THE FUTURE OF MARITIME SHIPPING

TREND REPORT 2023

CDTM
CENTER FOR
DIGITAL TECHNOLOGY
AND MANAGEMENT

The Future of Communication Technology

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A Project of the Center for Digital Technology and Management (CDTM)

The Center for Digital Technology and Management (CDTM) is a joint, interdisciplinary institution for education, research, and entrepreneurship of the Ludwig Maximilians-University (LMU) and the Technical University of Munich (TUM).

It offers the add-on study program "Technology Management" for students from various backgrounds, which provides students with tools and knowledge at the intersection of business and digital technologies.

The entire trend report was written by CDTM students under the close guidance of research assistants.

Visit www.cdtm.de for more information.

Kindly supported by Blue Star Group

Blue Star Group GmbH & Cie. KG is part of the Hamburg based family office of Mr. Erck Rickmers, with diversified activities in the areas of shipping, real estate, private equity and renewable energy. Blue Star Group was established in 2018 as the group's long-term shipping investment vehicle and serves as the co-investment platform for institutional investors, offering project development, structuring and investment management. The founders' expertise of the founders forms the foundation for the company's success and growth and spans various aspects of maritime business and logistics, including financial management, operational efficiencies, risk management, international trade relations and more.

We take a holistic approach that focuses on financial success as well as sustainability and social responsibility. The company strives to minimize environmental impacts and promote responsible business practices in order to have a long-term positive impact on the maritime industry.

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PREFACE OF THE PROJECT PARTNER

> **It allowed us to take a step back from our day-to-day business.**
> Michael Wax

Having graduated myself from CDTM in 2013, it was important for me to give back to the university and support the success of future entrepreneurs. CDTM has been a key milestone in my professional and personal life: this is where I met my co-founder and my wife. What CDTM does very well is just that: bringing together a mix of different and talented people and giving them the tools and the inspiration to grow.

In the same way that CDTM gave me much more than a degree, having Forto support the CDTM class of 2023 brought us more than a few polite conversations with unusually smart people: it allowed us to take a step back from our day-to-day business and keep on questioning the way our industry works.

I have been impressed not only by the speed at which our students have integrated detailed knowledge about the shipping industry but also by the conclusions they drew from it, thereby demonstrating their deep understanding of the challenges we face and the opportunities we still have to seize. The quality of the business ideas they presented and the tough questions they asked helped us take a fresh look at an ecosystem we have become part of by now. Last but not least, it was a pleasure to welcome the 2023 class in our Hamburg office and connect them with many other industry stakeholders who gave them a solid grasp of the numerous facets of logistics.

Class of 2023, I hope you learnt as much from us as we did from you.
Sail on and keep on surprising us!

Michael Wax
Co-Founder and CEO of forto

PREFACE OF THE PROJECT PARTNER

> **The shipping industry needs young innovative thinking heads.**
>
> Christoph Geck-Schlich

We are very pleased and thank you for allowing us to be part of such an impressive project. Without the conviction of Michael Wax (CEO - Forto) for the CDTM and his invitation to cooperate, we would not have had the opportunity to accompany such an outstanding project.
We had no idea what to expect from the CDTM and this Trend Seminar.
Prior to the first kick-off meeting, we were wondering, will our passion for this industry spark over?
We were met with bundled knowledge and a "fire and flame" atmosphere from the very first moment. The day left us more than impressed, exceeded any of our expectations and inspired our curiosity about the results to come.

Such motivation and eagerness of 25 students for an unknown topic is unique and probably only to be found at CDTM. It was sensational for us and our business partners to see at what speed an unknown branch and working topic can be understood and penetrated, in all its facets, strengths, weaknesses and blank spaces in such a short time.
For us, your fascination for such an abstract topic is an extremely positive sign for the future of maritime shipping. The shipping industry needs young innovative thinking heads. The journey this project has taken over the last weeks has been overwhelming to watch. From only rough ideas of the industry's needs over to 25 trends to 5 matured business models leaves us feeling positive about the future. We hope and would be happy to see some well-known faces in the shipping industry in the future.

Christoph Geck-Schlich
Managing Director of Blue Star Group GmbH & Cie. KG

Vera Eger 
Felix Dörpmund 

PREFACE OF THE EDITORS

> **Everybody can learn from the past. Today it is important to learn from the future!**
>
> Herman Kahn

As Herman Kahn, one of the founding fathers of modern scenario planning, nicely states, it is tremendously important for strategy and policymakers to get a deep understanding of possible future developments to be prepared for them.

The Center for Digital Technology and Management (CDTM) aims to connect, educate, and empower the innovators of tomorrow. It is our mission to equip our students with the tools and knowledge they will need to become responsible leaders who actively shape their future environment rather than only react to changes.

This Trend Report is the result of the course "Trend Seminar", which is part of the interdisciplinary add-on study program "Technology Management" at CDTM. About 25 selected students of various disciplines, such as Business Administration, Psychology, Medicine, Computer Science, Electrical Engineering, and others, work together on a relevant topic of our time.

Over the course of seven intense weeks of full-time work during their semester break, the participating students dive deeply into the topic of the Trend Seminar. Working in several interdisciplinary sub-teams, students apply the knowledge of their main studies and learn new perspectives from their team members. They conduct trend research, conduct in depth market research, generate ideas for innovative products or services, and develop them into concrete business concepts.

We would like to take the chance to thank everyone who contributed and made this CDTM Trend Report possible:
We want to thank Forto & the Blue Star Group for supporting this Trend Seminar. Particularly, we want to thank Achim Jüchter, Bastian Hagebeuker, Tim Ostermann, and Wencke Hansen for their collaboration, valuable insights, and feedback throughout the whole project. We hope our findings support you in driving innovation in the context of the Future of Maritime Shipping!

In addition, we very much thank all our lecturers, who shared their knowledge and largely contributed to this project's success:

Alena Strittmatter - CDTM
Allison Zhang - Munich Debating Club
Arne Maibohm - Hapag Lloyd
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Martin Neuendorf - HHLA
Michael Wax - Forto / CDTM
Nadine Schmidt - Coach / CDTM
Pia Schwanenberg - Forto
Prof. Dr. Laura Bechthold - THI / CDTM

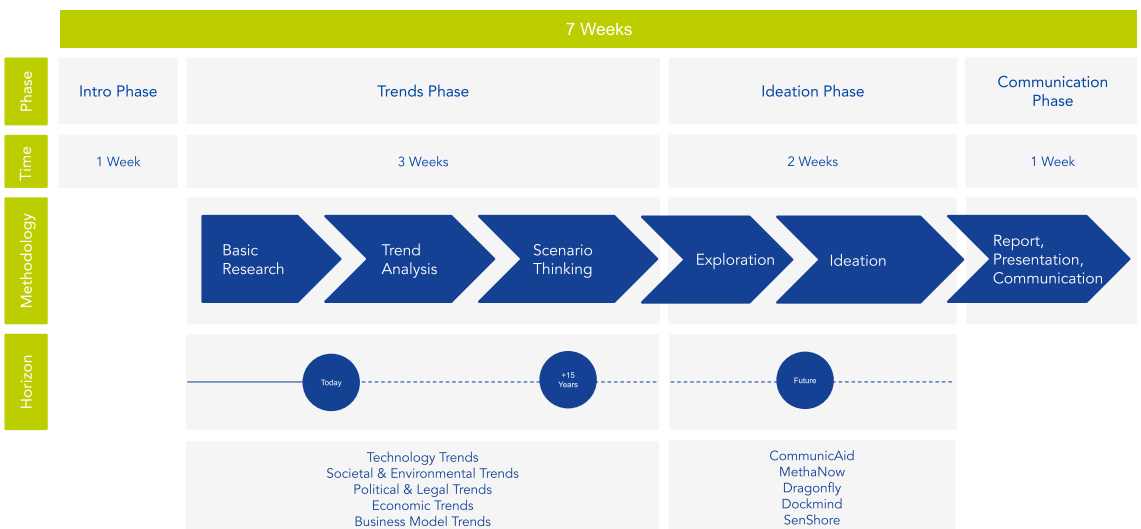
Last but not least, we would like to thank the CDTM students of the class of Fall 2023. They put great energy and enthusiasm into this project, which made it a pleasure for us to supervise the course and coach the individual teams. Special thanks to the Heads of the editing -, layouting- and QA-team (Susanna Heidbrink, Robert Richarz, and Cheng-Ying Kuo) for finalizing the report.

Vera Eger and Felix Dörpmund
Center for Digital Technology and Management (CDTM)

METHODOLOGY

The objective of the Trend Seminar is to provide a methodological approach for diving into a specific subject or industry sector and contemplating its future trajectory. The seminar guides its participants through three phases of trend research: trend, exploration, and ideation. Following this approach, the seminar first analyzes current trends and developments using in-depth desk research, site visits, and interviews with leading experts to establish a shared industry understanding. Next, participants identify areas within the sector where problems and opportunities will likely arise. In the final seminar phase, the students generate future-proof business ideas for products and services, addressing the identified problems and opportunities.

Up to twenty-six students, supervised by two doctoral candidates, pursue the Trend Seminar for seven weeks full-time during their semester break. The sector and framing for the seminar is provided by project partners from within the industry, who share their expertise and feedback, acting as sparring partners to the participants. In each phase, interdisciplinary subteams are formed with students from business, technology, and other disciplines. This interdisciplinarity allows for novel ways of thinking and the development of non-obvious ideas as well as leverages the students' professional and personal growth throughout the course.



During the introduction week, the participants are prepared for the intense trend research ahead. First and foremost, the students are introduced to the specific industry the seminar is diving into. Project partners and industry experts present past and current industry developments from their individual stakeholder perspectives, engaging in open discussions with the students. Additionally, interactive sessions teach trend research methodologies and refine the participants' communication and teamwork skills.

Following the introduction, the **trend phase** of the seminar covers desk research, expert interviews, and expert lectures, enabling the participants to dive deep into the topic at hand. During the expert interviews, students are empowered to pose specific questions to challenge their initial assumptions on how the industry will develop. Beyond that, site visits at the project partners' facilities complement the students' body of research and allow for further verification of their hypotheses. The derived trends are extrapolated 20 years into the future, providing a long-term perspective.

In the **exploration phase**, future opportunities and problems are clustered into specific spaces based on the research done in the preceding phase. The students are reshuffled into new teams and explore these spaces by looking into existing start-ups and projects. Through interviews and discussions with industry experts, the teams validate their hypothesis to identify unmet needs and existing gaps in the industry landscape.

During the **ideation phase**, students brainstorm solutions addressing the previously identified gaps. To facilitate the ideation process, structured and unstructured ideation methods are introduced to the students. This allows them to generate many ideas before consolidating them and building comprehensive business models. Finally, the research results and the business ideas are pitched to the project partners, industry stakeholders, and the general public.

LIST OF ABBREVIATIONS

AI
Artificial Intelligence

AR
Augmented Reality

AUVs
Autonomous Underwater Vehicles

BCG
Boston Consulting Group

BRICS
Brazil, Russia, India, China, and South Africa

BWM
Ballast Water Management

CAGR
Compound Annual Growth Rate

CDR
Carbon Dioxide Removal

CII
Carbon Intensity Indicator

COVID-19
Coronavirus SARS-CoV-2

CTA
Container Terminal Altenwerder

DaaS
Data-as-a-Service

E7
Emerging Seven

EEXI
Energy Efficiency Existing Ship Index

ESG
Environmental, Social, and Corporate Governance

ETS
Emissions Trading System

EU
European Union

EU-SRR
EU Regulation on Ship Recycling

G20
Group of Twenty

GDP
Gross Domestic Product

GHG
Greenhouse Gases

GSBN
Global Shipping Business Network

GT
Gross Tonnage

HKC
Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships

IHM
Inventory of Hazardous Materials

IMO
International Maritime Organization

IoT
Internet of Things

IPCC
Intergovernmental Panel on Climate Change

ITF
Transport Workers' Federation

LiDAR
Light Detection and Ranging

LNG
Liquified Natural Gas

MARPOL
The International Convention for the Prevention of Pollution from Ships

MASS
Maritime Autonomous Surface Ships

MLC
Maritime Labour Convention

MPA
Marine Protected Area

NIS
Network and Information Systems

NSR
Northern Sea Route

OCC
Onboard Carbon Capture

OECD
The Organization for Economic Cooperation and Development

OEM
Original Equipment Manufacturer

OIF
Ocean Iron Fertilization

ROI
Return on Investment

ROVs
Remotely Operated Vehicles

SAM
Serviceable Available Market

SEC
Securities and Exchange Commission

SFC
Smart Freight Centre

SOLAS
Safety of Life at Sea

SOM
Serviceable Obtainable Market

SRM
Solar Radiation Management

SRTI
Ship Recycling Transparency Initiative

TAM
Total Addressable Market

UNICEF
United Nations Children's Fund

VDR
Voyage Data Recorders

VHF
Very High Frequency

VR
Virtual Reality

WASP
Wind-Assisted Ship Propulsion

WEF
World Economic Forum

TRENDS

The following chapter lists current trends that have a strong influence on the development and long-term strategic orientation of the Future of Maritime Shipping. In accordance with the Trends Phase methodology, trends and related driving forces are structured into five areas: technology trends, societal and environmental trends, legal and political trends, economic trends, and business model trends.

TECHNOLOGY TRENDS

INFLUENCING THE FUTURE OF MARITIME SHIPPING

Alternative Fuels
Wind-Assisted Propulsion
Marine Drag Reduction
Digital Twins
On Board Geoengineering

Aviral Shrivastava 
Anna Neumann 
Vincent Jansen 
Gana Moharram 
Leon Sandner 

TECHNOLOGY TRENDS

Influencing the Future of Maritime Shipping

The maritime shipping industry has a reputation for being traditional and rather unaffected by technological advancements. The industry is entering a new phase, driven by technological innovations and stricter regulations. As global trade volume grows, the industry must adjust to these new demands and possibilities.

Technology can allow the maritime industry to face those challenges proactively, thereby ensuring its long-term sustainability. However, the plethora of available technologies is making the transition difficult. In what technologies should shipping companies invest their resources? Which technologies are here to stay? In the following pages, we present and elaborate on five technology trends that, according to our research, are here to stay. Those will shape the future of the industry and help transform the sector concerning three main pillars – sustainability, optimization, and digitization.

When it comes to sustainability, we explore the key question of propulsion. With impending stricter emission regulations and potential energy efficiency regulations, a transformative, long-term viable alternative to emission-heavy fossil fuels is needed. We delve into the alternative fuels that will allow for such a transition and discuss the various options available, both the different propulsion technologies, the multiple fuel alternatives, and hybrid systems. We especially identify wind-assisted propulsion as a promising avenue. Nonetheless, we also raise the challenges that such a transition into sustainable propulsion is facing.

Efficiency is the lifeblood of any industry. With expanding global trade routes, rising demand, and an increasingly diverse mix of propulsion methods, optimizing operational efficiency is more essential than ever [1]. Innovative hydrodynamic solutions are unlocking untapped potentials in ship design and operations.

Techniques like air lubrication, where tiny air bubbles reduce friction between the hull and water, or hydrofoil optimization, which minimizes drag, are leading to significant cost savings due to reduced fuel consumption, lower maintenance efforts, and increased longevity of hull materials.

Another ubiquitous topic is digitization. Could it be that the maritime industry will be the only industry unaffected by the digital revolution? We believe that the tide is changing, and digital solutions will soon be welcomed aboard. We present a very promising technology in Digital Twins. Digital twins have already transformed the manufacturing industry with resounding success. They are essentially virtual replicas of physics systems, mirroring every component and enabling a two-way data stream. The physical ship equipped with sensors can be monitored through its digital counterpart, and vice-versa, the virtual ship representation can be used to manipulate the physical ship. Thus, digital twins can unlock efficiencies across a ship's lifecycle.

We therefore invite you to explore the future maritime technology trends with the three pillars of sustainability, optimization, and digitization serving as our guiding stars.

ALTERNATIVE FUELS

Sustainable Chemical Propulsion Solutions for the Maritime Shipping Industry

With heightened awareness of environmental challenges, the maritime industry is at a turning point. The imperative to curb carbon emissions and enhance energy efficiency has driven the sector to explore propulsion alternatives. While it is clear that the traditional reliance on fossil fuel-based propulsion is unsustainable, it is not so clear what alternatives will become mainstream. From electrification powered by cutting-edge batteries to the utilization of hydrogen fuel cells and the integration of wind-assist systems that harness natural forces, there is no shortage of possibilities. Still, it is unlikely that any propulsion alternative will dominate in the way fossil fuels have for decades. Rather, vessels will have to rely on multiple propulsion systems and fuels. There have been multiple projects to build electric ships [2]. However, many studies asserted that direct electricity-powered vessels are only feasible for short-range trips or in hybrid applications [3, 4, 5]. Therefore, a multi-fuel chemical propulsion future is expected [6], with biofuels leading the way as they can be used as a drop-in fuel [7]. However, alternative chemical fuels like methane, methanol, ammonia, and hydrogen are needed for a long-term zero-emission future [7, 6]. Out of these, the carbon-free ammonia and the carbonaceous methanol are the most promising [8].

Facts

- In 2022, 99.8% of worldwide operational ships are running on conventional fuel; however, over 20% of the ships on order have alternative propulsion systems [9].
- As biofuels can be directly used without substantial retrofitting, they provide the only viable alternative to conventional fuels today; however, lacking availability, typically higher costs, and some carbon-emitting production methods highly question their future viability [10].
- Liquified Natural Gas (LNG) combustion engines are gaining traction due to lower carbon and sulfur emissions compared to traditional fuels [11]. There are 320 “LNG-ready” ships in operation as of 2022, with 99 more on order [12].

Key Drivers

- Stricter emission regulations and potential energy efficiency regulations drive the industry toward alternative propulsion technologies [13].
- Institutional and consumer pressures are propelling the maritime shipping industry towards greener shipping practices [14].
- Carbon neutral shipping demand is increasing as more than 80% of shipping customers are willing to pay a premium for emission-free shipping in 2022 [15].

Challenges

- For a transition to green propulsion, a comprehensive infrastructure is needed for emission-free fuel production, storage, and distribution [13] as well as charging or refueling capabilities.
- Without the necessary emission-free production infrastructure, fuel cells for marine transport are likely to rely on blue hydrogen or ammonia, which do contribute to CO_2 emissions, as opposed to green hydrogen [16, 17].
- Implementing the propulsion technologies, and especially retrofitting existing vessels, will require substantial upfront investment as well as engineering expertise [18].

Impact on the Future of Maritime Shipping

Alternative propulsion technologies could potentially significantly reduce maritime emissions, thereby mitigating environmental impact. Improved fuel efficiency and reduced reliance on fossil fuels can result in lower operational expenses over time. Another possible effect of wind-assisted fuel cell propulsion can be reduced vessel speeds and therefore, more goods transported at a slower pace. Potentially, this can provide a greater incentive for automation in ships, speeding up the off-loading and on-loading processes [19].

WIND-ASSISTED PROPULSION

Harnessing Nature's Power for Eco-Friendly Shipping

Before the 19th century, maritime transportation was strongly dependent on wind power. However, when steamships and motor vessels were introduced, wind propulsion was disregarded as the new technologies greatly enhanced the flexibility and reliability of transporting cargoes and passengers. But in recent years, as decarbonization has become a priority within the industry, wind-assisted ship propulsion (WASP) has re-emerged as a potential solution. The most relevant modern implementations are rotor sails, wing sails, and kites that augment traditional propulsion systems [20]. Wind cannot completely replace other propulsion methods due to the speed and accuracy required for modern shipping, but WASP offers a promising supplementary solution [21]. As fuel prices continue to rise, especially due to the shift to more expensive alternative fuels [22], and regulatory bodies impose stricter emission standards, integrating wind propulsion can help reduce operational costs and decrease the industry's carbon footprint – harnessing a free resource, with no additional infrastructure required.

Facts

- Over half of the operational costs in shipping are fuel expenses, making it the largest cost component [10]. Retrofitting existing vessels with WASP technology can lead to fuel savings in the range of 10-25% [21] and new cargo ships with vessel designs optimized for wind-assisted propulsion can reach average fuel savings of up to 50% [23].
- Currently, 30 large commercial ships are equipped with WASP globally and the number of installations is rapidly increasing with more than 100% growth rate each year [24]. Trends also indicate more experimentation with larger installations, varied larger ship types, and diverse ship owners [21].
- The Frontier Economics Report estimates that by 2050, at least 40-45% of the global large commercial vessel fleet will have wind propulsion systems installed [25].

Key Drivers

- Technological advancements in materials, design, weather routing, and automation allow for more efficient wind harnessing systems.
- The global regulatory and societal push toward reducing carbon emissions is driving the maritime industry to seek cleaner energy solutions. Wind-assisted propulsion can offer fuel savings in the double digits [26].
- Rising fuel costs due to carbon pricing and more expensive alternative fuels make wind-assisted propulsion an attractive financial option for long-term savings. Already at a price of 600-700 USD per tonne of fuel, WASP is commercially viable, according to the Secretary General of the International Windship Association [27].

Challenges

- The financial structure plays an important role, as the ship owner and the ship operator often are two different entities. Many charter agreements position fuel expenditure benefits solely with the charterer, creating an issue of split incentives where ship owners lack the motivation to invest in energy-saving methods [28].
- The maritime industry's conservative and cautious nature hinders the embrace of innovative solutions like WASP. Using wind as propulsion is perceived as a step backward and many ship owners require some existing adoption of the technology to be convinced [28].

Impact on the Future of Maritime Shipping

While WASP technologies might not be as prominent as other alternative propulsion forms, they could be crucial in decarbonizing the maritime industry. To overcome investment hurdles in the process, new business models are becoming relevant, such as a pay-as-you-save model [29]. As shipping companies increasingly adopt WASP technologies on a broad range of vessels, the influence of wind propulsion is set to expand. This growth will stimulate competition and enhance technological advancements, leading to further improvements and cost reductions [30, 31].

MARINE DRAG REDUCTION

Unlocking Efficiency Potential with Air Lubrication and Hull Modifications

Ships have been constantly redesigned and redefined to meet the expectations and challenges of growing trade. One of the constants that accompany it on its voyage is the relatively high water drag coefficient, which motivates fluid dynamic design. We present two innovative technologies, air lubrication systems and the strategic incorporation of hydrofoils into vessel architecture, which reduce hydrodynamic resistance [32]. This translates to higher fuel efficiency and promotes reductions in greenhouse gas (GHG) emissions [33]. Furthermore, the phenomenon of biofouling, characterized by the colonization of ship hulls by marine organisms and bacteria, presents a significant challenge. This encrustation can accumulate up to 150 tonnes of additional weight, affecting ship performance and fuel consumption [34]. Air lubrication technology also mitigates biofouling by limiting growth, ensuring the ecological and economic integrity of maritime endeavors.

Facts

- Air lubrication technologies require no structural modifications, making it ideal for retrofits as well as new builds, and can be easily configured below the ship in any shipyard [35]. This technology can lead to a drag reduction of up to 60% over the hull's flat area under experimental conditions, translating to up to 12% reduction in fuel consumption and global GHG emissions at normal speeds [36].
- The industry incurs extremely high costs due to biofouling, with losses of up to 16% in efficiency [37]. Air lubrication technology has been shown to prevent biofouling accumulation, thereby reducing repair costs for the industry significantly [38, 39].
- Retractable bow foil technology, currently being implemented on smaller container vessels and yachts, promises immense potential, as simulations show it can bring about significant fuel savings on wave-rich routes [40].
- Smaller vessels offer increased route flexibility, higher vessel utilization, and reduced reliance on transshipment [41].

Key Drivers

- Efficient vessels can offer a competitive edge in a market increasingly focused on sustainable practices [42].
- Adopting new technologies can lead to substantial cost savings over the vessel's operational lifespan. With a higher resale value due to better long-term conditions of vessels, it is generally an endeavor with a good return on investment [14].
- Antifouling is set to gain traction with increasing sea temperatures, leading to hull-clinging creatures growing twice as fast, restricting efficiency further [43].
- Providers need to and are expanding their fleets with smaller vessels, allowing the industry to maintain higher service frequency on routes and more port calls that cannot support or facilitate the larger vessels [44, 45, 46].

Challenges

- Before adopting new technologies, a careful cost-benefit analysis is essential. Since some technologies might not align well, thoughtful decisions and trade-offs will be required [47].
- With long investment cycles due to the nature of the industry, the speed of implementation of new technologies is predicted to be rather slow [48].

Impact on the Future of Maritime Shipping

Novel hydrodynamic technologies are revolutionizing the shipping industry by ushering in smaller ships equipped with hydrofoil systems. This trend is a game-changer, enhancing fuel efficiency and boosting ship speeds significantly. In a world striving for decarbonization, these innovations position the shipping industry as a greener and more competitive mode of transportation. Concurrently, air lubrication systems are gaining widespread adoption among industry giants due to their ease of retrofitting and remarkable benefits [49]. These systems reduce drag, enhance fuel efficiency, and combat biofouling, ensuring cleaner, more sustainable, and more efficient maritime operations.

DIGITAL TWINS

Digital Replicas Unlock Efficiencies Across the Ship's Lifecycle

A Digital Twin is a virtual representation of a physical object or system mirroring the asset's current state and behavior. In contrast to conventional modeling methods, Digital Twins evolve and adapt over the lifespan of an asset, continuously accumulating and incorporating data from the field [50]. This real-time capability enables engineers to test, monitor, and analyze an object's actual performance and supports operators in making informed and proactive decisions. Applications range from optimizing operational processes and forecasting maintenance requisites to conducting interactive simulations within a secure virtual environment [51, 52]. To build an all-encompassing digital model of a ship, the vessel needs to be outfitted with various sensors capturing data about different aspects of the physical object's performance, for example, energy consumption, temperature, weather conditions, and more. This data is instantaneously transmitted to a processing system, applied to the digital copy, and visualized in a 3D model. The simulated Digital Twin gives insights into current and possible future happenings. Their various use cases are able to reduce costs and raise efficiencies across the entire ship lifecycle [52].

Facts

- The Digital Twin of a vessel is a simulation modeling all onboard equipment, machinery, networks, and control systems, intricately connected and integrated within a digital environment [53]; what distinguishes it from a mere "digital shadow" is the ability to monitor and control the physical ship from its virtual counterpart [52].
- According to the Classification Society RINA (2022), Digital Twins could potentially reduce ship operating expenses by up to 40% and port time by as much as 30% [52].
- Predictive maintenance based on Digital Twin models can prevent unscheduled downtime losses, which can cost from 2M to up to 5M USD per day [54].

Key Drivers

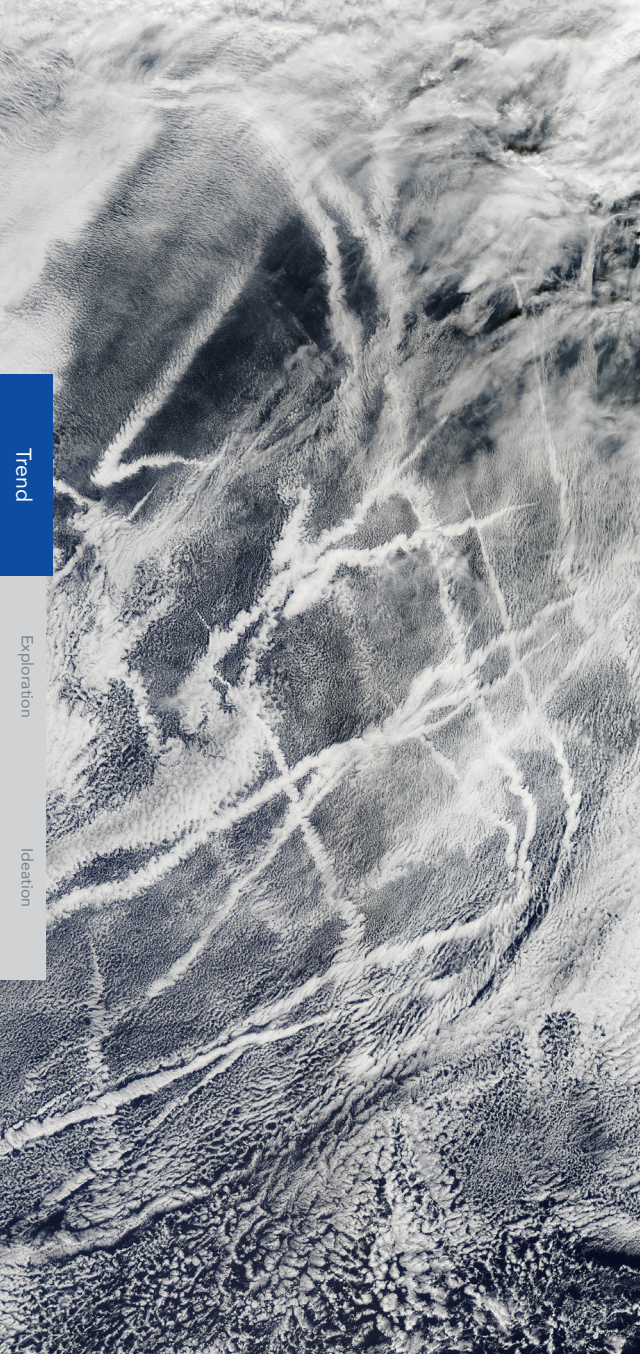
- Increased availability and affordability of advanced sensor technology enable access to live sensor data and the utilization of Digital Twins in the shipping industry [50, 51].
- Providers of satellite internet are tailoring internet solutions to the maritime industry, thereby allowing for reliable data transmission across the ocean [55].
- Success in the manufacturing industry, where the Digital Twin market is growing 56% annually and is expected to reach 48B USD by 2026, provides technological advancements and financial incentives to the shipping industry [56].
- Research on Digital Twin technology in the maritime industry is gaining traction [52].

