative to ship including the Oresund bridge. In order to be competitive to road, the speed is higher than to Frederikshavn where there is no similar alternative on land. Also, the sea journey is much shorter and therefore Stena today use a schedule with three roundtrips per 24 hours. According to the respondent, this would not be possible with a speed reduction to for example 11,1 knots (as proposed based on a 20% reduction from the ship size average 2012). It is believed to affect the customers and Stena´s profitability. Possible actions to compensate this would be to add another ferry (which will increase costs) or take more tonnage of freight (if space is available on ships).

Liner RoRo traffic

SOL runs liner RoRo traffic from the Northern Baltic Sea to Lübeck in Germany with several stops on the Swedish and Finnish coast, where the roundtrip takes two weeks. If a speed reduction is imposed to for example 11.4 knots (as proposed based on a 20% reduction from the ship size average 2012), this trip will take more than the two weeks. What effect would that have on the traffic schedule?

"Then we would not be in the same ports on the same weekdays. This would bring other disturbances. The connectivity to the ships going out on the North Sea are leaving every 14 days, not 15 days. The system will not work if we can´t keep today´s speed" (SOL).

The respondent points out that their ship to Egypt (not liner) can still work, however with increased costs and longer transport time. Thus, there is a large difference between liner RoRo traffic in comparison to other RoRo traffic.

DFDS runs RoRo services in liner traffic in Europe from for example Gothenburg. The schedules are based on customer needs. The offered number of roundtrips per week is based on the customer´s needs and what is possible for the vessel. The more roundtrips, the more capacity is available. One example is the company's Ghent service working close with the logistics flows from the automotive business.

"There are three vessels employed in this service. On Monday, the ship arrives at 07.00 in Gothenburg and depart at 22.00. This is a very long window but there is a reason for this. The following week she: does the crossing, stays in port for eight hours, does the crossing, stays in Port of Gothenburg eight hours, does the crossing, stays in port eight hours and then does the crossing back to Gothenburg. Then she stays in port for almost 18 hours. The first reason for this is that we need time in port to maintain the vessel (cannot be done at sea). The second reason is that we have time to catch up if we are delayed due to poor weather and so forth. The third reason is that if the ship would leave at 15.00, there will not be any cargo available" (DFDS).

How would a speed reduction to for example 11.4 knots (as proposed based on a 20% reduction from the ship size average 2012) affect the scheduling?

"Today we can make two roundtrips per week per vessel. If we had to reduce the speed -20% then we could not perform these two roundtrips. We would never, never make more than one roundtrip per week. Also, we will have less flexibility because the time in port is cut down to less than eight hours, which we need" (DFDS).

The respondent from DFDS pointed out that it is difficult to know what the general consequences would be, because they could be very different between the individual services. A different example is a vessel trafficking the UK service, where the described problem with roundtrips is not the same issue.

Chemical tanker traffic

Terntank prefer to work with a Just-in-time (JIT) system for their part of the transport chain with loading/discharge in port based on an agreed best time of arrival in order to reduce time at anchor due to early arrival. By agreeing on JIT arrival, a vessel can optimise speed/reduce consumption (and reduce anchoring time) and thereby CO_2 emissions.

6.3.3 The economy: costs and competitiveness

There are several, mainly negative, effects on the financials according to all respondents. A selection of answers is shown here to illustrate what was discussed on this theme in many of the interviews. One very expensive effect would be the need for *more ships*. Terntank has calculated that with a mandatory speed reduction of 20%, they would need about 25% more ships, which is equivalent to 2,5 vessels more. This means *higher costs*.

SOL estimates that one of their RoRo ships costs EUR 10 million per year to run including bunker. At the same time, a speed reduction would not increase the revenues. DFDS, in the RoRo segment, points out that more ships also mean *more fixed costs*, but also variable costs.

"A rule of thumb is that the total costs are roughly: 1/3 bunker, 1/3 port costs, 1/3 ship cost. There is only one actor that pays those costs and that is the customer." (DFDS)

DFDS would have to increase the capacity with more vessels, if the frequency is decreased.

