Sustainable Shipping

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The impact of digital solutions

Roland Berger

In brief

Sustainable Shipping

As shipping faces ever increasing environmental obligations, we evaluate the extent to which digital solutions can further reduce the emissions of the global industry. We begin by reviewing the industry's current level of emissions, its evolution and key drivers, as well as outlining the targets the industry has set itself. Reductions can be achieved via several mechanisms, but here we focus on the digital solutions available today. We categorise these solutions and outline their applications, before laying out our estimates for their potential to reduce emissions and describe the key barriers impeding their adoption. The variety of solutions available is very broad and constantly evolving, but despite the challenges of keeping pace with the technological wave and selecting the correct tools, it is evident that there are immediately achievable efficiencies to be gained from them, reducing emissions, saving money, and increasing safety.

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A shrinking environmental footprint

Shipping, like any other industry, is facing increasing pressure on its environmental footprint. The industry is one of the globe's major polluters and in 2019 produced around 885 MT of CO_2, roughly 2.4% of global CO_2 emissions[1] and of a similar scale to the aviation industry.

Unlike many industries, however, this footprint has already been reduced quite significantly. Since 2008 total emissions have fallen by 14%, despite a 44% increase in ton-miles[1].

This reduction, whilst impressive, was mainly driven by economic considerations. Slow steaming (sailing at 12-18 knots as opposed to the previous usual of 20-24 knots) became prominent in 2007 following rising bunker costs has continued to be practiced after the global financial crisis as a measure to absorb the surplus capacity in industry *(see graphic p. 4)*.

Slow steaming has, to some extent, become the new norm as supply chains and operators have adapted accordingly. Whilst some operators have pointed to potential further speed reductions (known as super slow steaming), average speeds across the industry have been largely stable since 2015, suggesting that any further speed reductions might only yield limited benefits, at least for most operators and existing vessel designs.

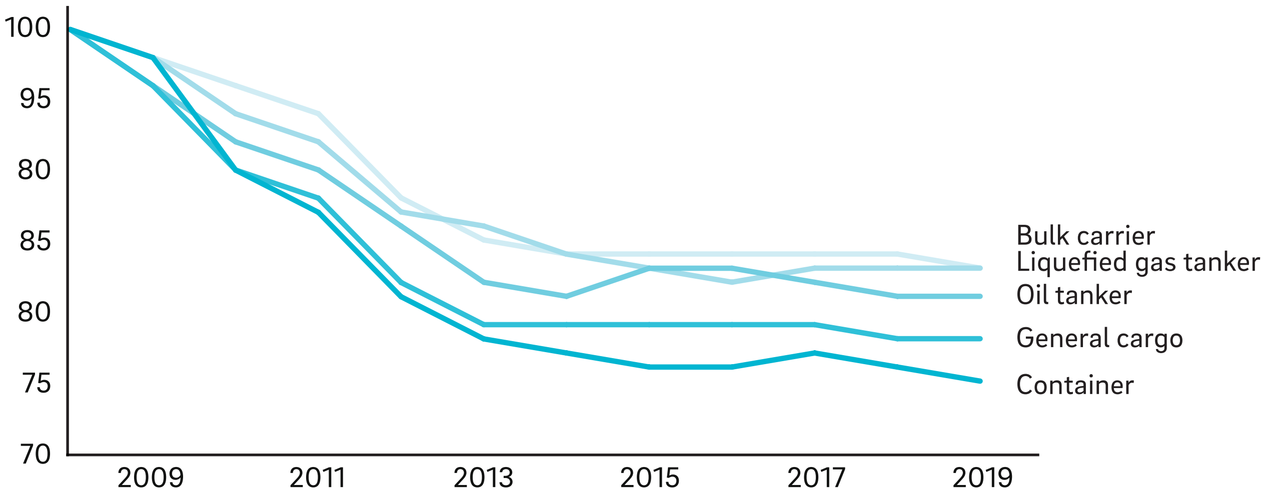
Speed is the most significant driver of emissions for a vessel, but new build vessels have also contributed the reduction in emissions of the industry; firstly through the development of new more energy efficient designs (including cleaner propulsion systems) and secondly though economies of scale via the construction of significantly larger vessels. Across all vessel types, the average vessel size of the active fleet has increased by 36% since 2008 (in DWT). Much of this growth has been driven by container ships, which are responsible for the largest share of the industry's emissions versus other vessel types (c. 22% in 2019[2]); the average vessel size of the container fleet has increased by 52% since 2008, influenced by the growing deployment of Ultra Large Container Vessels "ULCV" (more than 14,500 TEU) and more recently by the New Panamax class vessels. Ever increasing size of container ships is, however, practically more feasible versus other vessel categories, owing to their relatively lower draft. As such, and by contrast, the average vessel size in the tanker fleet has grown by only 13% since 2008[1].

The combined impact of new larger vessels and the wide adoption of slow steaming has been a significant reduction in the carbon intensity of the industry; since 2008 the average CO_2 emissions per ton-mile have fallen by 40% *(see graphic p. 4)*.

The leveling of this carbon intensity curve in recent years, however, suggests the primary benefits of larger vessels and slow steaming have largely been realised and thus highlights the need for further and continual efficiency improvements in other areas, especially considering the long-term growth expected in underlying seaborne trade volumes[3]. Without these additional efficiencies the shipping industry will not be able to meet its long-term emissions targets which we outline in the next chapter and may reverse the positive trend established over the past decade.

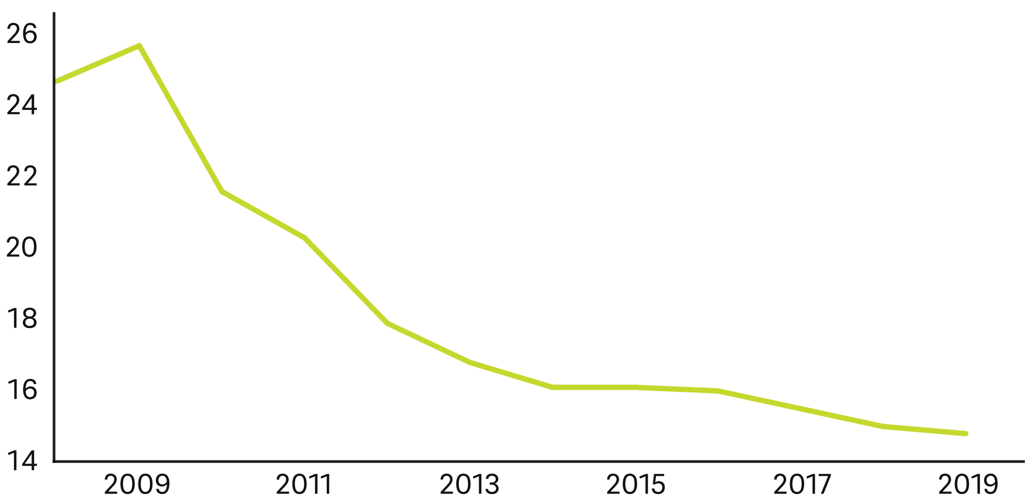
The adoption of slow steaming

Average vessel speed, 2008-19
[Index, 2008=100]



A significant reduction in carbon intensity

Average carbon intensity of the shipping industry, 2008-19 [EEOI, gCO_2/ton-mile]



Source: Clarksons, Roland Berger

How far is the industry from its emissions targets?

