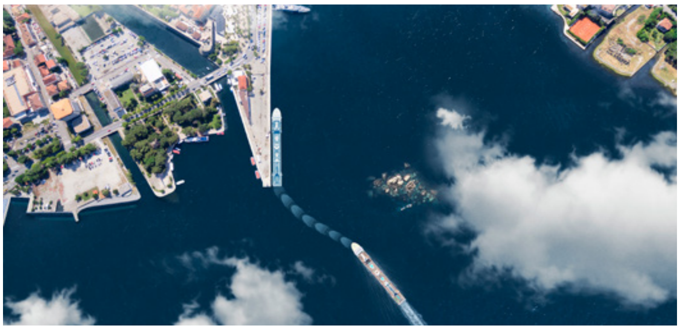
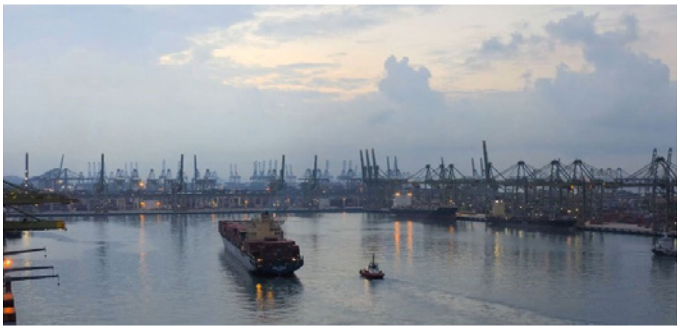
E-REPORT

The future of Smart Autonomy is here

WÄRTSILÄ





The Future of Smart Autonomy — Executive Summary

When it comes to autonomous shipping, grandiose visions of 100 % unmanned vessels sailing the world's oceans and ports are often painted—a picture far from present-day reality and filled with obstacles to overcome.

The Reality of Autonomy

- A common misconception is to equate "autonomous" with "unmanned."
- In reality, autonomy is a spectrum with various degrees of vessel automation.
- It is something that can already be harnessed to create benefits today, leading to smarter systems to enhance safety, cost-efficiency and environmental performance.
- In practice, this means reducing collisions or incidents, assisting with docking, saving fuel through optimised speed profiles, reducing associated emissions and optimising crew numbers.
- At Wärtsilä we call this "smart autonomy"—a stepwise and commercially viable approach for your operations to adopt autonomy that can be applied today.

Key drivers for autonomy and industry dynamics

The owners, operators and managers of today's maritime fleets find themselves confronted by a range of pressing challenges:

- Overcapacity
- Safety and human error
- Vessel efficiency
- Decarbonisation and regulatory measures
- Cyber security worries
- Crew challenges

Challenges autonomy can solve today

A few concrete ways in which smart autonomy can help solve today's shipping challenges:

- Increase safety
- Reduce chances of human error
- Fuel savings and voyage optimisation
- More efficient vessel design
- Decarbonisation

Building blocks of smart autonomy

To make these sorts of smart autonomous systems a reality, three broad capability areas and enablers are critical.

- Situational awareness—what's going on around the vessel?
- Decision making and logic capability—what needs to be done in a given situation?
- Action and control—how do we safely and efficiently make the vessel take action?

01

Introduction

When it comes to autonomous shipping, grandiose visions of 100% unmanned vessels sailing the world’s oceans and ports are often painted.

In reality, there are still many obstacles to overcome if we’re to reach such a vision. The main barrier is the lack of compelling business cases, along with the lack of an agreed regulatory framework to govern autonomous operations and uncertainty over whether fully unmanned vessels are even desirable. Indeed, a common misconception is to equate “autonomous” with “unmanned”.

Fragmented, incompatible solutions

The reality is that autonomy is a spectrum, with solutions that can offer decision support at one end and fully unmanned vessels at the other, with various degrees of automation of the vessel systems in between. Because autonomy is a spectrum, it’s also something that can already be harnessed to create benefits for the shipping industry today. To make this happen we need an understanding of what problems can be solved with autonomous solutions, what makes autonomous operation possible and how to start implementing solutions that can move your operations in the direction of more autonomy.

Instead of contributing to the debate around what the future of shipping will look like and what role unmanned vessels will play, this paper argues that the journey itself may turn out to be more important than the destination. The pursuit of autonomous operations is already leading to smarter systems that can enhance the safety, cost-efficiency and environmental performance of today’s vessels; in practice, this means reducing collisions or incidents—especially in busy ports—assisting with docking, saving fuel through optimised speed profiles, reducing associated emissions and optimising crew numbers. At Wärtsilä we call this “smart autonomy,” and it means a stepwise and commercially viable approach for your operations that can be applied today—as part of a longer journey towards an autonomous shipping future.

Naturally, automation is a key enabler for autonomous solutions. But this alone is not enough. In order to make autonomous systems a reality, three broad capability areas and enablers are critical.

Situational awareness

Creating awareness of what is going on around and onboard the vessel and collecting data by using sensors such as radars, lasers and cameras.

Decision making and logic

Intelligent algorithms that are able to interpret a scenario based on data and decide on a safe and effective course of action.

Action and control

The control systems that enable autonomous actions, where decisions made by algorithms are executed to accurately and safely take care of functions that are typically handled by humans, such as manoeuvring the vessel, adjusting speed etc.

