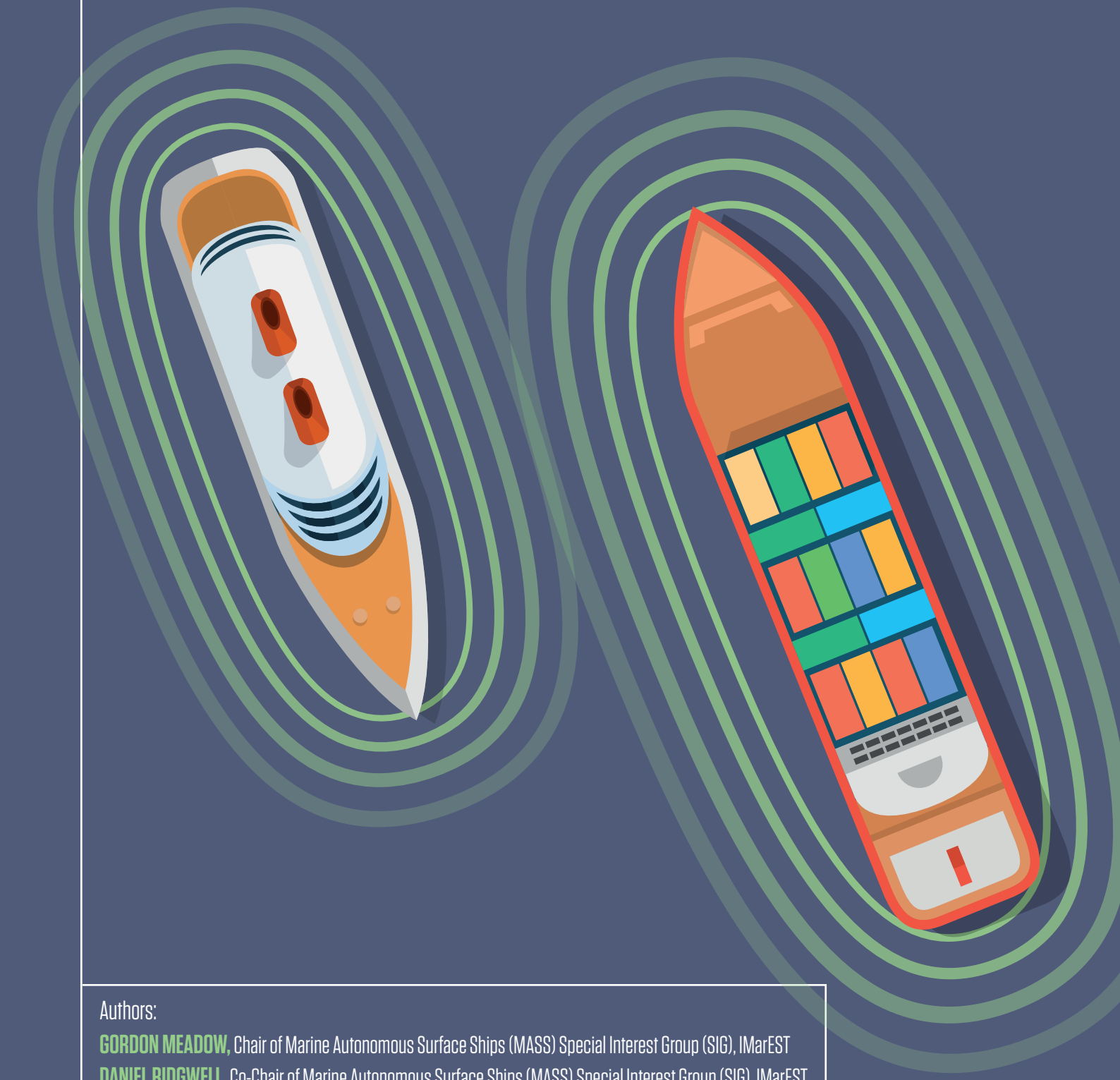
Institute of Marine Engineering, Science & Technology

IMarEST

AUTONOMOUS SHIPPING

Putting the human back in the headlines

SINGAPORE, APRIL 2018



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ACKNOWLEDGEMENTS

In producing this report, we have been greatly assisted by the many individuals and businesses who contributed to both the survey and subsequent round-table discussion. The 600-plus participants who responded to the survey gave us a scalable and valuable insight into current industry sentiment.