Challenges

- Significant effort is still required to assemble the essential building blocks for Digital Twin ships, including interconnected models and various embedded sensors generating standardized and reliable data streams [50].
- Creating an encompassing Digital Twin ship is obstructed by the traditionally siloed software systems and fragmented data management [57].
- Although research in Digital Twins for transport vessels is growing, most papers only focus on the operation phase of the ship's lifecycle and fail to consider the design, production, and retiring phases [52].

Impact on the Future of Maritime Shipping

From improved vessel operations, maintenance, and design to enhanced fleet management and port operations – Digital Twins are able to realize efficiency gains across the entire lifecycle of a ship. Utilizing Digital Twins for control system software replicates real-time asset conditions and thereby allows for quick responses to unusual events, remote inspection, and fraud detection, as well as risk mitigation and maintenance. Assessing the behavior of the virtual vessel in real-life scenarios enables validating required modifications in a cost-effective manner [50, 54, 57, 58], contributing to the evolution of more sustainable ship design and operation [53].



ON BOARD GEO-ENGINEERING

Offsetting Negative Effects From Excess GHG Emissions

As the maritime shipping industry contributes 3% to GHG emissions and regulatory measures tighten, businesses are actively seeking strategies to navigate these challenges. While the primary focus remains on reducing GHG emissions, the importance of proactively mitigating the impacts of current and future emissions is increasingly being recognized — especially in cases where conventional methods fall short. This has led to exploring maritime geoengineering solutions, sparking questions about their practicality and feasibility within the shipping domain. These solutions can be divided into Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM). SRM describes processes that increase the amount of light reflected, leading to an instant cooling effect [59]. Although many of these solutions are still in the realm of theory due to the uncertainties surrounding large-scale implementation, they have the potential to serve as more than a mere contingency plan.

Facts

- Onboard Carbon Capture (OCC) can reduce ship-to-wake emissions by up to 78% on LNG-fueled ships [60] and appears to be technically feasible [61]. The global OCC system market size was 924M USD in 2022 [62].
- Iron fertilization of the ocean (OIF) amplifies phytoplankton blooms that can absorb carbon dioxide (CO_2) [63]. Similarly, by liming the ocean with minerals, the water gets more alkaline and can therefore absorb more CO_2 [64].
- Ship wakes can be modified to elongate the lifetime of the microbubbles and have the potential to decrease the earth's surface temperature by 0.5°C by 2070 [65]. Similarly, marine cloud brightening involves ships injecting salt particles into the air, enhancing cloud reflectivity [66].

Key Drivers

- Companies are increasingly compelled to take responsibility for offsetting their emissions [67].
- The growing carbon credit market introduces a financial motivation for the integration of geoengineering solutions [68]. With the growing acceptance of the short-term durability of carbon credits [69], OIF becomes even more interesting.
- Ships emit sulfur, which is a GHG. But on the other hand, sulfur also makes clouds reflect more sunlight, reducing global temperature. Therefore researchers are now actively considering deliberate marine cloud brightening [70].

Challenges

- Given the complex nature of the climate, marked by intricate interdependencies and a multitude of external factors, it is difficult to simulate downstream side effects effectively on a larger scale. However, this is necessary to prove environmental soundness with certainty.
- Implementation will require global cooperation for coordinating efforts, including a robust and comprehensive regulatory framework.
- Capital costs must be decreased so that the costly technology adaptations remain economically feasible [60].
- Infrastructure regarding the long-term storage or usage of the captured CO_2 has to be environmentally sound and built up to the necessary scale.

Impact on the Future of Maritime Shipping

Vessel owners will retrofit their fleet with the technology to accommodate geoengineering efforts to ensure that they are able to actively and self-sufficiently offset the remaining unavoidable emissions that are caused by their operations. The most likely technology to be implemented is OCC, as it is estimated to be commercially available by 2030 [60]. Furthermore, geoengineering could create an opportunity to make each voyage more cost-effective by obtaining and selling carbon credits or gaining another stream of income for facilitating governmental SRM projects. Marine geoengineering, and especially OCC, has the potential to help the industry move to net zero.

SOCIETY & ENVIRONMENT TRENDS

INFLUENCING THE FUTURE OF MARITIME SHIPPING

Rising Environmental Awareness
Workforce Fluctuations
Extreme Weather Disruptions
Arctic Routes
Navigating Social Responsibility

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SOCIETY & ENVIRONMENT TRENDS

Influencing the Future of Maritime Shipping

The maritime shipping industry is the backbone of global trade, yet in the past, it has remained mostly hidden from the public eye. As our reliance on it is becoming clear due to shortages, scandals, and environmental crises, the industry practices receive more media attention than ever. Because climate change has become a focal point in today's public consciousness, governments and companies worldwide are striving to achieve net zero, at the latest, by 2050 [71]. Since the maritime sector makes up around 3% of global emissions [72], society is creating pressure on the industry to become more sustainable, with much focus on alternative fuel inventions. In addition to concerns about emissions, the industry faces scrutiny around other pollution, with efforts to protect marine life.

The maritime sector does not just influence climate change but is also affected by it. Business operations may benefit from melting ice caps in the Arctic, leading to more efficiency due to the opening of new shipping pathways. This can reduce travel times by up to 40% for specific routes [73, 74, 75]. If these pathways open, there will be increasing political concerns around nations that may fight over controlling arctic operations, adding another dimension of fragility to the ecosystem. On the other hand, the negative impacts of climate change outweigh other parts of the supply chain: melting Arctic ice also increases sea levels and leads to more unpredictable weather. Keeping this in mind, ship operators are anticipated to face even more disruptions due to extreme weather events, not just in the Arctic Sea but worldwide. As these events increase yearly, the industry must respond by building more resilient ships and ports that can withstand all kinds of weather.

Ultimately, it is still the people, the hardworking seafarers, who are the backbone of our globalized economy. Ships may become more automated, yet humans will always be in the loop. The workers on ships play a vital part in everything running smoothly, and they deserve, as well as demand, better working conditions, better work-life balance, and more opportunities for career development. If the industry does not accept these demands, there may be a significant labor shortage in the future. More than high-ranking officers are needed; equally important are low-skill workers doing tasks that are difficult to automate or work on older boats. Yet we must remember that automation is increasing, which is not reflected in seafarers' training, leading to a mismatch between acquired and required skills, especially among high-skilled workers.

Another essential factor is that individual consumers and big corporations are becoming increasingly socially responsible. They can create change in many ways, for example through viral social media campaigns. As a result, it is becoming increasingly crucial for companies to behave ethically. Issues like gender pay equality and equal pay across nationalities are gaining attention, areas where the shipping industry still has room for improvement.

RISING ENVIRONMENTAL AWARENESS

Growing Industry Awareness for the Environmental Effects of Shipping Operations

The maritime shipping industry significantly contributes to climate change, accounting for around 3% of GHG emissions [72]. However, the shipping sector's environmental impact is not limited to GHG emissions. It also includes oil, sewage, noise pollution, and inappropriate water discharge, affecting the marine ecosystem to a great extent. Hence, the rise in societal focus on environmental issues, fueled by activism and media, prioritizes sustainability in the industry. Efforts to mitigate these impacts are underway through stricter regulation, consumer awareness, and tech-aided research for cleaner shipping methods. However, transitioning to a more sustainable maritime industry is complex. It requires significant investment in green tech and infrastructure. A lack of collaboration among stakeholders complicates the path to sustainability, as does uncertainty about regulatory changes and an initial decrease in return on investment.

Facts

- The shipping industry must reduce and offset its emissions to achieve net zero by 2050 and avert a climate disaster, which also significantly impacts the industry [76].
- The industry faces growing scrutiny for non-gaseous pollutants such as oil leaks, toxic paint, poor ship recycling, and untreated waste, e.g., magic pipes, all of which harm marine environments [77, 78, 79, 80]. Noise pollution and collisions affect aquatic wildlife, spurring a global increase in marine protected areas (MPA) [81, 82].
- The industry and its representative associations recognize environmental effects and pollution reduction as the most important in shaping their business strategy and operations [83, 84].

Key Drivers

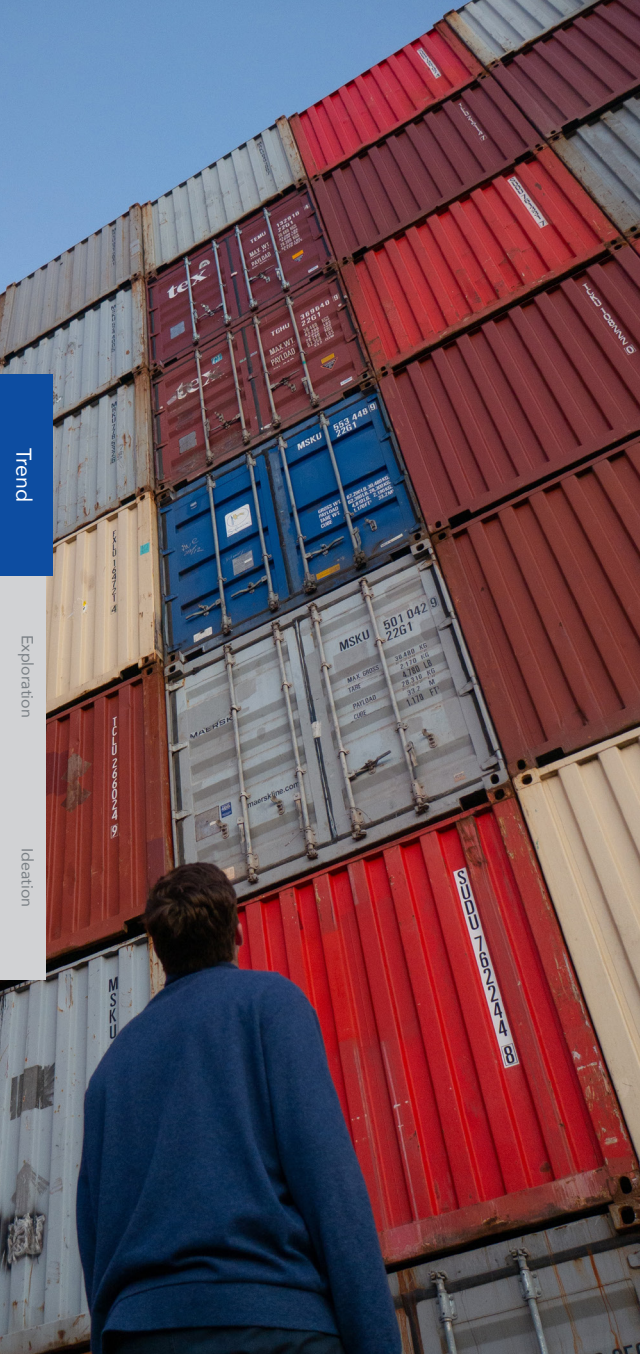
- Rising awareness of environmental issues in society pressures maritime shipping to become more sustainable. Additionally, whistle-blowing and activism increasingly expose industry malpractices [85, 86, 87].
- Regulatory bodies tighten shipping emission standards, exemplified by the IMO's (International Maritime Organization) net-zero goal [88]. Regional and international regulations like the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) are being established to comply [89, 90, 91].
- Consumers increasingly demand corporate action as climate change impacts grow [92]. Financing is shifting towards sustainability, and economic incentives promote greener maritime technologies and practices [93, 94].

Challenges

- Aligning the industry with eco-friendly changes is challenging due to varying national interests, priorities, and competitive factors [95]. Significant challenges include monitoring international waters for compliance and coordinating standardized practices among diverse maritime entities.
- Decarbonizing technology for shipping needs significant investment and multi-sector collaboration. Mitigating wildlife collisions requires more research and complex routing and may increase costs due to longer transit times [96].
- Despite technological advances, some ship emissions will persist, which need to be captured and stored to attain net zero [97].

Impact on the Future of Maritime Shipping

Environmental awareness affects all industries, but its impact is significant in shipping, having high Scope 1 emissions, and operating in a sensitive ecosystem. This growing awareness will make "business-as-usual" impossible to maintain. Regulatory compliance and operational monitoring will intensify, leading to mandated changes such as re-routing. Despite financial and collaborative challenges, stakeholders, including the industry, policymakers, and environmentalists, must find a sustainable compromise. However, this shift is not solely negative. Investments in sustainable practices may raise the competitive stakes and barriers to entry, offering potential advantages for industry leaders and changemakers.



WORKFORCE FLUCTUATIONS

Rising Seafarer Demand Coupled With a Workforce Decline From Demographics

The global maritime workforce is easily affected by international crises, with around 400,000 seafarers being unable to work during the Covid-19 (Coronavirus SARS-CoV-2) pandemic [98]. Since the shipping sector is closely interlinked with trade relations between countries, it is also easily affected by worsening diplomacy or conflicts. The industry is projected to face a labor shortage in the coming years due to various demographic and industry changes [99]. This will create challenges in meeting future demands and require preventive measures to build a sustainable maritime talent pipeline. Despite efforts by some governments in the European Union (EU) to reduce the seafarer decline, the number of European sailors continues to decrease [100]. Digitization trends are also reshaping the skills demanded by the industry faster than training systems can adapt [101]. Coordination between industry, governments, and institutions must be ensured to provide the necessary modernization of seafarer training. Moreover, to attract and retain professional workers, investing in training, improving working conditions, raising wages, and providing career development opportunities will be necessary [102].

Facts

- The IMO predicts that the global shipping industry will need around 90,000 workers by 2026 [99].
- Automation and digitization trends reshape skills demand faster than training systems can adapt. It is projected that over 800,000 seafarers will need retraining measures in the next one to two decades [101].
- Younger generations are showing declining interest in maritime careers despite high pay and efforts to increase popularity [103].
- Manning costs range between 30-45% of a ship's operating cost, depending on its size and automation level [104].

Key Drivers

- There is a shortage of institutions providing specialized training in the maritime transport sector, resulting in a limited pool of skilled workers. This leads to a mismatch in supply and demand [105].
- The maritime industry is struggling with a large portion of its workforce retiring soon, while there is low recruiting and retainment of younger seafarers due to their aversion to poor work-life balance [106].
- The expansion of international trade is expected to drive the demand for maritime shipping, leading to an increased need for new seafarers to operate and manage vessels in the future [107].

Challenges

- The nature of maritime work can negatively impact seafarers' physical and mental health, which may lead to more accidents and an overall unpopularity of the sector [108].
- The adoption of advanced technologies, such as automation and digitization, is transforming the maritime industry, requiring seafarers to possess new skills and adapt to changing work environments [109].
- There is a lack of fairness for workers of different nationalities who do not get similar wages for similar jobs and receive different benefits [104].

Impact on The Future of Maritime Shipping

Despite increasing automation, workers in high-skilled and low-skilled positions are vital for the maritime industry. In case of a labor shortage, we will see ripple effects leading to disruptions in global shipping operations and supply chains, which might lead to material or product shortages. Therefore, many other industries may be affected, leading to increased consumer costs and potential delays in shipping essential goods and services. Additionally, this workforce gap might force reliance on automation and digitization without adequate preparation or oversight, potentially leading to safety and security risks.

EXTREME WEATHER DISRUPTIONS

Climate Change Leading to Disruptions in the Shipping Industry

As climate change accelerates, its impact on the maritime shipping industry is becoming an urgent focus, not just as an environmental concern but as a complex operational challenge. Climate change and increasing global temperatures lead to rising sea levels and are fueling more frequent and severe extreme weather events, affecting operations at both the port and journey levels. These events are only going to increase with the progression of climate change. To deal with these systemic risks, the shipping industry must take adaptation measures to make their ships and ports more resilient. The uncertainty about the timing and location of the extreme weather events adds difficulty to this issue, propelling the need for more reliable weather forecasting technology. In the worst case, these disruptions in operations can have spillover effects on global supply chains, prompting the need for reduced dependence on international shipping [110].

Facts

- Climate change and rising global temperatures make extreme weather events more frequent and intense [111].
- The average downtime of ports due to climate disruptions lies at around 1.4 days per year and is projected to increase in the future [110].
- Already today, storm-related damages to port infrastructure are estimated to range from 46M USD (Hurricane Florence) to 2.2B USD (Hurricane Katrina) [112].
- Disruptions to port operations by storms can result in economic losses ranging from 10M USD (Port of Shanghai) to 65M USD (Port of Dalian) [112].
- Weather-related conditions are responsible for at least 20% of vessel losses worldwide [112].

Key Drivers

- Sea levels will rise as Arctic ice melts, increasing the risk of inundation and flooding in coastal areas and posing a threat to ports [112, 113].
- Rising temperature in the atmosphere and ocean surface increases wind speeds and water evaporation. This makes severe storms like tropical cyclones and hurricanes occur more frequently and intensely, causing more disruptions and damage to ships and infrastructure [112, 113].
- Inland flooding and droughts increase due to changing precipitation patterns. This can disrupt inland supply chains critical to shipping operations and cripple waterways like the Panama or the Suez Canal [112].

Challenges

- Estimating the economic impacts of climate change on the shipping industry is challenging due to uncertainties in climate projections and data limitations [112].
- The existing maritime shipping infrastructure, including ships and ports, needs more resilience to cope with the escalating impact of severe weather events [114].
- Disruptions in port and shipping operations can spill over global supply chains, leading to delays and uncertainty in planning for the shipping industry and customers [114].
- There needs to be a more reliable and precise technology for forecasting extreme weather events to grant sufficient preparation time [114].

Impact on the Future of Maritime Shipping

As the effects of climate change intensify, more extreme weather events will lead to more frequent disruptions in the shipping industry. Ships and ports must become resilient, which includes strategic changes and increasing investment to upgrade and create infrastructure like seawalls and storm surge barriers. This may also lead to increased insurance premiums for vessels and infrastructure. Furthermore, precise weather forecasting will gain importance. On a global scale, countries might adapt by diversifying trade routes and enhancing domestic production to reduce dependence on maritime trade. Additionally, companies could increase inventories to buffer against disruptions [110].

ARCTIC ROUTES

Climate Change Gradually Opening the Arctic Waters

The Arctic region is undergoing a significant shift primarily powered by climate change. The areas of permanent year-round ice are shrinking, and the possibility for new shipping routes is opening. The Arctic routes, such as the Northern Sea Route (NSR), offer 40% shorter transits from Europe to Asia [73] and enable shipping of the extracted natural resources of the Arctic region. Near-Arctic countries are preparing to utilize the Arctic shipping routes by building ports and ice-compatible vessels and putting territorial claims on the Arctic waters [115, 116, 117]. The Arctic routes become ice-free for an uncertain period each summer, making them less suitable for container shipping that requires long-term planning. To tackle that, Russia created the NSR, which lies in Russian waters, year-round accessible by nuclear icebreakers. However, the political tensions and sanctions between Russia and other countries limited the usage of Arctic routes to transport only LNG. As alternative routes are predicted to be usable only in the second half of the 21st century, the Arctic's economic use is currently at a halt [118]. In addition, shipping along the Arctic routes endangers the local environment and may disturb the Arctic Indigenous Peoples [119].

Facts

- Arctic routes can decrease the trip length between East Asia and Europe by 9,000 kilometers, accounting for 40% of the journey [73, 74, 75].
- The routes in international waters, such as the Transpolar Sea Route, are predicted to be seasonally ice-free by mid-century [119].
- Russia is building new ports on the north coast to facilitate year-round shipping along the NSR [115, 116].
- Since 2019, the NSR has seen over 30M tonnes of yearly shipments, predominantly LNG [120].
- China has committed to the Polar Silk Road policy that is supposed to make China a leading Arctic player [117, 121].
- At least four million people, including indigenous communities, reside in the Arctic region [122].

Key Drivers

- The Arctic region is warming four times faster than the world average, dramatically reducing sea ice [123].
- The shrinking ice cap makes the Arctic accessible for shipping companies [115].
- The economically viable shipping lanes between Europe and Asia must be diversified to prevent reliance solely on the Suez Canal [124].
- The Arctic encompasses a significant amount of unexplored resources, e.g., 30% of the world's gas [125], that will be mined and shipped out.

Challenges

- The unpredictability of the navigable periods interrupts the long-term voyage planning, which is crucial for liner shipments [126, 116].
- The most accessible and already in-use Arctic route is under Russian control, preventing Western countries from using it [127].
- The accidents and spills of heavy fuel oil in the Arctic can lead to ecological catastrophes, as means to collect and remove oil from the frozen sea do not exist yet [119, 127].
- Shipping over the Arctic routes requires special equipment, 20-100% insurance premiums, and route-specific fees that decrease the economic advantage [127].

Impact on the Future of Maritime Shipping

The Arctic opening for maritime shipping due to climate change will accompany increased infrastructure investments such as ports or icebreakers of near-Arctic countries. Smaller and medium-sized cargo vessels compatible with Arctic waters will be built to leverage the routes. As the Arctic will be navigable only seasonally for most of the 21st century, these vessels will also be used on the classical routes in the winter. While the outward transport of extracted materials such as gas will grow, the transit shipping through Arctic routes will severely depend on the geopolitical situation [127].

NAVIGATING SOCIAL RESPONSIBILITY

Ethical Considerations Playing a More Critical Role in Day-To-Day Business

The trend of increased social consciousness is gaining influence in various sectors, including the maritime industry. It is no longer solely about consumer choices or political activism. The zeitgeist has shifted to a point where every stakeholder, from the individual to large corporations, is expected to make socially responsible decisions. This is an era where viral social media campaigns can trigger widespread boycotts, and hashtag activism can draw immediate international attention to pressing issues, altering corporate strategies almost overnight. By launching targeted campaigns focused on maritime-specific social problems, such as human trafficking and worker exploitation, they serve as catalysts for change. Moreover, the trend of social consciousness is giving rise to a new way of doing business: socially conscious financing. Gone are the days when financial returns were the sole concern. Modern companies and investors increasingly seek investments that reflect their ethical stance, further intensifying the call for maritime companies to adapt. This changing landscape represents a challenge and fundamental evolution in corporate and industry success criteria.

Facts

- Over the past decade, volunteer participation in the EU has risen, indicating heightened social involvement [128].
- Socially aware consumers, once a niche market, now set the expectations for mainstream brand behavior [129].
- Due to the 28% growth rate for products with environmental, social, and governance (ESG) claims, compared to 20% for other products, corporates put increased focus on ESG-related offerings [130].
- A growing financial interest in ESG-related investments indicates more commitment to ESG compliance [131].

Key Drivers

- A quarter of a company's market value is directly related to its reputation, and 87% of executives consider reputational issues as top strategic risks. Thus, businesses are incentivized to act with social consciousness [132].
- Stakeholders, like employees and customers, increasingly consider social factors in their decisions, forcing companies to adhere to ethical and responsible practices [133].
- The rise of corporate activism, especially in advocating for racial and gender equality, could also lead to diversity efforts within the maritime industry [134].
- A rising societal demand for transparency and accountability pressures companies to be more open about their ESG contributions [135].

Challenges

- Despite growing numbers of socially conscious consumers, it is unclear how quickly this will translate into changes in consumer behavior, like the willingness to pay more for socially responsible marine services.
- Increased demands for transparency could necessitate costly investments in monitoring and reporting, a challenge for an industry already operating on thin margins.
- The historically male-dominated industry could face hurdles in implementing effective diversity and inclusion programs, which require policy shifts and significant cultural changes.

Impact on the Future of Maritime Shipping

As social consciousness gains momentum, maritime companies will likely confront increased demand for ethically sourced goods. This goes beyond traditional environmental concerns to cover fair labor practices and human rights in their supply chains. Moreover, the industry might see the rise of "social audits," akin to environmental audits, becoming a standard part of the annual reporting. Social pressure could also drive the development of tech aimed at worker safety and anti-exploitation measures beyond existing green technologies. Social consciousness will likely redefine corporate responsibility within the maritime landscape, adding new layers of complexity and expectation.

LEGAL & POLICY TRENDS

INFLUENCING THE FUTURE OF MARITIME SHIPPING

Green Maritime Laws
Sustainable Ship Lifecycle Management
Enforcing Cybersecurity
Increased Fragmentation
Lower Margin for Errors

Anne Roellgen 
Matteo Wohlrapp 
Susanna Heidbrink 
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LEGAL & POLICY TRENDS

Influencing the Future of Maritime Shipping

The maritime shipping industry is a cornerstone of global trade, transporting most of the world's goods. As the sector grapples with rapid technological advancements and increasing environmental concerns, the role of legal and policy frameworks becomes ever more critical. The following aims to present five legal trends and their implications for the future of maritime shipping.

Firstly, regulating emissions and pollution is gaining prominence as environmental awareness rises globally. Regulatory bodies like the IMO and regional governments are intensifying emission control and ecosystem preservation rules. Measures have been introduced to monitor ships' technical and operational GHG emissions. At the same time, broader forms of pollution are being addressed. Regulations concerning these matters aim to reduce the spread of invasive species, oil spills, and litter.

Secondly, the concept of a "Circular Economy" is beginning to influence regulations around shipbuilding and recycling. This approach aims to minimize waste and make the most of resources, thereby extending the lifecycle of ships. There is a shift from the traditional "take, make, dispose" model of production and consumption to a more sustainable, "reduce, reuse, recycle" model. Regulations for the safe and environmentally friendly recycling of ships are increasing at both global and local levels, with the EU leading the way.

Following the trend of maritime operations becoming more digitized, the industry is increasingly susceptible to cyber threats. Strengthening regulations aims to safeguard critical infrastructure and sensitive data. These measures are crucial in an era where a single cyberattack can cripple supply chains and have far-reaching economic implications.

Next to these concrete policy-related trends, regulatory fragmentation is increasing, highlighting the challenges of reaching an international consensus on maritime laws. As global agreements become more complicated, regional bodies are stepping in to enforce stronger regulations. This trend creates a complex patchwork of rules that shipping companies must navigate and an unlevel competitive playing field.

Finally, these and many more changes lead to a legal environment that requires companies to tighten their operations, as increased regulations and monitoring lead the industry towards a lower margin for errors. Companies are incentivized to comply with regulations as technological advancements allow for more precise monitoring, and fines are implemented to penalize non-compliance. At the same time, the emergence of social media and instantaneous news amplifies the repercussions of any misstep, highlighting the importance of reputation management as a crucial aspect of compliance.

The legal and policy landscape will play a pivotal role in the future of maritime shipping as policymakers tackle new challenges like regulating emissions, managing the ship lifecycle, and driving cybersecurity. As the sector evolves to require new legal frontiers, finding consensus in this global industry becomes increasingly complex. The convergence of legal changes and new regulations across multiple dimensions requires more day-to-day diligence from shipping companies.

GREEN MARITIME LAWS

Intensifying Rules on Emission Control and Ecosystem Preservation

Growing environmental awareness is resulting in increasingly stringent regulations in the shipping industry, focusing on reducing GHG emissions and protecting marine ecosystems. The IMO oversees measures, including EEXI and CII. Additionally, the International Convention for the Prevention of Pollution from Ships (MARPOL) covers a broader range of marine pollution, encompassing waste discharge and oil spills. The EU is also actively engaged and aims to expand its Emissions Trading System (ETS) to maritime shipping and initiate programs such as FuelEU to further reduce carbon emissions in the industry.

Facts

- The IMO implemented various measures to decrease GHG emissions. The EEXI evaluates the energy efficiency of ships based on different criteria, including engines and speed, whereas the CII assesses individual vessels' operational efficacy annually. Restrictions around those metrics are bound to increase in the future [88].
- Regional bodies implement further constraints, such as the ETS, which will incorporate CO_2 emissions from all large vessels (weighing 5,000 in gross tonnage (GT) or more) entering EU ports from January 2024 onwards [136].
- Since its creation in 1978, the MARPOL Convention has been fundamental in combating the various forms of marine pollution. Expanded from Annex I to VI, it addresses issues such as oil spills, garbage, or sewage [137].

Key Drivers

- The maritime shipping industry is accountable for 2.9% of global CO_2 emissions. By 2050, emissions could increase by up to 130% compared to 2008 [138], highlighting the need for immediate and rigorous regulatory action.
- Vessels also significantly contribute to other forms of pollution. Through ballast water or biofouling, they facilitate the transfer of invasive aquatic species [139]. In addition, maritime shipping is one of the primary sources of underwater radiant noise, significantly impacting marine life [140].
- The increasing focus on ESG factors in investment decisions drives sustainability within the industry [141].

Challenges

- Reaching a consensus on specific measures at a global level is a complex undertaking, considering that the IMO advocates for the interests of 175 member countries [142], which inevitably slows the pace of change. Moreover, even when regulations are in place, they must still be transposed into national law by each member state [143].
- Technologies that provide accurate information on emissions are not utilized, leading to CII being calculated based on fuel consumption and a CO_2 emission factor instead of actual emissions [144].
- Economic influences, such as the financial advantages of discharging bilge, may serve as motivators that weaken the potency of environmental policies [145].