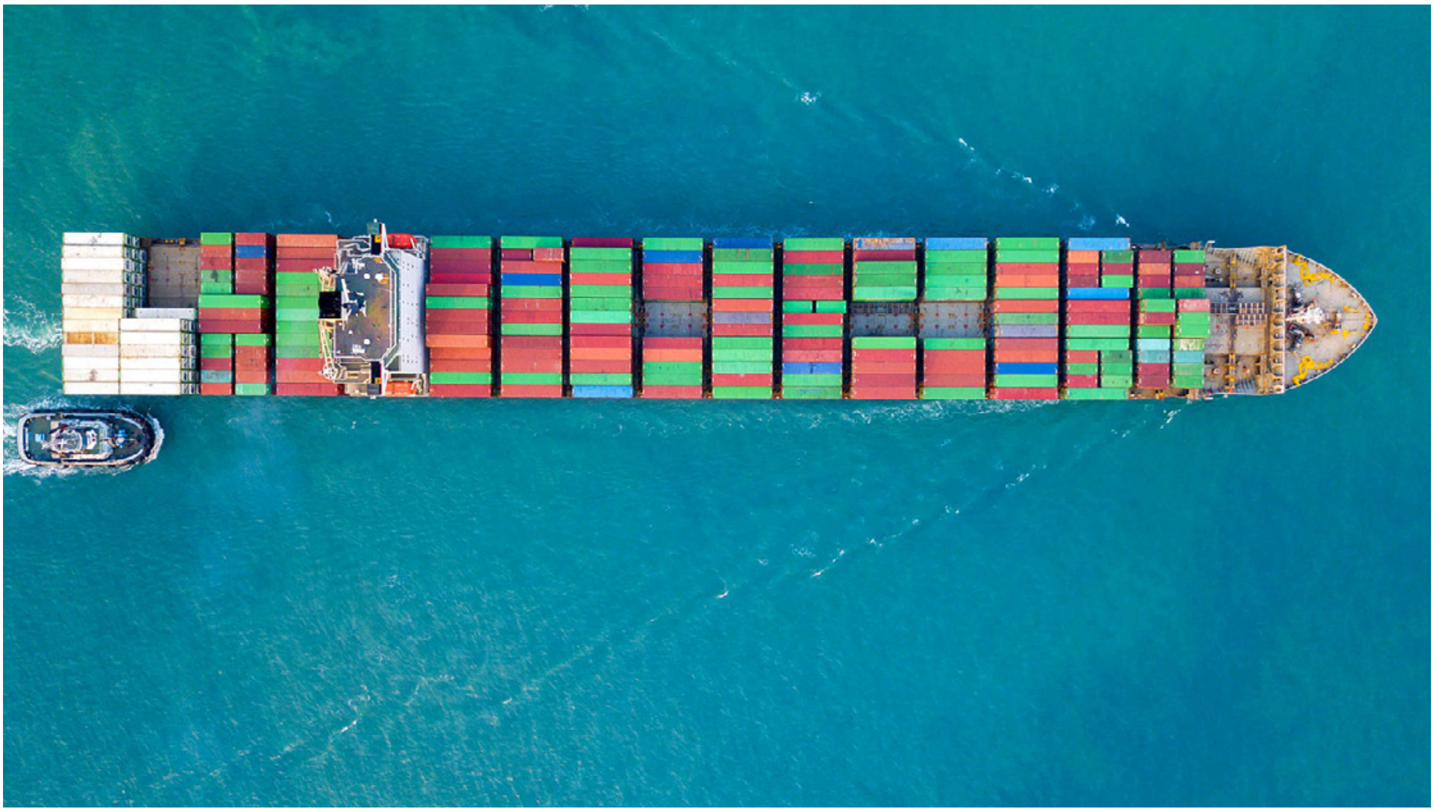
By implementing solutions to improve operational capabilities in any of these three areas, you are already on the path towards autonomous operations. In order to show how this is possible in practice, this paper will also look at examples of solutions and concepts from Wärtsilä Voyage in these areas.

02

Key drivers, trends and industry dynamics

The owners, operators and managers of today’s maritime fleets find themselves confronted by a range of pressing challenges.

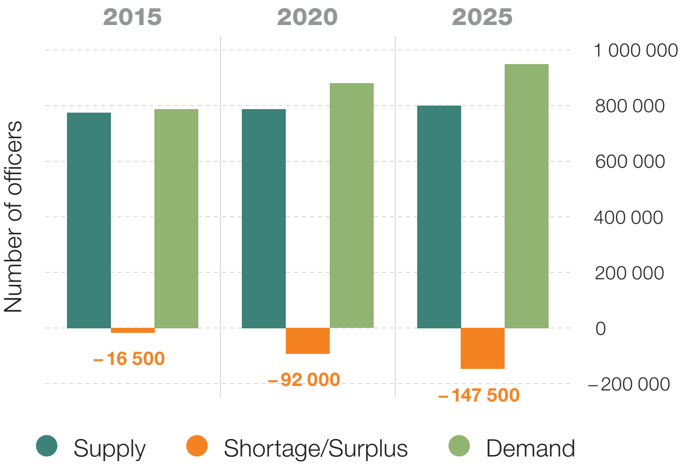
Overcapacity is leading to growing pressure to make savings without sacrificing vessel efficiency, while environmental and safety regulations are becoming increasingly strict. On top of this, the COVID-19 pandemic has added further pressure. Some of the key challenges facing the maritime industry are summarised below.



Crew challenges

Aging populations and changing career aspirations may lead to a reduction in available human resources and according to a BIMCO manpower report, there may be a shortage of workers in the maritime industry in the near future. However, a more pressing concern among many is finding enough qualified seafarers, especially officers, with the necessary skills to operate vessels at the high levels of efficiency desired today.