The industry leaders attending the roundtable added much to this and shared their own practical experiences and recommendations for addressing the remote and autonomous discussion. We are most grateful to them all.

> “...85% of those surveyed agreed that seafarer skills will remain an essential component in the long term future of the shipping sector.”

INTRODUCTION

The shipping industry is a rich, highly complex and diverse industry, which has a history of both triumph and tragedy in its adoption of technology. Regardless of this, appetite remains as the competitive advantage and cost savings which can be gained from the adoption of technology is significant. In the context of greater automation, the advantage is in creating guaranteed availability of the asset, therefore new systems less prone to failure and with more predictable failure are being sought. As a result, attention has turned to both the 'smart ship', and the remote and autonomous ship.

In light of the potential for the remote and autonomous ship, and to contribute to the assurance of safe and efficient operation, we seek to understand the impacts to the industry. We seek to better understand these impacts so as to measure the changes required in workforce capability, competency and training requirements so that the human can remain highly effective. We believe that the future for the shipping industry is to build in human performance into its technology, to mimic human functions intelligently and where appropriate, not simply to replace humans, but to pair the best qualities of human performance with the best complementary technologies. The expectation is that we will see an increase in capability of all assets by integrating more deeply and more cleverly with technology. Therefore, in this cyber-physical systems future, if we fail to build the technology around the human remaining as the parent and the robot the child, we may see the same accidents continue to happen when the technology fails to cope.

Therefore IMarEST has taken up the gauntlet in considering the skills and training needs of a future workforce in the journey towards increased automation and the scaling up of cyber-physical systems in the shipping industry, to ensure that automation is understood as a tool, and not the goal.

The taxonomy of automation between human and machine is vast and complex. However, what is perhaps most striking is the great irony that before a system can reach full autonomy and undertake independent decision-making, the supporting operator must be the most highly skilled they can be to respond to failure. People are inherently flexible and adaptable, but to be effective in responding to emergency or 'the save the day scenario': they must be taught the skills to do this; be allowed to practice and update these skills on a regular basis; and be provided with appropriate information by the technology in a timely manner. As a result, there are any number of potential operational challenges, from operator skill degradation, effectively and successfully responding to emergency, the maintenance of operative situational awareness, to information overload. This applies to both sea-based and a future workforce ashore.

The roundtable, held on Tuesday 24th April 2018 during Singapore Maritime Week in Singapore, explored the responses to a survey examining the likely impacts at the beginning of the journey to greater automation of functions in the operation of commercial ships. It sought an industry perspective on the strengths, weaknesses, opportunities and threats.

The roundtable invited key industry participants to respond to the findings of the survey as well as to share their views on both future training needs and skillset requirements of the operational workforce in order to more accurately map our journey to the future. The roundtable in Singapore was the first of a number of events planned under the *'Autonomous ships: Putting the human back in the headlines'* initiative, coordinated by the IMarEST's Marine Autonomous Surface Ships (MASS) Special Interest Group (SIG). The MASSSIG has a functioning programme that looks at the workforce training and skills required to maximise capability for this emerging area.

Through this initiative, the commercial sector, ship manning agents and ship owners will benefit from industry wide recommendations to understand workforce succession responsibilities and will help to produce fair treatment policies. Furthermore, it will highlight employers who understand the benefits of a well-trained workforce. We intend to work together with employers, organisations and regulators to understand the skills required of the future workforce and to define the training framework within which they will be taught.

AUTOMATING THE SHIPPING INDUSTRY

It is important to remember that the journey towards remote and autonomous shipping will be gradual. The implementation of various technologies and the steps along the way will include moving from part-automation to full remote operation and eventually to crewless vessels. It is unrealistic to assume that worldwide fully autonomous vessels will be operating in just a few years. Automatic and autonomous shipping technologies have been evolving for many years, and will continue to develop for many years to come.

The results of the IMarEST member survey with subsequent qualitative feedback from our expert panel created a number of discussion points. These points are summarised below, with the overarching recommendations highlighted towards the end of this report.