Impact on the Future of Maritime Shipping

The expanding regulatory sustainability landscape forces the maritime industry to make significant technological and operational adjustments. Such changes are expected to increase operating costs, with the added risk of financial penalties for non-compliance. In addition, the sector must adapt to an increasingly complex regulatory regime that requires a careful balance between environmental protection and operational efficiency. Failure to adapt could have serious consequences, including damage to reputation and disruption of operations. From a financial perspective, increased environmental regulation can lead to stranded assets or a two-tier market, but it can also increase confidence in green investments.

SUSTAINABLE SHIP LIFECYCLE MANAGEMENT

Introducing Circular Strategies to Ship Manufacturing

The comprehensive dismantling of vessels and the adoption of reutilization techniques are necessary for material and part retrieval from ships at the end of their operational life to achieve circularity in resource utilization. This approach can potentially improve economic and environmental sustainability [146]. With the EU leading the way, regulations for the safe and environmentally sound recycling of ships are increasing at both global and local levels. In the future, it will be crucial to investigate the management of end-of-life phases and ship dismantling procedures, considering their critical role in promoting sustainability within the ship value chain.

Facts

- The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) was adopted in 2009 and ratified by 22 states as of June 2023. It is expected to be enforced in June 2025. The HKC mandates the development of an inventory system for hazardous materials (IHM) for vessels over 500GT and the authorized recycling of ships at specific facilities [147].
- The EU Regulation on Ship Recycling (EU-SRR), enforced in 2018, adds to the HKC requirements by including stricter safety and environmental guidelines [148].
- The Ship Recycling Transparency Initiative (SRTI) is hosted by the Smart Freight Centre (SFC) and the Sustainable Shipping Initiative (SSI). It offers a transparent online platform for shipping companies to ensure the implementation of ship recycling policies [149].
- The Basel Convention with the Ban Amendment (1989) and the EU Waste Shipment Regulation (2021) handles clean and circular waste movement in ship recycling for vessels that deliver from/to the EU and the Organization for Economic Cooperation and Development (OECD) countries [150].

Key Drivers

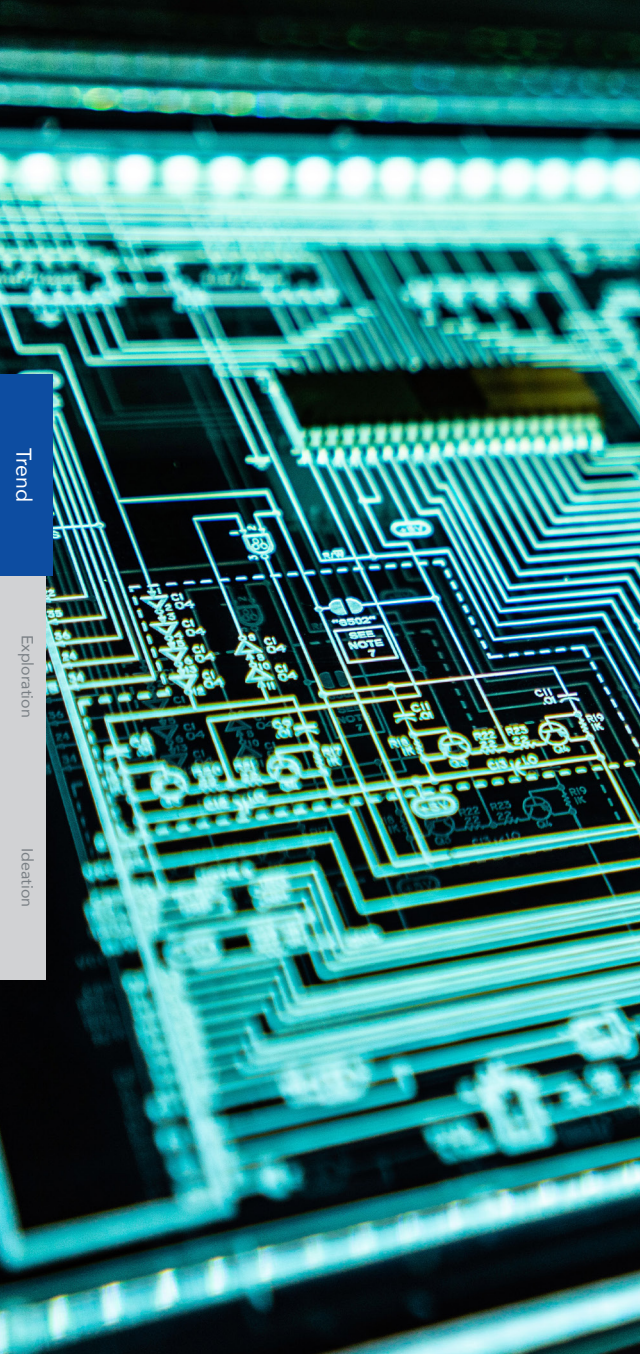
- Shipowners obtain a high price for their recycled vessels that is primarily driven by the price of scrap steel, which makes up 75-85% of the ship's material [151].
- Digitalizing shipping, yard, and recycling facility operations allows for more transparent ship lifecycle processes [151].
- The circular economy transition in the maritime shipping industry presents a huge opportunity for the financial sector, whose actors can benefit from the increased efficiency of scarce resources and the uptake and scaling of related innovations [151].

Challenges

- The HKC and the EU-SRR fail to consider concrete designs, use cases, and refurbishment for the recovered ship materials post-recycling [152].
- A ban on the import of waste by the Chinese government in 2018 has caused many ship recycling facilities in China to be under-utilized, further decreasing international capacities and capabilities for ship recycling [151].
- Increased number and size of ships lead to the projection that tonnage due for ship recycling will double by 2028 and quadruple by 2033 [151].
- Stricter EU-SRR regulations could incentivize European shipowners to register their vessels under a different flag and to profit from cheaper recycling processes abroad, e.g., in Bangladesh and Pakistan [153].

Impact on the Future of Maritime Shipping

Due to ship lifecycle management and a growing emphasis on creating an international circular economy, new networks will connect shipowners, shipyards, recycling yards, steel manufacturers, and other stakeholders. Developing a new recycling standard in the maritime shipping industry will create shared value across multiple sectors and countries, necessitating advanced multi-stakeholder coordination and substantial upfront investments. Due to the growing demand and changing attitudes toward the recycling and retrofitting of vessels, there is potential for new business models to emerge in the coming years.



ENFORCING CYBER-SECURITY

Strengthening Regulations to Safeguard the Industry Against Cyber Threats

The maritime industry is ushering in an era of Maritime Autonomous Surface Ships (MASS), ranging from partially to fully automated. This transition, aiming to reduce human errors, demands updated legal frameworks. With MASS comes questions regarding remote operators, training, liability, and international law compliance, and the IMO is responding with regulatory changes. Alongside automation, the maritime sector faces rising cybersecurity threats, evidenced by a 38% increase in cyberattacks in 2022 [154]. This leads to governments and organizations drafting cybersecurity legislation and guidelines for ports and the appearance of a budding cybersecurity insurance market. Both automation and cybersecurity underscore the need for revamped maritime regulations [155].

Facts

- Cyber attacks in the maritime industry have grown significantly, exemplified by five major cybersecurity incidents since 2022 [156].
- The IMO's Resolution MSC.428.(98) requires ship owners to incorporate cyber risk management into safety management systems starting January 1, 2021 [157].
- The 2022 EU Network and Information Systems 2 (NIS2) Directive, UK NIS Regulations update, and proposed US Securities and Exchange Commission (SEC) regulation mandate robust cybersecurity measures and reporting, safeguarding critical national infrastructure and public maritime entities by October 2024 [158].
- In April 2022, the Maritime Safety Committee 105 outlined a plan to create an optional MASS Code for adoption by mid-2024, following agreement among three committees. A mandatory MASS Code might follow, becoming active on January 1, 2028 [159].

Key Drivers

- Technological advancements will enable the remote operation of ships similar to unmanned military and research vehicles, enhancing safety efficiency and providing environmental benefits [155].
- The current shortage of ship officers in the world merchant fleet is expected to increase and will only be resolved if measures are taken to address the situation [160].
- Escalating cyber threats targeting critical maritime infrastructure and services drive governments to enact stringent cyber security regulations, emphasizing cyber risk management for maritime companies [161].
- The effectiveness of existing cyber regulations is questioned as compliance struggles persist, and the call is made to view cyber risks as safety risks, emphasizing the need for continuous improvement [162].

Challenges

- Autonomous ship deployment is hindered by complex regulations and ambiguous liability and insurance issues while also requiring dependable sensors and integrated navigation, communication, and power systems for reliably flawless performance [163].
- Compliance with evolving cybersecurity regulations demands meticulous measures involving training of company employees, implementation of security frameworks, and integration of management systems within companies to prevent potential attack vectors [156].
- Additional costs involved with implementing security measures, such as increasing enforcement powers, random audits, and fines [164].

Impact on the Future of Maritime Shipping

The maritime sector faces a transformation driven by escalating cyber threats and the advent of MASS. Enhanced cybersecurity necessitates increased cyber risk management. Concurrently, the rise of MASS demands updated legal frameworks to address remote operation, training, and liability complexities. With the IMO at the forefront, the push is towards a tech-centric maritime environment, balancing advanced automation with rigorous cybersecurity and legal protocols.

INCREASED FRAGMENTATION

Reinforcing Regional Regulation Due to Diminishing International Consensus

An incredibly complex legal landscape characterizes the maritime shipping industry, as policymakers must navigate the conflicting interests of many entities across the supply chain. Local shipping-related regulations and a fragmented regulatory environment are on the rise due to the IMO's inability to enforce the law, the lengthy process of adopting international standards, and the balancing act of even finding consensus for such standards. Although regional regulation can be very effective, e.g., in reducing emissions, fragmentation in the shipping industry can be dangerous due to its potential to create competitive disadvantages. As a global industry with strong competition within shipping and other forms of transportation, an unlevel playing field driven by differing regional regulatory requirements could significantly impact the maritime shipping industry of the future.

Facts

- The IMO proposes legislation, but member states are responsible for implementing and drafting the appropriate national law, leading to discrepancies in how IMO standards are enforced [165].
- As a frontrunner in the industry, the EU plays a significant role in driving innovation in maritime shipping. This is also due to their early adoption of new regulations to navigate innovative maritime topics [166].
- Local regulation can be very effective, as seen by the fact that regional zero-emission shipping mandates from three of the largest economies (China, Europe, and the US) could already lead to the decarbonization of 84% of the global fleet [167].

Key Drivers

- The shipping industry involves many countries and industries with varying interests. This leads to different priorities and incentives, challenging decision-making on common international regulations [166]. Even if the end goal is the same, e.g., a more sustainable industry, implementing specific measures can benefit some at the expense of other shipping players [168].
- With 175 member states and many involved organizations, the process of adopting and adapting IMO standards is very lengthy [169]. This difficulty in achieving IMO-mandated action can lead to countries implementing their own regulations [168].
- Fragmentation across other dimensions, like technological decoupling between global superpowers [170, 171] and growing trade restrictions [171], further drives legal and policy-related fragmentation.

Challenges

- Shipping is an industry in which competitiveness is essential. A fragmented legal landscape leads to an unlevel playing field, as seen in the cost of ship recycling in Europe compared to Asia. Additionally, competitive disadvantages could lead to companies trying to circumvent regulations, e.g., by re-registering ships in less regulation-heavy countries as they reach their end of life [150].
- Shipping is an inherently global industry and thus needs global regulation and standard solutions in the long run [150]. The difficulty of reaching multilateral solutions to shipping regulation is exacerbated by a decrease in the ability to collaborate between some significant economies in areas not only limited to shipping [170].

Impact on the Future of Maritime Shipping

In the long term, the growing presence of fragmented regional regulation could increase pressure on the IMO to achieve multilateral solutions faster [170] and push global standards in the same direction [150]. However, until this happens, the differences in regulations and the competitive disadvantages associated with them could lead to a shift away from sea shipping and towards land-based transport, as these two modes also stand in competition to another on a regional scale [168].

LOWER MARGIN FOR ERRORS

Creating Higher Incentives for Regulatory Compliance

The maritime industry is at a crossroads, grappling with a multi-dimensional regulatory tightening reshaping its operational landscape. From stringent emissions controls through EEXI and CII to labor laws under the Maritime Labour Convention (MLC), the industry faces escalating, country-specific fines and an uptick in securities class actions. Technological advancements, while aiding compliance, make violations easier to detect, increasing company accountability. The IMO is intensifying its enforcement efforts, adding another layer of complexity. At the same time, the rise of social media and instant news amplifies the consequences of any misstep, making reputational management a critical part of compliance. Emerging technologies like MASS introduce legal ambiguities, further complicating an intricate regulatory environment.

Facts

- The maritime industry faces tightening legal regulations across multiple dimensions, such as emission control through EEXI and CII [90], pollutant control through the Ballast Water Management (BWM), labor laws through MLC [172], and safety regulations through Safety of Life at Sea (SOLAS) [173].
- The industry has to deal with escalating fines for non-compliance with regulations such as the sulfur regulations. These fines are country-specific and can range from thousands of dollars per day, like in the US [174], to prison sentences in Singapore [175].
- Securities class actions are gaining momentum, with a 142% increase globally in 2022 [176]. Furthermore, new EU directives are streamlining class actions in sectors like the environment, a subject that is increasingly important for shipping [177].

Key Drivers

- The IMO has increased the pressure on flag and port states to pursue maritime crime, such as illegal ship-to-ship transfers and unregistered ships, highlighting the trend of increased enforcement of regulation [178, 153].
- Technological advancements in tracking technologies make tracing actions such as high sulfur pollution easier, leading to individual companies being held more accountable for their illicit emission-related activities [179].
- Increased needs for transparency along the supply chain, such as in the area of ESG, make the core activities of shipping companies more transparent and more subject to external scrutiny [180].

Challenges

- New innovative technologies, such as the development of MASS, cause legal ambiguity in regulation, as some of the potential risks remain uncertain [181].
- In an increasingly complex regulatory environment, it becomes challenging for shipping companies to comply with local and global legislations [172].

Impact on the Future of Maritime Shipping

The increasingly strict regulations in the maritime industry have significant implications. Companies now deal with greater operational risks because even minor compliance violations can lead to substantial financial penalties, legal consequences, and reputational harm. This situation demands additional resources for compliance and monitoring efforts. Whether investing in advanced tracking technologies or expanding legal teams, the emphasis on compliance draws resources away from other key activities. Consequently, the outcome is a more careful, resource-intensive operational approach that may affect the industry's overall effectiveness and competitive advantage.


ECONOMY TRENDS
INFLUENCING THE FUTURE OF MARITIME SHIPPING
Reshaping Global Trade Routes
Supply Chain Resilience
Surge in Alternative Energies
Rising Political Tensions
Shifting Financial Landscape

Alexander von Recum 
Pietro Belligoli 
Cheng-Ying Kuo 
Pary Zadeh 

ECONOMY TRENDS

Influencing the Future of Maritime Shipping

The maritime shipping industry, responsible for transporting nearly 80% of the world's trade volume, stands at the heart of an interconnected global economy. Its future, shaped by multiple evolving factors, has implications far beyond its borders.

One cannot emphasize enough the role of emerging economies in this context. As they grow, so does their demand for goods and resources. This shift does not only increase trade volume; it is also leading to a reconfiguration of global trade patterns. Maritime routes, once firmly established, now require adaptation in response to the economic ascension of these nations. Companies have to be flexible and prepared for these changes, and ideally anticipate how the economic changes impact their operations.

But the flow of trade is also vulnerable to unforeseen events. The Covid-19 pandemic, among other challenges, unveiled the fragility of supply chains worldwide. Not only that, but it showed how difficult it can also be to recover from sudden shocks and changes. In an industry where once the mantra was efficiency at all costs, the realization now enlightened another focus toward greater resilience and adaptability. That being said, supply chains are undergoing restructuring to withstand the shocks of unpredictable global events and geopolitical unrest.

Speaking of geopolitics: the landscape of international alliances is in flux. Historical powerhouses in trade are re-evaluating partnerships, highlighted by events, such as the US-China trade war and the aftermath of Brexit. Stakeholders in the maritime industry now find themselves in a position to re-strategize, with a heightened focus on Asian ports as new global logistics centers. The volatility caused by events, such as Russia's war on Ukraine or the intensifying US-China discord impacts the maritime sector, posing challenges and requiring adjustments.

In parallel, as climate concerns increase, there is a push in the maritime sector toward sustainable energy. With a sizable carbon footprint, the industry is exploring alternatives, such as LNG, hydrogen, and ammonia. Thereby, this trend is not only about mitigating environmental risks, it is also a strategic pivot that links energy politics with trade dynamics. Here, companies are required to make strategic decisions in the short term on how to develop their infrastructure and vessels to adhere to these climate pressures. Hereby, uncertainty in technological advancements, fuel requirements, and regulatory changes pose challenges on determining which alternative fuels companies should pursue.

Lastly, as the broader financial world evolves, so do the maritime industry's financing structures. The emergence of ESG investing is reshaping capital allocation, with the maritime industry both adapting to and benefiting from this shift.

In sum, the maritime shipping industry stands at a crossroads shaped by economic growth, geopolitical shifts, environmental concerns, and financial evolution. Each trend, while significant on its own, is part of a larger mosaic that will define the future of global trade. The industry's ability to understand and adapt to these intertwined forces will determine its trajectory in the coming decades.

RESHAPING GLOBAL TRADE ROUTES

Emerging Economies Fueling New Trade Routes

Emerging economies, characterized by rapid industrialization and rising consumer markets, remain fundamental in pushing the maritime shipping industry forward. Their evolution significantly impacts global economic growth, driven by their escalating import and export trades for raw materials, finished goods, and alternative energy resources. This transformation fuels the maritime shipping industry and reshapes the global trade landscape. New trade corridors and routes are becoming more relevant, responding to the diverging economic growth prospects between emerging and developed nations. These evolving trade patterns underscore the maritime shipping sector's need to adapt to changing routes and newly emerging trade relationships.

Facts

- By 2050, the Emerging 7 (E7) economies might increase their share of the world's Gross Domestic Product (GDP) from around 35% to nearly 50% [182, 53, 183].
- The United Nations reports that over 90% of global urban population growth between 2020 and 2050 is expected to occur in Asia and Africa, with many new urban residents living in emerging market cities [182, 53, 183, 184].
- The maritime shipping industry is poised to handle a substantial surge in trade volume driven by emerging economies. By 2030, it is estimated that global maritime trade volume could reach over 22B tons, with emerging economies accounting for approximately 65% of this total [185].
- Emerging economies are forecasted to invest approximately 1.5T USD in port infrastructure and transportation networks by 2035, enhancing their capacity to facilitate international trade [186].

Key Drivers

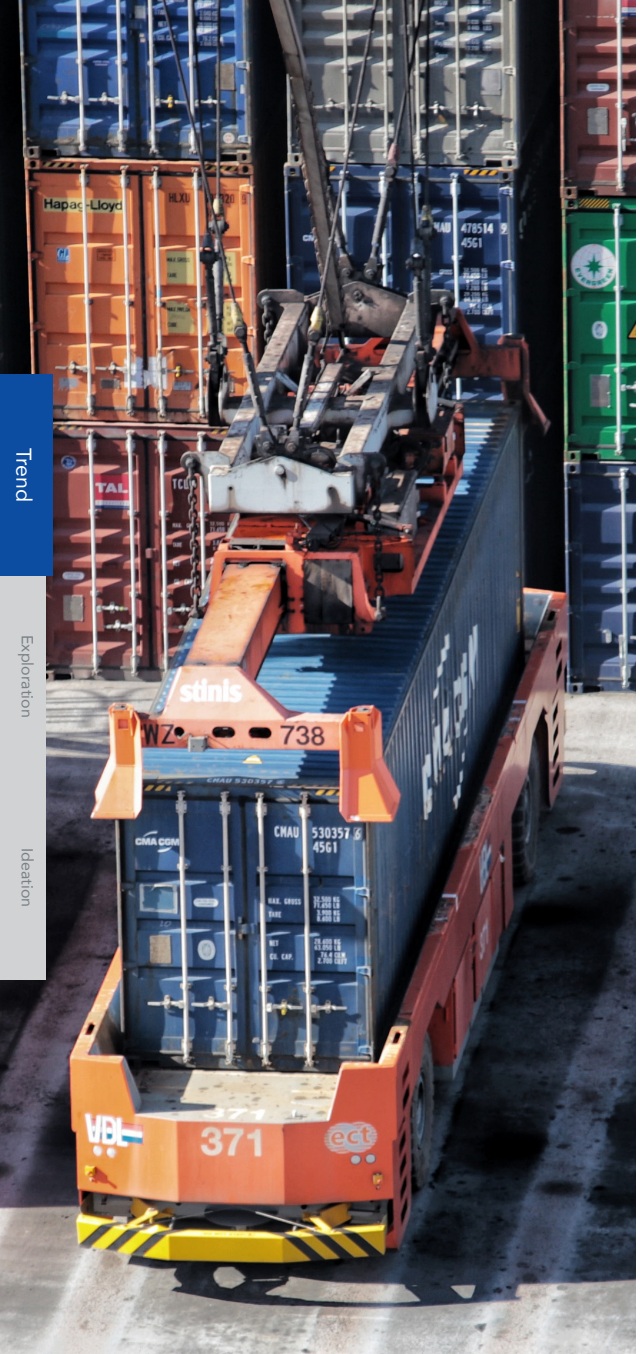
- Emerging economies are directing substantial investments into expanding and upgrading their transportation infrastructure, including ports and shipping facilities. As a result, these economies are becoming more attractive to global trade partners and shipping companies seeking smoother supply chain operations.
- Many emerging economies are rich in natural resources, such as minerals, raw materials, and energy. These nations are leveraging their resource wealth to engage in global commodity trade. Consequently, they are investing in maritime shipping to facilitate the export of these goods [184].
- Emerging economies increasingly attract foreign investments in their maritime and logistics sectors. Foreign investments support the expansion of new trade routes, port infrastructures, and the development of advanced supply chain technologies, enhancing their competitiveness on the global stage.

Challenges

- Meeting international maritime regulations, environmental standards, and safety requirements can be challenging for growing economies. Compliance often involves upgrading vessels, implementing safety measures, and adopting more sustainable technologies, which may require significant investments [185].
- To facilitate this expansion, emerging market governments must undertake structural reforms designed to enhance macroeconomic stability, diminish their overreliance on natural resources, and cultivate more robust political and legal institutions. [185].

Impact on the Future of Maritime Shipping

As emerging economies continue to grow and dominate the global economy, their increasing demand for raw materials, finished goods, and energy resources will drive a substantial increase in trade activity. Consequently, emerging economies play a dual role in the evolution of trade routes. They are expanding existing trade corridors and taking the lead in forging entirely new ones. Over the next two decades, trade routes linking emerging economies with both developed economies and other emerging markets are projected to gain increased prominence.



SUPPLY CHAIN RESILIENCE

Strengthening Global Supply Chains Against Disruption

In response to disruptions like the Covid-19 pandemic, natural disasters, and geopolitical tensions, businesses across industries recognize the imperative to fortify their supply chains. Traditional supply chain models, optimized for efficiency and cost savings, may not withstand unexpected shocks. Organizations are re-evaluating their strategies to prioritize adaptability, redundancy, and risk mitigation to meet customer demands and remain profitable.

Facts

- The share of trade conducted through nations ranked at the bottom of political stability rose to 28% in 2018, and 80% of the trade involved countries with declining political stability [187].
- Both companies and world organizations call for more resilient supply chains to maintain day-to-day operations. Examples include the United Nations International Children's Emergency Fund (UNICEF) pilot project with the World Economic Forum (WEF), Global Supply Chain Resilience Initiative, and the Indo-Pacific Supply Chain Resilience Initiative [188].
- Unexpected natural disasters are occurring at a higher frequency and have a higher impact than in the past, requiring supply chains to be agile and resilient to shock.
- In 2019, two-thirds of international trade occurs within global value chains [189], where disruptions in single steps of the chain can have great ripple effects.

Key Drivers

- Rising geopolitical tensions have increased the frequency of sanctions and unfavorable trade policies. Global supply chains that rely on suppliers dispersed worldwide suffer from unpredictable disruptions.
- Climate change models suggest extreme weather events such as floods, droughts, and epidemics will only become more frequent [190]. Events such as the Panama Canal drought harm supply chains [191].
- Consumer expectations in product continuity lead to higher consequences of a disrupted supply chain than in the past. Companies must ensure reliable supply to maintain their market share.

Challenges

- The transportation industry (particularly maritime shipping) lacks real-time visibility due to legacy technology and complex stakeholder systems [192].
- Traditionally, resilience and cost efficiency have been trade-offs in supply chain management. Technology application and business model innovations will be needed to balance the two aspects.

Impact on the Future of Maritime Shipping

The maritime shipping industry must become more agile and develop new strategies to address unpredictable regulations and climate-driven disruptions. This will involve investments in new technologies to enhance resilience and reconsidering legacy systems for improved efficiency. Additionally, the possibility of forming close collaborations or new alliances may arise to facilitate the sharing of risks, and resources, and the swift coordination of crises.

SURGE IN ALTERNATIVE ENERGIES

Climate Change Forces Shipping Companies to Adapt Fast(er)

The maritime shipping industry, responsible for about 3% of global carbon emissions, is increasingly prioritizing sustainability due to growing climate change concerns and stricter regulations. Companies are investing in greener alternatives like liquefied natural gas, hydrogen, ammonia, and methanol, along with offshore solutions. These alternatives offer potential cost reductions and long-term supply chain stability through enhanced energy efficiency. This shift in energy resources also influences global economic power dynamics and trade routes, as renewable energy sources like solar, wind, and hydrogen become valuable commodities. Developing nations, rich in renewables, are not only meeting domestic energy needs but also exporting surplus green energy.

Facts

- The use of hydrogen and ammonia is expected to increase from 0.1% in 2021 to 2.2% by 2030 [193]. However, to achieve zero emissions by 2050, these fuels should account for 30% of maritime fuel [194].
- The OECD forecasts maritime trade volumes to triple by 2050, implying greater energy source demand [195].
- The Paris Climate Accord declares that the Maritime Organisation will halve GHG emissions by 2050. To meet the IMO's current 2050 emission targets, it is estimated that up to 1.9T USD needs to be invested in alternative resources. Here, the need for investment is largely in energy and fuel production - approximately 87% of total investment [196].
- Global installed offshore wind capacity is expected to reach 630 GW by 2050. This implies new infrastructure development and transportation of energy sources [193].

Key Drivers

- Technological investments in these alternative resources are expected to be driven by stricter environmental regulations, such as the Paris Climate Accord, and financial penalties, including carbon taxing [197].
- Companies are realizing financial opportunities by diversifying their energy sources. These opportunities include cost reduction, greater planning stability, ship design changes, and enhancing the longevity of ships [198].
- Naturally, countries have access to different resources to supply new energy sources, which is a key driver for emerging trading routes and power distribution. For example, China's economic power is likely to further increase, as the country accounts for 30% of global ammonia production, and investments in this fuel are expanding [199].
- The projected increase in global trade demand and manufacturing sector growth implies an increased need for available energy sources that fuel the trade.

Challenges

- Alternative energy sources require heavy infrastructure investment and changes to an undeveloped supply chain. New supply partnerships will have to be made and fleets will have to adapt their designs.
- To date, there is an insufficient supply of resources needed for implementing alternative energies. Along with high costs, that imposes uncertainty in new ship design, as current vessels and fleets are aging and require replacements soon. That said, this deployment is challenged by the current state of the resources.
- Transportation of energy, including coordination of new offshore (wind) facilities, will be necessary to facilitate these changes.

Impact on the Future of Maritime Shipping

Fuel is essential for maritime shipping, impacting competitiveness and profitability. Fluctuations in carbon-based fuel prices require companies to rethink their fuel sources and adapt to changing economic partnerships and trade routes. Sustainable alternatives promise increased energy supply and supply chain stability. Climate change pressures make sustainability a necessary industry investment.

RISING POLITICAL TENSIONS

Turbulent Tides: How International Disputes Disrupt Maritime Business

With the recent increase in international tensions, maritime businesses have been dealing with significant uncertainty. With Russia's war on Ukraine and escalating US-China rivalries affecting both trade and tech, the globalization trend has become stagnant in recent years. These upheavals, which have their roots in territorial disputes, power shifts, and ideological differences, are further intertwined with economic and environmental challenges, casting a shadow over the maritime sector.

Facts

- In 2022, global tensions rose as Russia invaded Ukraine, with other conflicts in Ethiopia and Yemen, and crises in Afghanistan and Myanmar among others, contributing to a 96% uptick in global conflict deaths. Cumulatively, more than 238,000 people died in global conflicts last year [200].
- The Bank of England estimated that the trade policy uncertainty caused by the US-China trade war and Brexit reduced global GDP by around 0.8% in 2019 [201].
- The number of trade restrictions imposed yearly has risen. From 292 trade restrictions imposed in 2010, with the number hovering around 300-500 until 2017, it has risen to almost 3,000 restrictions imposed in 2022 [202].
- The European Central Bank reported that by 2017, more than 50% of exports from the Group of Twenty (G20) countries were subject to harmful trade measures, up from 20% in 2009 [203].