Basic forecast for the future supply-demand balance for officers

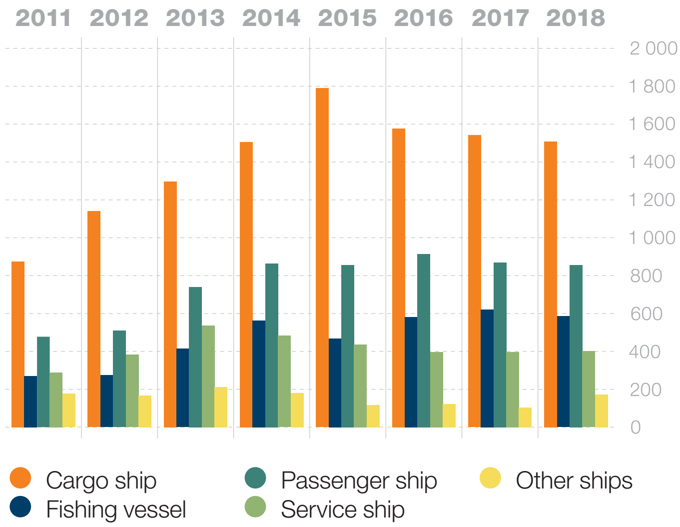


Distribution of accident events for 2011–2018

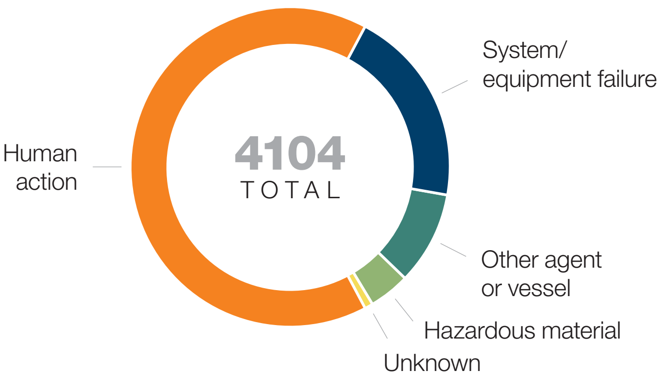
Safety

In general, shipping has a relatively poor safety record. According to the Shell Zero Incident report (LISW 2019), the safety record for the maritime industry is approximately 20 times worse than the average onshore worker and about five times worse than the construction industry. Within the maritime industry, the worst-performing segments were general cargo ships and passenger ships. The cargo ship figures could be a result of the ever-increasing size of vessels, meaning more blind spots, though the passenger vessel figures may be a reflection of better transparency in reporting in that segment. In 2018, there were a total of 3174 casualties and incidents, with 25 ships lost and 3515 ships involved (EMSA 2019).

Distribution of ships involved by main category



Distribution of accident events for 2011–2018



From a total of 4104 accident events analysed during the investigations, 65.8 % were attributed to a human actions' category and 20 % to system/equipment failures.

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Key figures for 2011–2018

25 614
Ships involved

2 304
Ships lost

23 073
Casualties and incidents

665
Very serious casualties

7 694
Persons injured

696
Fatalities

1 377
Investigations launched

Cyber security worries

With vessels increasingly using systems that rely on digitalisation, integration and automation, marine cyber security risk management is a growing and justified concern.

There is also a regulatory aspect to this. As the IMO has recognised that cyber security is becoming critical for data protection and reliable and safe marine operations, from January 2021, it requires that cyber security be addressed in safety management systems. In 2017, the IMO adopted resolution MSC.428(98) on Maritime Cyber Risk Management in Safety Management Systems (SMS). Any digital systems should have a robust cyber security framework based on best practices and guidelines to ensure the security of operations.

Human error

Mistakes made by humans are the source of most incidents in the maritime industry. According to Allianz Global Corporate & Speciality, 75 % of shipping insurance losses, equivalent to USD 1.6 billion, are caused by human error. There are many reasons for human error, including poor visibility, inclement weather, fatigue resulting from long hours and insufficient rest, the nature of the working environment onboard vessels and poor leadership both onboard and ashore. This is increasingly relevant as more decision-making capability moves onshore, a trend supported by the digitalisation of the maritime industry and the improved connectivity of vessels.