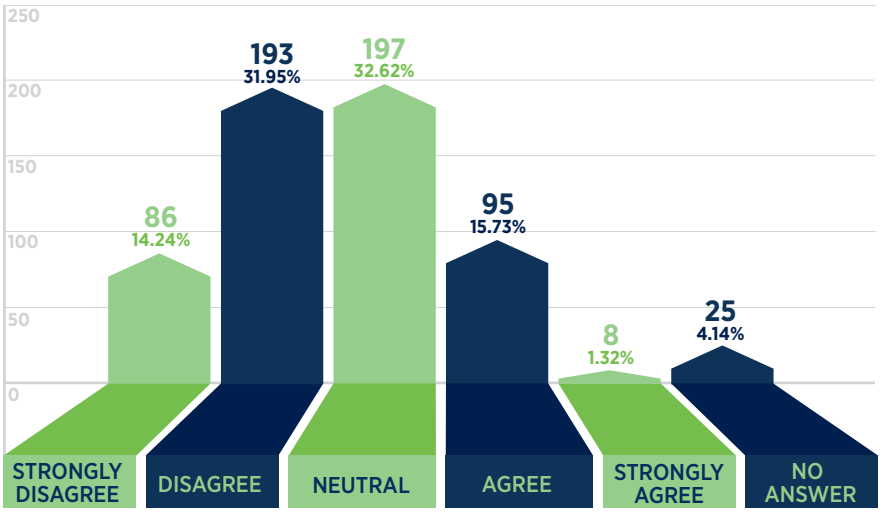
What do we mean by automation?

In relation to the survey and subsequent roundtable, the term automation referred to and extended to the following contexts. The redistribution or reallocation of any of the functional requirements currently performed by the on-board in situ human, essential to the safe and secure operation and management of a vessel at sea in the transportation of cargo from one port to the next. The context also relates the relocation or automation of functions, partly or in full, from *in situ* to remotely located operation, management and interventions from a remote location. This will be achieved with the use of sensory feedback and the adoption of human machine mimicking through varying orders of human and machine cooperation in the performance of vessel operational functions.

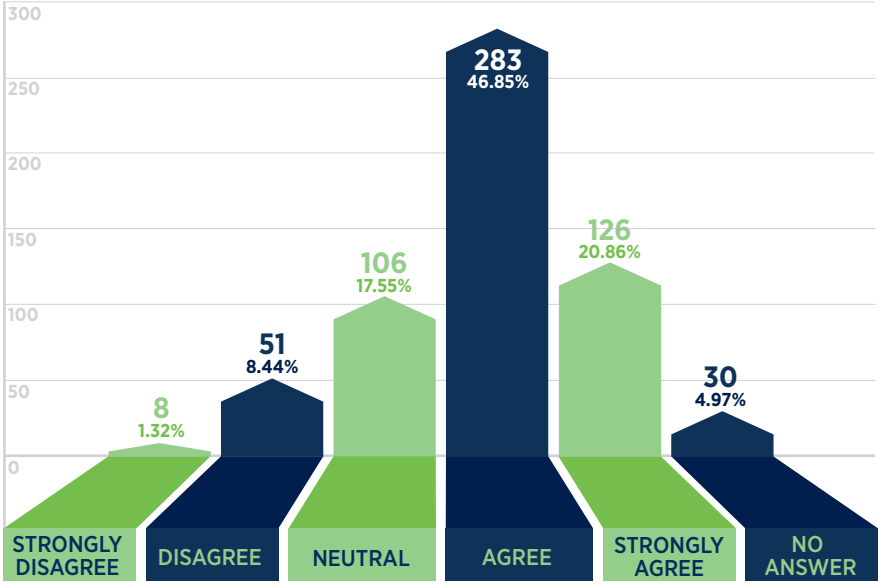
What are the drivers behind automation?

Identifying the drivers behind automation was a key discussion point and is of course central to any significant adoption of the remote and autonomous vessel in the future. We therefore set out to obtain the views of what industry considered to be the main drivers behind greater adoption of automation and remote operation.