Key Drivers

- The Covid-19 pandemic has led to a rise in both intra- and inter-country economic inequalities, driving support for isolationist arguments and populist political figures. This is linked to a higher probability of armed conflict [204].
- Climate change is linked to an increase in conflict. According to a 2017 International Growth Centre study, a one standard deviation increase in temperature results in a 10.8% average increase in conflict incidents and a 16.2% average increase in the violent crime rate [205].
- Globally, polarization is on the rise. According to Pew Research, 65% of people surveyed across most developed nations reported increasingly strong or very strong disagreements between supporters of different political parties in their countries [206].
- A slowdown in economic growth and increased sovereign debt levels increase the probability of armed conflict [207].

Challenges

- Humanitarian and security crises such as famine due to disrupted logistics pose urgent threats to human lives and require fast and effective government responses.
- Emerging and transnational issues such as climate change, cyberattacks, or pandemics necessitate increased levels of cooperation and coordination between nation-states.
- Lack of political will and mutual trust among the conflicting parties or the international community can hinder the negotiation, implementation, or monitoring of peace agreements or resolutions [208, 209].
- Choosing an energy source often means indirectly supporting the political systems of countries with abundant resources for that fuel.

Impact on the Future of Maritime Shipping

International trade, driven by emerging trade alliances such as that of Brazil, Russia, India, China, and South Africa (BRICS), is becoming more compartmentalized, with outsized intra-alliance trade compared to inter-alliance trade [210]. This trend entails higher costs and risks in the shipping sector due to disruptions in logistics [211]. Additionally, industries must adapt to longer distances and transit times due to rerouting, congestion, or delays caused by conflict zones, sanctions, or unpredictable security threats [212, 213]. Global maritime shipping also faces increased physical and legal damages resulting from piracy, armed robbery, sabotage, and the seizure or detention of ships, crew, or cargo by both state and non-state actors [213].

SHIFTING FINANCIAL LANDSCAPE

Emphasis on Green Financing and De-Risking Investments

A decade after the 2008 financial crisis, banks and financial institutions persist in risk reduction and exposure containment efforts [214]. The financial landscape is further shaped by heightened regulatory demands regarding credit prerequisites and the pursuit of ambitious carbon reduction goals. Consequently, industries find themselves requiring substantial capital investment. In response, novel business and financing models are emerging to cater to the demand for innovative technologies [214].

Facts

- The financing structure in the shipping industry is changing. Traditionally funded by bank loans, the industry is now turning to alternative funding sources, such as leasing, private equity, public markets, and private investors [215].
- As ESG investments tend to outperform non-ESG investments [216], most retail investors are integrating ESG into their investment decisions, and corporates are following their lead [217]. Investments in ESG have experienced almost a twofold increase since 2016 and are projected to exceed 50 trillion USD by 2025 [218].
- The IMO has set a 50% carbon reduction target by 2050, which will require 214.5B USD capital investment for ships alone [219].

Key Drivers

- An increasing number of investors are showing a preference for ESG investment, as demonstrated by the Poseidon Principles [220]. This requires ship operators to engage in transparent reporting.
- Following the 2008 financial crisis, regulations on capital requirements and investment risk evaluation have increased the cost of capital allocation. Specifically, Basel IV introduces additional capital requirements for the shipping industry. It further increases the interest rates of loans and reduces the willingness of banks to invest in the risky shipping industry [221].
- The growing number of fleets and the need for advanced technology to decarbonize the industry naturally raise capital requirements and investment demand [221].

Challenges

- Despite an urgent call for decarbonizing the shipping industry, neither ship owners nor the financial market are willing to pay the premium (upfront cost) associated with innovative technologies and projects [222].
- There is a risk of greenwashing and misalignment that undermine the credibility and effectiveness of ESG-related products and providers [223].

Impact on the Future of Maritime Shipping

New methods of financing are emerging within the shipping industry, particularly for innovative technologies needed to comply with environmental regulations. This evolution could lead to a shift toward a pay-per-use model for technology providers [224], similar to the relationships seen between engine Original Equipment Manufacturers (OEMs) and airline operators. Consequently, financing activities may transition from ship operators to potential new participants in the shipping sector, namely technology providers from both established companies and startups. With the introduction of private equity and alternative funding sources, the industry might witness increased transparency, as these investors anticipate higher Return on Investment (ROI) [225]. The rising prominence of ESG investing is increasing the pressure and incentives for shipping companies to reduce GHG emissions and adopt cleaner fuels and technologies [225, 226].

BUSINESS MODEL TRENDS

INFLUENCING THE FUTURE OF MARITIME SHIPPING

Digital Platforms and Services
Emission-based Pricing
Data Monetization
Vertical Integration
Deep Sea Mining

Robert Richarz 
Laura Stotko 
Lena Reißiger 
Michal Cherczynski 
Janik Sauerbier 

BUSINESS MODEL TRENDS

Influencing the Future of Maritime Shipping

The maritime shipping industry is the backbone of global trade, facilitating the flow of goods across continents and oceans. Characterized by a complex and multifaceted environment, the maritime industry is underpinned by various business models that dictate how shipping companies generate revenue, interact with customers, and navigate regulatory waters. Each segment has unique financial dynamics, market demands, and operational requirements – from container shipping and bulk cargo transport to tanker operations and specialized services, such as ice-breaking or salvage. Furthermore, these business models are continuously evolving, shaped by technological innovations, regulatory shifts, and global economic trends. These can be further categorized into five key trends.

The first trend is Data Monetization, made possible by the digitization of operations. Shipping companies are generating more data points that can be monetized, increasing their value. Tightening emission standards and supply-chain resilience are two key drivers that have emerged. Companies can significantly reduce emissions by using data to optimize routes and save fuel. Additionally, data for supply chains can increase reliability, reduce costs, and lead to new digital products and services.

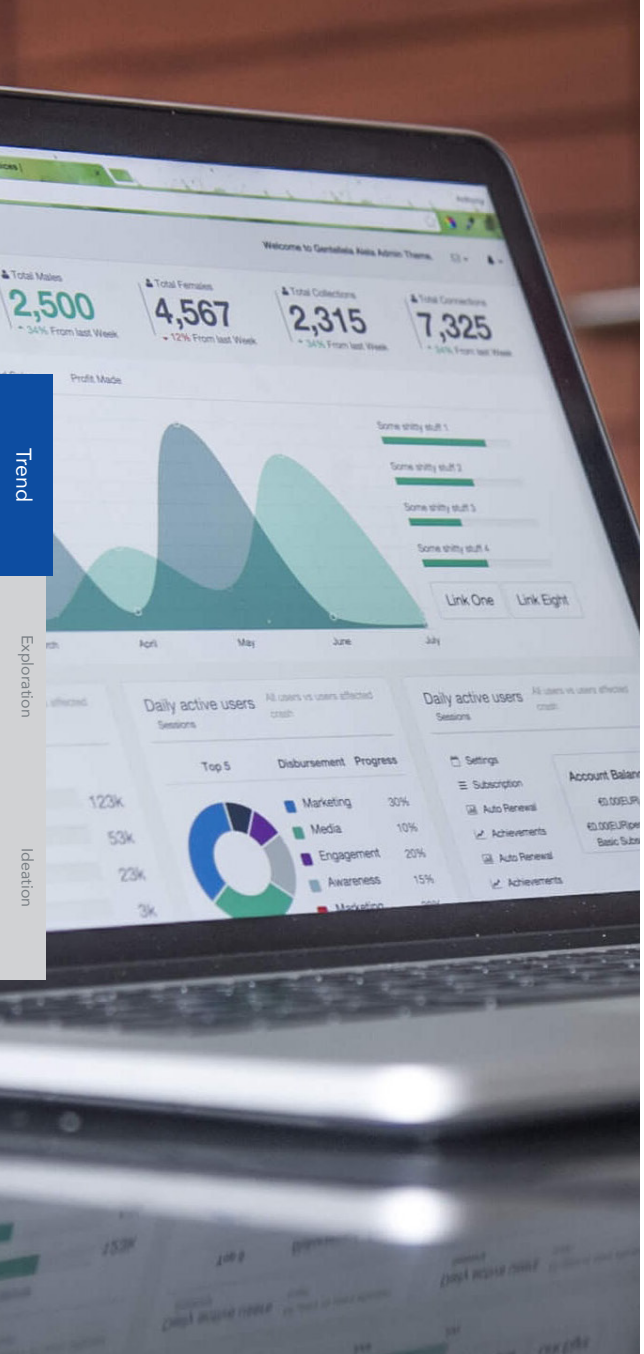
Digital Platforms and Services mark the second trend as shipping companies transition to digitized solutions. These platforms address maritime needs like digital document verification, maintenance, fuel optimization, regulatory compliance, and vessel tracking to boost operational efficiency and market accessibility. Increasingly, stakeholders are forming strategic partnerships and exchanging data, thereby transforming the industry and strengthening supply chain resilience.

Another significant transformation in the maritime shipping industry is Emission-based Pricing, which is becoming more prevalent as the industry shifts towards more sustainable practices. Companies that offer low- or zero-emission options may gain a competitive edge in the market and fulfill rising demand. The sector faces both a challenge and an opportunity as the risk of tighter regulations and emission-free shipping demand increases.

The fourth trend is Vertical Integration. It has become a promising strategy for achieving supply chain resilience in the maritime shipping industry. Covid-19 has exposed weaknesses in global supply chains, emphasizing the need for greater resilience. Vertical integration will likely play a critical role in the future of international trade.

Deep-sea Mining is the final trend, as it can unlock new natural resource reserves and pave the way for innovative business models in the shipping industry. With efficiently transmitting electricity from renewable sources being a huge upcoming challenge, the demand for batteries and other storage technologies will increase significantly. They require rare earths e.g., scandium, nickel, cobalt, and lithium, which are already in short supply. Deep-sea mining could close this gap.

A deep understanding of these models is crucial for stakeholders within the maritime sphere and anyone involved in international trade, logistics, and global supply chain management.



DIGITAL PLATFORMS AND SERVICES

Unlocking Digital Maritime Collaboration to Enhance Efficiency in the Industry

The maritime shipping industry is undergoing a radical shift catalyzed by digitizing services and introducing digital platforms. Service-based business models focus on delivering specific solutions to maritime stakeholders, catering to various needs, including digital document handovers and verification, maintenance and repair services, fuel optimization, regulatory compliance, vessel tracking, and environmental services. These models offer specialized expertise and support to enhance operational efficiency by accelerating cargo handling and reducing port congestion. A broad spectrum of maritime industry stakeholders, such as shipping companies, ports, and logistics providers are increasingly forming strategic partnerships and exchanging data to enable these collaborative services. At the same time, digital platforms increase accessibility and transparency, enabling shippers – particularly those of small to medium scale – to more readily avail shipping services, thereby democratizing access and stimulating industry competition. This democratization can reduce costs and augment the caliber of customer service. Digital services and platforms fundamentally reshape the maritime shipping landscape as stakeholders become more interconnected, supply chain resilience is fortified, and the industry becomes more agile, responsive, and cost-effective.

Facts

- Digitalizing the bill of lading, which accounts for 10-30% of trade documentation costs, could unlock more than 15.5B USD in direct benefit to the shipping ecosystem and up to 40B USD in increased trade [227].
- The market for maritime digital products is predicted to grow to 345B USD by 2030 [228].
- The Global Shipping Business Network (GSBN), a collaboration of major shipping lines, aims to digitize and streamline the industry's document exchange [229].

Key Drivers

- The market entry of start-ups focusing on digital services pushes the entire industry's efforts to innovate by increasing competition [230].
- The customer demand for holistic and reliant supply management systems calls for digital platform solutions that enable them to compare and book offers, monitor shipments, and implement this data into their operations [230].
- Digital services offer value-added services, including real-time tracking, secure communication, and accelerated cargo handling, that meet the demand to increase efficiency in operations further [231].

Challenges

- International shipping and logistics are subject to many regulations that vary by country. Ensuring compliance with customs, trade regulations, and other local laws can be complex and ever-changing. Non-compliance can lead to delays, fines, or even legal actions [232].
- Diverse processes and systems across the industry hinder seamless collaboration. Achieving standardization and interoperability is a significant challenge [233].
- Platforms usually rely on external stakeholders, including carriers, warehouses, and customs officials. Disruptions or inefficiencies in these external entities can impact the service delivery [230].

Impact on the Future of Maritime Technology

The maritime shipping industry is transforming significantly due to digital platforms and services. These innovations foster collaboration, enhance efficiency, and promote growth. They address needs such as digital document verification, maintenance, and vessel tracking, streamlining operations, and improving safety. The potential benefits are immense, with increased trade prospects of up to 40B USD. Platforms, such as the GBSN, are digitizing processes, but challenges such as cross-border regulations and data security remain. Despite these hurdles, it is evident that digital services are revolutionizing maritime shipping, enhancing its connectivity and resilience.

EMISSION-BASED PRICING

How to Win in a Net-Zero World

The maritime shipping industry faces a more sustainable future, leading to more emission-based pricing. This trend links shipping costs directly to a vessel's carbon footprint. As climate change awareness grows and companies race to meet net-zero targets, sustainable shipping is not just an ecological necessity but a market differentiator. Firms that can offer low or zero-emission options may not only fulfill rising demand but also gain a competitive edge in the market [234]. The inertia of the industry and the fear of "betting on the wrong horse" regarding the fuel of the future presents a unique chance: Most players will not be able to adapt quickly when market dynamics change drastically in the future, and governments enforce even tighter regulations. The risk of a domino effect towards tight regulation and emission-free shipping demand is high in the near future and might cause radical changes in the industry.

Facts

- A third of the world's 200 largest companies by revenue made public commitments to achieve net zero by 2050. The trend continues to accelerate, and companies develop more and more tangible action plans [235].
- The Boston Consulting Group (BCG) surveyed 125 large companies from various industries and geographies that ship cargo by sea, and 82% are willing to pay a premium for emission-free shipping. The willingness to pay and sense of urgency is increasing fast [15].
- Stringent regulations from IMO require emission reductions. The international shipping industry shall reduce its emissions compared to 2008 by 20-30% until 2030, achieving net zero in 2050 [236].

Key Drivers

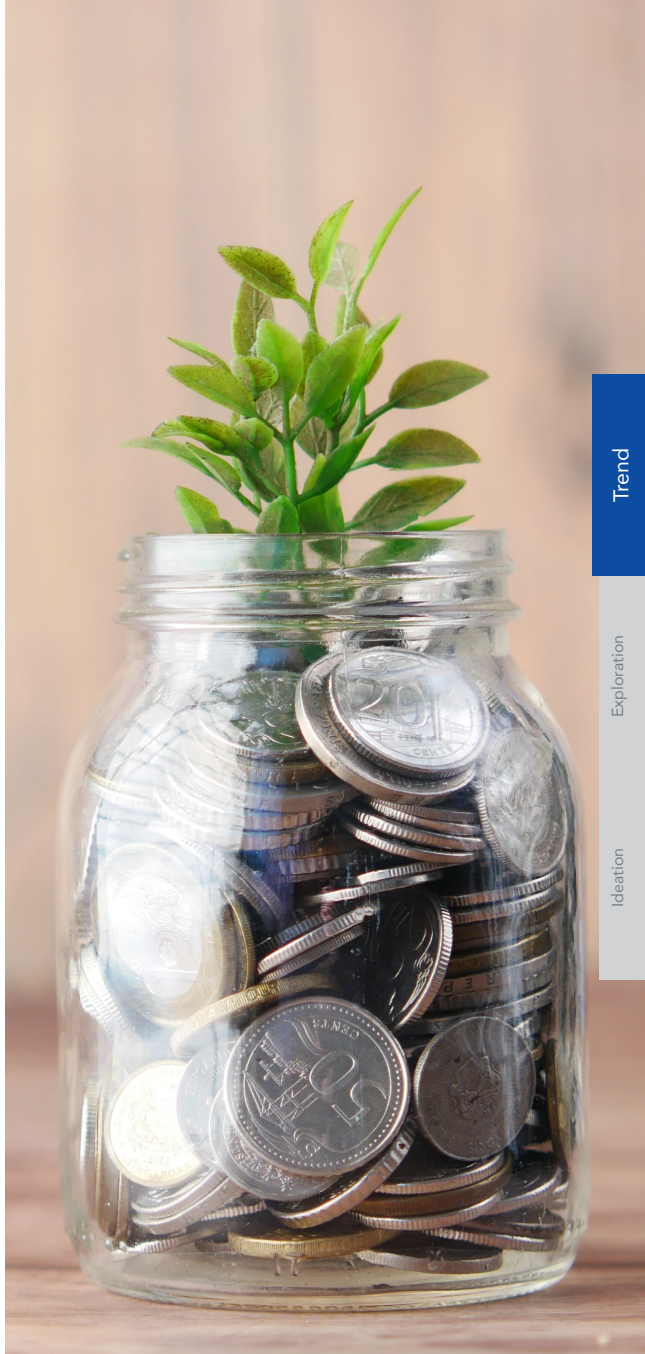
- Environmentally aware consumers and companies seek greener shipping options. To meet this demand, shipping companies offer low-emission and offsetting options.
- To comply with emission standards, shipping companies must adopt low-emission vessels due to strict international and regional regulations, such as IMO's sulfur emissions limit and upcoming carbon reduction mandates [236].
- The shift to a sustainable future impacts investments, elevating the importance of ESG criteria for investors. ESG investments surged by 68% from 2014 to 2019 [237].
- The EU Taxonomy establishes cross-industry classification, promoting sustainable activities and mandating transparency. Ships above 5,000GT already have to report annual fuel consumption and CO_2 emissions [238].

Challenges

- Emission-free fuels and infrastructure for vessels are very limited. Many technologies are still in development, requiring high upfront investments [239].
- Investments in low-emission technologies and ships can put early adopters at a disadvantage if their prices are higher than competitors not offering sustainable options. This leads to increased fear in the market [240].
- The financial sector still needs to work on investing in green technologies due to the risks associated with new technologies. Investments in developing countries increase slowly [240].

Impact on the Future of Maritime Shipping

Over the next 20 years, emission-based pricing will revolutionize the maritime shipping industry in several ways. First, the necessity of shifting towards cleaner technologies will drive investments in environmentally-friendly technologies. Second, this pricing model will offer competitive advantages, benefiting early adopters as global emissions standards tighten. Third, sustainability will become a market differentiator, creating customer loyalty and higher revenues for companies leading the green transition. The long lifespan of maritime assets makes rapid change challenging but highlights a golden opportunity: those who adapt quickly will carve a significant competitive edge. In a sector often slow to evolve, emission-based pricing will become more than a trend – it will be a critical factor in shaping the industry's sustainable future and global competitiveness.



DATA MONETIZATION

Stakeholders from the Shipping Industry Harness Data to Increase Efficiency and Revenue

The shipping industry has recently begun embracing digital transformation, accumulating a growing amount of data, enabling businesses to optimize internal processes and explore new revenue streams. This is largely due to three reasons. First, supply chain resilience is a demand that customers are increasingly calling for. It requires higher efficiency and better predictability from the shipping industry. This matter has picked and gained particular prominence following disruptions caused by the Covid-19 pandemic. Secondly, tightening climate regulations plays a significant role by making inefficiency very expensive, especially concerning the inefficient use of fossil fuels. Thirdly, there is a noticeable increase in companies offering digital services and products to the shipping industry and their customers. These services heavily rely on data quality and quantity, opening up new revenue streams for stakeholders wanting to sell their data. The rapid advancement of technologies, such as Artificial Intelligence (AI), Internet of Things (IoT), and Blockchain, further amplifies these trends. When monetizing the data, there are different approaches in the industry. While more prominent companies typically do it internally, smaller companies more often cooperate with technology companies to leverage and monetize their data. This can range from optimizing portfolios by assessing risk and enhancing commercial decisions to operating vessels more efficiently.

Facts

- The data economy will account for 6% of the EU GDP by 2025, reaching 829B EUR [241].
- The market size for maritime information is currently at 1.8B USD and will grow at a CAGR of 9% over the next ten years [242].
- The market size for route optimization software is expected to grow from 3.52B USD in 2023 to 5.45B USD by 2028 at a CAGR of 9.16% (2023-2028) [243].

Key Drivers

- Leveraging data analytics enhances operational efficiency and reduces harmful emissions. This dual benefit allows companies to realize financial gains while promoting a sustainable environmental footprint [231, 244].
- The continuous digitalization in the industry, aided by widespread sensor usage, results in vast digital data. This abundance of data facilitates the application of predictive AI models and analytics [245].
- In the face of just-in-time production and intricate supply chains, resilience becomes paramount. The need for a robust supply chain is closely tied to data gathering and exchange, with customers recognizing its competitive advantage in their operations [246].

Challenges

- Cybersecurity risks pose a significant challenge for businesses that rely on data-driven processes [155].
- Selling the data outside the organization is challenging due to the legislative pressure on data privacy [247].
- The slow-moving shipping industry and long life cycles of ships are barriers to gathering and processing data.
- Industry fragmentation makes creating a unified data platform challenging, with interoperability still being a significant issue [248].

Impact on the Future of Maritime Shipping

A burgeoning market for maritime data is emerging. Currently, the dominant data type for sale includes information about ship routes and orders. However, data on emissions, meteorological and oceanic conditions, vessel operations, and port activities will become increasingly significant. Various forms of data monetization will benefit maritime entities by allowing for optimized fuel consumption, more efficient routing, and smoother port operations, among others. However, this data can also have advantages for external stakeholders such as the producers of shipped goods, marketing agencies, insurance companies, governments, and other supply chain segments.

VERTICAL INTEGRATION

Improving Resilience in Maritime Shipping

Covid-19 has shown weaknesses in the global supply chains, highlighting the need for more resilience. Vertical integration is a strategic approach for reinforcing maritime logistics and achieving stability across the supply chain. By integrating distinct supply chain stages under a single administrative entity, shipping companies can respond to contingencies more efficiently and comprehensively oversee the end-to-end shipping process. Similarly, shipping companies can expand their operations to fuel sourcing. Floating ammonia production has been identified as a promising solution for integrating the fuel source in the future. Vertical integration and floating ammonia production are promising strategies for achieving supply chain resilience in the maritime shipping industry, and they will likely play a critical role in shaping the future of global trade.

Facts

- In 2016, Maersk started moving from being a container shipping giant to an integrated logistics provider, investing in air and land services [249].
- CMA CGM, another shipping giant, expanded its integrated logistics capabilities by acquiring CEVA Logistics in 2019 for approximately 1.65B USD. This allowed the company to offer more comprehensive logistics services beyond sea transport [249].
- An industrial-scale concept for a floating production unit to produce green ammonia has secured Approval in Principle from DNV, a maritime classification and services provider, affirming the technical feasibility of the design [250].

Key Drivers

- Supply chain resilience enables firms to prepare for, effectively cope with, and recover from probable disruptions caused by routine or non-routine events. The companies became especially mindful after the disruptions caused by the Covid-19 pandemic.
- High fixed costs, inelastic limits on capacity in the short run, and rigid structural interdependence between constituent activities within a plant encourage integration with shipping.
- Economies of scale and scope drive vertical integration in the maritime industry, allowing companies to achieve cost efficiencies and operational collaboration by integrating various supply chain functions and activities.

Challenges

- By integrating vertically, a company may become too reliant on its resources and capabilities [251]. This could limit its ability to respond to changes in the market or take advantage of new opportunities.
- The efficient scale of operation can vary between adjacent stages, leading to challenges. One way to address this is by opening up the market. Another approach is to take on multi-plant operations. However, these solutions come with drawbacks [252].
- Disposing the unused joint products in maritime shipping profitably can be problematic. Integrating them into activities that utilize the by-products can result in biodiversity issues. Hiring shipping services from an independent line may be beneficial to avoid such problems.

Impact on the Future of Maritime Shipping

By uniting different supply chain stages under a single administrative entity, shipping companies can respond to contingencies more efficiently and comprehensively oversee the end-to-end shipping process. Moreover, vertical integration can facilitate the implementation of floating ammonia production, contributing to a more resilient and sustainable maritime supply chain. As the industry faces a lot of uncertainty, adopting such strategies will play a significant role in shaping the future of global trade and ensuring the continued success of the maritime shipping industry.

DEEP SEA MINING

Innovative Business Models in the Shipping Industry Amid the Rise of Deep Sea Mining

One of the most pressing concerns of our time is where electricity will come from in 2050. While solar and wind power show promise, the challenge lies in efficiently transmitting electricity from these renewable sources, often far from our industrial centers. Batteries and storage technologies are essential but rely on specialized materials such as nickel and cobalt, which are already in short supply and expected to see increased demand in the coming years. Deep-sea mining can unlock new reserves of essential materials, but it needs infrastructure development. This is paving the way for new and innovative business models in the shipping industry. Collaborative ventures, such as joint ventures, provide opportunities for the shipping industry to embrace the new era of energy supply. Moreover, tailored solutions for vessel leasing, transportation logistics, port management, and research and development are poised to diversify existing business models.

Facts

- A substantial portion of these rare earth elements lies beneath the sea, at depths of 2,000 to 6,000m, and accessible only through deep-sea mining [253].
- The ISA has granted 31 exploration contracts since 2001, including 19 for manganese nodules in 75,000km² areas each, seven for massive sulfides, and five for polymetallic crusts on seamounts in the Northwest Pacific, covering 3,000km² each [254].
- The growing global demand for minerals, such as cobalt, nickel, silver, manganese, copper, specialty metals, and rare earth metals, is largely fueled by their indispensable roles in high-tech industries and renewable energy solutions. This surging demand creates a profitable market for deep-sea mining [254].

Key Drivers

- Currently, the production of rare earth is focused on a few big players. Almost half of the rare earth materials are sourced from China [255]. Due to growing global uncertainties, such as the conflict in Ukraine, more industries and nations are seeking greater self-sufficiency in acquiring rare-earth elements.
- Advanced technologies, such as remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and specialized mining equipment, have made deep-sea mining more feasible and efficient. Shipping companies are providing related services.
- Shipping companies diversify revenue streams by expanding into green technologies and deep-sea mining, capitalizing on their maritime expertise in new ways [256].

Challenges

- Compliance with deep-sea mining regulations can be challenging due to the many international, national, and regional rules that shipping companies must navigate [257].
- Deep-sea mining can have significant ecological impacts, including habitat destruction and disturbances to marine ecosystems. The industry should minimize these impacts and comply with strict environmental regulations [258].
- The deep-sea mining sector is becoming increasingly competitive as more players enter the industry. Shipping companies may need to differentiate their services to secure contracts with mining companies [259].
- With resource availability changing, shipping companies should consider long-term sustainability – especially as deep-sea mining may deplete finite resources.

Impact on the Future of Maritime Shipping

Deep-sea mining presents two significant challenges: regulations and environmental impact. Nevertheless, the technology is ready, and the demand for rare-earth elements and self-sufficiency makes it highly attractive. The shipping industry is well-positioned to provide specialized research, extraction, and transportation solutions. This presents many potential business models, but whether the shipping industry will seize this opportunity and drive the transformation is yet to be determined.

EXPLORATION

In the upcoming chapter, the outcomes of the process for validating market hypotheses and problem statements are explored. This phase primarily revolved around the discovery of white spaces and opportunity areas in the established sector of Maritime Shipping. Through the clustering of the topic, findings are distilled into five key opportunity spaces, and the most critical problems and opportunities within the chosen domain are identified. The exploration phase placed a priority on the testing and re-evaluation of hypotheses with expert insights, alongside an examination of the existing landscape to pinpoint key market players.

WORKFORCE EMPOWERMENT

OVERCOMING WORKFORCE CHALLENGES IN THE MARITIME INDUSTRY

Language Barriers
Facing Workforce Shortages
Technology-Enabled Seafarer Training

Lena Reißinger 
Vincent Jansen 
Thomas Menzel 
Matteo Wohlrapp 

WORKFORCE EMPOWERMENT

Overcoming Workforce Challenges in the Maritime Industry

The maritime shipping industry operates with slim profit margins, emphasizing the need to unlock competitive advantages through efficiency gains. There is immense potential within the concept of workforce empowerment. Due to the Covid-19 pandemic, maritime shipping companies are grappling with the labor shortage they had anticipated, but its arrival has been earlier than expected. Projections indicate that this shortage will peak by 2026 [260]. Vessels are still in operation, but the industry remains on high alert. Three potential avenues to foster the talent of the future in an industry often known for its conservatism have been identified.