Safety and shipping review 2018 in numbers

90%
Of global trade transported by shipping

1 129
Total losses over past 10 years

94
Vessels with ECDIS, including charts and publications

53
Simulators in maritime schools around the world

21
Losses due to bad weather

180
Piracy attacks in 2017, lowest total for 22 years

61
Losses caused by foundering in 2017

6
Vessels lost to fire in 2017

Safety and shipping review 2018 in numbers

3 regions account for almost half of all losses

30 losses in South China, Indochina, Indonesia and Philippines—the main hotspot

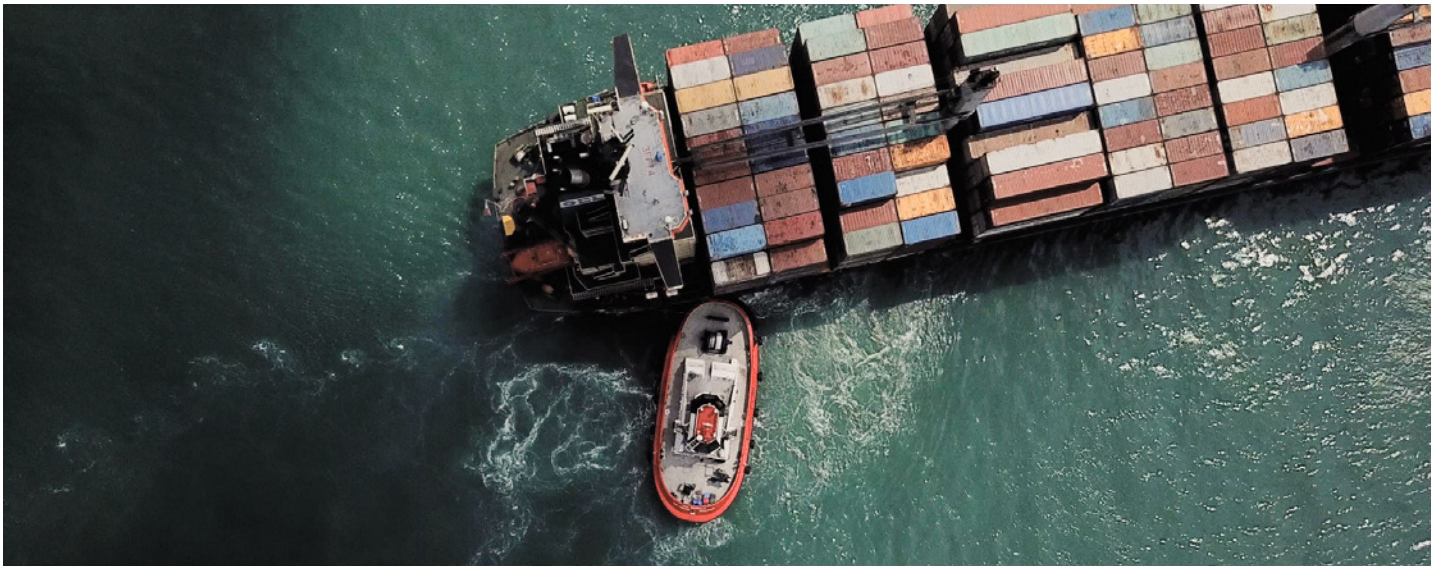
Major risks

- Busy seas
- Typhoons
- Piracy
- Safety standards
- Political risk

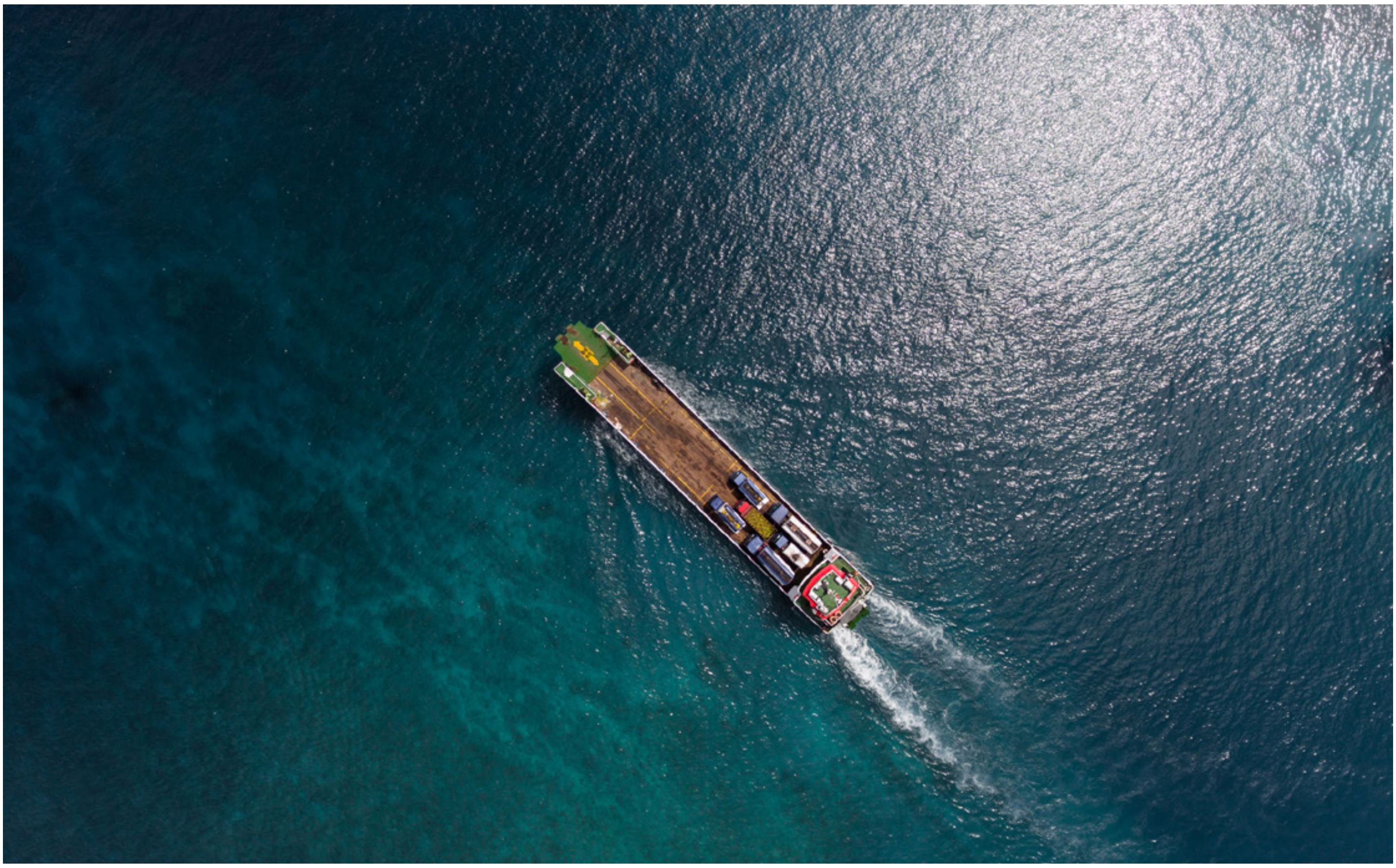
Container ships are getting bigger, capacity has increased by almost 1500 % in 50 years