"The transport price would go up, but if it would be higher than the bunker saving is difficult to say. The pure fact, if we would deliver the same capacity on the market and we have to employ more ships, that means that all our costs would go up. " (DFDS)

The company has already upgraded a vessel to a bigger size, but it performs the same schedule as a way of getting more capacity into the system. *Larger vessels* would be needed even more with a speed reduction. Another effect of decreasing the frequency would be that the trailers would stay longer in the terminal, from 24 to 48 hours in the example of Gothenburg-Ghent service, which "will have a huge implication". The *costs for investments in terminals* for increased capacity would be needed and have a negative impact on the finances. (DFDS)

The discussion above about the reduction of frequency and that DFDS cannot perform the current schedule anymore, will have **large impact on business**.

There would be lost customers and major implications in relation to for example Volvo's logistical flow, which would require "a totally different setup because we would have to depart earlier and arrive later" (DFDS).

Also, if the shipping companies would order new ships, the delivery time would be several years. In the meantime, an option to increase the capacity could be to use time-charter vessels. DFDS is one company that already uses time-charter for some of their RoRo ships. A normal delivery time for these ships would be two to three years. However, the respondent from DFDS believes that if the company cannot provide the necessary capacity with their ships, the freight will go by road. Time-charter is not a realistic alternative to increase capacity since their ships are highly specialised and the demand for time-charter will go up.

"We have high productivity on our vessel where we have a close dialogue with the captains employed by DFDS on the vessels. They go the extra mile to give a good service. Our service lines from Gothenburg are hard to build up on the charter market. It will be hard to find a vessel with the same quality as we have right now. So, it will be difficult, but it can be done of course, to find vessels that lift the volume that our customers require. The problem is that we will not be the only one and there will be a deficit of vessel tonnage on the market" (DFDS).

The respondent explains that the RoRo charter market differs a lot from the bulk charter market (DFDS). The bulk vessels represent about 60% of the fleet in the world, which makes it possible to get hold of vessels. This is not the case with the RoRo vessels; they are specialised and there is a limited number in the market. So, the option with using time charter for DFDS can be summarised as: the vessels can be hired, the price will go up because of the shortage in the market, the chartered ships would not be delivered as needed by customer requirements, and the next alternative is building vessels which will take 3 years.

6.3.4 The safety area

Safety is another concern with a mandatory speed reduction.

"If the commander cannot decide course and speed on his/her ship, bad things can happen. It must be his/her responsibility. For example, to be able to increase speed to get to the port fast in order to avoid an approaching storm. This is fundamental." (SOL)

6.4 Effects on the market of a mandatory speed reduction

6.4.1 Effects on ships: the number and types on the market

All four companies interviewed put forward that the main effect of a speed reduction will be an increase in the *number of vessels* in order to carry the same amount of cargo as today.

“If we have more vessels on the ocean running at a lower speed with the same amount of cargo, this means more CO_2. It is a quick fix to impose a 20% reduction of speed, but the effect will be the opposite; more CO_2 and more vessels. This is not so modern and efficient. “ (Terntank)

New ships will be built as soon as possible but it will take time. The time for this is estimated to 3-5 years by the actors, before the supply equals the demand. In the meantime, the demand for time charter ships will rise.

“A bulk carrier from Brazil to China runs at the optimal speed to reduce bunker consumption. If a speed reduction of 20% is enforced, 20% more capacity is needed, or prices go up. This is good for the shipowners with time charter. The winners are the ones in the segments tanker and bulk” (SOL).

There is especially a concern for the effects of the liner traffic segment.

“A compulsory speed reduction would saber the whole setup for liner traffic. This is not the case in tank or bulk traffic” (SOL).

“In the liner RoPax segment, we have a fierce competition to road traffic; short routes and high frequency. In dry bulk, you don’t have that competition” (Stena).

The next question is what type of ships will be on the market.