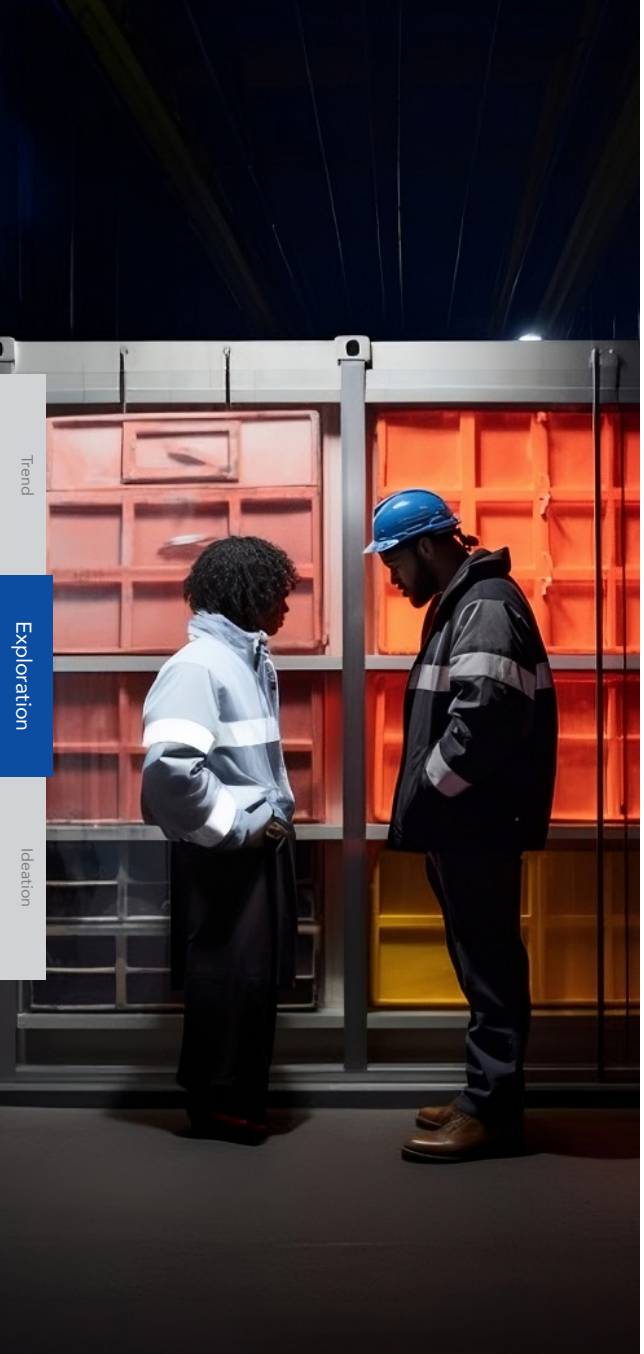
Tackling this issue starts with enhancing working conditions and making seafaring more attractive as an occupation. This helps address the labor shortage and gives shipping companies a substantial competitive edge, particularly those leading in this traditionally slow-moving and conservative environment. One promising approach is the introduction of corporate well-being programs with a focus on improving the mental health of seafarers.

Simultaneously, the demand for training, equipping, and empowering new workforces is growing. As a highly skilled workforce is notably lacking, retraining can address this while offering low-skilled workers the opportunity to move up. To facilitate this, Virtual Reality (VR) and Augmented Reality (AR) stand out as promising solutions for improving existing training processes, resulting in significant gains in training efficiency and quality.

Staffing a vessel involves working with individuals from diverse backgrounds. Crew members range from highly educated engineers to less skilled positions like deckhands. This diversity often leads to language barriers, as seafarers with academic backgrounds may have different language skills than those in supporting roles, typically recruited from low-wage countries in the global south. These language barriers, combined with stress and sleep deprivation, can pose significant safety risks at sea. Communication barriers alone account for 35% of all maritime accidents [261].

Consequently, addressing these language barriers, managing stress, providing comprehensive training, and attending to mental health issues is essential to ensure a safer and more efficient maritime supply chain.

In the highly competitive maritime shipping industry, seizing every opportunity is imperative. Workforce empowerment, previously given lower priority, can no longer be overlooked. With the looming labor shortage, a battle for talent has already begun. The question is which companies will emerge as leaders in this fiercely competitive new era.



LANGUAGE BARRIERS

A Root Cause for Accidents, Exclusion, and Discrimination

Safety is paramount within the shipping industry. With nearly 80% of the world's merchant ships operating with multilingual crews [265] who do not have English as their first language [266], language barriers have become a daily challenge. Effective communication is not only crucial onboard but also for ship-to-ship and ship-to-shore interactions. Communication deficiencies contribute to 35% of maritime accidents [266].

With English serving as the lingua franca, everyone involved in maritime operations must possess a comprehensive understanding of the essential terminology for safe navigation. In this high-stakes environment, there is little room for error. Meanwhile, ensuring that everybody involved in navigating the seas will be sufficient in English is an impossibility.

Consequently, there is a pressing need for technological advancements to not only aid in avoiding accidents but also to empower those involved in the maritime sector by circumventing English as a requirement and helping with integration on board. This need finds validation in the actions of the US Coast Guard, which is currently developing a handheld language translation device [267]. The solution lies in the form of AI-driven, real-time, embedded, and offline language translation.

> "Over the past few years, maritime safety has been impacted by communication problems due to language barriers [262]."
>
> Aarthi Suresh, Research Associate of Management Studies at Saveetha School of Engineering

Selected Players

duolingo, +Babbel, SPOT Learning, Timekettle, WAVERLY LABS

FACING WORKFORCE SHORTAGE

Attracting Talent Through Tailored Corporate Wellbeing Initiatives

Following the Covid-19 pandemic, the maritime shipping sector is confronted with a pressing labor shortage [265], which is anticipated to worsen in the coming years, especially among highly skilled individuals like engineers, officers, and captains [260]. A significant contributor to this scarcity is the waning attractiveness of seafaring as a profession [268].

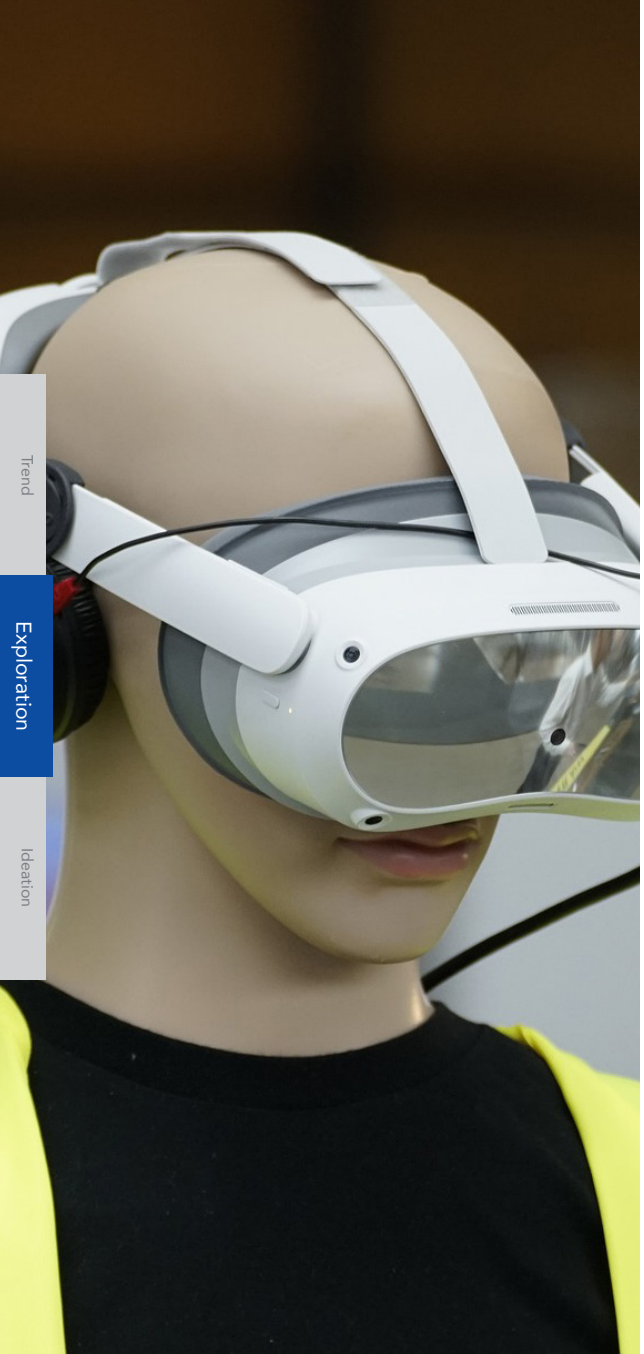
Companies must entice skilled individuals with compelling incentives in the competitive job market. While other sectors increasingly prioritize mental health awareness and witness a growing demand for corporate well-being programs, the maritime industry has yet to tailor solutions for its workforce [267]. Seafarers face a multitude of risk factors, including isolation, limited access to nutritious food, and scarce opportunities for exercise. So far, only a few specialized initiatives have addressed these pressing challenges.

Introducing a corporate well-being program designed explicitly for seafarers could yield numerous benefits. Firstly, it would enhance employee satisfaction, potentially fostering dedication and strengthening brand loyalty within the industry. Secondly, such a program would improve safety at sea, as fatigue is a significant source of errors and accidents, often exacerbated by risk factors such as isolation, unhealthy food, sleep deprivation, and missing routine [108]. Thirdly, it would elevate a company's reputation within the maritime community, bolstering its ability to attract top-tier talent in an increasingly competitive recruitment landscape.

> "The mental health and well-being of merchant navy seafarers and their families are of paramount importance. Acknowledging and addressing the pain points they face is crucial for creating a supportive environment [263]."
>
> Dr. Anamika Chawhan, Ph.D.at Indian Institute of Technology Bombay

Selected Players

Fooducate, ISWAN, URBAN SPORTS CLUB, meru health, Gympass, lyra, spring health, WELLNESS AT SEA



TECHNOLOGY-ENABLED SEAFARER TRAINING

E-Learning and VR Enable Quick and Effective Training of Maritime Personnel

The maritime industry is operationally intricate and hazardous, requiring extensive training for personnel to manage ships and orchestrate port operations. Traditional training methods often involve costly on-site simulations, classroom lessons, and apprenticeships, which are time-consuming and limited in their adaptability. In addition, these methods can be inadequate for complex or rare scenarios like oil spills or pirate attacks that demand quick and decisive action based on profound understanding [264].

E-learning methods, specifically VR, make it possible to teach expert knowledge to seafarers at scale while significantly improving task enjoyment, behavioral changes, and perceived learning [264]. VR also offers data-driven insights into performance, enabling continuous improvement and AI automation of dangerous tasks through learning from human interpretation.

With multiple large companies, including Apple, entering the AR and VR market, we are expected to see mass adoption of headsets and significant research progress in optimizing their experience and performance. This development is a golden opportunity for new companies to enter the market and sell VR- and AR-based training programs to large shipping companies, who can then decrease their costs, increase employees' learning rates, and mitigate safety risks.

> "VR technology can be used broadly with employees from developing countries who have a low level of technology literacy [264]."
>
> Guido Makransky, Professor in the Department of Psychology at the University of Copenhagen

Selected Players

seably, ARVR, OMS, Motive.io, ONELEARN GLOBAL, virsabi, OCEAN Technologies Group, EMERITUS, STRIVR

MULTIFUEL FUTURE

NAVIGATING THE COMPLEXITY OF COEXISTING FUELS IN DECARBONIZED SHIPPING

Commercial Green Fuel Production

Increasing Fuel Efficiency

Coordinating a Multifuel Future

Jiehua Wu 
Susanna Heidbrink 
Leon Sandner 
Pary Zadeh 
Michal Starý 

MULTIFUEL FUTURE

Navigating the Complexity of Coexisting Fuels in Decarbonized Shipping

Decarbonization is among the most critical and challenging topics facing the maritime shipping industry [269]. With emission regulations tightening and the IMO aiming for a net-zero industry by 2050, it is evident that there is a dire need for immediate action [270]. Fuel combustion is responsible for the vast majority of emissions in the sector, highlighting the need for ships to change their fuel sources to meet sustainability targets [271]. Although the industry agrees on this, a new fuel that dominates the market similarly to petroleum-based fuels is yet to emerge. The industry probably navigates towards a multifuel future – a world in which multiple fuels with different requirements and use cases coexist [272].

Currently, a variety of alternative shipping fuels are on the rise. These range from more immediate solutions like biofuels to LNG and hydrogen-based fuels like methanol and ammonia [1]. Each of these fuels comes with its own technical challenges and safety requirements. Shifting away from fossil fuels and moving towards a future where multiple fuels coexist requires massive infrastructural changes. While this obliges capital-intensive investments and economic measures, it also offers spaces for startups to innovate. When considering where startups have the greatest potential to add value in this multifuel future, three spaces have emerged: cheaper production methods, increased fuel efficiency, and facilitated collaboration.

Although technologies to produce alternative fuels exist, they have yet to be commercialized due to their high production costs. This especially holds true for fully green alternative fuels, which will be crucial for the industry to become carbon neutral in the long term. Beyond that, the shipping industry competes for green fuel with other industries, such as aviation and road transport [272]. This increases the importance of developing production methods for green fuels that are scalable in an economically viable way.

Increasing fuel efficiency can play a major role when considering additional ways to lower the adoption barrier of alternative fuels. This not only reduces the demand for fuel, which puts less pressure on suppliers, but it also lowers total fuel costs, thereby easing the financial burden of the transition. Further, increasing fuel efficiency is environmentally beneficial, as using less fossil fuels leads to decreased emissions [272].

The global and intertwined nature of the industry requires careful coordination among all shipping stakeholders. The need for this will drastically increase with the added layer of complexity that arises through the introduction of multiple fuels. A greater flow of information will be necessary going forward with the need for reliably sustainable fuels that can also be proven.

Transitioning to a multifuel future is imperative for the shipping industry to decarbonize. Although this movement is driven by local and global regulation, the financing of this shift remains a significant challenge.

COMMERCIAL GREEN FUEL PRODUCTION

Increasing Efficiency and Scalability of Green Fuel Production

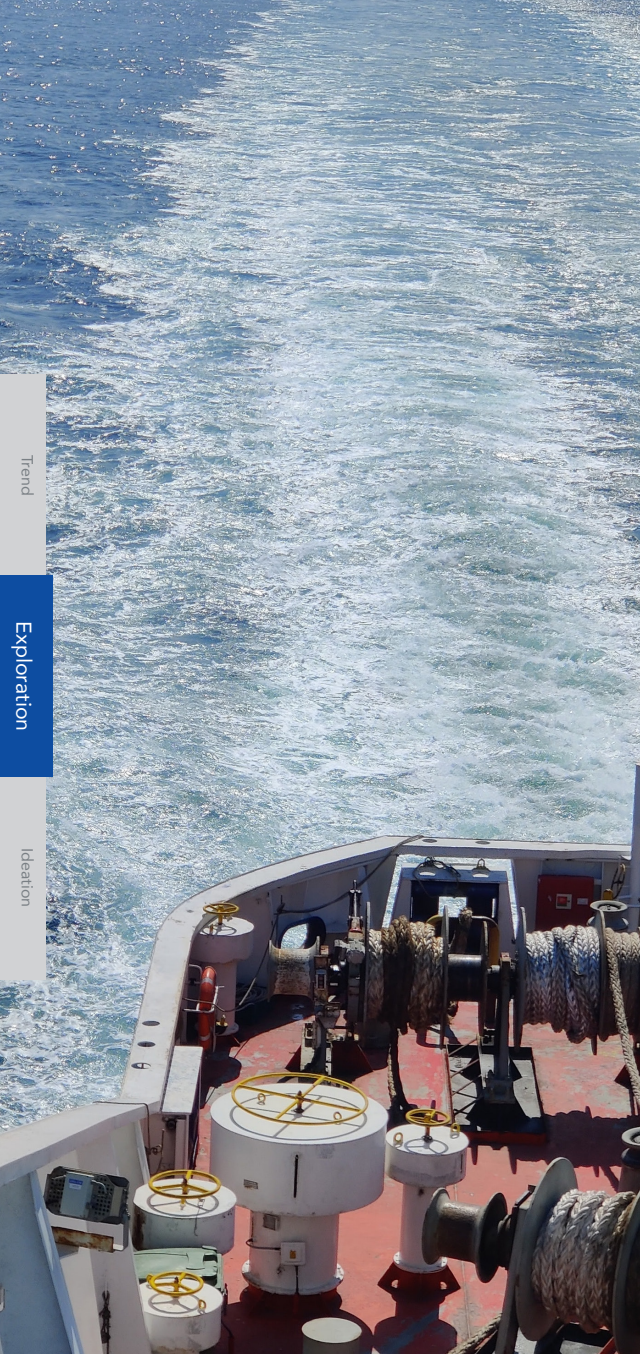
Green alternative fuel production methods almost always rely on renewable electricity [274]. Due to the high cost of renewable energy and the low efficiency of transferring this electricity into green fuel, for example, only 17% for ammonia [275], the cost of green fuel is high. Although offshoring production facilities may mitigate this cost, the commercial viability remains a challenge, especially when compared to cheaper fossil fuel alternatives [274]. Introducing carbon certificates to maritime shipping makes green fuels more attractive. Still, the price of one certificate would need to surpass 200 USD per tonne of CO_2 to make green fuel production profitable [273].

Nevertheless, as the typical lifetime of a ship is around 25 years, big companies are starting to launch ships powered by alternative fuel [276], thus creating a window of opportunity for innovation. Efficient and scalable production of green fuels is a crucial area to innovate in. However, complications arise from uncertainty about the winning fuel in the long-term future. Nevertheless, there are some shared factors. For instance, green hydrogen serves as the primary ingredient for the production of both green ammonia and methanol. [277]. As a result, solutions such as commercializing green hydrogen production will be relevant, independent of which green fuel eventually dominates the market.

> “There are a number of companies out there producing alternative fuels, and all of these technologies are more or less mature, but the cost for setting up these production facilities is enormously high [273].”
>
> Asset manager in the maritime shipping industry

Selected Players

Linde, ioort energy, Enapter, Ørsted, azolla HYDROGEN, AMOGY, NitroFix, Dynelectro, ELECTRIC HYDROGEN, Shell, ico dos, CARBON RECYCLING INTERNATIONAL, WASTEFUEL, Marine, CIRCULAR CARBON CHEMISTRY



INCREASING FUEL EFFICIENCY

Decreasing Costs Through Reduced Consumption

The shipping industry is gradually recognizing the importance of fuel efficiency for cost savings. To achieve this measures such as speed limits are being implemented to reduce fuel consumption for the same distance traveled [278]. However, the fuel inefficiency problem persists, leading to waste and emissions, for example, because bunker fuels are unnecessarily used to catch up for lost time after port queues [279]. Looking into the multifuel future, inefficient fuel use is gaining new importance due to the competitive disadvantage of using expensive alternative fuels [22]. Rethinking fuel use and thus reducing the cost of green fuel consumption can be done in many ways, e.g., through optimization and prediction software products, changes in ship design, and other forms of propulsion.

Increasing fuel efficiency is an excellent opportunity in maritime shipping due to its short- and long-term benefits. While heavy fuels remain at the forefront of the industry, consuming less fuel helps to lower emissions [280]. Simultaneously, increasing fuel efficiency facilitates the shift to green fuels, which are currently both scarce and expensive – two issues that can be mitigated through a reduced need for fuel [272].

> “When using some alternative fuels, such as hydrogen, energy density becomes a challenge – and using the same amount of fuel can require five times more space on the ship, which then becomes a tradeoff between utilizing the space for cargo or fuel [272].”
>
> Benjamin Weber, Associate Partner at McKinsey & Company

Selected Players

13 MARI, Movolytics, ULSTEIN, Marine Digital, Blended Fuel Solutions NZ, WÄRTSILÄ, ABB, B9 SHIPPING, DELTAMARIN, norsepower

COORDINATING A MULTIFUEL FUTURE

Enabling and Harmonizing Multifuel Shipping Operations

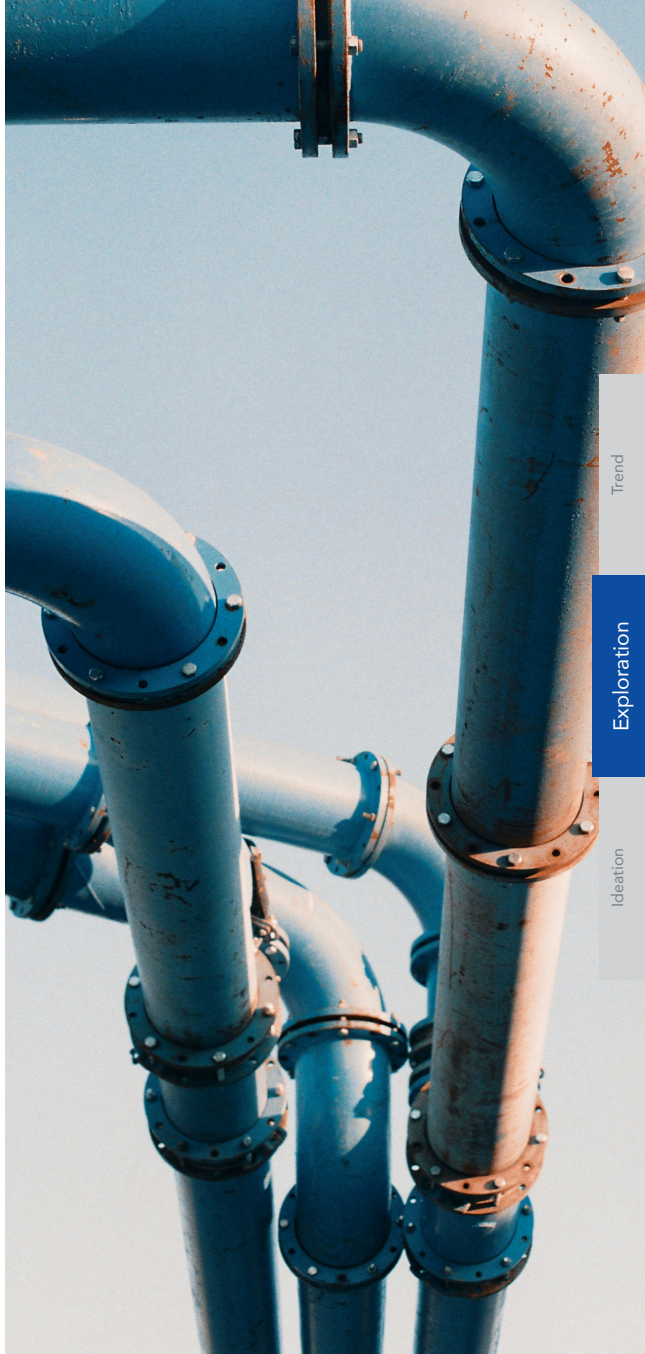
The shift to multiple alternative fuels significantly increases the complexity of operations and presents logistical challenges across the entire shipping value chain [281, 282]. Ship operators managing ships powered by different fuels will face a variety of operational procedures and need to consider fuel availability and emissions when planning routes. Fuel purity and green quality need to be assured [283]. Ports must adapt to this shift by providing diverse fuels, anticipating and meeting demand, and streamlining refueling processes to ensure timely and accurate fuel delivery. Consequently, crews will require specialized training tailored to their ship's specific fuel, which must be factored in when assembling and staffing crews.

Currently, maritime infrastructure is designed for fossil fuels, and most infrastructure is not ready to support the multifuel scenario. This presents a significant business opportunity to develop hardware and software systems that seamlessly integrate and consider all these factors in day-to-day operations [272]. As the industry grows and decarbonization efforts increase, the use of multiple fuels will become highly prevalent in the next decades [284]. At the moment, new solutions are needed to prevent operational inefficiencies and increased costs. Facilitating coordination is essential to achieve cost-effectiveness, fulfill regulatory obligations, and ensure safety. Failure to address these challenges will compromise the industry's sustainability efforts [285].

> "If you want to coordinate between all these different stakeholders who are also commercially competing, a digital solution can help with data exchange and planning, and also create transparency [272]."
>
> Benjamin Weber, Associate Partner at McKinsey & Company

Selected Players

ZERO44 · VESSELLINK · NAUTILUS LABS · FUELTRUST · ZERO NORTH · OILX · SHIPERGY · Integr8 Fuels



VESSEL DESIGN & LIFECYCLE

OPTIMIZING RESOURCE EFFICIENCY IN VESSEL MANUFACTURING AND MANAGEMENT

Maintenance
Vessel Design
Circular Economy

Robert Richarz 
Laura Stotko 
Michal Cherczynski 
Ulugbek Isroilov 
Anna Neumann 

VESSEL DESIGN & LIFECYCLE

Optimizing Resource Efficiency in Vessel Manufacturing and Management

The shipping industry, tradition-bound, has had few vessel lifecycle innovations. With stricter emission rule costs, innovation urgency is escalating. The industry first emphasized "easy-fix solutions" like optimized routing. Bigger efficiency gains now demand hardware changes and data-driven manufacturing innovations. With rising cost pressures, it's increasingly viable to invest in efficient vessel designs, retrofits, and maintenance in the upcoming decades. These chances offer potential for a revived industry aligned with global green goals, signifying a route to sustainable innovation.

Predictive maintenance is determined to optimize vessel use and minimize unplanned downtimes associated with financial losses of 2-5M USD per day a vessel is in the yard [54]. Since vessel inspection and maintenance are still being handled highly manually, with a lack of data collection and documentation throughout the process [286], it carries a lot of unrealized potential for digitization and automation. By incorporating IoT devices gathering data and identifying potential risks and frauds upfront, predictive maintenance can be enabled [287], resulting in tremendous cost savings. The limited availability of spare parts, especially for older vessel designs, often extending downtimes and raising costs [288], can be overcome by 3D printing. Further, introducing robotics to the maritime sector can redefine operational efficiency, safety, and compliance in maintenance processes [289].

Enhancing vessel design to improve fuel efficiency is an effective measure towards a Net Zero shipping industry. Due to stringent regulations, the maritime industry is under pressure to improve hydrodynamic efficiency and reduce carbon emissions. Historically, the focus was on speed rather than fuel efficiency, but new regulations have shifted priorities towards more efficient voyages, emphasizing operational measures, such as slow steaming [290]. Including shipping in ETS trading has made these hardware retrofits a more attractive financial option [291]. Stakeholders are exploring technical efficiency solutions, such as hull coating [292], air lubrication systems [293], and onboard carbon capture [294], which are nearing commercialization.

Lastly, shifting from a linear to a circular ship lifecycle, advancing material recycling processes [152], and introducing modularity [295] gains significance. Amid rising environmental concerns, the maritime sector is adopting circular economy principles. Companies are investing in efficient ship recycling, with certifications like ISO 14001 underscoring their commitment [296]. Modular structures enhance vessel longevity and resource optimization [297], while investments in modular marine electrification and propulsion systems further promote energy efficiency. By prioritizing these circular principles, companies differentiate themselves in the market and achieve cost savings and sustainability, benefiting both the industry and the environment.

MAINTENANCE

Automated Maintenance Enabled by IoT Devices and Robotics

Maintenance in the maritime industry is crucial to ensure the daily operability of vessels and to guarantee safety, compliance, environmental responsibility, and crew well-being.

Previously, companies often addressed maintenance problems to onboard ships urgently and without proper documentation [286]. Lacking a structured approach hinders monitoring machine performance, detecting potential faults upfront, and preventively maintaining the vessel [299]. As a result, the industry experiences unnecessary downtimes, resulting in financial losses of 2M to 5M USD per day per vessel [54]. The limited availability of spare parts for older vessel designs exacerbates this inefficiency [288].

Furthermore, ship inspection has become increasingly complex, especially for large vessels, making it challenging and time-consuming for inspectors [289]. A shortage of onboard engineers complicates maintenance efforts, as fewer crew members must manage extensive machinery [300].

There is an excellent opportunity to embrace IoT devices to collect real-time data for predictive maintenance, aiming to reduce breakdowns and associated repair costs [287]. Even though predictive maintenance solutions are already available, installing sensors to gather and utilize data effectively remains challenging [273]. Further, high-tech camera drones and AI-based image processing software can enhance risk detection [301]. Robots also have the potential to enable automated and even remote maintenance, taking over the often manual maintenance processes [289].

> “[Automation] is essential in Germany due to high labor costs and a shortage of skilled workers. For example, drone inspections can be automated by using a drone to take photos. However, achieving 100% efficiency requires automated data processing. [298].”

Martin Neuendorf, Senior Manager Strategic Business Development at HHLA Next

Selected Players

C3.ai, SIEMENS, FLUIX, Waygate Technologies, ALICIABOTS, FLYABILITY, DNV, thyssenkrupp, INCASS

VESSEL DESIGN

Increasing Fuel Efficiency by Enhancing Vessel Design

Bulk, container, and tanker vessel design is crucial for ensuring their hydrodynamic efficiency, speed, and stability. The maritime industry faces significant challenges in increasing fuel efficiency and decreasing GHG emissions. Especially since tightening regulations and emissions standards penalize non-compliance in a costly manner, the pressure to innovate is at a new peak.