Major risks

- Fire-fighting capability
- Cargo misdeclaration
- Salvage challenges
- Ports of refuge



75 % of shipping insurance losses are caused by human error, equivalent to $ 1.6 BN



Decarbonisation

In 2018 the International Maritime Organisation (IMO) imposed a target to reduce greenhouse gas emissions from the global shipping fleet by at least 50 % by 2050 compared to 2008 levels, with the aim of achieving full decarbonisation by the end of the century. Along the route to the 2050 requirements there are also some challenging legislative milestones. By 2030, emissions—primarily CO_2—from new and existing ships must be cut by 40 % on average compared to 2008 levels. To meet and comply with this legislation is an immediate concern and requires a step change in the design and operation of next-generation vessels. In response the IMO target, the Poseiden Principles and Sea Cargo Charter are initiatives launched by a group of leading financial and leasing institutions that make acquiring finance/refinance and cargo dependent on a vessel's environmental performance.

In addition to global programmes, there are also regional initiatives such as in the EU, with its target to move more freight transport from roads to rail and inland waterways.

Autonomous operations are often touted in industry publications as a way of solving or helping to deal with many of these challenges, but what does it mean in practice? In the next section we look at Wärtsilä Voyage's definition of autonomous operations in more detail.

03

How smart autonomy can help solve today’s shipping challenges

In this E-Book we refer to “smart autonomy,” which means moving towards autonomous operations in the future, by finding targeted autonomous solutions that solve specific problems today.

This approach allows for further evolution as needed and provides the ability to respond to changing regulatory environments related to emerging standards for autonomous operations. The end goal is not necessarily fully autonomous unmanned vessels. Instead, the goal is to harness existing—or co-create—modular autonomous solutions that solve specific problems and make commercial sense today, while offering the extensibility to install additional solutions in the future, allowing our clients to tailor their own pathway to autonomy.

The types of concrete challenges that autonomous solutions can help solve are summarised below

Increased safety

Autonomous solutions have the potential to reduce the incidence of human error and therefore the number of mistakes and accidents. Removing humans from the equation or giving them the tools to enhance their capabilities for carrying out repetitive routine tasks improves performance and safety. Such changes also allow the crew to focus on more important tasks and key decision-making duties. By increasing situational awareness of what is happening around the vessel, these solutions also increase safety for those onboard surrounding vessels. This will be particularly important in areas where incidents are most common, such as busy ports.

Decarbonisation and fuel savings

Autonomous solutions support efforts to sail in the most fuel-efficient manner, which leads to both economic and environmental benefits. This approach builds on earlier digitalisation efforts which provide actionable insights on fleet operations, squeezing more efficiency out of existing assets and operations and fostering a new operating culture and ways of working.

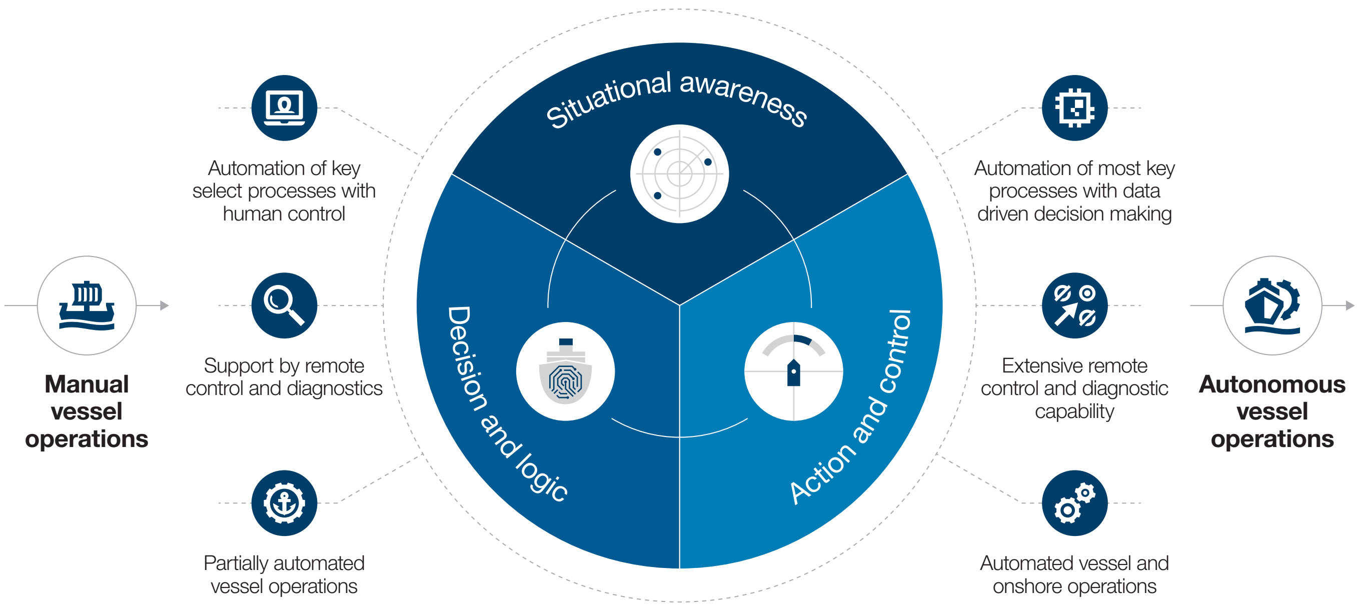
Autonomous solutions improve efficiency by allowing vessels to reliably and consistently replicate precise and safe vessel performance. For example, we've seen that for ships on shorter voyages, reducing the average docking time by a single minute can have a significant impact on the overall fuel consumption (reducing it by two to three per cent per minute on a two-hour voyage). For longer voyages, fuel savings of 10 % or more are possible through route and speed optimisation, and using autonomy solutions can help ensure a more consistent level of performance across vessels and voyages in a fleet.