Whilst much of the reduction in the industry's environmental footprint has been driven by operators pursuing more financially sustainable and efficient operations, international and national regulatory bodies are playing a significant part in steering the industry forward.

The IMO has been championing the international regulation efforts, whilst relying on national maritime authorities to monitor vessel compliance and impose necessary enforcement and penalties. The IMO has regularly raised the bar since updating its International Convention for the Prevention of Pollution from Ships (MARPOL) in 1997, with the creation of the "Prevention of Air Pollution from Ships" — also known as Annex VI. This piece of regulation has seen continuous improvements and sets out targets and requirements for tackling both CO_2 as well as other emissions, notably as NO_x and SO_x — the latter of which is the main focus of IMO 2020. As the regulations have evolved, it has also led to some maritime authorities introducing novel technologies to monitor compliance, such as the Danish Maritime Authority's deployment of "sniffer" drones *(see case study p. 5)*.

As part of the developments in emissions regulations, ship owners and operators have also faced increased reporting requirements. Two of the most notable pieces of legislation are EU-MRV and IMO-DCS, which require ship owners and operators to annually monitor, report and verify CO_2 emissions as of 2018 and 2019 respectively. Ships larger than 5,000 GT are

Case study DANISH SULPHUR SNIFFING

The Danish EPA and the Danish Maritime Authority (DMA) are deploying technology to monitor compliance with and enforce sulphur emission rules in its waters. In addition to taking fuel samples (as per other maritime authorities) they are using "sniffers", an instrument able to "smell" whether ships are emitting too much sulfur. These instruments have been installed on the Great Belt Bridge, on helicopters patrolling the waters, and more recently on drones. The 0.1% sulphur cap was introduced in 2015 and now ~95% of vessels are compliant, with any truants being published on a public register on the DMA website.

Regulatory measures

The impact on CO_2 emissions of vessels

Measure	Description	Constraints imposed	Vessels in scope
NEW BUILD VESSELS			
Energy Efficiency Design Index (EEDI)	KPI for vessel design: theoretical amount of CO_2 per ton-mile of transport work EEDI = (power installed * specific fuel consumption * carbon conversion) / (available capacity * speed)	Attained EEDI must be lower than target (based on vessel size and type) 30% reduction in EEDI by 2025 versus "reference line" (average of vessels built between 1999–2009)	New build vessels >400GT across most vessel types Covers vessels responsible for 85% of the industry's emissions
FLEET			
Ship Energy Efficiency Management Plan (SEEMP)	Document for operating vessels explaining the measures taken to improve the vessel's energy efficiency (improvements planning, implementation and monitoring — see EEOI) and self-evaluation for further iterations, as well as the vessel's fuel consumption data collection processes	A version of the document applying the guidelines must be on board Fuel data must be shared with regulators	All existing vessels >400GT
Energy Efficiency Operational Indicator (EEOI)	KPI for operating vessel (part of SEEMP): amount of CO_2 per ton-mile of transport work for all voyages EEOI = (fuel consumption * carbon conversion) / (distance sailed * cargo transported)	Option to fulfil SEEMP monitoring requirement, (IMO recommended measure, but possible to use another KPI)	Optional

Source: Roland Berger

affected by both pieces of legislation and following the introduction of IMO-DCS, all voyages, worldwide and irrespective of flag state are affected. With data collection done on a per voyage basis it has led to the development of automated reporting tools such as the EU-MRV and IMO-DCS modules offered by We4Sea.

CO_2 emissions

Regulatory measures from the IMO impacting CO_2 emissions of vessels can broadly be divided into two; firstly those that impact new build vessels, which focus on more efficient vessel designs, and secondly those that apply to the existing fleet, which focus upon improving vessel operations and management *(see graphic p. 6)*.

The scope and requirement of these measures is regularly amended and expanded, for example in 2014 the scope of the Energy Efficiency Design Index (EEDI) was extended so that it encompassed vessel types that are collectively responsible for 85% of the industry's CO_2 emissions, up from 73% previously.

Reviewing the EEDI of recent ship building, however, it highlights that further improvements are still necessary. On average, new build vessels from 2017-19 saw EEDI reductions versus the target "reference line" of around 25%, below the IMO target for 2025 of an overall 30%[4] reduction. Indeed, only one vessel category, containerships, achieved an average reduction in excess of the 2025 target, highlighting that further investments into more efficient new build designs are still necessary.

Other emissions

The IMO also sets out specific emissions regulations tackling other pollutants, notably SO_x and NO_x. Similar to the CO_2 standards, regulations for SO_x and NO_x have become increasingly stringent over time, and are stricter still for vessels sailing within an ECA (Emission Control Area). The most recent iteration of these regulations, IMO 2020, which came into effect on 1st January 2020, saw SOx emissions thresholds reduce by 7x outside an ECA from 3.5% to 0.5%, versus 0.1% within an ECA (reduced from 1.0% in 2015). This has required operators to either switch to low sulphur content fuel (0.5% VLFSO or 0.1% MGO), or to invest in the capital expense and lost time in service from switching to LNG or installing an exhaust gas cleaning system known as a "scrubber" which allows vessels to continue using 3.5% sulphur heavy fuel oil (HFO). Most operators have begun operating with low sulphur fuels, as of March 2020 only ~4,000 vessels had scrubbers installed[5], out of the ~70,000 that are impacted by the regulations.

This figure will likely continue to grow with the economic choice of whether to install a scrubber being impacted by the VLSFO-HFO spread and the associated daily fuel savings from continuing to use cheaper HFO (which is most attractive for large vessels), but further regulatory revisions concerning scrubbers may come. Most scrubbers are open-loop systems (>80%[2]) which discharge washwater into the sea, effectively turning air pollution into water pollution, and an increasing number of ports and countries are already banning the discharge of scrubber wastewater owing to concerns about its impact on marine life.

Self-imposed targets

In support of and in addition to the regulatory targets set out by maritime authorities, many vessel operators have established their own sustainability initiatives and targets which seek to significantly reduce vessel emissions.

For example APM-Maersk has set out an ambitious target of a 60% reduction in CO_2 by 2030 (versus a 2008 baseline) and net-zero by 2050; it has also gone as far as linking its USD 5 billion credit facility to its environmental performance further evidencing its dedication to the targets. Similarly CMA CGM is targeting a 30% reduction in CO_2 emissions per TEU km over 2015-25, following a 50% reduction over 2005-15, and Hapag-Lloyd is aiming for a 20% reduction in emissions per TEO-mile over 2016-20, having reduced this metric by 46% over 2007-16.

Many of these aim to significantly surpass IMO objectives but will only be achievable through coordinated efforts by participants throughout the maritime and logistical value chains. One of the most prominent initiatives is the "Getting to Zero Coalition", which consists of more than 90 leading stakeholders (including vessel operators, ports, energy companies, ship builders, banks and research institutions) with the primary objective of having commercially viable zero-emission vessels (ZEVs) operating along deep sea trade routes by 2030, supported by the necessary infrastructure for scalable zero-carbon energy sources.

What digital solutions are available today?

There are three broad ways in which the shipping industry can reduce its emissions intensity; through operational improvements, vessel design (including propulsion technology) and fuel choice.

As has been seen with IMO 2020, switching fuels (across an entire industry) is not a straightforward exercise and requires considerable investment and change not just by vessel operators and owners but throughout the marine fuel value chain, across refiners, storage and distribution. Similarly, for improvements in vessel design, whilst being completely essential to the long-term sustainability of the industry, it can only have limited impact on shipping's medium-term footprint, and of course comes with its own carbon footprint from the production of new vessels itself.