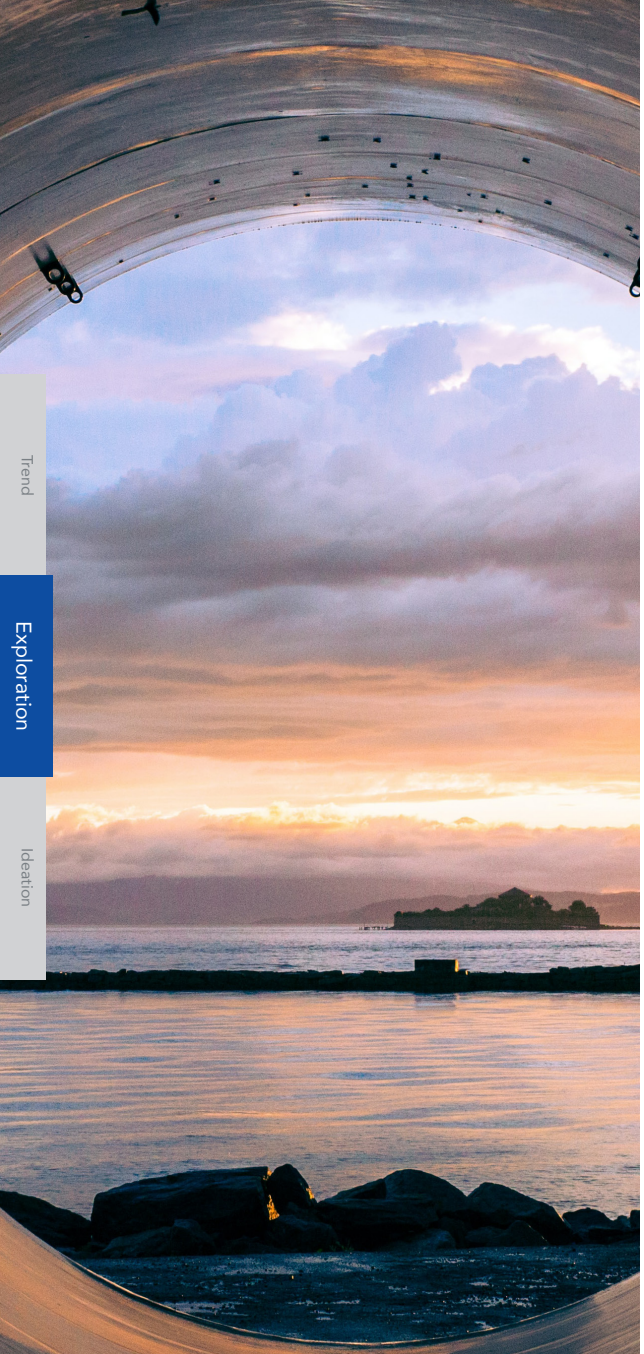
Previously, efficiency gains in fuel consumption did not play a significant role, as only minor economic improvements were achievable and often sacrificed speed. With new regulations, the financial pressure increased, leading to efforts toward more efficient voyages, still primarily focused on operational measures, such as slow steaming [290] and route optimization [302]. With the inclusion of shipping in ETS trading [291], the business case for looking into actual hardware retrofits becomes more viable.

Internal and external industry stakeholders benefit from this opportunity by identifying and tackling the different technical efficiency levers. Promising solutions, such as retrofitting the bow of an existing ship, can bring savings of up to 1.7M USD per year, amortizing the 1.25M USD [269] investment within the first months. At the same time, other additional solutions, such as hull coating [292], air lubrication systems [293], or onboard carbon capture [294], are being developed and are moving towards commercialization.

> “[It is] important is to make the vessel more efficient. We’ve seen Maersk being a bit more innovative than others in the past, and they claim that they have about 20% less [fuel] consumption on their new build compared to existing vessels, which is significant [273].”
>
> Asset manager in the maritime shipping industry

Selected Players

EverLoNG · Naval Architect · TRIBO BLEND · SEABOUND · WÄRTSILÄ · NEURAL CONCEPT · syroco · nl comp



CIRCULAR ECONOMY

Navigating the Circular Economy Wave in Maritime Shipping

As environmental concerns continue to grow, various industries are showing interest in circular economy principles. The maritime industry is no exception, as companies increasingly adopt a circular economy to reduce waste, optimize resources, and enhance sustainability.

Three critical elements of the circular economy are modularity [295], vessel design, and recycling [152]. Modular structures can be easily customized for various purposes, reducing waste, optimizing resources, and enhancing vessel longevity. Recycling retired vessel materials is another critical aspect of the circular economy [303], with technology and infrastructure investments making ship recycling more cost-effective and environmentally responsible. Certifications, such as ISO 14001 [296] for environmental management, indicate a company's commitment to circular practices. Modularity in vessel construction enhances efficiency and sustainability [297] while reducing construction costs. Some companies are investing in modular solutions for marine electrification and propulsion systems, making vessels more energy-efficient and environmentally friendly.

The circular economy principles of vessel design, modularity, and recycling are the building blocks of a sustainable maritime shipping industry. Companies prioritizing these will differentiate themselves in the market and enjoy a positive reputation, customer loyalty, and partnerships with like-minded organizations. Furthermore, embracing circular economy practices can lead to cost savings, increased competitiveness, and enhanced sustainability, creating a win-win situation for the industry and the planet.

> "[One] issue the industry has no clue about is a cradle-to-cradle approach. So, having the end of life of a vessel in mind when it's built in the first place [and knowing] how you recycle [or reuse] the resources on board [in the] most efficient and environmentally friendly way [273]."
>
> Asset manager in the maritime shipping industry

Selected Players

WÄRTSILÄ · ReFlow® · NORSEPOWER · DELTAMARIN · KNUD E. HANSEN · N·V·L LUERSSEN AUSTRALIA

PORT INNOVATION

TRANSFORMING PORTS THROUGH DIGITALIZATION AND AUTOMATION

Robotics and Automation at Port

Port Connectivity and Interoperability

Natural Disaster Prediction and Adaption

Aviral Shrivastava 
Janik Sauerbier 
Cheng-Ying Kuo 
Thomas Zebala 

PORT INNOVATION

Transforming Ports Through Digitalization and Automation

Port operations, vital for supply chain integrity, frequently do not receive the necessary level of attention. Disruptions like dock-worker strikes can lead to billion-dollar economic losses [304]. Amid strong global demand for shipping, port work generates favorable margins. On- and off-loading operations function efficiently with minimal human intervention to maneuver the vast amount of machinery. For example, as Martin Neuendorf at HHLA Next highlighted, the CTA (Container Terminal Altenwerder) Terminal in Hamburg boasts nearly 90% automation. However, the industry's innovation levels vary widely, from complete digitalization in some ports to others continuing to function with outdated methods.

Many ports and shipping operators still rely on traditional methods of communication, such as emails or phone calls. These practices hinder effective stakeholder management and communication, resulting in data leaks, such as shipment locations or documentation details. The inefficiencies and unpredictability of operations become even more evident when speaking to industry insiders. They describe the unreliability of the whole process.. For example, customers often do not know whether their shipment made it to the destination. Such operational uncertainty suggests that the industry lacks the drive to fix those common problems – and this is in times when technological breakthroughs occur daily.

Three areas where innovation can fundamentally improve current processes and operations stand out. The first area is robotics and automation. There is vast potential to streamline operations with technology. Automation, robotics, IoT, and drones are existing technologies with the potential to improve port operations. Through reducing human intervention, there is potential to significantly increase efficiency, reduce costs, improve safety, and enhance the predictability of workflows. DPWorld's statement about the "average delay of just over five days" emphasizes the dire need for such interventions [305]. The second area is port connectivity and interoperability. Here, many stakeholders in the industry grapple with non-standardized and manual processes, fragmented operations, and often frustrating stakeholder communication. Lastly, natural disaster prediction and adaptation are a third area of innovation potential. As ports are located at the seaside, it is highly impacted by the effects of climate change. Increasingly frequent weather extremes, such as droughts or floods and rising sea levels, lead to disruptions and operations downtime. While the industry is not yet experiencing the immediate threat of climate change, the writing is on the wall – ports must prepare for the inevitable environmental changes.

Port operations might appear efficient at a glance, but the industry still faces several challenges, such as workforce shortages and operational unpredictability. These difficulties need urgent attention and can be addressed by introducing different degrees of digitalization and automation. There is a pressing need for innovation, adaptation to emerging environmental norms, and a broader vision that encompasses the entire supply chain. The maritime industry is at a crossroads, with an urge to innovate or risk being left behind.

ROBOTICS AND AUTOMATION AT PORTS

Port Management's Robotic Revolution: Challenges and Opportunities in Labor-Intensive Tasks

In addition to being labor-intensive, port management is an industry that is coping with the continuously increasing irregularity of port traffic and fluctuations in labor demand [307]. This challenge has only been exacerbated by the Covid-19 pandemic, with container ships at many ports not having enough labor capacity to unload them and with the shortage of truck drivers to further transport the cargo [308]. Despite the given circumstances, many of the most critical port and harbor operations are still handled manually, which continues to confounds experts.

Take the example of hull cleaning, which is still performed by highly skilled divers in extremely dangerous, challenging, and tedious conditions [309]. Interestingly, this maintenance significantly affects fuel consumption, reducing fuel costs by up to 12% [289]. Another example is the risk crew members face when securing and releasing ships. Hereby, inadequate control of winch latches and the potential for getting entangled in lines can pose significant safety concerns [310]. This becomes even more challenging with larger ship sizes.

One possibility to tackle these issues could be robotic technology, such as drones to inspect cargo holds or underwater robotic vehicles to facilitate precise mooring.

> "[There is often a] shortage of experts that are needed for operations of current [port] infrastructure [298]."
>
> Martin Neuendorf, Senior Manager Strategic Business Development at HHLA Next

Selected Players

BLUE ROBOTICS ATLAS
CAVOTEC
SPHERIE
TRELLEBORG
ALICIABOTS
HHLA Sky
RANMARINE
MAVISOFT

PORT CONNECTIVITY AND INTEROPERABILITY

Navigating the Transition to a Smarter and More Efficient Port Ecosystem

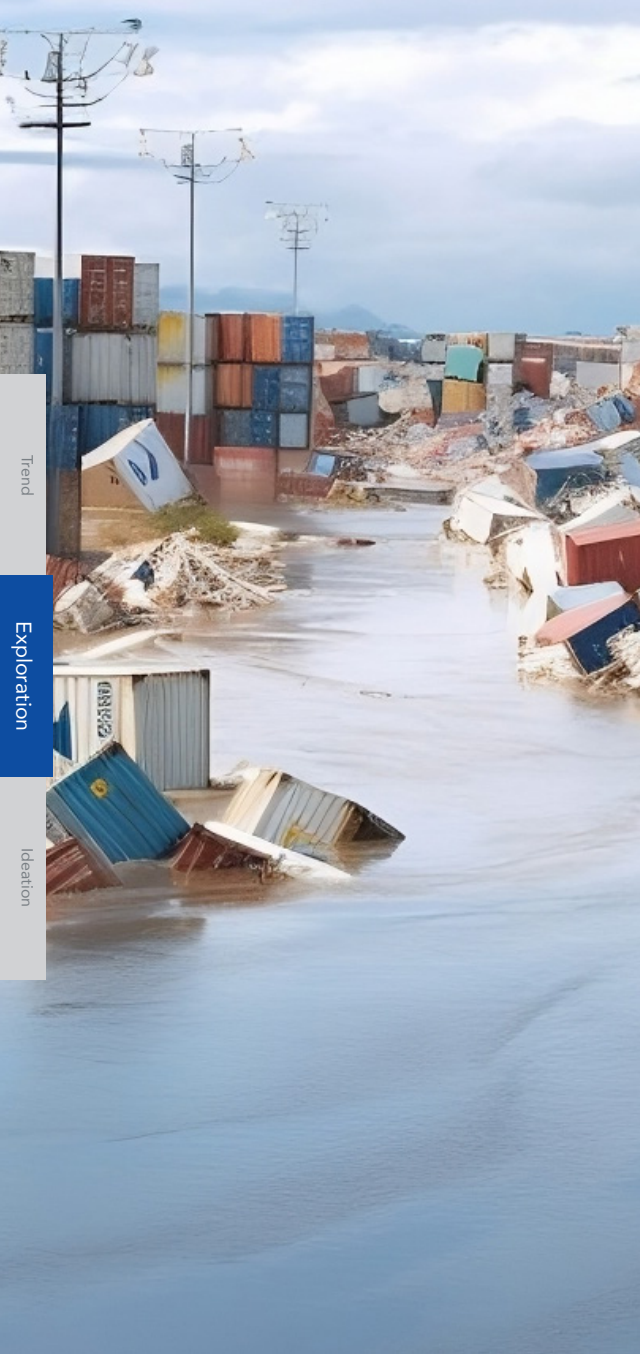
From port calls to hinterland logistics, port operations grapple with fragmented and manual processes. Digitalization efforts in the maritime sector have primarily targeted vessel technology and the sea environment, often overlooking ports [311]. Moreover, digitalization requires substantial capital investment, necessitating a demonstrator case to validate the viability of infrastructure investments [312]. Within ports, different stakeholders, including competing terminal operators and hinterland transporters, create a complex web of conflicting interests. This often leads to reluctance to share information. Port entities within the same harbor compete for optimization but may inadvertently compromise overall port efficiency [313]. Even if consensus regarding investments or global optimization is reached, the unequal distribution of investment costs among stakeholders can deter action [314]. However, ports actively seek solutions to enhance operational efficiency, reduce costs, and increase customer responsiveness. Global trade expansion has intensified inter-port competition, giving port users a wider array of port choices within a hub [315].

Additionally, shipping industry alliances have increased the bargaining power of port users, all demanding higher throughput and superior services. Privatization of port operations offers opportunities to transfer best practices and introduce new financing channels necessary for implementing technology [315]. Substantial opportunities are arising among digital technologies, including comprehensive platforms for integrated operations like digital port calls and real-time berth and crane scheduling based on hinterland transportation availability [316].

> “[Shipping and port operations] are incredibly unreliable. You often do not know if your cargo is on the ship [272].”
>
> Benjamin Weber, Associate Partner at McKinsey & Company

Selected Players

awake.ai
WINDWARD
THE POWER OF MARITIME AI™
FreightFlows
PORTCHAIN
eeSea
heyport
portbase
PORTCALL.COM



NATURAL DISASTER PREDICTION AND ADAPTION

Enhancing Port Resilience for Natural Disaster Forecasting and Mitigation

The frequency and severity of natural disasters are escalating due to anthropogenic climate change, as evidenced by findings in the Intergovernmental Panel on Climate Change (IPCC) report [317]. Studies have shown that these changes have an immediate impact on maritime port infrastructure, posing an increasing challenge for future resilience. Oxford's Environmental Change Institute states that 86% of global ports are vulnerable to more than three categories of natural hazards. The estimated annual risk associated with ports, consisting of revenue loss and damaged assets, is approximately 7.5B USD. Additionally, trade volume valued at 63.1B USD is expected to be disrupted annually [306]. The highest climate-related risks are predominantly borne by major port facilities in Asia, the Gulf of Mexico, and Western Europe. While high-income nations may experience the highest absolute risk of increasing natural disasters, middle-income countries could endure more severe operational disruptions due to limited adaptation.

This emerging vulnerability landscape presents significant opportunities for technological innovation aimed at the detection, prediction, and adaptation to natural disasters. Engineering considerations for enhancing port resilience may include improving the structural integrity of quay walls in earthquake-prone regions, the orientation and design of breakwaters in locations susceptible to extreme wave and storm surge events, and assuring the efficiency of drainage systems in areas vulnerable to fluvial and pluvial flooding [318, 319].

> "We found 86% of all ports are exposed to more than three types of climatic and geophysical hazards [306]."
>
> Jasper Verschuur, Postdoctoral Researcher at Oxford's Environmental Change Institute

Selected Players

DOCK TECH
ocean THERM
stormglass.io
aquaplot
Flood Modeller by Jacobs
SAILDRONE
tomorrow.io

DATA-DRIVEN OPERATIONS

LEVERAGING DATA TO UNLOCK MARITIME PRODUCTIVITY

Financial Solutions

Capacity Optimization

Data Assets

Magdalena Bachinger 
Pietro Belligoli 
Gana Moharram 
Anne Röllgen 
Alexander von Recum 

DATA-DRIVEN OPERATIONS

Leveraging Data to Unlock Maritime Productivity

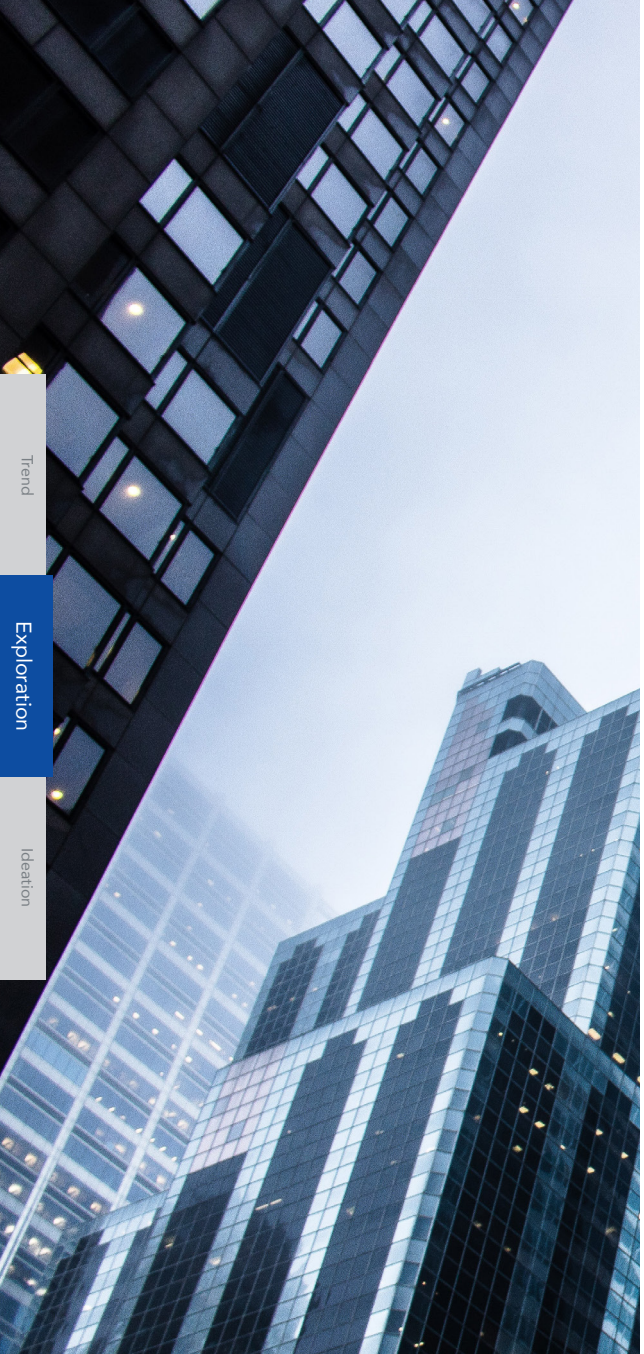
Efficient resource management and allocation are crucial in the maritime shipping industry. This involves using financial, data-related, and technological resources to enhance operational outcomes. It goes beyond cost reduction and encompasses utilizing various resources, such as employee knowledge and skills and the wealth of big data, to improve efficiency and achieve higher profitability.

The complex nature of global supply chains has transformed the modern business ecosystem. These intricate chains are also influenced by geopolitical uncertainties and disruptions caused by changing climate patterns [98]. These challenges emphasize the importance of operational efficiency, which is not only a desirable trait but also a fundamental necessity for the long-term sustainability of the shipping industry. Effective resource management and allocation are key for competitiveness. In today's challenging environment, with limited financing, strict environmental regulations, and high consumer expectations, resource-efficient businesses are more likely to adapt, innovate, and succeed.

Challenges in the maritime industry include financing for smaller enterprises, underutilized ships, and untapped data. Traditional banking support for small and medium-sized shipowners is declining, necessitating innovative financial solutions. Real-time data accessibility can revolutionize insurance models, potentially reducing premiums and making the maritime sector more attractive to insurers.

The data reservoir in the shipping industry is untapped and holds immense potential. When utilized effectively, data can revolutionize existing operational structures and lead to new business paradigms. One such example is the Data-as-a-Service (DaaS) framework [320], which enables data monetization and provides actionable insights for businesses to enhance their resource distribution strategies [321]. However, optimizing resource utilization, particularly in capacity optimization, presents challenges. Mismatches between supply and demand, compounded by opaque supply chains, increase costs and reliability issues [322]. Thankfully, technology offers a solution. Modern technologies can enhance demand forecasting and refine ship deployment, promoting efficiency, cost-effectiveness, and reduced environmental impact, which is increasingly crucial in the industry [321].

In summary, the maritime shipping industry finds itself at a pivotal juncture. Its competitiveness and sustainability hinge on effective resource management and allocation. This necessitates a comprehensive approach that combines innovative financial solutions, meticulous data asset management, and a focus on capacity optimization. This strategy serves as a blueprint for addressing current challenges and guiding the industry toward a future characterized by agility, responsiveness, innovation, and growth.



FINANCIAL SOLUTIONS

Transforming Financial Services for the Shipping Industry Through Innovative Solutions

The necessity to handle uncertainty in international trade resulting from emerging technologies, geopolitical tensions, and increasingly extreme weather events [323] is growing in the maritime sector [98]. As a result of the increased risk and uncertainty, access to finance from conventional banks has decreased significantly, driven in part by the withdrawal of European banks from the shipping industry due to financial losses and increased regulations. Small- and medium-sized shipowners, in particular, need help to secure financing for their businesses [324]. This has led to an increase in the amount of investment from institutions and private equity funds [325].

In addition to the struggle to find financing, shipping companies have faced challenges obtaining insurance coverage for their assets and operations in recent years. This is because maritime insurers are exiting the market due to unprofitable returns, resulting in higher premiums and reduced coverage for shipping companies [326]. The increasing data availability in the industry could provide new solutions to this problem, particularly real-time risk assessment. This data could then be used to create dynamic insurance premiums that are adjusted based on the current level of risk. As a result, the shipping industry could become more attractive for insurers again by providing them with more accurate and timely information to assess risk.

> “Insurers and investors are now also considering greenhouse gas emissions and other sustainability factors in their decisions, making it a key driver of change in the financial and insurance landscape [273].”

Asset manager in the maritime shipping industry

Selected Players

Concirrus
InsurWave
MARITIME
PayCargo
OneConnect Financial Technology Co. Ltd.
eShipfinance.com Easy. Fast. Secure.
MarTrust
oceanis
SHIPMONEY

CAPACITY OPTIMIZATION

Enhancing Efficiency Through Advanced Technologies and Transparent Global Trade

The shipping industry is usually one of the first to suffer from an imbalance between supply and demand, exacerbated by global market shocks and increased competition. In the worst case, these imbalances lead to suboptimal vessel utilization safety and stability [322]. In addition, the industry's slow adoption of advanced data models and technologies further contributes to inefficient operations [321].

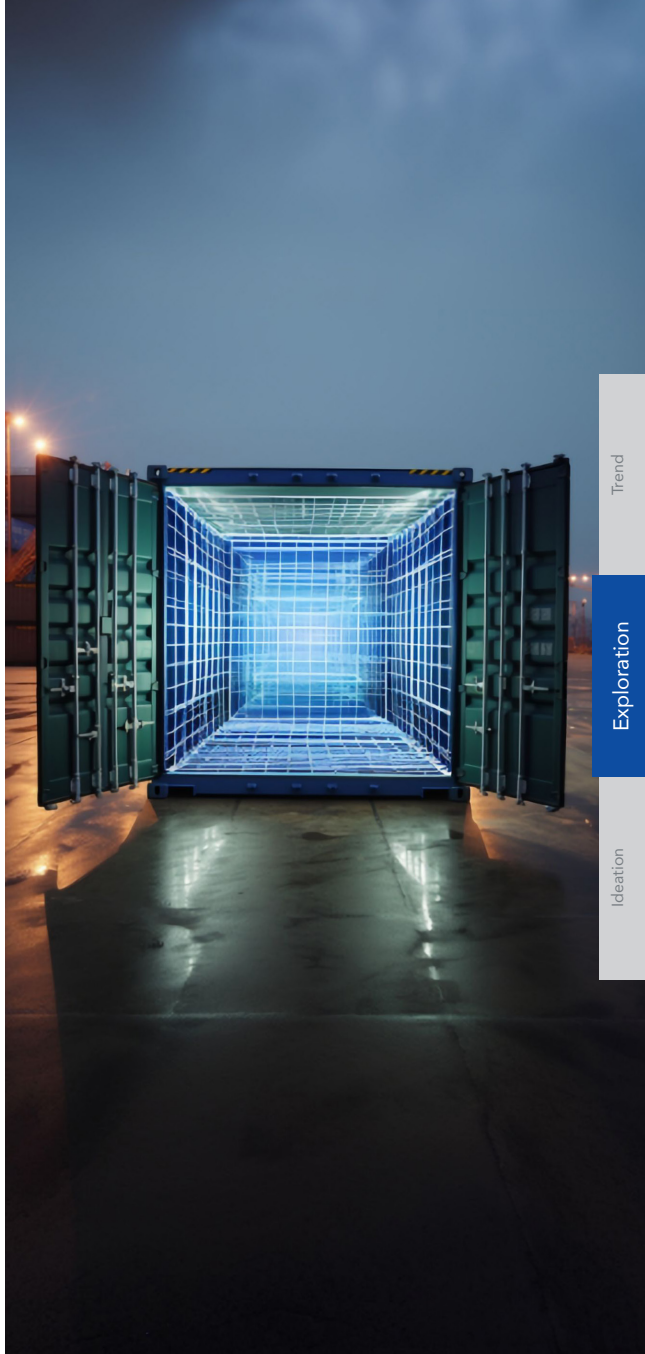
From an economic standpoint, these inefficiencies increase operating costs and decrease profit margins for all involved parties. They also result in higher voyage fuel, crew, and maintenance costs. From a customer service standpoint, these inefficiencies cause delays and diversions, worsening port congestion and diminishing the reliability and quality of shipping services [327]. Furthermore, the environmental consequences of these inefficiencies, such as increased emissions and broader ecological harm, are becoming increasingly unsustainable [321].

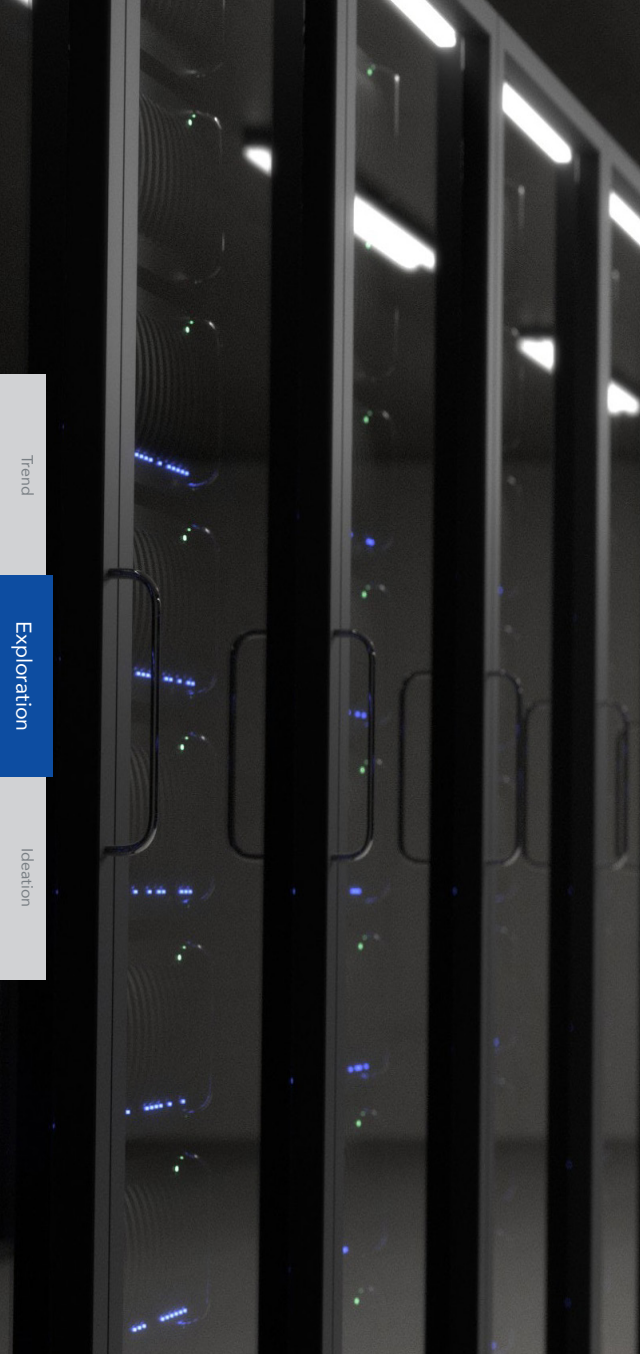
The future of capacity optimization depends on enhancing transparency in the global movement of goods. This involves leveraging technologies such as artificial intelligence and big data analytics to build demand forecasting simulation models to understand better and quantify global trading patterns. The industry can optimize vessel deployment, repositioning, and cargo/container routing through monitoring, tracking, and measuring cargo volumes. These advances offer the potential to harmonize supply with demand, fundamentally changing capacity optimization plans and directing the industry toward increased efficiency.