“It is better to talk about reduction of CO_2 per ton mile instead of just speed reduction. That is done by modernizing the fleet. The competition in the market with this proposal will make older ships continue running and be more competitive. The average age of the fleet will with no doubt go up.” (Terntank)

6.4.2 Effects on competition between modes of transport

The changes in the transport services offered at lower speed will lead to a changed competitive landscape. The question is in what way. In the shipping market, the prerequisites would be the same for all shipping companies:

“The competition between shipping lines will face the same problem, but the competition from road traffic will be higher. It will be a shift towards road traffic, and I am not sure that we want that from an environmental point of view” (DFDS).

“The actors in the shipping market will get the same prerequisites, although there will probably be some unpredictable disruptions in competition in the market that needs more thought. However, it will be much more momentarily disruptions between other modes of transports. Traffic is like water; it takes the easiest way. Traffic goes where it is easiest and cheapest. I am 150% sure that sea transports will lose competitiveness to land transports, especially trucks, when this alternative is available” (SOL).

”To lower the average speed for ships may not benefit the overall effect. Customers might choose land transports and less sea transport. Our ferry to

Germany (Gothenburg-Kiel) is competing directly to the E6 highway and the Öresund bridge to Denmark" (Stena).

When the destination of goods (today in liner RoRo traffic) is Europe, land transport is also an option to sea transport:

"If the companies (customers) experience higher costs and less flexibility, they will then use more road traffic. If you look at our service to Ghent for example you can go all the way on road. And our service to the UK, yes you can do that under the channel, but it is a bit more complicated. When the price tag goes up, they will find better alternatives in their view" (DFDS).

The chemical tanker category does not face the same competition from land-based modes:

"If you want to transport the same amount of cargo that we carry in one ship on road, you will need 1000 trucks" (Terntank).

6.5 Effects on actors of a mandatory speed reduction

6.5.1 Shipowners

The companies that own ships mention two changes in their fleet if there would be a 20% speed reduction: larger ships and more ships.

Larger ships are needed and demanded from customers in order to transport the same amount of cargo as today. Therefore, the ships in their fleet would have increased size. This is considered more sensitive for the infrastructures such as ports, canals, locks etc., according to SOL. The shipowner is building new larger ships, going from 16 000 tons to 30 000 tons, which is the maximum size that the surrounding infrastructure can handle. "These ships are 65% better in CO_2 footprint per transported ton with the same frequency in comparison to the prior generation of ships" (SOL).

The shipowners will probably *increase the number of ships*. **"**For us as a shipowner, this speed reduction will be good because we can build more vessels. More vessels are needed for the same amount of cargo. Today we have one vessel on the Norwegian coast, but we would need another vessel if we were to reduce the speed. However, the effect for the environment would be terrible." (Terntank).

The effects are not only larger and more ships, but also *the type of ships that will be built*. A serious concern is that the proposed speed reduction would penalise companies that are building top modern ships. Terntank consider themselves in this category, as they have reduced the bunker consumption substantially and use LNG (and LBG in the future). "Why penalise a ship owner that are building more fuel-efficient vessels and then imposing on them to reduce the speed on that vessel so it doesn't become financially viable to build modern ships anymore?" (Terntank).

Another possible risk of the proposed speed reduction for shipowners concerns the *legal issues regarding time charter contracts*, since many of them define the consumption for example the speed of 14 knots. If a customer has a long-term charter contract and the market is very bad, then the customer may look at all the possibilities to get out of a contract. (Terntank)

6.5.2 Customers

As a consequence of a higher demand for more ships, as discussed above, it will be hard to meet this demand in the short run (SOL). There will be *higher prices*.

"It will affect the financials of our customers as they will pay more for charter rates and bunker. They will get pressured by the charter rates since they for example will have to pay for two instead of one chartered vessel. The customers will probably try to negotiate lower time charter rates and put the cost on their customers." (Terntank).

"The main effect for the shipping companies' customers will be higher prices, if it will be an enforcement of speed reductions. This will affect the customers profitability negatively and they will try to pass on the higher prices to the end-consumer". (SOL)

Will the *customer's logistical systems* be changed in response to speed reductions?