Operational improvements, therefore, stand as the main lever that the industry can pull to continue the reduction of CO_2 emissions in the short-term and digital solutions often serve as a key enabler. Such services can broadly be divided into two main groups — Vessel & Fleet solutions, and Port solutions.

1. Vessel & Fleet solutions

Over the course of a voyage, digital solutions have the potential to improve emissions in four main ways: voyage optimisation, fleet management, cargo optimisation, and equipment performance.

Voyage optimisation solutions seek to manage the route (across planning, execution and post voyage monitoring) and speed of the vessel, to ensure that the safest and most efficient route is taken, and resultant fuel burn is minimised to within ETA constraints.

Route optimisation has a high level of complexity, which includes adherence to safety, compliance and regulatory requirements and the trade-off between ETA and efficiency whilst taking into consideration external factors such as weather, tide and NavArea warnings — all of which need to be considered, calculated and incorporated into the passage plan in a short period of time. The number and variety of inputs that need to be considered whilst appraising and creating a passage plan is considerable and extremely time consuming, especially considering the need to prepare information for each waypoint of a voyage (often hundreds). Digital route planning solutions, such as OneOcean's PassageManager, StormGeo's NaviPlanner BVS and ChartWorld's MyRA, not only drastically simplify the passage planning process, saving considerable amounts of time, but also automatically create fully optimised and economical passage plans. Furthermore, such systems have large safety benefits by automating safety checks, avoiding human error (e.g. from data entry) and minimising opportunities for bridge officers to cut corners.

The time saving element is not to be underplayed, as part of the ENABLE-S3 project, where a test was undertaken using Navtor's NavStation, the time spent on passage planning tasks using the automated passage planner was just 30 minutes compared to 3.5 hours for the traditional manual approach (based on a voyage from Barcelona to Las Palmas). This allows for potentially faster turnaround times (an improved efficiency), but also for safer sailing.

There is of course a large financial incentive to provide facilities to mariners to allow them to focus on safely sailing a vessel. AGCS analysis of almost 15,000 marine liability insurance claims between 2011 and 2016 shows human error to be a primary factor in 75% of the value of all claims analysed — equivalent to over

"We see that bridge officers are often preparing passage plans whilst on approach or when they should be focussing on something else. Being able to prepare a plan quickly with our solution means they can be looking out and ensuring they are sailing safely."

BJØRN HJØLLO, E-NAV MANAGER, NAVTOR

USD 1.6 billion of losses[6]. Quality of crew performance is an increasing concern, as explained Steve Schootbrugge, CEO of Chartworld: "There is a big drive for automated passage planning with an emphasis on fuel savings. But it also saves time for crew and improves safety. Crew quality is declining due to lower pay, worse training and poor retention rates. Systems such as ours ensure quality passage plans are created and help keep vessels sailing safely".

Weather routing is one solution within route optimisation that has the potential to directly generate significant emissions reductions by avoiding areas of bad weather, where higher fuel burn is necessary in order to maintain speed. Furthermore, such services are also critical to ensure that damage to both vessel and cargo are minimised, helping to avoid expensive dry-dock bills. Weather routing may be performed by the crew using basic weather information (such as wind charts) but the most effective solutions are provided by third-party providers that have developed advanced computer models to not only predict weather patterns but model how this will impact an individual vessel's course and speed, based on numerous ship specific variables (e.g. ship type, dimensions, draft, load line). Key providers of weather routing include StormGeo and DTN, and such solutions can either be provided as a software on board a vessel or offered remotely from a shore based service which regularly updates the master on board *(see case study p. 9)*.

Case study

ROUTING OPTIMISATION STORMGEO

StormGeo is a leading global provider of innovative decision support services and data science solutions for weather sensitive operations. Within the maritime industry StormGeo provides solutions and services across Route Advisory, Planning and Navigation and Fleet Performance Management.

"Route optimisation and fleet performance management are both easy to implement for a client and show a high impact in emission reduction. No hardware installations are required to use StormGeo's services."
***Søren Andersen**, CEO*

Halifax — **Bremerhaven**

New route avoided a large storm system and maintained ETA, saving

195 MT of fuel | USD 64,000 | 585 MT of CO_2

English Channel — **Cabot Strait**

New route at higher latitudes to avoid large northwesterly swell, saving

85 MT of fuel | USD 33,000 | 49 hours sailing

San Francisco — **Tsugaru Kaikyo**

More northerly through the Bering Sea to avoid heavy westerlies, saving

38 MT of fuel | USD 17,000

Speed optimisation solutions enable higher fuel efficiency due to the non-linear relationship between engine thrust and fuel burn. The required thrust scales with speed in a roughly cubic fashion, dependent on factors such as hull design, trim, weather conditions and ship type, so even given the same average speed, fuel burn can vary significantly. Slow steaming has developed over the last 15 years to take advantage of this fact, has already reached a relatively high level of maturity. The main thrust of speed optimisation is to discourage 'rush to wait' speed profiles, where unnecessarily high speeds are maintained across a voyage only for hours or even days to be spent waiting for an open port slot upon arrival; this practice is stimulated by many ports operating first-come first-served policies. Providers with solutions which focus on speed optimisation (c.f. more general voyage optimisation) include Lean Marine *(see case study p. 10)*, Nautilus Labs and NAPA. The end-target of speed optimisation is a 'Just-in-Time' operation, where vessels are in open (and potentially automated) communication with ports and operate at the minimum necessary power levels to arrive at their ETA, minimising waiting times and increasing fuel efficiency.

Fleet management solutions are widespread in the industry but are often heavily focused on monitoring

Case study

SPEED OPTIMISATION
LEAN MARINE

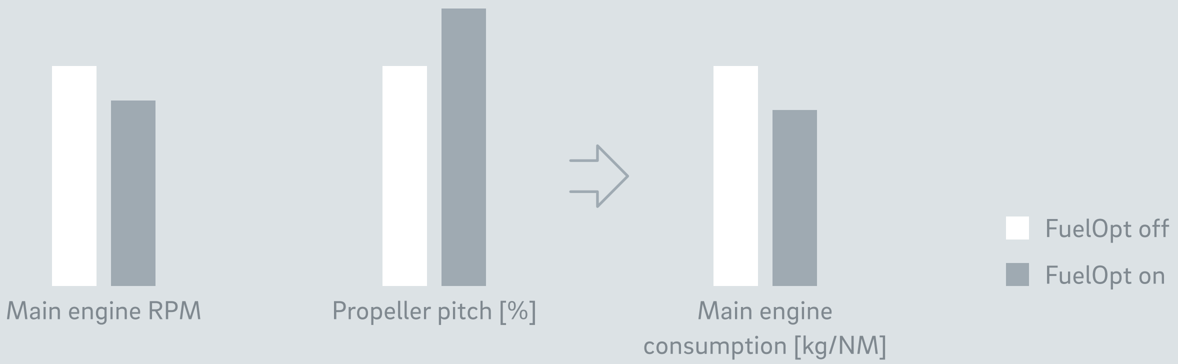
Ship engines are traditionally controlled by their RPM, which correlates to water speed. Lean Marine's FuelOpt enables shaft power to be directly controlled, enabling fuel savings by avoiding significant peaks and troughs in power as external conditions vary.

The system can also work with controllable pitch propellers, enabling further savings by regulating propeller pitch with the engine at a constant RPM or a preset combination of pitch and RPM.