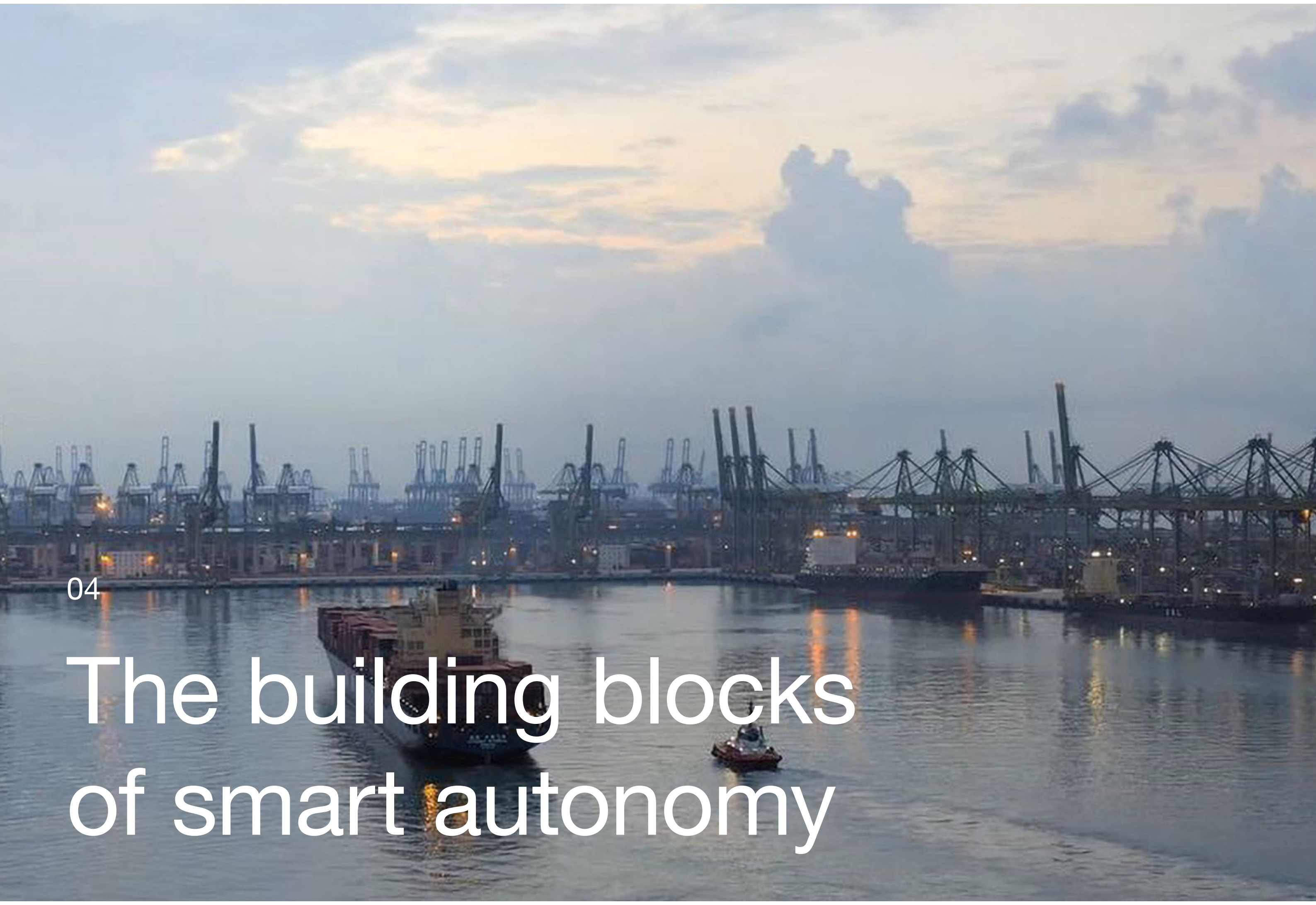
Meeting crew challenges

In the future, there may be an opportunity to operate with fewer crew, which will be important in order to make up for the projected shortfalls in finding experienced, skilled crew as mentioned earlier. This is also important in the context of initiatives that will increase the demand for shipping, such as the EU's target to move more cargo by rail and sea instead of road, which may well increase the number of ships needing to be crewed. Autonomous solutions may also allow redeployment of crew, for example, if ships can be steered remotely from land-based centres instead of from the bridge. Re-deployment onshore can make the maritime profession more attractive, but will require re-training. For this reason, high-quality simulators will become more important and useful in assisting with testing, training and transitioning to autonomous solutions.

More efficient vessel design

Autonomous solutions are already being retrofitted to existing vessels, integrating sensors, data collection, processing and cabling. Doing this in a new build enables a more holistic 'digital by design' philosophy for vessels. Looking further ahead, as the nature of crew deployment, the role of shoreside responsibilities and the usage of vessels changes, vessel design can also be optimised. This means naval architects will have more freedom when allocating space to cargo, and integrating solutions for maximum efficiency and safety. For example, a key change will be enabled by enhanced situational awareness—when operators no longer need a direct line of sight, this will impact vessel design in terms of bridge placement.