On one hand, many companies today build their logistical system around *just-in-time deliveries* (SOL). The shipping companies are handling this today. Speed reductions may lead to a lower frequency of departures which may reduce just-in-time deliveries. This mean that the time for storage will be longer for example in ports and more warehouse capacity is needed (DFDS). This will also increase costs. SOL gives an example of this in liner traffic, where the paper mills have departures twice a week over the North Sea. A lowering of speed might reduce the speed to one departure, meaning that half of the volume is not shipped which will double the volumes stored. This also binds the double amount of capital. If the paper mill has its' transport need to mainland Europe, they will switch to truck instead (SOL).

On the other hand, the demand for sea transport is there and many times there are no alternatives to ships for transporting that amount of cargo, for example bulk cargo, around the world (pointed out by Terntank). However, maybe the covid19-virus may affect companies to bring their production back from China to the home markets in the long run (Terntank).

6.6 Incentives for investments in new ships.

One point of discussion is whether the mandatory speed reduction proposal would affect new-built ships negatively, since they are usually more energy-efficient than older ones. One opinion put forward was that these ship-owners already made a large investment for reduction of energy and emissions.

"If you have a new RoRo ship in one and a half year, it will use 50% less fuel per transported ton. If you are to reduce 20% more, they will not get pay-back on their investment. Why should a ship-owner do investments for better environmental performance then?" (SOL).

The respondent saw a risk that shipowners will hesitate to do these investments when the benefit is taken away. Even though he considered it good to "punish out" old ships, but economically it is not a good idea for the shipowner. Therefore, the shipowner prefers to run an old ship another year if possible, rather than scrapping it and building a new one.

Lowering the speed with 20% on a new ship is not possible, says another respondent:

"All measures for making the ship more energy-efficient has already been built-in in a new ship. Then the changes of the time-table are all that is left" (STENA).

Terntank is one shipping company that has invested in their older vessels and increased the fuel-efficiency and thus reduced the CO_2 emissions. Also, they have invested in new ships and the difference in efficiency is large; instead of consuming 21,5 tons per day with an older ship, a new ship consumes 13-14 tons a day. Although an older vessel can run 15 knots, some charterers choose to run 11.7 knots in order to make it the most economical and most fuel-efficient ship with less CO_2. If the speed is below 11.7 knots, the CO_2 emissions will increase. The speed can be at 9.4 knots in the new-buildings, but that is because of for example the "extremely good hull efficiency".

"When you reduce speed, then the most fuel-efficient ship will not improve the CO_2 -efficiency as much as a 15-year-old ship, especially at low speed. On our most modern ship, the fuel efficiency is not 8 tons fuel saving per day as for an older ship when speed is reduced to for example 10 knots, rather only 2 tons per day. In terms of CO_2 emission reduction, you get the benefit, but you would not be seeing more modern, fuel-efficient ships being built." (Terntank)

Another contributing factor whether to invest in more fuel-efficient ships pointed out by the respondents are the fuel prices. When fuel prices are low, as now, a respondent points out that the financials are not there to make such investments. Terntank has customers in the tanker time-charter segment that want to reduce their CO_2 footprint in their transport chain and is prepared to pay a little more for it. That has enabled the company to invest. However, this is pointed out to be an exception specific to their trade environment i.e. if a company run short-sea tankers in the North European market.

The lifespan of a vessel may be prolonged if a mandatory speed reduction is imposed. Today Terntank has an oil tanker deployed in time-charter for up to 20 years, which is the oil companies required age limit, and then the vessel is sold to e.g. Russia or China and used for example as a bunkering vessel for fishing vessels in 15 more years. If the speed is lowered, a high fuel-consuming older vessel will be more competitive in the time-charter market than it was before.

6.7 The proposal of mandatory speed reduction

6.7.1 Suggested exceptions

The respondents were asked about whether it would be any exceptions if mandatory speed reductions were enforced. The respondents discussed two suggested exceptions: safety and ship category.

Safety

Exceptions should be in place for safety.

"The possibility to have a higher speed to reach a port faster in order to avoid a storm or make it there before the tide. If the ship can only enter in high tide and arrives too late, it means a 12-hour delay. This is the case in England, Canada, France and other parts of the world" (SOL).