For example, a 50,000 dwt chemical/product carrier with a controllable pitch propeller undertaking Pacific to Atlantic voayges will result in an annual saving of 600-tons of fuel, equivalent to 1,800 tCO_2 with FuelOpt enabled. This is a fuel saving of around 20%.

Lean Marine provides two main digital solutions. FuelOpt, which allows for improved engine efficiency, and Fleet Analytics, which allows for performance monitoring, data analysis and reporting.

Lean Marine currently serves c. 175 vessels globally with FuelOpt, and in total its solutions are estimated to save c. 150 m tCO_2 annually.



"The biggest limiting factor for operational efficiency today is the reliance on noon data to make operational decisions — because it bases decisions on lagging, infrequent, and error-prone information, and because it doesn't create real-time business awareness."

MATT HEIDER, CEO, NAUTILUS LABS

and management of vessel equipment and maintenance (including drydocking projects), procurement, compliance and crewing. Solutions allow for emissions reduction, however, through two main areas of attack: improved performance monitoring, and better schedule management. Typically, these solutions focus on revenue maximisation, however they also have potential from an efficiency perspective. Examples of these solutions are OneOcean's Fleet Manager, We4Sea's Performance Monitor, Lean Marine's Fleet Analytics, and the platform of Nautilus Labs.

Performance monitoring can be both automated and greatly advanced by digital solutions. Historically performance monitoring has been largely derived from static noon reports manually prepared by a ship's chief engineer and sent just once a day to shore-based management teams. These reports contain limited information, covering metrics such as the vessel's position, average speed and engine rpm since the last report, weather/sea conditions, ETA and fuel/lube volumes (R.O.B.). Whilst this allows for some degree of monitoring and planning, its potential for performance improvement across a fleet is gravely limited by the brevity of data provided in noon reports, even before we consider the potential for manual data entry error. For example, the average speed provided might mask significant changes in vessel speed during that period, and the weather information could hide a heavy storm encountered during the night, both of which can have a significant impact on fuel efficiency.

Monitoring vessel performance digitally in real-time, not only ensures accurate data are collected, but provides a sufficient volume and frequency of data to allow for informed improvements to be made. These improvements, however, extend far beyond a vessel's current voyage and reducing fuel spend. Technical teams can better plan hull cleanings, efficiency improvements and planned engine maintenance, and chartering teams can market the vessel based on an informed understanding of its true performance and help reduce the risk of claims for underperformance. Some solutions, such as We4Sea's Performance Monitor, allow operators to understand which factors are driving vessel performance (e.g. speed, draft, trim) against long-term effects such as hull faring. The importance to technical teams is particularly pertinent if you consider that more than one third of the reported 26,000+ shipping incidents over the last decade were caused by machinery failure or damage[6]. Digitally monitoring vessels in this manner creates large data-sets that can allow for advanced AI and machine learning solutions to guide improvements, but as explained by Dan Veen, CEO at We4Sea, the simple act of recording vessel performance can lead to efficiency improvements: "We see that fuel usage actually improves through accurate and regular reporting of fuel usage. Monitoring alone makes crews perform better in the same way that your driving does with someone watching you... We find regular monitoring alone delivers a 1-3% reduction in fuel consumption".

Noon reports are also used to help plan fuel, lube oil and water orders, an area that can also be optimised digitally. For example, BunkerPlanner, the bunker procurement optimisation tool offered by BunkerMetric, provides automated guidance on the optimal quantity and type of fuel to lift at each location based not only on bunker pricing and availability information, but the vessel's route, consumption pattern and operational constraints such as tank capacities, comingling requirements and SECAs (Sulphur Emission Control Area).

"Using our tool we typically see fuel cost savings of between 2-4%, which might save tens of thousands of dollars on a single voyage. It also saves a lot of time with differing environmental regulations and new fuel grades that have to be considered alongside the normal complexity of bunker procurement."

CHRISTIAN PLUM, CO-FOUNDER BUNKERMETRIC

Currently, vessels only spend c. 55% of their time sailing[7], with the remainder spent either in port, or at anchor. Better schedule management enabled by digital solutions can help to improve EEOI at a fleet level, thanks to better fleetwide capacity utilisation, largely through lower occurrence of ballast legs. Schedule management solutions are more critical for tramp services, where vessels have no fixed route, itinerary or schedule, as opposed to liner services with fixed schedules where cargo optimisation is more important.

Schedule management naturally requires the balancing of supply and demand, with an increasing number of digital platforms being developed to allow cargo owners and ship owners to efficiently plan their schedules by jointly sharing relevant information. One such platform has been developed by the Finnish start-up Seaber, which focuses on the commercial aspects of bulk shipping, where currently communication is driven by endless amounts of emails and multiple excel sheets used for itinerary planning. The platform automates the management of cargo orders, plans regional balances across fleets, optimises vessel schedules and minimises ballast runs, thus helping to improve fuel efficiency.

Cargo optimisation is already widely digitalised, at least within container shipping. Loading computers and digital stowage planning systems such as Navis's MACS3 and NAPA's Loading Computer are commonplace within the container industry — such solutions are largely essential considering the average container ship has over 4,000 TEU capacity. Such solutions are primarily designed to ensure safe carriage of cargo, avoiding over-stressing the ship's structure and ensuring necessary regulations are complied with (such as lashing forces), however they also allow for improved hydrodynamics through trim and ballast optimisation, and thus better fuel efficiency from vessels.

Equipment performance can also be boosted through digital solutions. Traditionally, key settings such as propeller pitch and thrust, have been set based on best practice and averaged conditions. Digital solutions (such as Lean Marine's FuelOpt, *see case study p. 10*) have the potential to automate setting choices based on real-time conditions, with significant potential for improved fuel efficiency at iso-speed. Other solutions also exist which address performance of non-propulsion systems as part of overall fleet management, such as cargo heating and cooling systems or on-board generators *(see case study p. 13)*.

2. Port solutions

On the port side there are two main areas where digital solutions currently show significant promise: value chain combination and port call optimisation.

The logistical chain that shipping is part of is incredibly complex. It requires interaction between vessel operators and owners, 3PLs and freight forwarders, intermodal operators, customs authorities and regulators, ports and financial service providers to name but a few. Interaction between each party requires extensive documentation, review and approval which is often completed via manual document handling and across multiple different systems. By combining systems between ports, land carriers, freight forwarders and vessels, the overall efficiency of shipping operations can be increased allowing for lower total emissions through less time spent waiting outside ports and higher overall ship utilisation. Examples of these solutions include Wärtsilä's Navi-Port and TradeLens (launched by IBM and Maersk), with the latter aiming to digitise document flows within the container industry and wider logistical chain. Linking systems through APIs and similar formats will reduce data blockages and allow for higher efficiency. Virtual arrival, in which vessels notify ports of their arrival a significant distance away from shore, is one key area in which value chain combination can enable a lower fuel burn, by allowing for lower approach speeds without compromising ETA. Additionally, these same linked systems between ports and vessels are vital to ensure that port queue constraints are minimised, further enabling Just-in-Time shipping. The potential efficiencies that such systems could drive are large, but they are in very much in their infancy, in part owing to the number of parties involved, issues relating to data standardisation and system interoperability, as well as a willingness amongst value chain participants to share data *(see graphic p. 14)*. These issues are gradually being addressed and are discussed later in the report, but the full transition to e-navigation[8] and smart shipping is still a way away.