04

The building blocks of smart autonomy

In Wärtsilä Voyage’s view there are three key areas that need to be considered to enable autonomous solutions

Very often these build on each other as a solution combines elements of all three areas, but solutions can also exist in just one of these areas, which we will look at later in this paper. To begin, let’s define what each of these areas entails in practice.

- Situational awareness
- Decision making and logic
- Action and control

Situational awareness—what's going on around the vessel?

As an enabler of autonomous operations, situational awareness refers, among many other things, to building a digital understanding of the vessel's surroundings and own operating state. Situational awareness around the vessel is important for vessels of all sizes and is achieved by combining data from several different sources to digitise the environment and provide an accurate picture in order to detect and recognise hazards. These sources include radar, laser, cameras and environmental sensors (GNSS, wind sensors, MRUs, Echosounder etc.) to build up a complete and reliable picture of the environment around the vessel. Ensuring a complete overview of what's going on also requires integration between all these sensors. This kind of integration requires action in three areas.

The services

The hardware stack

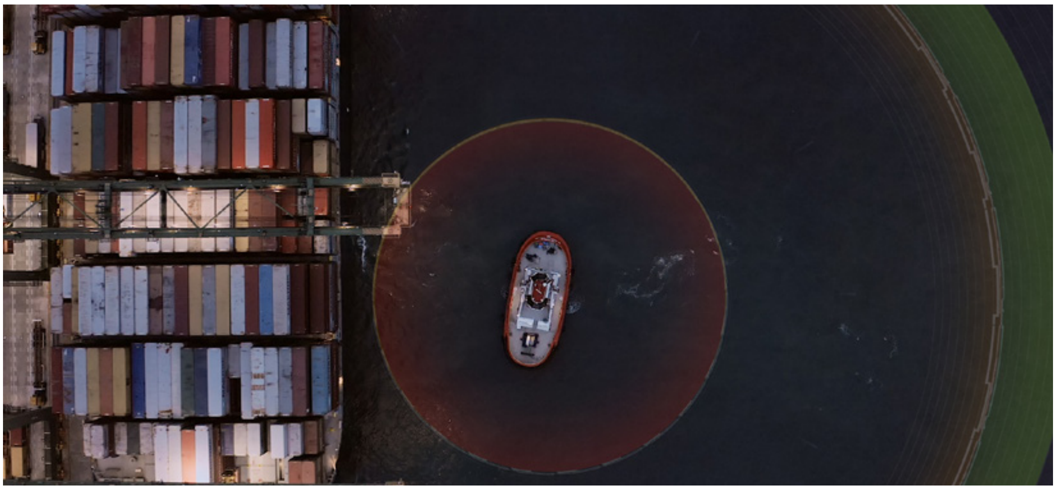
Including a server with enough computing power to process huge amounts of data and predict/plot in real time, as well as peripheral hardware, power management and a well-balanced sensor suite.

Software/data

The fusion and treatment of data is needed as every sensor generates both high volumes of data and different interpretataions of the ship's environment.

Governance/management

A process is needed to patch and update the various applications within the entire suite to maintain cyber security without impacting/breaking the entire system.



Based on that understanding, the crew or an autonomous system receives the inputs needed to decide on a safe and optimal course of action, which is handled by the decision-making and logic capability. In many ways modern technology can already be used to augment the detection and tracking capabilities of crew and in some ways greatly surpass human capabilities. Human eyes and ears still play a central role in a mariner's hazard detection but the advent of night vision, laser, LIDAR and short-range radar technology makes information accessible under conditions where humans are literally blind. In addition to knowing what is happening around the vessel, onboard situational awareness is also important for autonomous operations. This can include the state of the plant, cargo, ongoing maintenance activities on board and power management, which all have an impact on navigational decision making.

Decision making and logic capability—what needs to be done in a given situation?

At the heart of autonomous systems are decision-making algorithms that can apply machine learning to interpret a scenario based on data provided by situational awareness solutions and decide a safe and effective course of action. At its simplest, decision-making and logic capability is the ability to understand a vessel's situation and make good decisions. In certain situations, such systems can help relieve some of the cognitive load on the crew and optimise operations onboard.

Decision-making algorithms have become more and more sophisticated, leading to smarter systems that have increased autonomous capabilities. For example, the goal of a future smart navigation system is to take a vessel from port to port in a safe manner while avoiding collisions or other hazards and maintaining compliance with COLREGS. Such systems would take advantage of digital modelling of the vessel and its environment.

Because of the risks of testing on real vessels at sea, simulation is a critical part of developing autonomous solutions. The computer models that underpin simulationbased training—capable of replicating almost infinite permutations of marine environments, vessel traffic situations and ship equipment—are the same that can be used to inform the decision-making capabilities of intelligent systems. Deployed in real time with real people in simulators, those same models can be used to test and validate autonomous solutions. These simulators can also be used to train crew to understand and use new systems.

Autonomous solutions can help humans make better decisions based on existing information and also make consistent, accurate calculations based on given and programmed data. At the same time while working alongside humans, this provides great feedback opportunities to ensure such algorithms are sufficiently robust and reliable when it comes time to switch from human control to a more autonomous control system.

Action and control—how do we safely and efficiently make the vessel take action?

When we talk about action and control, we're talking about how a vessel executes the decisions made by algorithms to precisely take actions onboard. For the purpose of this paper, the focus is mainly on solutions for navigation as they can offer immediate benefits to operators in today's markets. Smart vessel control and drive systems are needed to safely travel from port to port and to handle such tasks as docking, harbour entry and remote pilotage.