Ship category

The ship category RoPax is pointed out as a possible exception to speed reduction.

"The fierce competition from land transport in short-sea shipping, especially RoPax, brings a risk to increased truck transports on land, which would probably increase the CO_2 emissions (Stena).

A general reflection from one respondent was the following:

"If you ask shipowners around the world, you will have different answers from them. Look only at the ballast water that has been discussed for 10-15 years and it is not in place yet. It depends on many things for them: what ships do you operate, what are the customer demands, and so on. I don't think you should ask shipowners because they will not be able to agree."

6.7.2 A suggested alternative to the speed reduction proposal: a CO_2 tax

One of the interviewed companies (Terntank) emphasised another policy measure for reducing CO_2-emissions from ships: a CO_2 tax. Instead of regulating the CO_2 level, it is lowered by putting a monetary benefit for shipowners to invest in modern ships: the more you emit the more you pay. Then shipowners would scrap older, less efficient, ships sooner. It is also an incentive to run the vessels more CO_2 efficient. One model to do this is the NO_X-fund in Norway, where emissions of NO_X is taxed and put in a fund where shipowners then can apply for money to do investments in emission reductions. The respondent believes there are many advantages with a CO_2 tax:

"If a shipowner can do a 10% saving by investing in technology in an old vessel and another 10% in digitalisation/fleet tracking management, then you are getting this 20% anyway. The high investment cost in an old vessel does not stop this, if the shipowner can apply from this fund for this. It is not only about investing in hardware but also investing in software and educated people to run the ship more economicly. The CO_2 tax is targeting towards the behavior directly. That would fulfill the CO_2-target in the long-run. From a political point of view, it is easier to say that those who emit most CO_2 must also pay most in tax. This could change people's behavior on a daily basis, trying to reduce their CO_2, which would affect their financials. Otherwise you encourage people to run with very old vessels. If IMO wants to impose something that is equal worldwide, the CO_2 tax is easier to follow up than a speed reduction as you know your tonnage and your bunker onboard" (Terntank).

6.8 Reactions to the proposal

6.8.1 Stena

The respondent from Stena considers the proposal "devasting". The lowering of speed as 20% of the annual average speed will have a negative effect. If the lowering would be in absolute terms on each trip, it would be even worse. This would disable the ability to do a certain number of roundtrips in 24 hours. More importantly, today the high season is used to transport more freight, to compensate the low season on a yearly basis. This would not be possible with an absolute reduction on each trip, which would hit the commercial side very hard.

6.8.2 DFDS

The respondent from DFDS does not support the proposal. It is problematic to establish the yearly average (that the reduction of 20% would be based on) as the data available in 2012 is far from reality today. Also, the speed reduction would be in absolute terms on each trip, it would be even worse "a catastrophe". This is especially troublesome with bad weather conditions:

"If we should have any chance of maintaining service to customers and have capacity, then we have a window of possibility with a higher speed to get goods in on time." (DFDS)

6.8.3 Terntank

The respondents from Terntank think that a speed limit on existing ships would just penalise the building of modern ships and the vast majority of shipowners. The only way speed limits could function would be on new buildings.

"It is possible to optimise on 11, or 10 knots as a maximum, and it would be equal on all new-buildings. But the existing fleet is optimised on a totally different level."

6.8.4 SOL

The respondent from SOL is negative to the proposal of speed reduction ("worthless"). The strongest argument against is that with a mandatory speed reduction, more capacity is needed (ships) as the same amount of freight needs to be transported. The transport work per ship will go down. The demand for time charter will increase until new ships will be delivered, which probably will take five years. In the short term, this would benefit certain countries which are heavy on time-charter of tankers and bulk, and which support this proposal. This will have a large impact on the shipping industry:

"The sad part is that the proposal creates a pseudo-debate that shift the focus from what is important for the environment: developing alternative fuels and new technology for ships in the future. If we build a ship now, it will last for 30 years and therefore we must develop it now."

A major problem is if the basis for speed reduction is the average speed in 2012. Their liner schedule traffic looked totally different in 2012 than today: other time schedules, ports, departure times etc. If the lowering would be in absolute terms on each trip, it would be even worse. "It would be a total disaster. We would have to re-do everything. In liner traffic, nothing will work."