> "Current capacity optimization will likely be incremental over the next few years. The real innovation in capacity optimization will come from having a transparent supply chain and optimizing it. That could have the potential to really change the industry [272]."
>
> Benjamin Weber, Associate Partner at McKinsey & Company

Selected Players

awake.ai
KALERIS
Transmetrics
HawkEye 360
Quantum-South
TRAXENS connecting the dots





DATA ASSETS

Unlocking the Maritime Shipping Industry's Data Potential for Efficiency and Profitability

The data generated by shipping operations is an untapped resource that the industry must learn to harness, as it can drive innovation, efficiency, and profitability. The use of data from various sources, including environmental data (e.g., carbon emissions or temperature), cargo-tracking information (e.g., busiest routes/destinations), and satellite data, can lead to the creation of new business opportunities, including the sale of data and the optimization of traditional maritime business processes through data-driven approaches [320, 321].

The maritime industry generates vast amounts of data that can be monetized in several ways. One such way is the DaaS business model, which allows other companies, hedge funds, governments, industry stakeholders, or academic researchers to gain access to these data sets. This access enables them to use advanced analytics to predict global trade movements. In addition, companies can analyze internal and external information from multiple sources to gain valuable insights into their day-to-day business operations, such as accounting, reporting, and payroll automation. As a result, these insights can help them make more informed decisions that lead to increased efficiencies and cost savings, ultimately driving profitability in the industry [321].

> "Building and retrofitting ships with data collection technology will increase the use of data in the long term and bring data-driven decision-making to shipping offices [273]."
>
> Philipp Joerss, Head of Asset Management at Hapag Lloyd

Selected Players

Marcura · GateHouse Maritime · 90 POE · Marine Digital · NAVATOM SHIP MANAGEMENT SOFTWARE · ShipIn · VORTEXA · Datarade · MARITIME DATA

IDEATION

The following chapter describes five novel business models that are of great relevance for the Future of Maritime Shipping, especially in view of the identified future trends. Each of the business models was developed to solve a specific problem in the identified problem spaces.

Vincent Jansen 
Lena Reißiger 
Matteo Wohlrapp 
Thomas Menzel 

COMMUNICAID

Your Copilot for Maritime Safety

Maritime accidents have catastrophic effects on people's livelihoods and the environment, as well as serious business implications. As the global cargo volume is forecasted to increase, this will lead to an increase in the number of ships on sea, channels, and ports. Consequently, the frequency of accidents is expected to rise [328]. With 80% of all ship accidents resulting from human error [329], and communication failures accounting for 30% of those incidents [330], the impact of communication on maritime safety cannot be neglected. Among various factors, language barriers are a specific concern in the literature that adds to communication breakdowns in this global industry. Although the issue of communication failures is widely recognized in the sector [331], technological solutions have yet to become widely available.

CommunicAid is changing the status quo by acting as a co-pilot for maritime safety. Our product is designed to monitor, evaluate, and improve onboard communication in real-time by providing valuable insights for key decision-makers. Moreover, our mission is to improve safety onboard by leveraging data that is currently untapped: human communication data.

Seafarers, communicate onboard, inter-ship, and to shore using Very High Frequency (VHF) radio and satellite services. To ensure seamless dialogue, CommunicAid connects with this infrastructure, pooling data from communication networks and hub sensors specifically installed for this purpose. After aggregating this wealth of verbal interaction data, it is then processed in the cloud.

CommunicAid provides AI-driven real-time advice for ship staff. Suggestions are categorized by requiring urgency, issues deviating from routine, or noting long-term improvements. Accepting is streamlined with dashboard to voice command options. After approval, instructions are relayed to crew via intercom. Bridging language gaps, CommunicAid instantly translates and broadcasts on a maritime frequency. This ensures clarity, minimizing errors and incidents. If an accident happens, CommunicAid's solution acts as an impartial record, like an aircraft's black box, furnishing crucial data. CommunicAid offers shippers a tool for enhanced safety and communication.

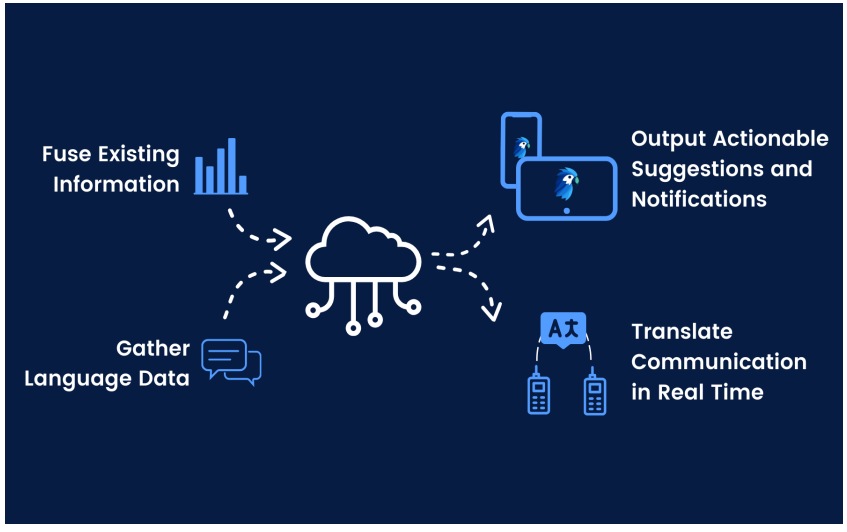
Although primarily focusing on enabling the crew on the vessel, the benefits of CommunicAid extend to a wide range of stakeholders, including maritime operating companies, insurance companies, and search and rescue organizations.

In conclusion, CommunicAid is built on the belief that human workers remain indispensable to maritime operations. Therefore, safety remains the most pressing concern for the well-being of seafarers on board. Rather than replacing them, CommunicAid wants to empower and aid them with innovative technology, ultimately guaranteeing safer waters for all.

Problem

- Human errors are responsible for over 80% of all maritime shipping accidents. Miscommunication accounts for approximately 30% of these incidents [333].
- Accidents caused by human error can be very expensive depending on the cargo, location, and the accident's severity. Allianz calculated a worst-case scenario of 4B USD in losses for a collision between a container vessel and a cruise ship [330].
- Decision makers on the ship lack clear access to onboard communication data, neglecting the human factor and spoken word.
- This limited information access can lead to suboptimal decisions in high-stakes situations.
- Seafarers onboard a vessel speak many different languages, leading to unclear communication, exclusion, and less effective work. Elevated stress levels during accidents exacerbate the situation, potentially leading to hazardous conditions that endanger health and, in the worst-case scenario, the lives of seafarers.

The maritime industry must take urgent steps to improve clear communication and avoid accidents



Solution

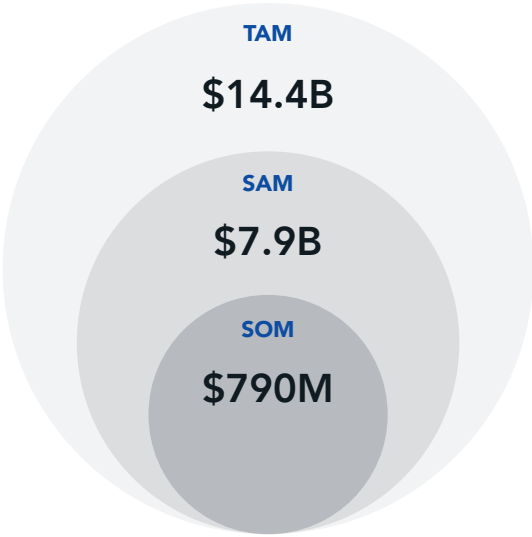
- CommunicAid aims to centralize and unify all forms of communication, including ship-to-ship, ship-to-shore, and onboard. Simultaneous communication data is collected, processed, and evaluated.
- This communication data is then fused with existing ship data.
- Based on the combined data, CommunicAid generates AI-enabled actionable suggestions to support decision-makers onboard in choosing the less error-prone options for improving safety. These suggestions are easy for end-users as they come fully integrated into a dashboard showing real-time vessel data.
- To overcome the language barrier, CommunicAid also offers a real-time language translation tool that can be integrated into the existing communication infrastructure.
- Leveraging its advanced tech, CommunicAid proactively addresses safety concerns by monitoring interactions, providing real-time insights, and ensuring transparent, unified communication onboard.

CommunicAid utilizes language data to empower the onboard workforce by optimizing decision-making and overcoming language barriers

Market

- CommunicAid operates at the intersection of maritime communication and safety, bridging both sectors and reshaping both markets.
- In 2022, the Maritime Safety System market was valued at 27.6B USD, while the Maritime Communication System market reached 4.7B USD. Both markets are projected to experience significant growth, with an estimated annual increase of around 5-7% in the midterm [338, 339].
- CommunicAid suggests an annual price of 120K USD. This represents approximately 1.3% of a vessel's average overall operating costs.
- Considering the 120,000 vessels globally, the total addressable market is 14.4B USD. CommunicAid targets 68,000 medium to large ships, narrowing their serviceable market to 7.9B USD. CommunicAid intends to capture a 10% market share, generating a potential annual revenue of 790M USD [340].
- In the long term, there is high potential for expanding CommunicAid's solutions to other industries where effective communication is vital for a safe working environment.

Rethinking maritime communication and shaping a new market by fusing safety with communication



Competition

- The core offering of CommuicAid combines safety features with communication services, which puts it at the intersection of the maritime safety and communication markets.
- As communication and safety systems are closely related, various players approach this market section differently to address its challenges.
- From a communication perspective, Garmin, known for radio and satellite systems, uses its technology to address safety concerns, such as voice alerts and notifications transmitted through the systems.
- Deeply rooted in the safety and security market, Saab tangents the communication market by providing solutions that integrate vessel positions and communicate collision alerts to stakeholders on the ship.
- What makes CommunicAid unique is leveraging language data as a new source of information for data-driven decisions. This puts it at the forefront of technological advancements, providing innovative solutions to pioneer the market intersection.

CommunicAid pioneers the intersection of safety and communication with innovative technology, surpassing incumbents from both sectors

Assumption Tree

Human Labor Remains Essential

Even in the future, humans will remain essential for operating ships. There will always be the need for at least a small crew running the vessel. In case human operators become replaceable or unnecessary, a copilot solution would be irrelevant. To evaluate this, we can examine the advancements in humanoid robotics and the corresponding ethical implications of liability in the event of an accident.

Language Data as Key

Language data is highly beneficial and is currently completely neglected in ship operations. Expert reports suggest obtaining additional information through communication can enhance ship operations. If language data is currently harnessed and centrally collected, our product can be simplified. To verify this, we should engage with vessel operators and investigate the specific communication data being collected.

Widespread Internet Connectivity

Reliable satellite internet will be available soon. According to experts, partnerships between major shipping companies and firms, such as Starlink, will significantly improve connectivity within vessels [332]. Some of the largest companies are already planning to equip their fleet with internet connectivity. This is a crucial step for CommunicAid, as internet access is essential for audio transcription and cloud-based AI operations.

Communication as a Safety Factor

Communication errors significantly contribute to maritime accidents. Miscommunication, information neglect, and language barriers have a very high influence on the probability of human error, leading to more maritime mishaps. This assumption can be backed up by several studies [333, 266]. Also, it can be tested by speaking to seafarers and gathering firsthand experience from day-to-day operations.

Recording is Possible

Radio transmissions and recording devices provide enough data for our solution to offer valuable recommendations. Crew members will have no issue with being monitored if it enhances their safety. From a regulatory perspective, we do not foresee issues with recording communication, as the use of Voyage Data Recorders (VDRs), which save communication data for accident investigation purposes, has already been mandatory for passenger ships [334].

Spotlight on Liability

Since our solution provides suggestions, we maintain that the captain retains full responsibility, in line with the current practice. However, it is important to acknowledge that the issue of liability remains somewhat uncertain, and we may potentially face legal action, with the possibility of being deemed partly responsible for accidents. Thus, we need to examine legal precedents from other industries and closely monitor changes in relevant laws.

Workforce Empowerment

Our software significantly reduces the probability and severity of maritime shipping accidents by enhancing and unifying communication. This helps us accomplish our overarching goal of empowering the workforce. Moreover, our solution can be integrated into pre-existing communication systems without additional overhead. This has to be validated through trial runs.

Leon Sandner 
Susanna Heidbrink 
Pary Zadeh 
Michal Starý 
Jiehua Wu 

METHANOW

Make Green Methanol Happen Now

Maritime shipping's urgent decarbonization stems from its fossil fuel reliance. As a significant GHG emitter, it must move towards greener fuels. This shift aims for net zero by 2050, an IMO goal against climate impacts [270]. While the maritime industry is moving toward a multifuel future with various alternative fuels tailored for specific use cases, green methanol stands out as one of the most promising options. Similar in handling to conventional fuels, it is poised to dominate market share. Current developments and investments already indicate that green methanol will become the leading alternative fuel.

However, green methanol is still far from reaching commercialization. This is primarily related to the high fuel production costs – and MethaNow is here to solve that. MethaNow is an optimization software that enables green methanol plant operators to increase their efficiency and profitability.

Green methanol can be produced as bio- or e-methanol, relying on renewable energy. Bio-methanol relies on biomass, whereas e-methanol requires water and captured carbon. Storage and transportation, volatile renewable energy prices, and uncertainties about carbon capture and biomass availability create a complex optimization problem around methanol production. MethaNow's value lies in its intelligent optimization software, which considers the essential dimensions of green methanol production. MethaNow has two core offerings based on similar optimization problems: plant localization and operation.

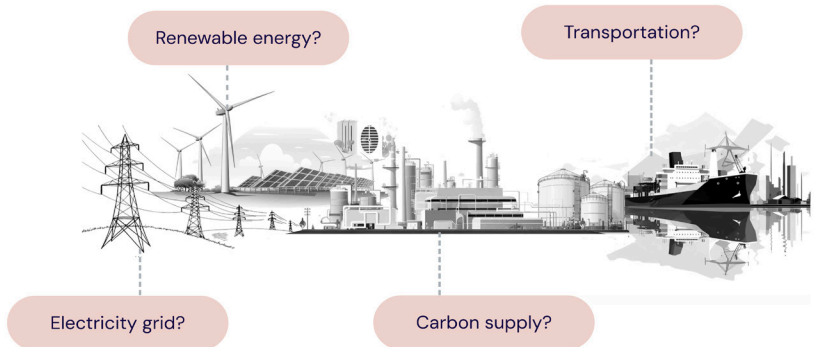
MethaNow's plant localization enables producers to determine the optimal location for their methanol plants. When optimizing plant location, MethaNow considers various key data dimensions: geography data, encompassing topography, land use, and proximity to vital infrastructure such as ports, rail, and electrical grids. Market data also holds significance, specifically emphasizing the plant's proximity to methanol consumers or distribution networks. Historical weather data helps to forecast renewable energy yields. Depending on the chosen production method, CO_2 and biomass data are assessed to determine proximity to CO_2 sources or biomass. Additionally, local regulations, including environmental regulations and construction permits, are considered.

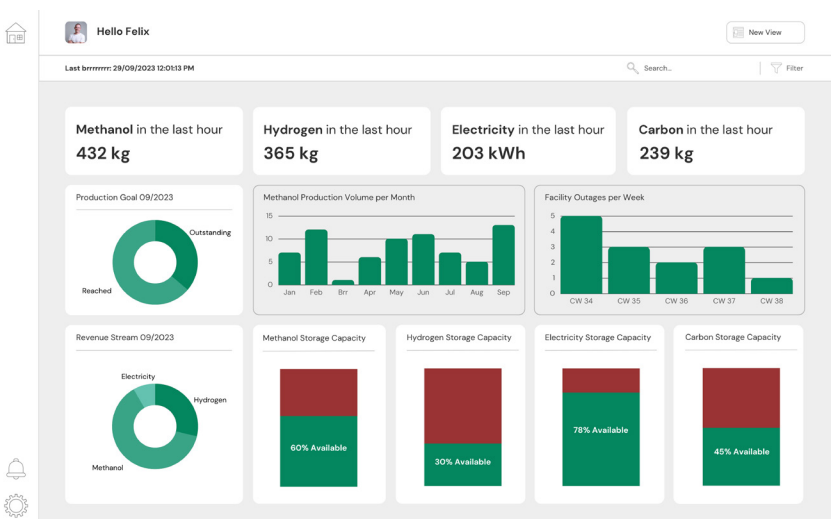
Additionally, MethaNow uses real-time data to optimize plant operations and help the production company make intelligent choices, e.g., when to produce to optimize profit or energy usage. While MethaNow offers a visual dashboard for plant operation managers, the real value creation happens in the background, where the software automatically makes these optimizations. The process thoroughly examines several crucial dimensions. Weather data is scrutinized to measure the plant's capacity to generate renewable energy. Energy data provides insights into the current renewable energy prices, while grid data contributes information on the electricity grid load and scheduled maintenance. CO_2 data sheds light on carbon capture rates, and plant data provides a comprehensive view of storage capacities and equipment status. Lastly, market data offers insights into current prices and demand forecasts.

Problem

- The maritime shipping industry is responsible for more than 3% of global GHG emissions [72] and must achieve net-zero emissions by 2050 [71].
- Traditional ship fuels are the most significant driver of CO_2 emissions in the maritime shipping industry. The shipping industry has several options for transitioning to sustainable fuels, including green hydrogen, green ammonia, biofuels, LNG, and green methanol.
- Switching to green methanol appears to be the most probable and promising solution toward achieving net-zero emissions, primarily due to its current safety and technological advantages over other types of sustainable fuels [283]. Furthermore, major shipping companies such as Maersk have opted for methanol as their preferred choice of fuel, as indicated by present orders on methanol-based ships [276].
- However, transitioning the maritime shipping industry to green methanol will be slow and costly since green methanol is up to four times more expensive than established fuels [341].
- Operating a green methanol plant is complex and inefficiencies can arise when coordinating resources such as green electricity and captured carbon.

Optimizing the operations of production plants is necessary to reduce the cost of green methanol





Solution

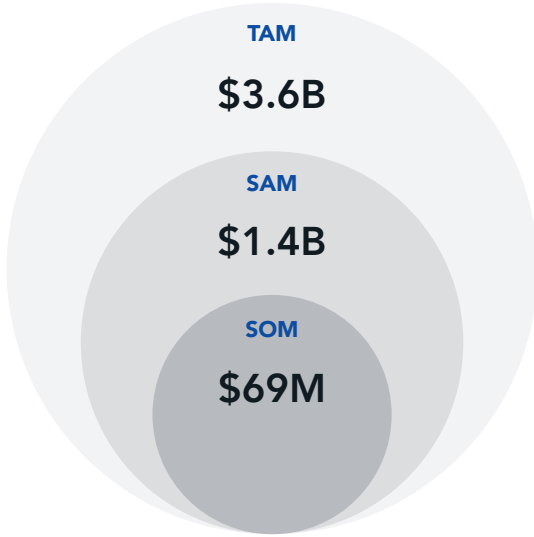
- Methanol plants must optimize various factors, including the cost of green electricity, hydrogen pricing, the availability of captured carbon, transportation logistics, delivery commitments, and more. The optimization of these resources is essential to meet their promised production quantities while minimizing expenses.
- MethaNow optimization software efficiently handles all these data points and constraints while forecasting future prices and availabilities. Thus, the software models various scenarios and finds the optimal way of balancing all requirements.
- For instance, MethaNow will assess whether it is advantageous to sell excess electricity to the grid, increase methanol production, or expand carbon storage capacity to gain better profits. The software will then suggest the necessary measures to steer plant operations.
- MethaNow provides plant operators with a real-time dashboard that enables them to understand the decisions made by the software and monitor key data points.
- According to industry standards, the optimization software is expected to deliver a 20% increase in cost efficiency for methanol plants.

MethaNow considers all relevant data to optimize plant operations for cost efficiency

Market

- The global renewable methanol market was valued at 622M USD in 2022 and is expected to expand with a promising CAGR of 55% from 2023 to 2030 [342].
- By 2050, global green methanol production is projected to reach 400M tonne annually with an expected price per tonne of 450 USD, resulting in a total market size of 180B USD [341].
- MethaNow aims to charge methanol plants 2% of their annual revenue to capture a portion of their efficiency gains. This translates to a Total Addressable Market (TAM) of 3.6B USD.
- MethaNow's position as an early entrant in this rapidly expanding market, coupled with its data-driven optimization and forecasting algorithm, will lead to a series of product improvements as the customer base grows. This is expected to result in a 40% market share, translating to a Serviceable Available Market (SAM) of 1.4B USD.
- Within the next five years, the green methanol market is expected to grow to 8.6B USD [342]. MethaNow wants to capture 40% of that market and charge 2% of the plant's revenues, which results in a Serviceable Obtainable Market (SOM) of 69M USD by 2028.

MethaNow takes advantage as an innovator within the exploding green methanol market



Competition

- Since decarbonization is one of the most pressing problems in present days, and green fuels are an essential part of a more sustainable future, there are already companies and startups working in similar spaces.
- ABB optimizes green hydrogen production with a similar approach as MethaNow. For example, they steer the operation of electrolyzers depending on hydrogen demand and the availability of cheap electricity [343].
- Reverion builds plants that take in biogas and produce hydrogen. They also follow the approach of taking energy from the grid when it's comparably cheap [344].
- Eternal power covers the entire hydrogen production value chain, including scouting for suitable hydrogen plant locations based on similar dimensions to the ones MethaNow uses for production optimization. However, they don't use software to automate key parts of their process [345].
- In the last few years, startups like Icodos and Circular Carbon Chemistry started working on green methanol plants, but they don't build software for automation of processes [346].

MethaNow has the first-mover advantage in building optimization software for green methanol plants

Assumption Tree

Effective Regulatory Pressure

Binding decarbonization regulations are expected to become effective within the next five years and intensify after that. This belief stems from the trend research and expert interviews, which have underlined the demand for more green regulations. However, it is worth noting that current regulations are fragmented and lack enforceable execution. For validation, one can conduct expert interviews with policymakers and delve deeper into desk research.

Green Methanol Adoption

Green methanol is set to become the dominant alternative fuel in the maritime industry. This hypothesis is supported by the significant increase in orders for methanol-powered vessels. To validate this assumption, in-depth interviews and consultations with industry experts, including representatives from major shipping corporations, shipbuilding entities, and producers of alternative fuels can be conducted.

Data Availability

All crucial data within the fuel production plant, like equipment status and storage capacity, is digitally accessible. This assumption is based on the observed availability of products using similar data sources in related plants, such as green hydrogen facilities. Validation involves expert dialogues with green hydrogen and methanol plant operators and startups developing new plant concepts in this space.

Resource Price Stability

The cost reduction potential of green methanol over time is limited. It arises from the fact that the resources essential for its production, like green hydrogen and carbon-captured CO_2, are expected to remain costly compared to conventional fossil fuels. This assumption is rooted in research papers and past technology learning curves. Testing could involve a meta-analysis of renewable energy costs and carbon-capture efficiency projections.

Methanol Demand Surge

The demand for green methanol is anticipated to increase nearly 100-fold within 15 years, indicating a pressing need for highly efficient green methanol production facilities. This assertion originates from numerous projections from scientific research and industrial analyses. A comprehensive review of existing projections is essential to validate this claim, aiming to identify the most plausible multifuel scenario for the future maritime landscape.

Software Boosts Efficiency

Software solutions optimizing plant location and daily operations will reduce the cost for green methanol plants. To validate this perspective, one could actively consult with experts in green fuel plant construction and operation and undertake rigorous digital simulations of innovative software prototypes.

Transferable Efficiency Gains

The optimization algorithm for daily operations is adaptable across various methanol plants with different configurations, offering unique efficiency gains justifying the subscription cost. This assumption is based on desk research indicating similar production steps across methods and expert insights into production step coordination. Further testing could involve a deeper exploration of individual plant setups and customer interviews.

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DRAGONFLY

Making Your Inspection Fly

Dragonfly is a holistic solution designed to revolutionize engine inspection in the maritime industry. Its mission is to cut inspection time and cost, raise accuracy, and optimize long-term engine performance utilizing autonomous inspection drones and advanced data analytics.

The engine is the heart of every vessel, keeping the ship up and running. However, alarming statistics reveal that machinery damage and breakdown contribute to one-third of shipping incidents, and future projections determine that this is unlikely to change anytime soon [287]. To prevent such incidents, engines are inspected daily in highly manual processes, demanding the engineers to physically enter the engine room. Due to the size of the engine room, being as large as a three- to four-story building, human inspection is a time-demanding, costly, and error-prone process. Research states that visual inspection has a 30% human error rate [335], with unstandardized paper-based inspection documentation and mouth-to-mouth communication as additional levers that can increase it. When potential frauds are not detected, it can lead to costly downtimes of 2-5M USD per day [54]. This opens the opportunity to monetize efficiency gains through autonomous inspection utilizing robotics and data analytics.

Dragonfly's inspection drone, the Dragonfly Nano 1, is equipped with high-resolution cameras and advanced sensors along with LiDAR (Light Detection and Ranging) technology, autonomously navigating intricate engine components. These cameras detect visual anomalies like cracks and corrosion. Thermal sensors spot temperature shifts, flagging issues like overheating and coolant leaks, while ultrasonic ones gauge metal thickness, identifying wear and degradation. Humidity, air quality, gas, and chemical sensors monitor engine conditions, detecting harmful substances and ensuring safety – vital for future ships using ammonia or methanol.

Data from inspection drones merges with sensor information from engine components in the Dragonfly database. The dashboard displays aggregated data, offering ship operators comprehensive reports. Upon detecting risks or frauds, engineers access specific component data via the dashboard. Besides monitoring component health and performance, the dashboard alerts operators of inefficiencies and suggests optimizations. Dragonfly's system empowers operators to make informed decisions on maintenance, repair, and operation, reducing inspection time and costs.

To benefit from Dragonfly's offering, ship operators buy the drones, including the base station, in a one-time purchase. The software, including data analytics and a support and repair service, is available as a monthly subscription. The price is set for each business customer individually to optimally meet the individual customer needs.

Problem

- Machinery damages and breakdowns account for about one-third of shipping incidents, with little chance for improvement [287].
- Visual inspections currently rely on manual methods, which have a 30% error rate due to human involvement, creating the possibility of overlooking important details [335].
- Undetected faults can result in machinery breakdowns, contributing to costly downtimes ranging from 2-5M USD daily [54].
- The size of the engine room makes manual inspection expensive and time-consuming. Finding effective and economical substitutes for manual inspections is critical to optimize resources and enhance operational efficiency.
- Although engines have built-in sensors, their data is not always functionally integrated with visual inspection data. This results in potential gaps in comprehending the overall health and performance of the engine.
- The absence of a centralized source for documenting information during manual engine inspections implies a risk of inaccurately and inconsistently recording essential details.

A high error rate in manual inspections leads to expensive downtimes, machinery breakdowns, and inefficiencies

Solution

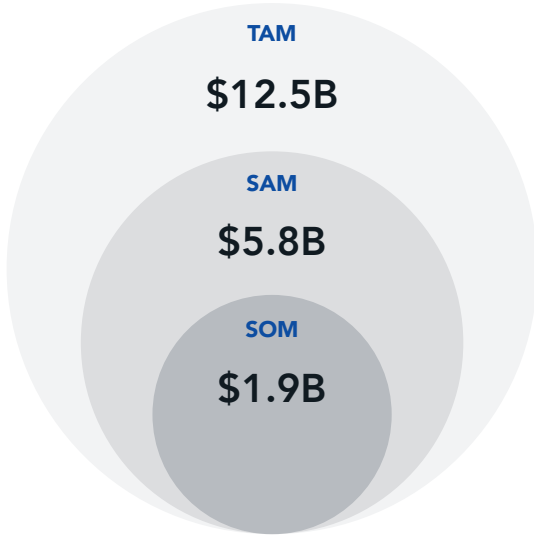
- To capture detailed visual and sensor data, a fleet of advanced drone robots equipped with high-resolution cameras and sensors autonomously navigates the engine room, enhancing inspection accuracy and efficiency.
- By programming the drones according to official protocols, manual inspection walks become unnecessary, saving valuable time and reducing costs associated with traditional inspection methods.
- The drone data seamlessly merges with the data generated by existing engine sensors, creating a comprehensive dataset that provides a holistic view of the engine's condition.
- A streamlined dashboard presents the merged data collected by the drones and generated by the engine sensors, offering detailed reports, analyses, and actionable insights to optimize engine performance and maintenance strategies.
- The customer makes a one-time investment in the drones and base station, along with monthly payments for a software subscription, data analytics, and support services.

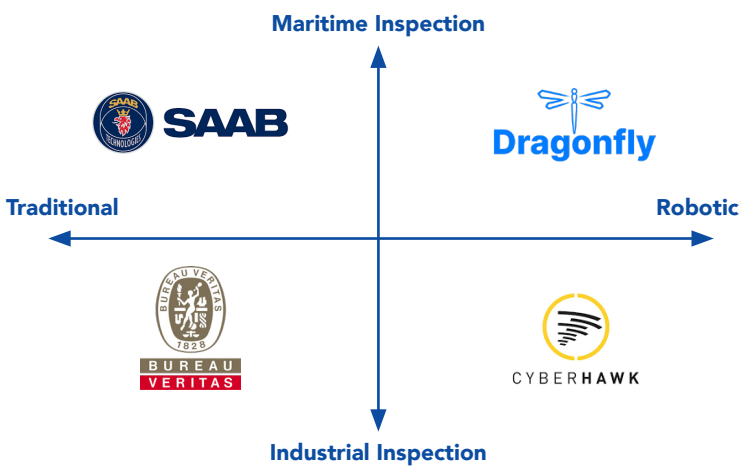
Dragonfly pioneers the future of maritime inspections with advanced drone technology for efficient and holistic engine health assessments

Market

- The total addressable market that Dragonfly targets is the marine engines market, valued at 12.48B USD in 2022 [347].
- The growing need for high-performance engines in industries like automotive, aerospace, and energy, along with advancements in design and manufacturing, is opening up business prospects.
- In 2030, the marine engines market is expected to reach 15.71B USD, resulting in a CAGR of 1.9% from 2024 [347].
- As marine engines have become increasingly sophisticated, the demand for advanced inspection methods and cutting-edge tools to maintain efficiency and compliance has surged.
- Dragonfly aims to secure a significant share, around 15%, of the marine engine inspection market, valued at approximately 1.87B USD.
- The evolving needs for environmental compliance and advanced inspection services enable Dragonfly to innovate in this space.