Remote and autonomous technology providers understand the shipping sectors requirements



Remote and autonomous operation of ships is being driven by the technology providers



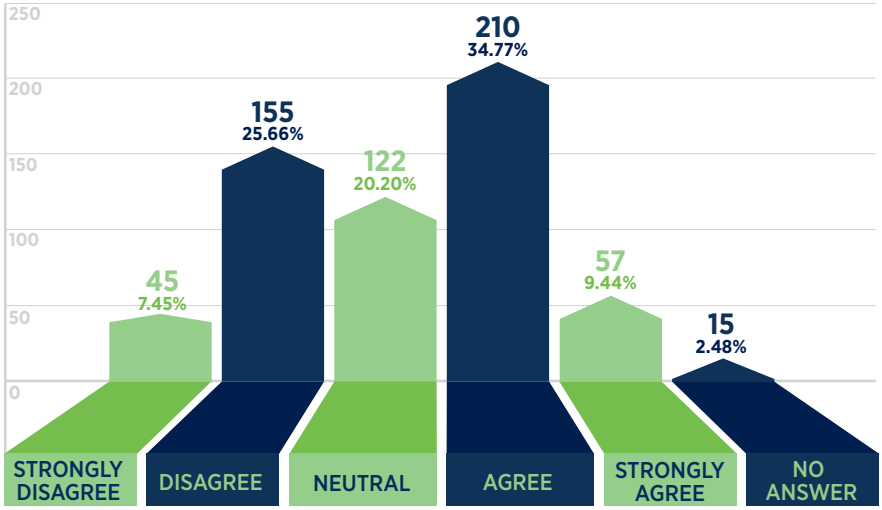
As shown left, more than two-thirds of those surveyed believed technology providers were the main drivers behind ambitions toward the adoption of the remote and autonomous operation of commercial vessels. However, less than 20% of respondents supported the view that providers of remote and autonomous technology fully understood shipping industry requirements. If this is the case, it will lead to a disconnect in the perceived value of this technology and may hinder progress. It is recommended therefore that more evidence is produced relating to the tangible benefits manifesting from the adoption of this technology. The panel discussed this at length suggesting that whilst there is general support for the above statistics, and whilst there are slow changes happening at an international regulatory level, to help understand the benefits of adopting such technologies, a substantial body of unambiguous information needs to be collated by all stakeholders.

AUTOMATING THE SHIPPING INDUSTRY

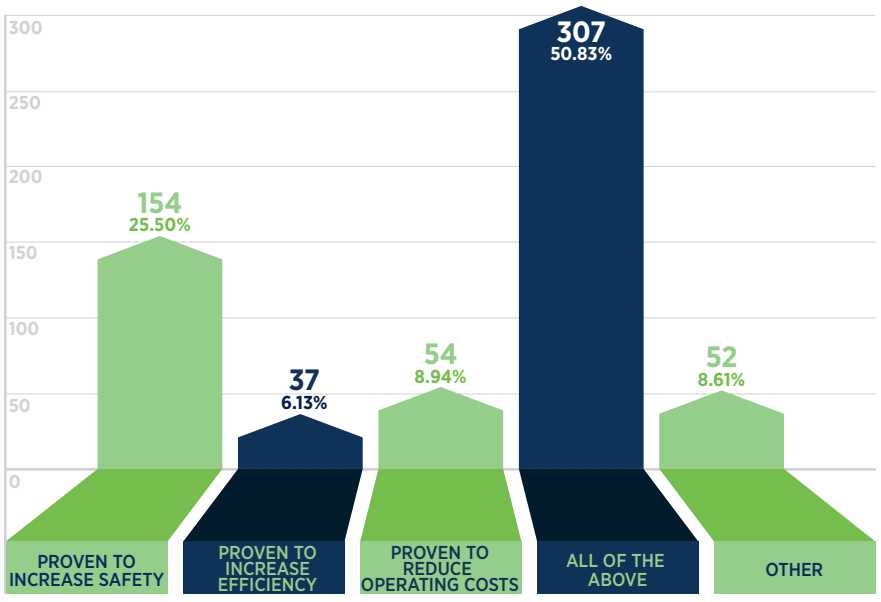
Industry willingness to adopt greater automation and remote operation

Our next questions examined the basis on which shipping industry would be willing to support a move to the wider adoption of the autonomous vessel into the shipping sector. We cited other industries that have successfully embraced automation.

Other Industries such as rail and mining are successfully utilising and implementing remote and autonomous operation and the shipping industry should follow suit



On what basis would you be willing to support a move to the adoption of the autonomous vessel?