7 Analysis and discussion

It is time to summarise the results of this study, both from the quantitative calculations and the qualitative interviews with shipping companies and compare them to prior studies and research conducted.

Previous studies have looked at slow steaming, when the shipping companies at times reduce the speed significantly below the vessel's design speed with the aim to reduce bunker consumption and accordingly costs and emissions (Finnsgård et al., 2020, Cariou, 2011 and Maloni et al., 2013). This is often triggered by overcapacity as slow-steaming ties up ship capacity benefitting shipowners attempting to raise prices (Cariou, 2011, Ferrari et al., 2015, Finnsgård et al., 2018 and 2020). This study focuses on mandatory speed reductions, where the aim is the same as in slow-steaming but not driven forward by an overcapacity or high fuel prices but by regulation.

There was an expressed concern among the interviewed shipowners that this regulation would create a shortage of ship capacity (assuming that the same amount of transport work needs to be carried out) in the short run (3-5 years). The shipping companies with time-charter would benefit during this time period before new-built ships reach the shipping market, also those in the market with old vessels with high CO_2 emissions whose lifespan is prolonged and become more competitive due to the increase in demand. Interestingly, even an interviewed shipping company with time-charter (that potentially might benefit in the short run) was still negative to mandatory speed reductions as it would have a negative impact on willingness to invest in new energy- and CO_2-efficient ships and that reduced speed does not always lead to reduced CO_2 emissions. One respondent pointed out that it is not possible to lower the speed with 20% on a new ship, as all measures for making the ship more energy-efficient have already been built-in, and all that is left is the changes of the time-table. Another respondent said that it would be better to discuss reduction of CO_2 per ton-mile instead of just speed reduction. That is done by modernizing the fleet.

A general assumption in the discussions of slow-steaming and speed reductions is that fuel consumptions goes down when speed is lowered, and thus CO_2 emissions. However, the calculations of fuel consumption at different speeds on a product tanker in this study, shows that the fuel consumption can instead increase although the speed is lowered significantly. This is based on specific speed-consumption data for the vessel being studied.

The calculations in this study show that there is an optimum speed for any certain ship at a certain load condition for which the vessel consume the least of fuel per moved amount of cargo. Raising speed or lowering speed from that optimum would increase the fuel consumption and the CO_2 emitted. In prior research studies, this relationship is highlighted as well. Many studies that show large potential savings from slow steaming are based on models that do not take the actual relationship between significant speed reductions and possible negative effects of such reductions into consideration and might possible overestimate the savings from slow steaming. This is in line with statements in Psaraftis (2014) that highlights that it is important to be careful with the assumption that the daily fuel consumption is a cubic function of ship speed, and it may not hold true for all ship types and speeds (an assumption which many models of fuel consumption calculations and savings through speed reductions build on). It is reasonable for some ship types (such as tankers, bulk carriers, or ships of small size) but may not be realistic at slow or near-zero speeds and for some other ship types such as high-speed large container vessels. This is in line by a recent study by Adland et al. (2020) showing that the classical cubic law for fuel consumption is valid only near the design speed. The results in this study and in prior studies indicate that there is a risk that the potential savings of the fuel consumption and the carbon dioxide emitted from slow steaming, are overestimated.

In the interviews, all four companies describe how they have actively worked with speed reductions and finding the optimal speed, not at least from an economic perspective. Optimal speed is described by one liner company as the trade-off between fixed costs, bunker consumption, charter days and the ship's performance i.e. how many trips it can do in a year). This trade-off varies over time with fuel price. One respondent points out the distinction between liner traffic and time charter traffic. In liner traffic, speed reductions and reduced fuel consumption have been in focus for many years due to costs (high oil prices), but most of the world fleet (tank, bulk etc.) use time charter where the vessel owners and crew do not have the same incentive to save bunker. The measures implemented for achieving lower fuel consumption and/or lowering environmental impact, have been bunker-saving projects onboard including engine optimisation, use of alternative fuels, better scheduling of departures, reduced energy consumption onboard, etc. Investing in optimisation of the main engine is considered a "quite high" investment cost and it has been done by many shipowners already when the SECA regulations of 2015 came in place.