For example, an autonomous navigation system can dynamically plan a route in real time that avoids collisions based on situational awareness and decision-making and logic. These instructions are then sent to the action and control systems to execute. If manual control is required, the crew can intervene at any point.

The benefit of action and control in autonomous solutions is that, in applications ranging from ferries to long-distance voyages, the ability to repeatedly and consistently deliver the same course of action greatly increases levels of efficiency and operational safety and helps reduce crew fatigue. In the future, action and control solutions will be essential to fill in for humans once they have left the control loop.

How smart autonomy fits in to current autonomy classification schemes

At Wärtsilä Voyage, we see that situational awareness, decision making, and action and control are the enablers for autonomous solutions. It's up to each customer to decide how far they want to move in the direction of fully autonomous operations. How these levels are defined, and how useful they actually are, is still being discussed— here are two prominent examples.

Lloyd's Register has defined different levels of autonomy as a scale with capabilities as follows:

AL0
Manual—no autonomous function

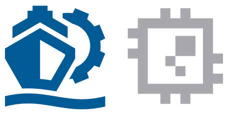
AL1
On-ship decision support

AL2
On and off-ship decision support

AL3
"Active" human in the loop

AL4
Human on the loop—operator/supervisory

AL5
Fully autonomous, rarely supervised



AL6
Fully autonomous, no supervision

The IMO's view on autonomous shipping is based on four levels

- Vessel with automated processes and decision support for onboard crew
- Remote controlled vessel with humans onboard
- Fully autonomous vessel that can make and execute all needed decisions

It's important to note that Wärtsilä Voyage is not proposing an alternative or replacement level of autonomy scale in this paper—instead, we are focusing on clarifying the enablers and the opportunities that already exist in this area. This ensures that Wärtsilä solutions relate to customer needs while also being mappable to relevant class levels and regulations in the future.

05

Challenges to the adoption of smart autonomy

Currently, there are several potential blockers that need to be considered when rolling out autonomy solutions, including technical, organisational and regulatory. These key obstacles can be summarised as follows.

An evolving regulatory environment

This is perhaps the biggest obstacle to rolling out fully autonomous operations. The IMO is looking into a regulatory framework for autonomous shipping and is currently undergoing a scoping exercise.
In the meantime, the IMO's Maritime Safety Committee (MSC) has released its Interim Guidelines for Maritime Autonomous Surface Ships (MASS). These guidelines have been used to guide recent trials such as Wärtsilä and PSA Marine's IntelliTug trial conducted in collaboration with the Maritime and Port Authority of Singapore.
In practice, rolling out autonomous solutions means operating in a fragmented and changing environment based on regulations set out by flag states and local authorities.

Regulations that impact remotely operated and unmanned vessels

- The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW Convention)
- The United Nations Convention on the Law of the Sea (UNCLOS)
- The International Convention for the Safety of Life at Sea (SOLAS Convention)
- The Convention on International Regulations for the Prevention of Collisions at Sea (COLREG Convention)

Human and organisational inertia

Whenever rolling out a new solution, it is critical to ensure the people who are supposed to use it not only understand it and are properly trained, but also see its benefits. Such changes are not always easy as they require adjustments to ways of working, challenge old methods and routines and also raise fears about job security. Added to this is the fact that the shipping industry has relatively long innovation cycles, due partly to its operating nature, but also linked to expensive assets and asset lifetime. To Wärtsilä Voyage, autonomous technologies are foremost about helping existing crew operate more efficiently and safely. Autonomous operations should not be just equated with unmanned vessels, but seen as technologies to help operate vessels better, today.

Moving from more traditional operations to the smart autonomy operations model requires a shift in mindset and the adoption of new processes and competencies across the entire organisation. Rolling out new solutions requires bespoke training in order to ensure buy-in from all stakeholders. Commitment from leadership is key—it will be up to management to help set out the vision and guide the process of both choosing a solution and evolving roles, processes and partnerships to ensure successful uptake of autonomous solutions.

Technical challenges and lack of interoperability and system integrators

While massive improvements have been made in machine learning and AI, these technologies are still developing and will need to develop further to ensure that fully autonomous operations are both realistic and safe. Development of integration between sensors into a single system needs to continue to ensure there are no blind spots and that small-object detection is reliable. One of the challenges in this area is that some of the more mature sensors (such as GNSS and AIS) have well established data standards. Other sensor types are still maturing and there are new areas of innovation (such as LIDAR and video) where the data standards are not as established—this will mean customisation is required. Furthermore, it's worth noting that most of the available current sensors are not built to support autonomy; their data frequency is fine for situtional awareness but it isn't high enough for the real-time decision-making needed by an autonomous system.

Multiple players make single systems that do one thing (and may do it very well) but expanding from there is difficult if not impossible. As these solutions are not mutually compatible it leads to multiple data silos as more onboard systems are added, increasing rather than reducing complexity. The solutions are often not linked to real-life operations or a specific business goal, which makes it hard to see any concrete benefits and hence define a compelling business case for smart autonomy.

One of the ways to improve systems is through simulation before deployment to test that they function as expected. These systems can then be further improved through gathering real-life operational data that filters back to continuously improve the system with the help of machine learning.

Cyber security concerns

As autonomous solutions rely on digitalisation, integration and automation, marine cyber security risk management is a growing and justified concern. There is also a regulatory aspect to this. As the IMO has recognised that cyber security is becoming critical for data protection and reliable and safe marine operations, from January 2021 it requires that cyber security be addressed in safety management systems.

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