A quarter of respondents claimed they would support a move to remote and autonomous shipping based on increased levels of safety, whereas 6% believed support would emerge from increased efficiency, and 9% emphasised reduced operating costs. However, half of survey participants said support for remote and autonomous shipping would only come about from a mixture of all three elements.

Some 44% agreed that the shipping industry should follow the example of other industries such as the rail, mining and nuclear sectors that are successfully implementing and utilising remote and autonomous operation. This was compared to 33% who disagreed that this was a solid basis from which to implement such a move; 23% remained neutral or did not answer. After examining these statistics, the roundtable delegates concluded that there were additional factors which would have to be demonstrated in addition to the justifications contained in the survey. The panel suggested that the following should be addressed before the adoption of remote and autonomous operation can move forward:

- International regulatory framework would have to be modified via the International Maritime Organization, however the mechanism needed to be more agile so as to leverage potential benefits more quickly;
- Further discussion was required in industry more generally, but with more coordination, and with greater alignment in subject matter and outputs;
- That data and details of technology available need to be made more widely available and made more clear as to the actual capability offered; and
- That there needed to be a clear business case available and in place, for each sector.

Most notably missing was a clear business case on which to base informed decisions around thinking about and implementing autonomous systems. Whilst safety was a major concern, the business case to reduce cost and/or increase revenue was not there and was perceived to be lacking.

Again, the panel discussed this area at length with the opinion that shipowners/operators in general are sceptical as to the raison d'être for the significant investment necessary to move into automation and remote operation, especially in an economic climate that is challenging many sectors of shipping.