The decision on speed is in general a trade-off between time-dependent costs of crew and capital tied up in ship and cargo on one side and operational costs, mainly bunker costs, on the other side (Stopford, 2009). This is dynamic as interest rates and bunker costs are volatile. Also, time-charter rates affect this. In this study, a cost-calculation of different speeds was conducted, and the CO_2 emissions were incorporated in order to see the trade-off between speed, costs and CO_2 emissions. The speed - cost- carbon dioxide calculation for a product tanker with real speed consumption figures shows also clearly that costs per moved amount of cargo raises significantly with lowered speed. This is primarily a result of the time charter rate, for the vessel, being more dominant as a cost factor at lower speed.

In the interviews, the cost effects of a mandatory speed regulation and also, on competition were discussed. More capacity (ships) would be needed resulting in more fixed costs, but also variable costs. A rule of thumb for a RoRo ship is that the total costs are roughly: 1/3 bunker, 1/3 port costs, 1/3 ship cost. The transport price would go up, but if it would be higher than the bunker saving is difficult to say. The pure fact, if we would deliver the same capacity on the market and we have to employ more ships, is that all costs would go up. At the same time, a speed reduction would not increase the revenues. Therefore, it is the customer that would have to pay these costs.

Returning to Stopford (2009) and the time-dependent costs of crew and capital tied up in ship and cargo, including time-charter. In the interviews it was pointed out that time-charter is a less attractive option in some segments. The bulk vessels represent about 60% of the fleet in the world, which makes it possible to employ time-charter ships. This is not the case with the RoRo vessels; specialised and limited number in the market. Even though they can be hired, the price will go up because of the shortage in the market, the chartered ships would not be delivered as needed by customer requirements, and the next alternative is building vessels which will take three years. In RoPax, time-charter is not a realistic alternative to increase capacity since the ships are also highly specialised and the demand for time charter will go up. Therefore, the risk if the necessary capacity in the RoRo and RoPax liner services cannot be not provided, is that the freight will go by road in Europe instead.

Liner shipping is a problematic type of shipping from an operational/logistical point of view, where a shipping company normally must make a complex compromise between different shippers' time demands. In the interviews conducted, the shipping companies in the RoPax and RoRo segments expressed deep concern for the operational consequences of mandatory speed reductions. This would also increase costs, that the customers must pay in the end. The longer sea transport times in the RoRo segment would not be compatible with the time-sequencing in their customers' supply chains (e.g. automotive industry) and therefore they might shift to truck transports within Europe. Also, the changed timing of arrivals to ports would negatively impact several factors such as the number of turnaround trips performed, missed connections to other sea-legs due to changed days and timing of a weekly or bi-weekly service. This is in line with Woxenius (2012) that argues that RoPax operators also must consider turn-around times, resting times for drivers and convenient departure and arrival times. In another study by Raza et al. (2019), it is found that RoPax is the segment with the widest set of customer demands to satisfy as both passengers and goods are mixed. Time-critical cargoes are loaded on lorries on board and mixed with less demanding goods loaded in unaccompanied semi-trailers or containers. The authors conclude that deciding on speed in RoPax shipping is hence a complicated issue with many constraints.

From a Swedish horizon, shipping's market share also depends on the port selection, that is, if the maritime distance is minimised or maximised (Stelling et al., 2019). Speed is a factor in the latter case as Sweden's oblong geography implies that shipping competes head to head with road and rail transport for services such as Gothenburg-Kiel and Nynäshamn-Gdansk. In the interviews conducted, this came up as very important as the RoPax ferries to Denmark and Germany experience direct competition to road, for both trucks and car passengers, so a modal switch to road was considered an evident risk. The whole business case could be threatened by this but also due to risks of reduced number of departures and on less attractive departure times for goods.