Port calls can themselves be improved by digital solutions focusing on workflow automation, reducing time spent by people working port side completing paper work. Examples of these solutions include Saab's Portcontrol and the Port of Rotterdam's Pronto. Additionally, loading computers (as discussed above) are enabling more efficient loading of vessels, particularly through lower planning times. Both solution classes have the impact of reducing turn-around times, thus increasing the rate at which slots become available, reducing the need for idling and queueing outside ports, lowering EEOI and increasing utilisation.

Case study EQUIPMENT PERFORMANCE

"Depending on the type of vessel, generator fuel consumption can be very high, if for example they are used to power propulsion or support high reefer load on the vessel.

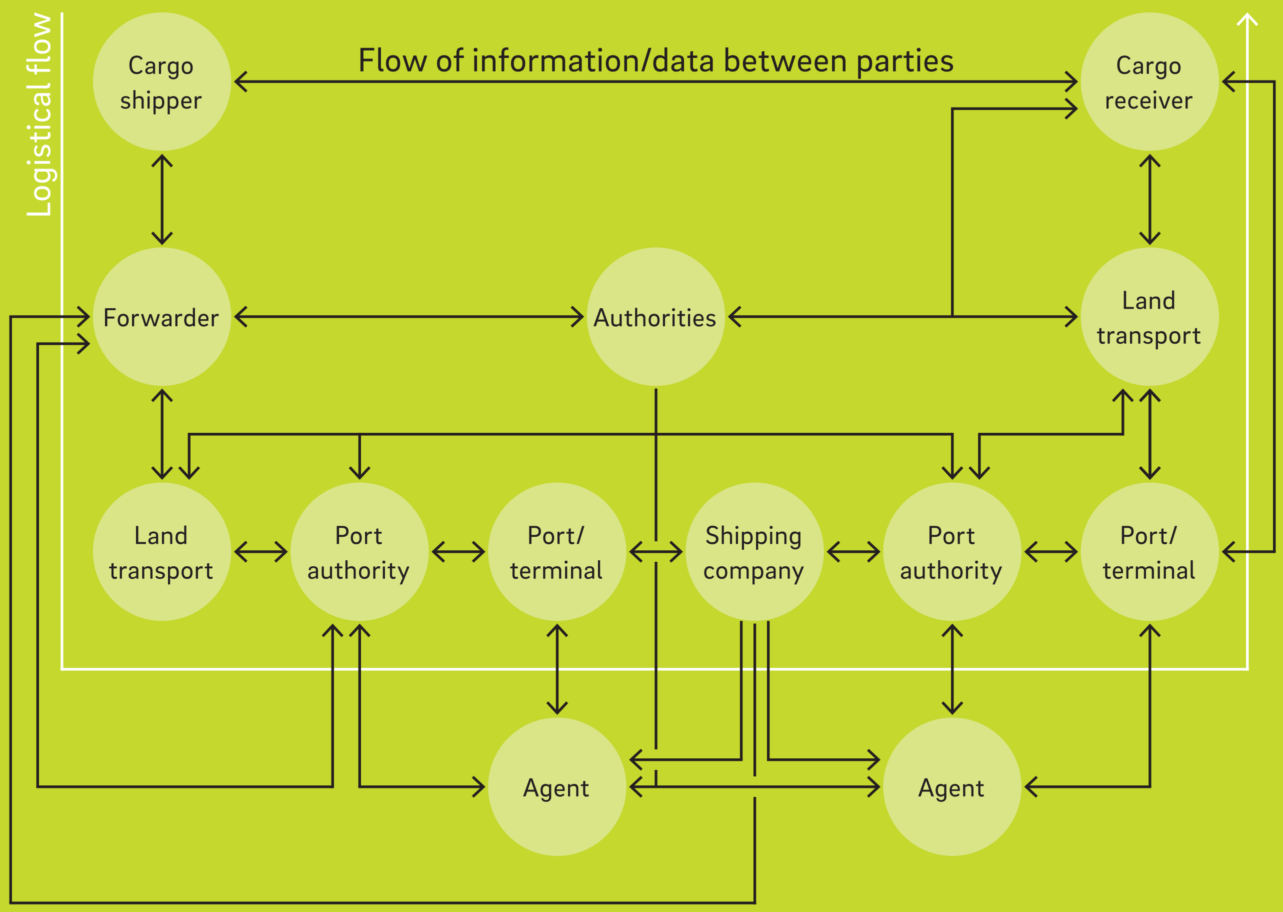
It's also true that it can be difficult for an individual to assess in real-time if a) a system of generators is configured efficiently and b) take an action to bring them into optimal configuration. Leveraging our platform, teams are able to report on, alert, and change the load balancing to have a massive impact on overall fuel consumption.

For one client, they found that their generators were optimally configured only 24% of the time while the vessel was underway, producing over USD 300,000 of excess fuel consumption and 2,160 MT of additional CO_2 emissions.

With proper decision-support in place, they have captured a majority of these fuel savings, by having the shoreside teams and crews work more closely together to tune their configurations."

***Matt Heider**, CEO, Nautilus Labs*

The flows of information within shipping supply chain are numerous and complex

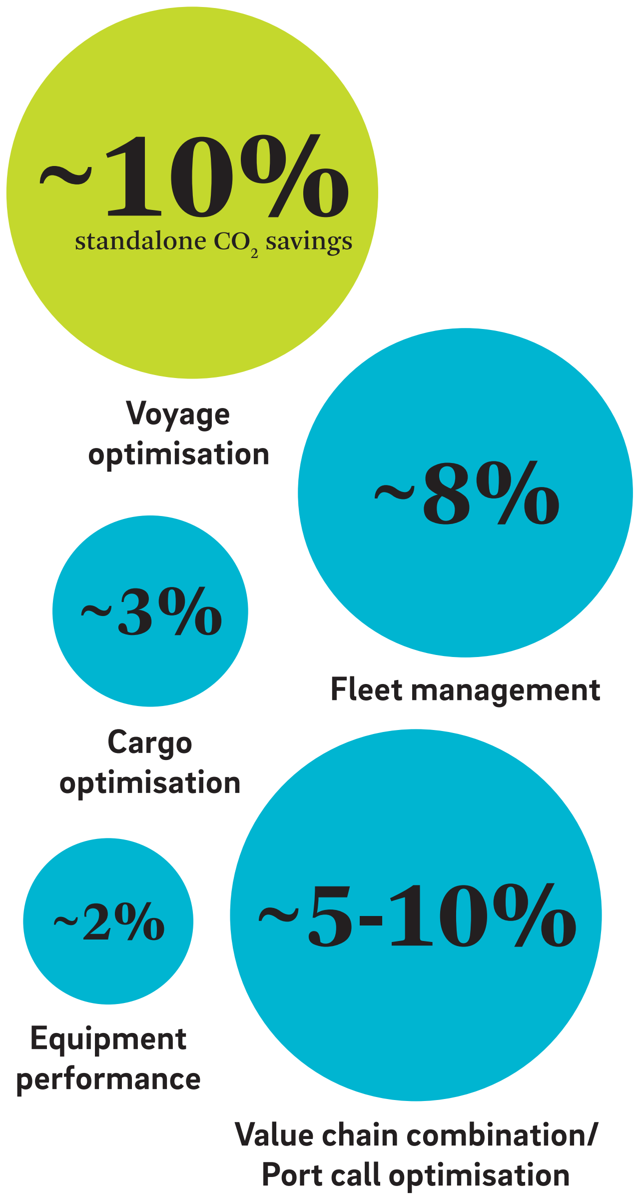


Source: Traficom, Roland Berger

Where will the solutions be most effective?