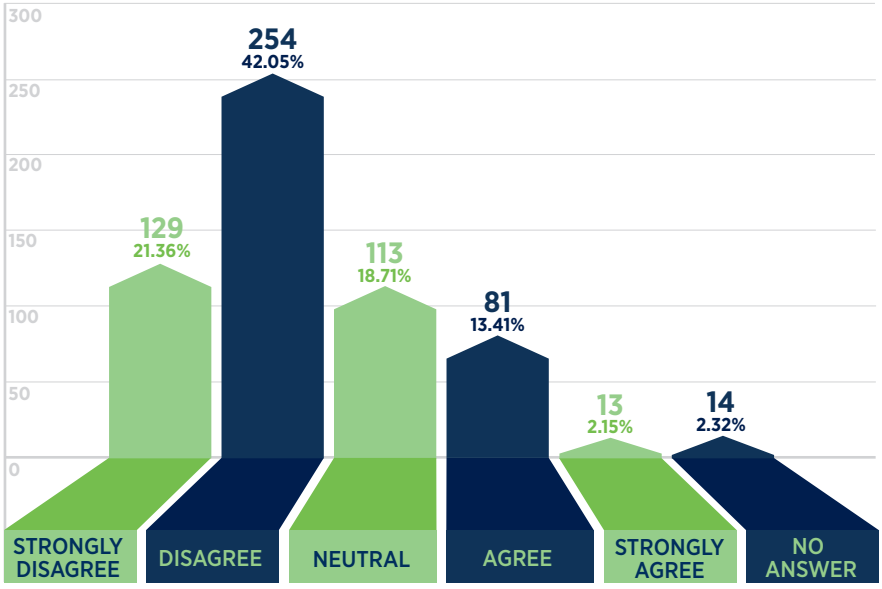
AUTOMATING THE SHIPPING INDUSTRY

Addressing the challenges

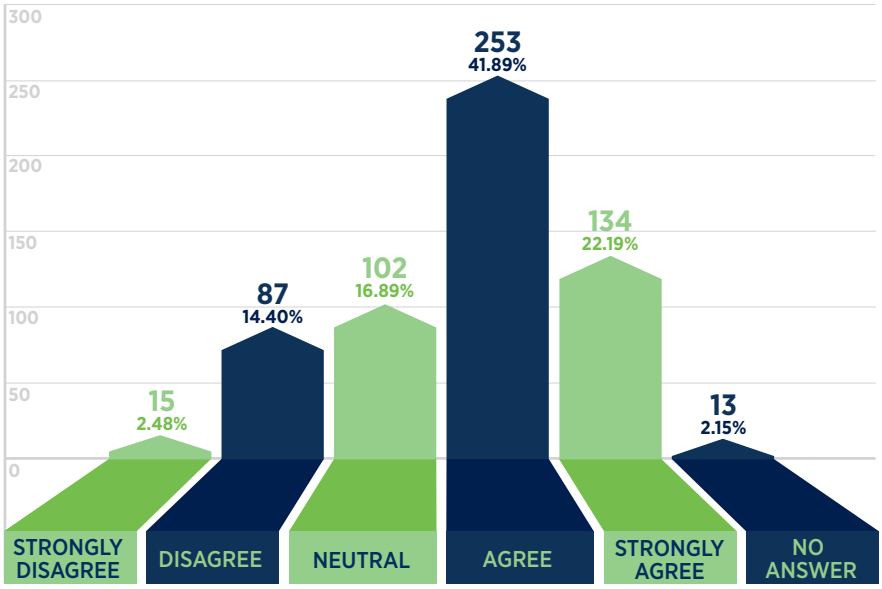
Turning to the challenges of adoption of remote and autonomous operation, only 15.5% of survey respondents think that the shipping industry is currently 'geared up' to support the implementation of remotely operated or autonomous vessels.

> "...the potential saving in manpower costs by reducing 2-3 crew members on board even initially, and placing them onshore has no significant meaning to 'big players', as compared to the total expenses and safe operation of a vessel."

The shipping industry is geared up to implement the operation of autonomous ships



There are too many barriers to see full adoption of remote and autonomous operations in the shipping sector



The roundtable delegates added that the technology was not yet sufficiently advanced to support substantial adoption and that more tests would have to be completed before the industry could start to adopt.

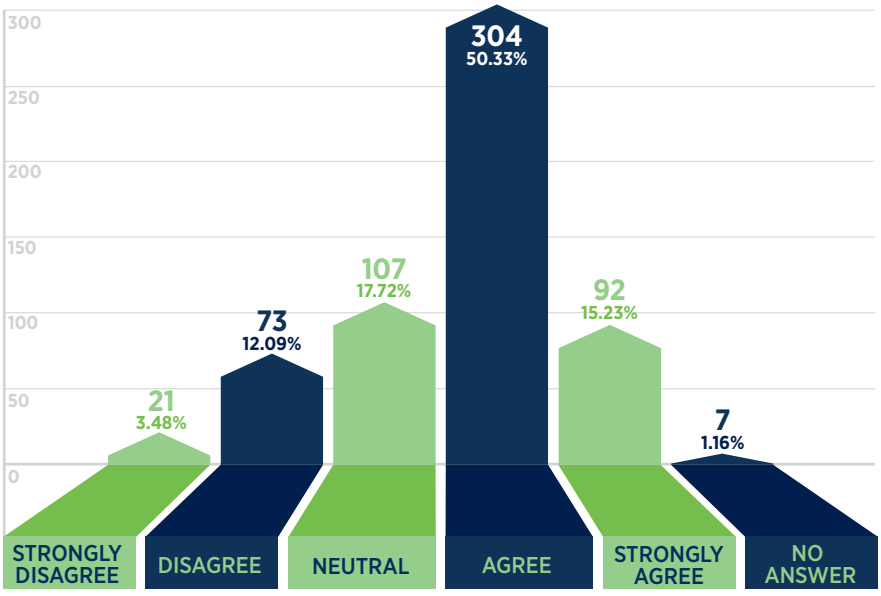
Furthermore, it was pointed out that countries with different geographical features tend to have different appetites or requirements for developing/implementing autonomous shipping. Countries with inland waters for transport, for example, may have a higher appetite and face less challenges in implementation as there is no need to wait for an international regulatory framework. Again, regulation is a theme here and the panel recommended that these varying appetites needed to be understood.

Over 64% of the survey respondents purported the view that currently there are too many barriers to see significant adoption of remote and autonomous operations. This was somewhat supported by the roundtable panel where the consensus was that a number of significant challenges remain. The panel suggested vessel size to be an important factor, together with the nature of the segment in which it operates. The panel concluded that the potential saving in manpower costs by reducing 2-3 crew members on board, and transferring them onshore is inconsequential to 'big players', when compared to the total expenses and safe operation of a vessel .