DragonFly's innovative inspection methods lead to a pole position for capturing significant market shares in the marine engine market





Competition

- The competition can be classified according to two key features, resulting in four distinct groups. One characteristic is the degree of specialization, ranging from generalists to domain experts in the maritime sector. The level of implemented robotics technology defines a characteristic that varies from conventional businesses to technology pioneers in robotics.
- Traditional inspection companies specialized in the maritime sector, like SAAB, have vast experience and knowledge in conducting inspections for the industry.
- Bureau Veritas can be classified as a conventional inspection company, offering inspection services across various industries without a specific focus.
- Robotic inspection companies like Cyberhawk use automated inspection technologies but do not specialize in any particular industry.
- Dragonfly occupies the untapped space, specializing in robotic inspections for the marine industry. Accurate and safe engine inspection services can be provided using advanced robotics and inspection technologies.

Dragonfly differentiates itself from competitors by focusing on specialized robotic inspections for the maritime industry

Assumption Tree

Engines Impact Incidents

Engine issues, e.g., damages and breaks, significantly contribute to shipping incidents. To understand whether engine problems make up a noticeable share of these machinery damages and breakdowns, further desk research has to be conducted to verify the need for advanced engine inspection. Specifically, investigating existing reports on this matter can help validate or reject these claims.

Manual Inspection Processes

Engine inspection onboard vessels is still a manual process. To visually inspect the engines, engineers physically enter the engine room, which is as tall as a three to four-story building. Expert interviews must be conducted to understand whether the inspection process is as manual as described. Additionally, the time- and cost-intensity of the process needs to be verified to justify the economic value of an automated solution.

Drone Data Adds Value

The data Dragonfly collects is instrumental for informed decision-making regarding repair, maintenance, operation, and planning. This helps prevent unplanned downtime and reduces maintenance costs. As engines are already fitted with sensors that allow data collection, it is critical to investigate whether the additional data points collected by the inspection drones add noticeable value in detecting risks.

Automation Permitted

The solution is viable from a regulatory perspective, making physical inspection walks obsolete. To validate whether robots can take over engine inspection, legislation and regulations regarding ship engine inspection must be screened. Engaging with a maritime lawyer or an insurance company can clarify potential legal conflicts arising from ship incidents after automated inspection procedures.

Feasible Technical Solution

The solution is viable from a regulatory perspective, making physical inspection walks obsolete. To validate whether robots can take over engine inspection, legislation and regulations regarding ship engine inspection must be screened. Engaging with a maritime lawyer or an insurance company can clarify potential legal conflicts arising from ship incidents after automated inspection procedures.

Precise Robotic Inspection

Image-processing algorithms used by Dragonfly raise inspection accuracy, outperforming human inspection and judgment. As the manual inspection process, completed by humans, is highly error-prone, it can lead to undetected risks. With Dragonfly, these human-originating errors should and will have to be eradicated to deliver its value. Desk research and expert interviews can help validate this, as there are comparable processes in other industries.

Economic Benefit

Dragonfly offers tangible economic benefits to ship operators. This is important for the system to be adopted by the industry. According to its mission, Dragonfly aims to reduce inspection time and cost, raise inspection accuracy, and optimize engine performance. An extensive business model has to be established to test whether the savings of Dragonfly customers in inspection and maintenance costs exceed the expenses for the solution.

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DOCKMIND

Where Ports Meet Peak Efficiency

Maritime shipping is the invisible backbone of global trade. However, while other industries have already adopted tech-driven solutions, the maritime industry still adheres to conventional practices. Consequently, operational inefficiencies lead to delays, costing the industry billions annually. Significantly, 80% of these delays occur at ports [336]. Research further reveals that 80% of ports have not fully embraced the transformative potential of digitization yet [337].

To meet the ever-evolving demands of global trade, DockMind is on a mission to revolutionize port operations through cutting-edge process optimization. It aims to not only uncover the hidden inefficiencies at ports but also eradicate them. By investigating operational complexities and identifying patterns, bottlenecks, and areas of improvement, the software optimizes port processes and enables substantial cost reductions. The real value of DockMind's platform is its effortless integration into the existing infrastructure at ports. DockMind utilizes already available data from sensors as well as digital port systems, such as Port Management Information Systems or Port Community Systems.

Featuring a user-friendly interface, the platform accompanies port workers in their day-to-day task. Every process a worker undertakes through the app is meticulously recorded, creating a granular operations map. Workers can flag disruptions and receive notifications of disruptions affecting their workflow. This enables colleagues or other stakeholders to respond to these disruptions in real-time. By collecting large amounts of data across operational processes, DockMind can achieve its core promise: a detailed process understanding, actionable suggestions for optimization, rigorous tracking of implemented changes, and tangible process improvements.

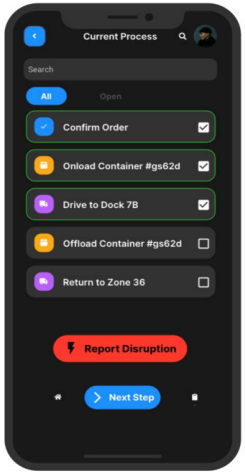
A live dashboard provides port managers an extensive view of all operations, facilitating decisions based on accurate data, not on intuition or outdated reports. The port industry is traditional, facing a complex stakeholder structure, which poses significant challenges to adopting digital technologies. Recognizing this, DockMind is following a partnership-centric go-to-market strategy. By establishing developmental partnerships with forward-thinking port operators, compelling success stories are created that serve as testaments to other potential clients. Moreover, DockMind employs a comprehensive outreach strategy, combining direct sales with diverse content marketing tools, including whitepapers, case studies, and research publications. Consulting and advisory services enhance this offering, enabling ports to adopt the technology and exploit its full potential.

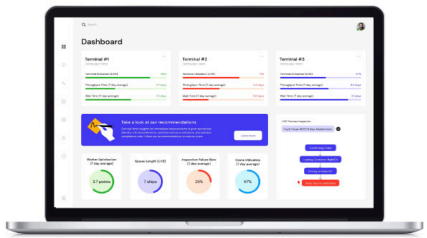
Within maritime operations, ports have historically been central points of inefficiencies. DockMind aims to rewrite this narrative, transforming ports into sleek, efficient, and technologically advanced global trade hubs by offering a transformative tool that redefines the foundation of port operations.

Problem

- Port operations are a significant bottleneck within the shipping process – 80% of shipping delays occur at ports [336], and only 20% of the ports worldwide are digitized [348].
- These operational inefficiencies translate into significant financial losses, as ships wait an average of 6.2 days per port visit [349], with one congestion leading to an 18M USD loss [350].
- To service one ship, operations at each port terminal have to involve many stakeholders. These include the harbor master, tugboat companies, and pilot organizations.
- Ports may have multiple terminals operated by different organizations, increasing the complexity of coordination and communication.
- Each stakeholder is incentivized to optimize their processes and resource allocation, often leading to mistrust in sharing information.
- Overall, there is little transparency in the workflow, which is coupled with manual and unstandardized processes. The management level is currently struggling to define bottlenecks, identify root causes, and as a result, optimize operations.

Ports are a major bottleneck for shipping operations, resulting in significant financial losses and demand for optimized port operations





Solution

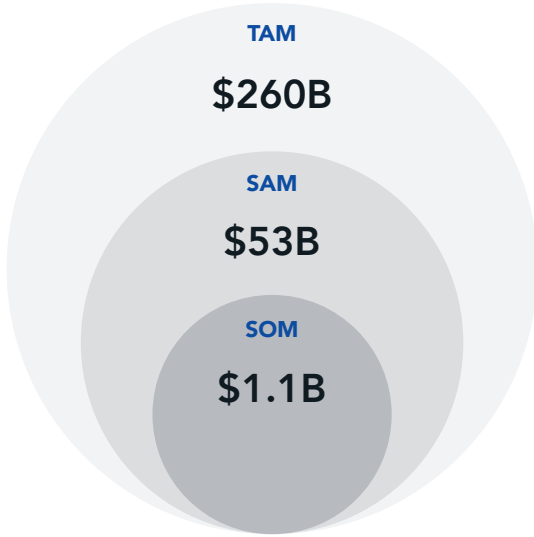
- DockMind employs advanced process optimization to assist all stakeholders engaged in port operations by identifying and addressing inefficiencies.
- DockMind's solution integrates into the existing port infrastructure and complements the insights with the user-centric application for real-time data collection.
- With the DockMind App, port workers can actively track processes, report disruptions, and receive alerts, ensuring a proactive approach to operational challenges.
- The app seamlessly integrates with the existing workflow, reducing overhead and adoption resistance. The user-friendly interface minimizes the learning curve, making it accessible to all workers.
- Ports' management team benefits from a live dashboard, enabling data-driven decisions and optimized workflows.
- Using existing infrastructure and a lightweight application that works on almost any smartphone, DockMind does not incur high upfront costs. Customers can benefit from process optimization and expect valuable insights with as little as one week's worth of data.

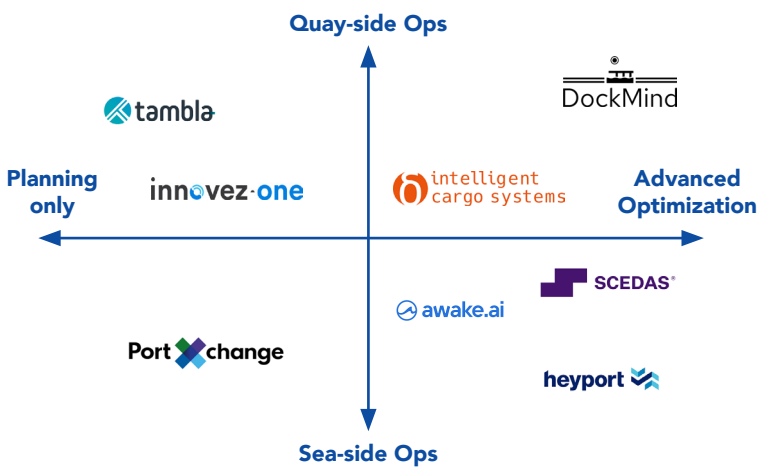
DockMind's seamless integration into the port's infrastructure empowers stakeholders with real-time insights to optimize operational workflows

Market

- In 2023, global seaports will handle over 870M containers, representing a massive market valued at 260B USD [351, 352].
- The cumulative cost of various factors, such as frequent delays, persistent congestion, equipment and labor shortages, and operational inefficiencies amounts to a substantial value of 53 billion USD annually [353, 354, 355, 356, 357, 358, 349, 359].
- Assuming that DockMind will be able to capture 20% of terminal operators in key global hubs and recover more than 10% of the costs lost due to port inefficiencies, the achievable market size in 2023 will exceed 1.1B USD, thus highlighting a significant opportunity.
- DockMind focuses on mid-sized and large port operators, aiming to reduce the costs associated with delays and inefficiencies that disrupt operations.
- Unburdened by legacy challenges, greenfield ports present an especially appealing prospect for DockMind, offering a clean slate for innovative solutions.

Targeting the port operations market, Dockmind strategically targets mid-sized and large operators and capitalizes on greenfield ports





Competition

- In recent years, the maritime industry has witnessed a surge in startups, creating a promising innovation supply.
- Current solutions revolve around cutting-edge prediction engines for arrival time prediction, port call optimization, and berth planning. Notable startups in this field include Wartsila, PortXchange, Portcall, and Portchain.
- Companies like SCEDAS, Awake.ai, and Heyport offer comprehensive, AI-driven optimization toolsets. However, these solutions primarily target sea-side operations near ports.
- The port-side operations sector offers substantial untapped potential, with limited solutions providing in-depth insights. For instance, startups such as Tambla and Innovez One specialize in intelligent cargo systems and assist in port tasks and workforce management.
- While these solutions effectively address operational inefficiencies, they often fail to address the core problem. DockMind aims to revolutionize the industry by tackling inefficiencies at their root.

In a changing competitive landscape, DockMind focuses on the underserved port segment, addressing the inefficiencies at its core

Assumption Tree

Digital Infrastructure

To integrate DockMind's platform effectively, ports must possess a foundational digital infrastructure. Many already employ software-based systems for data management. However, the extent to which modern tools and sensors are adopted varies. To understand the customers' foundational setup, it is necessary for DockMind to get in touch with as many software providers and port operators as possible to prepare the software and adjust it accordingly.

Static Workflows & Procedures

Although many ports already apply modern technologies, including robotics and self-driving machinery, the workflows and processes have mostly stayed the same. As port operations are part of a long-standing and rather unchanged industry, processes are still being documented on paper. DockMind's strategy is to integrate workers, managers, and third-party workforce into a unified platform, modernizing terminal processes for the 21st century.

High Cost of Inefficiencies

DockMind's value proposition is based on its ability to provide real-time data insights to reduce inefficiencies and irregularities in port and terminal infrastructure. Research indicates that minor disruptions at ports can result not only in substantial costs within the port itself but also across the entire supply chain. Similar solutions to discover process inefficiencies, such as Celonis, have already achieved great success in other industries.

Receptivity to Change

For customers to benefit from DockMind's solution, the management must be open to data-driven decision-making. When there is a strong reluctance for change based on digital insights, even the most precise recommendations may be useless. Given that terminal operations often deviate from pre-established plans, which leads to complications, it is assumed that port operations management is open to digital support.

DockMind's Outreach

Given the conservative nature of the port industry, DockMind's outreach needs to be exceptionally compelling. It must resonate with the industry's pain points and visions and convincingly showcase the platform's potential for efficiency gains and competitive advantages, especially compared to traditional port management. It is thus important to portray and communicate the product in an industry-appropriate manner.

Feasibility of Implementation

As DockMind identifies operational inefficiencies and suggests remedies, it is crucial that these solutions are practical, affordable, and integrable without massive disruptions. Ports would naturally hesitate if the proposed changes entail exorbitant costs or complex overhauls. As a similar impact in other industries due to novel process optimization solutions could be seen, it is believed that DockMind can achieve similar goals in port handling.

Tangible Return on Investment

The peak of DockMind's promise is to revolutionize port operations which will lead to substantial reductions in delays and costs. As a result of using DockMind, ports will experience a noticeable return on investment – both in terms of time and money – justifying the ongoing investment in and adoption of the platform. This final assumption underpins DockMind's core value proposition and long-term market viability.

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SENSHORE

Make Data Make Sense

In an era of increased maritime traffic, heightened environmental concerns, port congestion, and security threats, data availability and analysis are vital for industry sustainability and growth. SenShore simplifies this with advanced ship sensors, real-time analytics, and a clear mission: transform sensor tech into streamlined decision-making.

Specializing in state-of-the-art ship sensors, SenShore installs, maintains, and repairs these advanced sensors. These sensors collect a vast amount of data, including trajectory information, weather data, ship surroundings, onboard data, and critical engine data. SenShore's high-speed satellite internet facilitates real-time streaming of this data back to its cloud services. By equipping ships with these sensors, fleet owners and operators can gain valuable insights into their fleet at an unprecedented speed and detail. In addition to the hardware, SenShore offers services that enhance the value of this data. Its web-based SaaS platform provides shipping companies with a centralized hub for accessing and interpreting the data collected by the sensors. This dashboard offers historical data, real-time analytics, and actionable suggestions, empowering organizations to make informed decisions quickly. SenShore's business model involves two primary stakeholders: shipping companies and third parties, resulting in two distinct revenue streams. Firstly, shipping companies subscribe to the platform's services by paying an annual fee. This fee covers the installation and maintenance of ship sensors, access to its software solution, and real-time alerts. Secondly, SenShore generates revenue by monetizing the data it collects. It offers this data to third parties such as governments, research institutes, and financial institutions. These entities can easily access the data through a user-friendly interface, enabling them to make predictions or conduct analyses in various domains.

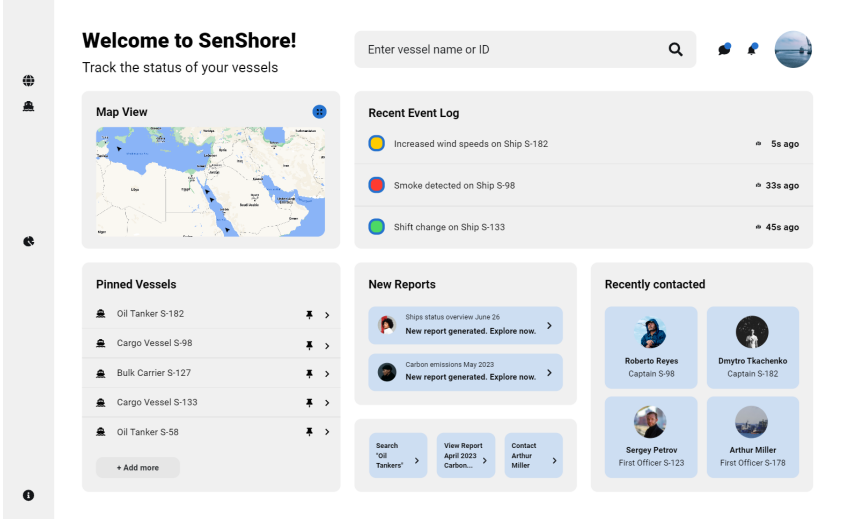
Tailored pricing plans cater to the diverse needs of SenShore's customers. SenShore offers three tiers for shipping companies: the Basic Plan provides access to essential trajectory and weather data. The Advanced Plan includes trajectory, weather, and surroundings data, offering more profound insights into the operating environment. Finally, the Premium Plan offers a comprehensive package encompassing trajectory, weather, surroundings, onboard, and engine data, utilizing advanced AI models to extract the most detailed insights for optimal decision-making. On the other hand, third parties seeking data gathered by SenShore can choose between consuming real-time event-driven data streams or utilizing any of its 15 available REST API endpoints to access data according to their specific requirements and preferences.

Overall, SenShore aims to revolutionize the maritime industry by simplifying the complex process of collecting and analyzing data. It empowers shipping companies to effectively navigate challenges through ship sensors, a comprehensive dashboard, and a robust data network. Simultaneously, the solution unlocks the value of maritime data by offering it to third parties, thereby enhancing decision-making processes across different sectors. SenShore's vision in the constantly evolving industry is to enable a brighter, data-driven future for maritime operations and beyond.

Problem

- Environmental and technological developments in the maritime shipping industry require enhanced safety measures.
- There is a 108% year-over-year increase in the demand for maritime data from container shipping companies [360], highlighting the growing nature of this market. Additionally, in 2022, there was a 70% increase in data usage among maritime shipping customers [360].
- The Ever Given was stranded in the Suez Canal in 2021 despite having sufficient weather data [361], meaning that the correct conclusions were not drawn from the data in time.
- In 2021, 81% of marine incidents and casualties were caused by human error [362].
- Increasingly extreme weather conditions due to climate change emphasize the need for more accurate weather forecasting [363].
- Several cases of ships with sonar technology colliding with underwater objects in ports have been reported [364].

The maritime industry's increasing need for data coincides with safety challenges, highlighting the requirement for advanced solutions



Solution

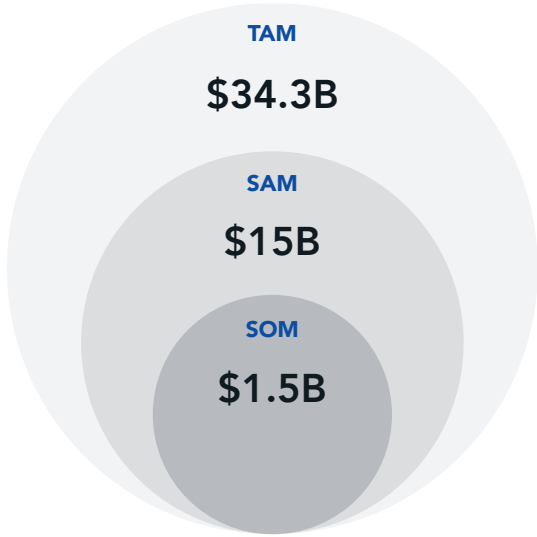
- SenShore provides a wide range of tools for a holistic view of the customer's fleet and the best real-time information, helping to operate ships most effectively.
- Once installed and maintained, advanced sensors capture a spectrum of data, from trajectory and weather to onboard conditions and engine metrics.
- A centralized SaaS platform offers an intuitive interface, showcasing ships and their real-time sensor data, aggregated for the whole fleet on a map and on a vessel-by-vessel basis.
- Using sonar data, the platform crafts detailed ocean floor maps and, with gyroscope and camera inputs, depicts the vessel's surroundings in 3D.
- The system's real-time data analysis triggers notifications when detecting anomalies or outliers in recently collected data.
- As the internal data network expands, the system enhances its capability to send timely alerts about weather shifts, port congestions, or proximate ship hazards.

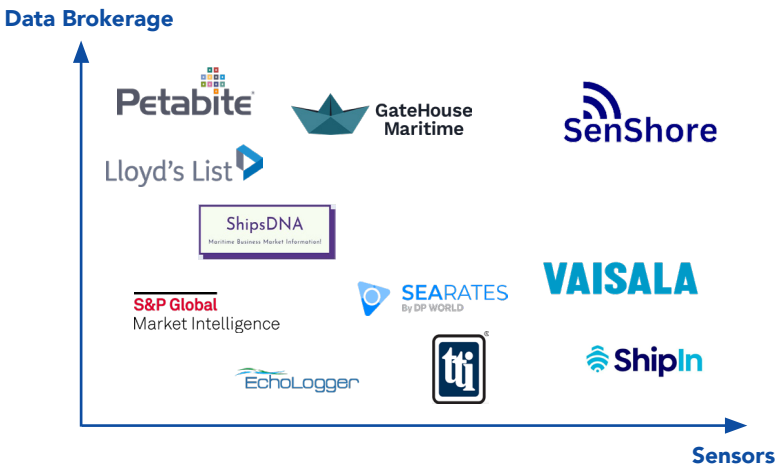
SenShore's tools provide the maritime industry with unparalleled fleet insights, real-time data, and proactive alerts, ensuring optimal operations

Market

- SenShore targets two distinct stakeholder groups: shipping companies and third parties like financial and research institutions and governments.
- The total addressable market, therefore, consists of the global markets for marine sensors, valued at 33B USD, and maritime analytics, valued at 1.3B USD [365, 366].
- The emergence of new technologies, coupled with stricter regulations for safety and fuel efficiency, is driving an increase in the demand for comprehensive sensor data.
- Both markets are expected to grow significantly in the coming years. By 2028, the maritime analytics market is expected to double in size, while the market for marine sensors is projected to grow to 45B USD by 2029, showing a CAGR of 4.8% [365].
- Because Asia Pacific and Europe are the fastest growing markets in the marine sensor industry, making up around 15B USD of the total market volume, SenShore will focus on these areas first.
- SenShore is implementing an ambitious strategy to capture at least 10% of the attainable market within the first five years and to establish an industry standard for sensors on ships.

SenShore bridges the growing markets of marine sensors and maritime analytics, aiming to set the industry benchmark amidst evolving demands





Competition

- Satellite monitoring has revolutionized the maritime industry, providing substantial advantages for ship operators. Petabite and other companies lead the way, utilizing satellite technology to track ships accurately.
- The industry is also counting on real-time tracking. Here, ShipsDNA provides detailed vessel information, while Gatehouse ensures instantaneous monitoring, elevating safety and efficiency standards.
- In operational data analytics, industry leaders such as Transmetrics and Awake.ai are harnessing the power of predictive analytics. Their advanced tools and methodologies enable more precise transportation planning and optimize cargo flow.
- Meanwhile, weather and environmental monitoring are championed by Tide Tech and Wind Ward, supplying crucial data for safer navigation and anticipating ecological challenges.
- Lastly, the advent of data aggregation platforms like MarineTraffic offers a consolidated view of maritime activities, reflecting the industry's move towards data-centric decision-making.

SenShore combines satellite monitoring, real-time tracking, and predictive analytics to provide the maritime industry with a unique, holistic solution

Assumption Tree

Real-Time Data in Shipping

Many shipowners need more real-time data on their vessels. The basis for this belief stems primarily from expert interviews and data on marine accidents attributed to human errors and informational gaps. To verify the validity of this assumption, one could conduct a series of interviews with representatives from various shipping corporations. Through these conversations, a clearer picture of the industry's data accessibility can be drawn.

Data Collection and Analysis

The type of data collected and its analysis frequency are crucial for optimal results in maritime operations. Proper planning and execution, informed by the generated insights, can enhance performance, reduce costs, and empower shipowners to make better decisions, laying the foundation for sustained success. Engaging with industry experts can offer insights into cutting-edge technology and its best application.

Satellite Internet on Ships

Ships can use low-orbit satellite internet, like Starlink Maritime, to stream large amounts of data while on the move. This new technology provides fast and low-latency internet globally, including at sea. A pilot test can be conducted with Starlink Maritime or similar services to confirm this assumption. The test would assess data transmission bandwidth, latency, and reliability.

Ship Data for Third Parties

Third-party entities, such as financial, research, and government institutions, invest in ship data for various purposes. Hedge funds use it to estimate GDP, while governmental agencies and climate research organizations can benefit from aggregated fleet data. Market research interviews can be conducted, or a prototype can be introduced to potential third-party clients to validate this hypothesis.

Data Sharing by Shipowners

Shipowners are willing to share anonymized data with third parties, trusting SenShore's robust anonymization and consolidation processes to mitigate privacy-related risks. To validate this assumption, engaging in in-depth conversations with shipowners is essential. This will help understand their comfort levels and apprehensions about data sharing, especially considering the competitive implications of such actions within the industry.

Accurate Estimations

The projected range for costs and time required to install and maintain sensors and transmission systems on ships, which is the basis for the business model and pricing strategy, should be accurate. To test this assumption, it is essential to carry out pilot installations on different types of vessels. This will provide concrete insights into the real-world costs, potential challenges, and time commitments.

Maritime Goes Digital

As maritime challenges grow in complexity, there is an increasing adoption of integrated digital ecosystems that combine sensor technology, analytics, and cloud services. The hypothesis is that platforms like SenShore, offering a holistic data collection and analysis approach, will become industry standards. Validating this would involve assessing the adoption rate of such platforms among top shipping companies and measuring their satisfaction levels.

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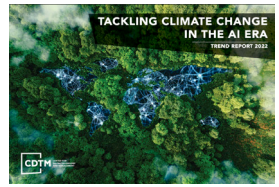

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THE FUTURE OF MARITIME SHIPPING

The maritime shipping industry is of paramount importance as it serves as the lifeblood of the global economy, facilitating the movement of approximately 80% of the world's trade by volume and 70% by value. Its cost-efficient and vast network of sea routes connects producers, consumers, and nations, ensuring the availability of goods, raw materials, and energy resources worldwide. Beyond economic significance, it creates millions of jobs, supports energy security, and plays a pivotal role in sustainability efforts, making it an indispensable driver of both prosperity and environmental responsibility on a global scale.

Driven by trade, the development of the maritime shipping sector is closely tied to global economic outlooks and geopolitical tensions. In an era with looming armed conflicts in areas that are key to global trade, the future landscape seems difficult to navigate. While these ties fundamentally do not change, the shipping industry is evolving in other directions and facing new challenges as the world transitions from a fossil fuel-based economy to one driven by green energies and goods. What does the future hold for this critical industry? How are transported goods evolving? Are we seeing new trading hubs emerge? What will the propulsion of the future look like? How is climate change going to affect global trading infrastructure?

Advancing technologies, data availability, and completely novel business models emerge, promising answers to these questions and long-term value for the shipping industry. This report looks at key challenges, reasons why the maritime shipping industry is evolving, and where new technologies could aid in tackling the big challenges that lie ahead. It is divided into three core sections: Trends, Exploration, and Ideation.

The first section covers current trends in the technical, societal, environmental, regulatory, economic and business model streams and examines how these will impact the industry going forward. Next, key problems and opportunities are clustered and investigated, also with regard to what incumbents and current innovation leaders are doing. In the final section, everything culminates in five different business ideas, covering a wide range of areas: advanced analytics for fleet management, facilitating ship-to-x communication, automating engine inspection, portside automation and optimization, and methanol production optimization.

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CDTM offers the interdisciplinary add-on study program "Technology Management", which is part of the Elite Network of Bavaria. Students from various study backgrounds with creative ideas, great motivation and an entrepreneurial mindset are offered the tools to put their ideas into practice. As a research institution, CDTM closely cooperates with the industry, startups and public sector concentrating on topics at the intersection of technology, innovation, and entrepreneurship.

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