The potential impact that the above solutions can have on GHG emissions varies widely, both across solutions but also within each category owing to the greater applicability of each to certain vessel types, fleet sizes and voyage types (e.g. open ocean versus short sea) for example. Based on interviews with solution providers, examination of case studies and academic research, we provide estimates for the potential emissions savings that each solution can generate — the savings shown are for each solution and are not cumulative given the overlapping benefits and applications between some of the solutions.

Across the range of solutions covered a ~10% reduction in fuel usage and subsequent CO_2 emissions appears immediately accessible through the adoption of digital solutions. If deployed across the global fleet, such a reduction would equate to a saving of ~90 MT CO_2 — equivalent to the annual energy consumption of 10 million homes in the United States[9], or the total carbon footprint of Bangladesh[10]. Those relating to voyage solutions (as opposed to port solutions) are more addressable in the short-term since they can be implemented by individual operators, or even individual vessels. The reductions achievable from port solutions are more challenging to implement in the short-term effectively due to the number of parties involved, but whilst the estimated efficiencies for the shipping industry are lower than for voyage solutions, they have the potential to generate additional efficiencies further down the logistical chain.



VOYAGE OPTIMISATION

There is potential to reduce emissions by around 10%, via either route or speed optimisation (or a combination of the two). This potential is impacted by both the route of the vessel and equipment on board. In terms of route, the potential is greater for large vessels making open ocean crossings as explained Matt Corey, Senior Product Manager at DTN; "When a vessel gets to a certain point, it is outside the route network. Once you are in open ocean there is much more flexibility in where a vessel can sail and deliver greater savings". In terms of equipment, a controllable pitch propeller, for example (which is more common amongst ferries and cruise ships), allows for much more sophisticated speed optimisation which can by enabled automatically via a solution such as Lean Marine's FuelOpt.

Critical to reducing fuel burn via speed optimisation is not simply a case of slowing down. The benefits of the maturing practice of slow steaming have begun to diminish as they have become widely adopted; reducing speed further impacts not only revenue generation for the operator but also stresses the propulsion system which is typically optimised for a certain shaft power output. Rather, the key is to smooth the speed profile while not necessarily reducing overall average speed. Speed optimisation solutions can reduce emissions by 5-10% but for certain voyages this can be as much as 15-30%.

Route optimisation solutions alone are estimated to generate 1-5% reduction in emissions, particularly via avoidance of areas of adverse weather. With extreme weather becoming more prevalent (the occurrence of extreme weather events has grown by ~3% p.a. since 1980[11]) such systems are becoming increasingly important from a safety perspective, helping to avoid costly vessel damage or loss and potentially fatalities. It should be remembered however — regardless of the suggestions made by a voyage optimisation solution and the potential fuel savings — "that the navigation of the ship is ultimately the master's decision and he can at any time ignore the advice given by the weather routing services if he believes that following that particular advice would threaten the ship, its cargo or crew"[12].

"If you can measure it then you can manage it."

MIKAEL LAURIN, CEO, LEAN MARINE

FLEET MANAGEMENT

Emissions reduction within fleet management is mainly driven by two key levers: performance monitoring and schedule management. Performance monitoring is applicable for all fleet sizes and has many overlaps with voyage optimisation. It can however, extend beyond the voyage into vessel condition monitoring and predictive maintenance for example, but ultimately most processes can be optimised provided they can be monitored.

For schedule management, potential savings are heavily impacted by several factors including the nature of the service being operated (tramp versus liner, short-sea versus open ocean etc.), the type of cargo (and underlying market dynamics), and the size of the individual operator's fleet; naturally there are greater options to optimise schedules for operators of large fleets. Average utilisation rates across cargo types serve as a rough guide on the degree to which schedules could be further optimised within the industry *(see graphic p. 17)*, however this is not to say that all markets can expect to meet the capacity utilisation levels of the container industry. The evolution of the crude oil tanker market over the past decade (especially 2018 and the contrast between H2 2019 and H1 2020) demonstrates how wider market dynamics are the ultimate trump card when it comes to determining fleet utilisation.

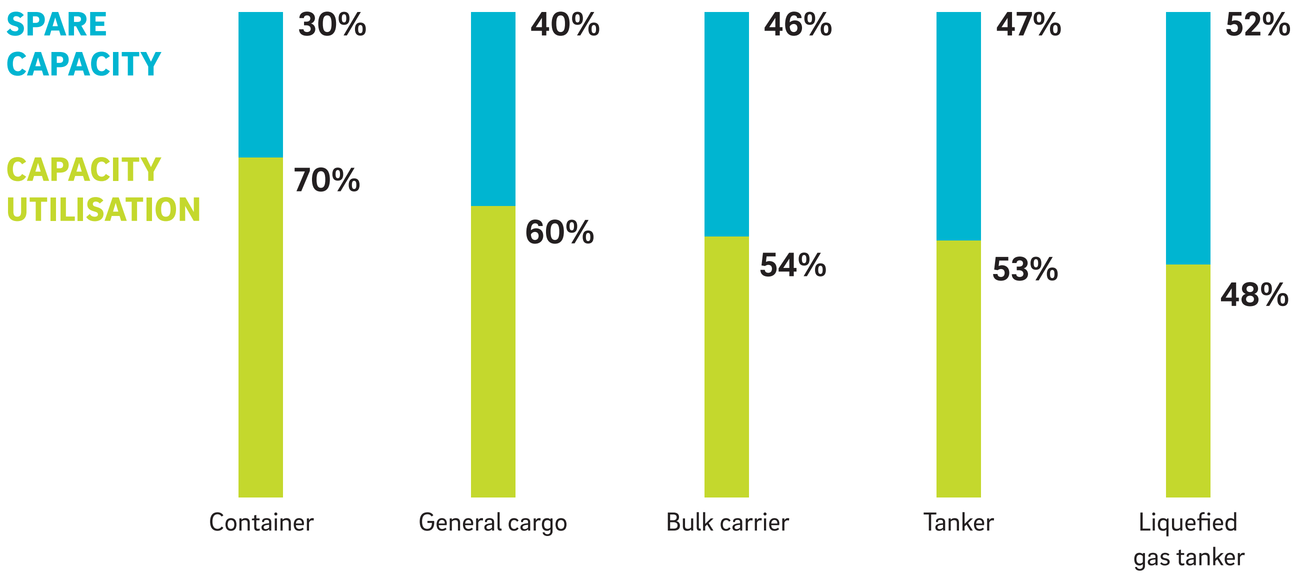
Across the fleet management solutions surveyed we estimate that an ~8% reduction in emissions could be generated, assuming no excessive supply-demand imbalance in the market, which would mitigate any gains from schedule management.

CARGO OPTIMISATION

Digital cargo optimisation solutions can improve vessel efficiency in two main ways: firstly through more efficient loading and discharging of cargo (reducing rime spent in port) and secondly through loading cargo in configurations that optimise trim

Further opportunities to improve utilisation through schedule management

Average yearly capacity utilisation by vessel type



Source: IMO, Roland Berger

and ballast to improve hydrodynamics and directly reduce fuel consumption. Trim and ballast optimisation is estimated to result in ~3% fuel savings but has the greatest potential impact for vessels with more variable cargo stowage options (e.g. containers and multi-purpose cargo ships).