The respondents were asked about whether it would be any exceptions if mandatory speed reductions were enforced. One suggested exception was safety and the possibility to have a higher speed to reach a port faster in order to avoid a storm or make it there before the tide. The other one was the liner traffic RoPax and RoRo where the fierce competition from land transport in short-sea shipping brings a risk for increased truck transports on land, which may increase the CO_2 emissions. The latter was mentioned by these companies active in these ship segments so it is a biased opinion, but on the other hand the competition for short-sea-shipping is fierce and the possible severe consequences of modal switch to land-based transports are hard to argue against. One respondents pointed out that shipowners around the world will have different answers for exceptions depending their business: what ships do they operate, what are the customer demands, and so on. They will never be able to agree.

The conclusion from the interviews are that all shipowners were very negative to the speed reduction proposal investigated in this study. If the alternative proposal of lowering the speed by 20% in absolute terms on each trip instead, it would be even worse. They all agree on lowering the CO_2 emissions, but it is the regulation in itself that would have large negative effects on the costs, the business case and the environment. A CO_2 tax was suggested instead as an alternative policy measure for reducing CO_2-emissions from ships. It is easier to implement from a political point of view (polluter-pay-principle), it is equal worldwide and it is easier to follow up than a speed reduction as you know your tonnage and your bunker onboard. The CO_2 tax is targeting towards the behavior directly and could change people's behavior on a daily basis: it is also an incentive to run the vessels more CO_2 efficiently and their financials are also affected positively.

8 Future research and need for knowledge

There is a need for further studies in relation to speed reductions in shipping, whether it is mandatory through regulation or on the initiative of shipping companies.

When comparing real data for vessels' fuel consumption over time for many trips in different conditions it seems like the fuel savings are often overestimated for vessels at slower speed or at super-slow-steaming when theoretically calculated with the often-used formulas for simplified power-speed . A relationship between speed and propulsion for substantial speed reductions would be beneficial and enable more accurate estimates of such effects.

The economic relations between speed and transport cost will vary with many factors such as the perspective looking from the shipowner, the shippers and passengers, or from the society. In addition, ports are affected as they will be expected to work faster to guratnee the vessels more time at sea. It would be of great interest to understand more in detail how costs related to speed reductions will be also in relation to alternative measures such as improved technology with improved efficiency and other measures. Within the proposals to IMO on mandatory slow steaming requirements, the consequences have been described mostly in terms of lowered transport costs which is the opposite of what's been found in the two specific cost estimations made in this study. We therefore suggest more detailed cost benefit calculations to be made in case going further with speed regulations.

An alternative policy measure for reducing CO_2-emissions from ships, instead of the speed reduction proposal, emphasised by shipowners interviewed was a CO_2 tax. Instead of regulating the CO_2 level, it is lowered by putting a monetary benefit for shipowners to invest in modern ships; the more you emit the more you pay. Then shipowners would scrap older, less efficient, ships sooner. It is also an incentive to run the vessels more CO_2 efficiently. In the interview, one model mentioned to do this is the NO_X-fund in Norway, where emissions of NO_X are taxed and put in a fund where shipowners then can apply for money to do investments in emission reductions. A CO_2 taxation is a widely discussed measure today, including design issues, within the IMO and also in the EU.

The recent amendment to the EU Emissions Trading System (ETS) Directive (the Directive (EU) 2018/410 of the European Parliament and the Council) emphasises the need to act on shipping emissions. It states that the Commission should regularly review IMO action and calls for action to address shipping emissions from the IMO or the EU to start from 2023, including preparatory work and stakeholder consultation. Therefore, more research is needed and studies involving stakeholders in shipping on possible scenarios regarding CO_2 regulations and especially from a Swedish point of view. Further studies could look into the pricing of CO_2, either as a tax or as an emission trading shceme, and how price would affect the trade-off between speed, costs and CO_2 emissions among shipping companies.

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Lighthouse samlar industri, samhälle, akademi och institut i triple helix-samverkan för att stärka Sveriges maritima konkurrenskraft genom forskning, utveckling och innovation. Som en del i arbetet för en hållbar maritim sektor initierar och koordinerar Lighthouse relevant forskning och innovation som utgår från industrin och samhällets behov.

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