EQUIPMENT PERFORMANCE

Equipment performance has much overlap with fleet management (depending on the extent of monitoring) and potentially speed optimisation, when relating to the propulsion system. Since other pieces of equipment do not directly influence the speed or route of the vessel (the main drivers of fuel usage) the potential emissions reductions are lower, with the notable exception of cruise ships where fuel consumption for auxiliary power and hotel functions (ventilation, lighting, water etc.) can be extremely significant and even outweigh that needed for propulsion[13].

Furthermore, and as covered later, often the data generated by on board systems are the preserve of the system supplier, further limiting the extent to which operators can analyse and optimise the performance of other systems.

Overall, we estimate the potential emissions reduction from equipment performance (excluding elements related to speed optimisation) to be ~2%.

VALUE CHAIN COMBINATION AND PORT CALL OPTIMISATION

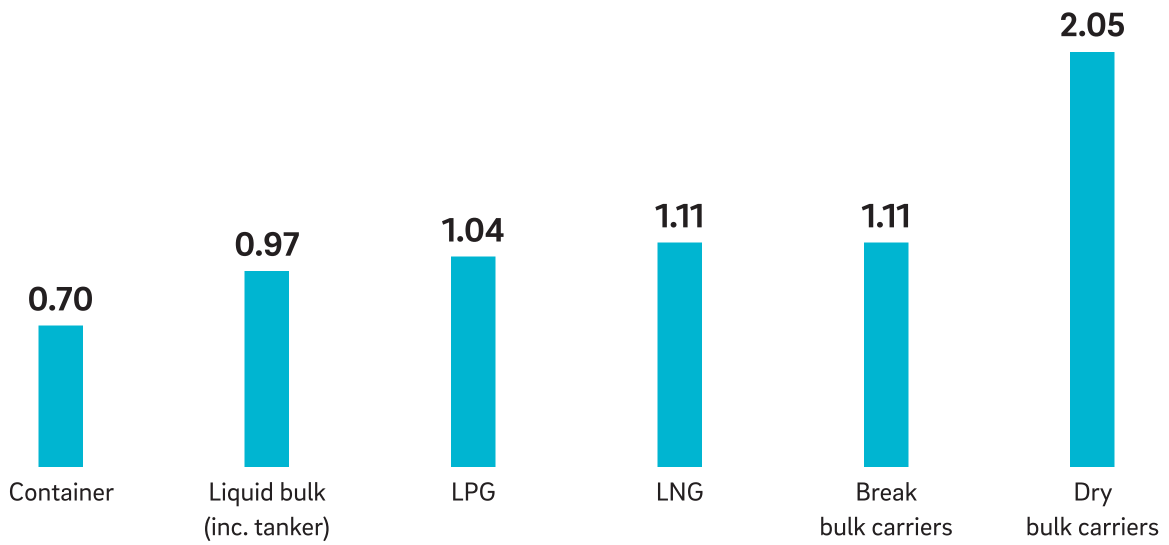
The main impact that value chain combination and port call optimisation can have on GHG emissions is through fuel savings from unproductive waiting time at port, and faster vessel loading/discharging being used to reduce average sailing speeds whilst still maintaining current voyage times and schedules.

Waiting time in port can be extreme in some cases and driven by a wide range of factors and parties in the value-chain (operators, charterers, port authorities, terminal operators, customs authorities etc.); "rush to wait" is commonplace in the industry as are "first come first serve" policies amongst ports. The median time spent in ports ranges from 0.7-2.1 days by vessel type, however spending several days in port is far from uncommon particularly in ports with a lower number of total port calls and lower maximum vessel sizes[5].

Digital solutions could help unlock this waiting time and allow vessels to spend more time sailing at lower speeds and lower fuel burn. Jia et al.[14], through empirical analysis of over 5,000 large tanker voyages, found that if excess port time was reduced by 25%, then the average fuel consumption saving from subsequent slower voyage speeds is 7.3% and rising to 19% if all apparent inefficiencies could be removed. Such savings across the global fleet are potentially even greater when you consider that the median time spent in port is higher across all other vessel types (except container ships) than the tankers analysed by Jia et al[14] *(see graphic p. 18)*.

Excess port time could be used to reduce vessel speed

Median time spent in port in top 25 economies by vessel type, 2018 [days]



Source: UNCTAD, Roland Berger

Where do the challenges lie?

The environmental benefits that digital solutions can deliver are clear, as are the potential cost savings, which many would argue is a far more attractive consequence than GHG emissions for operators today. Nonetheless, there are numerous barriers that inhibit the adoption of digital solutions and slow the pace of emissions reductions across the industry, of which we highlight four that we feel are most significant. Two relate to industry-wide systems, namely the disconnect in the value chain and a lack of consistent standards. The other two relate to the historical lack of digitalisation at a company level: impacted by a lack of technical expertise and limitations in offshore data transfer capacity.

1. Value chain disconnect

The fragmentation of the shipping industry and wider logistical value chain stands as the largest impediment towards both wide adoption of digital solutions and the development of expansive systems that would enable deployment of industry-wide e-navigation or smart shipping. This disconnect can broadly be divided in two, firstly between differences in incentives of value chain participants and secondly in the complexity of the incumbent systems and processes.

Split incentives within the shipping industry are numerous and nothing new. Their existence is fairly unsurprising when you consider the variety of potential parties involved (ship owners, ship operators, ship managers, charterers, cargo owners etc.) as well as the variety of legal contracts that might exist between them (bill of lading, charter party, contract of affreightment). As an example, under most charter party terms, the charterer pays for the fuel yet does not own the ship and so has no incentive (or even ability) to invest in the ship to make it more energy efficient. Whilst there is a natural benefit for charterers to use more fuel-efficient vessels, such as those adopting leading digital solutions, recent research by Poulsen & Sampson[15] has indicated that charterers do little to pressurise or incentivise the adoption of digital methods (such as virtual arrival) despite the financial benefit for themselves. As they also suggest — and confirmed by our own interviews — a lack of trust between value chain participants (e.g. between operator and port), concerns over data transparency and commercial sensitivity all act as further impediments to adoption.

Some of these issues can, however, be addressed via the selection of an appropriate solution. We4Sea's CEO, Dan Veen, acknowledged that one of the largest challenges to the adoption of digital solutions is "the current chartering system. There are different and opposing incentives for different stakeholders". As such We4Sea's Performance Monitor is largely focused on serving charterers since its performance monitoring platform requires no investment in on-board equipment. Equipment-less or -light solutions stand

"Across the ecosystem, the other major bottleneck for solutions is often a lack of collaboration and partnership between key stakeholders."

MATT HEIDER, CEO, NAUTILUS LABS

as one option to circumnavigate the above issues (rather than solve them) and further the efficiency gains of the industry.

In addition, the complexity of the value chain brings complexity of processes and IT systems which acts as a further impediment. Between each party where there is a transfer of information, there are issues of interoperability between each party's system, and often the data flow is not even digital, but performed on paper by hand. Such issues are further magnified due to the fragmented nature of the value chain, adding significantly to the friction in information sharing. As a result, providers of digital solutions not only need to deal with overcoming technical issues of interoperability but also displacing entrenched incumbent practices and ways of working — an issue that was mentioned as a key challenge by Sebastian Sjöberg, CEO of Seaber: "A challenge is the traditional way that shipping is done. Many decisions are based on experience and information from personal networks; there is a reluctance to use digital platforms. Seaber's vision is to support business processes by providing information that is still not available in a digitally usable format".

2. Lack of standards

The issue of interoperability is amplified by the lack of consistent data standards even between different systems with the same function. This adds significantly to the complexity of integrating systems and sensors from multiple providers into what is needed by solutions as explained Mikael Laurin, CEO of Lean Marine: "It is a significant challenge for us to parse data. There are very different signals from different meters for the same purpose, depending on the supplier. We need to act as an investigator to convert it to something that our solutions can process". Even within individual regulatory systems, such as the EU's Single Window, documents need to be filled out in different formats. Additionally, due to historical digitalisation efforts, individual organisations can have parallel, overlapping systems which are hard to integrate.

As penetration of sensors and IoT devices grows rapidly on-board vessels, the issues of missing data standards and data ownership are increased even further as mentioned by Captain Henrik Ramschmit, Chief Business Officer at NauticAI: "Key challenges include the general lack of transparency, the difficulties in accessing data from on board systems and the lack of openness in ship and shore data interfaces. Traditionally almost all ship system sensor data interfaces are controlled by the system suppliers, whereas it should be controlled by the vessel owner who has bought the system".

To overcome this will likely require a significant push from the IMO or similar regulatory body, as individual players have only a limited incentive to improve openness of systems as said Steve Schootbrugge, CEO of Chartworld: "The biggest issues for adoption of digital solutions are the willingness to share data and data standards. Data standards could be solved first but willingness will be hard to change. There are many ongoing efforts to standardise data but regulatory intervention will likely be required to change the willingness". The lack of a global ports regulator presents a further layer of complexity to this issue and key barrier to optimising the logistical chain between land and sea. The need for wider cooperation between regulators and across industries was mentioned by Bjørn Hjøllo, e-NAV Manager at Navtor: "You can easily optimise one element,

"You can easily optimise one element, such as with automated routing but you need to look at the whole system — you cannot solve it just in the shipping domain. We need to make sure that the IMO and IALA are working together with the ports and the land logistics. For e-navigation, an intelligent transport system between sea, port and land is the ultimate solution."

BJØRN HJØLLO, E-NAV MANAGER, NAVTOR

such as with automated routing, but you need to look at the whole system — you cannot solve it just in the shipping domain. We need to make sure that the IMO and IALA are working together with the ports and the land logistics. For e-navigation, an intelligent transport system between sea, port and land is the ultimate solution".

Until such changes are made however, solutions providers will need to ensure that their systems are agile, open and interoperable whilst themselves being willing to collaborate with regulators and competitors alike.

3. Lack of technical knowledge

Many shipping companies, particularly SMEs, have a very low level of digital maturity. Whilst this means that there is a high potential for solutions with these companies, they lack the capabilities to implement them. Many solutions need a baseline of data to be effective, which is often also a challenge, as operators with low maturity will likely have poor internal data quality. Many operators have significant data security concerns, as even major maritime shipping operators have seen large-scale cybersecurity breaches, which increases hesitancy to increase levels of digitalisation. Additionally, given how much additional data can improve performance of various solutions, operators with low maturity will not immediately see the full benefits of solutions.

As a consequence of the highly variable internal technical capabilities amongst vessel owners, operators, and charterers, particular importance is placed upon providers of digital solutions to produce actionable insights from the data their systems are able to monitor; "One of the fundamental sources of fuel waste is the lack of actionable insight to take an action to reduce consumption — for both shoreside teams and crews. By providing real-time awareness of performance relative to standard KPIs, everyone is able to see if a vessel is performing as expected — and if it's not, why it's not, so that teams can work together to improve it" commented Matt Heider, CEO of Nautilus Labs.

> "You often have to lift operators out of their spreadsheets into something more sophisticated by demonstrating the potential."
>
> CEO, BUNKERMETRIC

4. Vessel connectivity and off-shore data transfer capacity

Adoption of digital solutions is also hampered by poor connectivity across the global fleet; still only around half the global fleet has a high bandwidth VSAT connection. Traditional reporting mechanisms, such as noon reporting, have required low data connectivity but many of the solutions available today, particularly fleet management and voyage optimisation solutions, require and/or are improved significantly by the presence of real-time data. Due to challenges with data security, lack of reliability and pricing models, operators are often wary about transfer of unnecessary data even if a VSAT terminal is installed.

Connectivity, however, is growing rapidly within the industry, with maritime VSAT installations having more than doubled over 2015-19[16]. Interestingly, a significant driver of VSAT adoption is crew welfare; internet access is one of the most highly sought after requirements after wages[17]. Efforts to retain crew members and reduce recruitment and training costs therefore, may act as an enabler for further adoption of digital solutions.

> "Real time access to the data which fleet management systems need to perform optimally requires VSAT, which still only has limited penetration."
>
> CAPTAIN HENRIK RAMSCHMIT, CHIEF BUSINESS OFFICER, NAUTICAI

Navigating the future

The global shipping industry has already achieved remarkable reductions in emissions; since 2008 total emissions have fallen by 14% despite a 44% increase in ton-miles. Much of this reduction, however, was generated through the adoption of slow steaming which in turn was stimulated by high oil prices and sustained as a measure to absorb global surplus capacity.

Regulators have continued to push environmental targets and legislation which, providing they are enforced, will drive participants within the shipping industry to adopt a variety of solutions. In the long-term the industry, as per other forms of transportation, will need to transition to alternative and more sustainable forms of propulsion. The necessary partnerships have been established to develop these technologies over the next 10-15 years, and it is through further partnerships and a greater openness to collaborate that will facilitate the full potential of digital solutions within the shipping industry and enable true e-navigation.

Nonetheless, there exist numerous solutions in the marketplace today, such as automated routing or speed optimisation, that can generate significant immediate savings. As outlined, the practical barriers to installing these solutions are low, often without significant hardware installation, and thus overcome to some extent the well established split incentives in the industry.

Change within this industry is always gradual, but the effectiveness of the solutions highlighted shows that change will be inevitable. The benefits of adoption extend beyond simply reducing fuel burn and emissions, into improved maintenance, crew welfare, compliance and safety. Unlike longer term technological trends such as autonomous shipping, these benefits are accessible today. As such operators, owners and charterers can either continue to ignore these solutions or sail forward with the support of digital undercurrents, and do a bit of good for the planet on the way.

A 10% reduction in emissions across the global merchant fleet, enabled by immediately accessible digital solutions, equates to the carbon sequestered by 12 million acres of forest.

Special thanks to all our interview participants

Søren Andersen
CEO, StormGeo

Bjørn Åge Hjøllo
e-NAV Manager, Navtor

Matthew Corey
Senior Product Manager, Shipping, DTN

Dan Veen
Co-founder, We4Sea

Mikael Laurin
CEO, Lean Marine

Steven Schootbrugge
CEO, Chartworld

Capt. Henrik Ramm-Schmidt
Chief Business Officer, nauticAi

Matt Heider
CEO, Nautilus Labs

Sebastian Sjöberg
CEO, Seaber

Christian Plum
Co-founder, Bunkermetric

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Contact details

William Adkins

Principal
william.adkins@rolandberger.com
+44 20 3075 1100

Hrishikesh Potey

Partner
hrishikesh.potey@rolandberger.com
+44 20 3075 1100

Siongkoon Lim

Project Manager
siongkoon.lim@rolandberger.com
+44 20 3075 1100

Publisher

ROLAND BERGER LTD

55 Baker Street
London W1U 8EW
United Kingdom
+44 20 3075 1100

www.rolandberger.com

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