The business case for automation and remote operation

Here we found that any suitable business case would have to demonstrate enhanced safety, cost savings and the creation of a competitive advantage.

The adoption of autonomous technology could create a competitive advantage for shipping companies



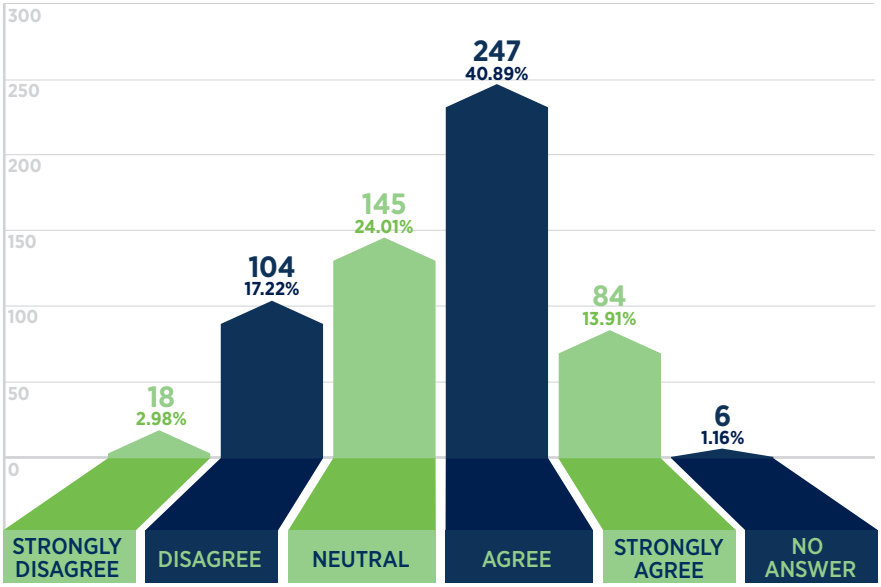
> "... any suitable business case would have to demonstrate enhanced safety, cost savings and the creation of a competitive advantage."

AUTOMATING THE SHIPPING INDUSTRY

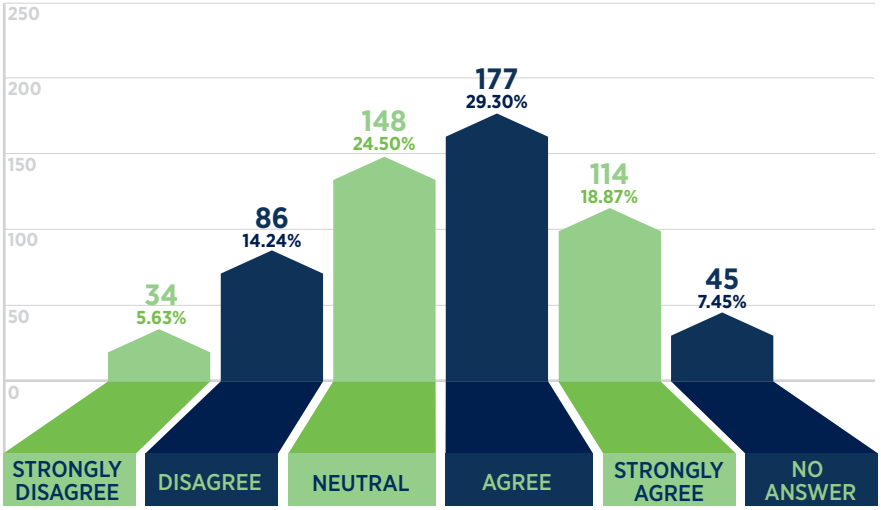
Two-thirds of survey respondents agreed that autonomous technology could create a competitive advantage for some shipping companies on a sector by sector basis. Whilst only 15.5% felt that the shipping industry is geared up for autonomous and remote operation technology at present, a much larger percentage could see the longer term benefits. Furthermore, just over half thought that autonomous technology could create cost savings for the industry.

Whilst there are perceived economic advantages of adopting technology within the sector, there was a trend among survey participants that the autonomous ship is going to have an impact on their business.

The adoption of autonomous technology will create cost savings



The autonomous ship is going to impact my business

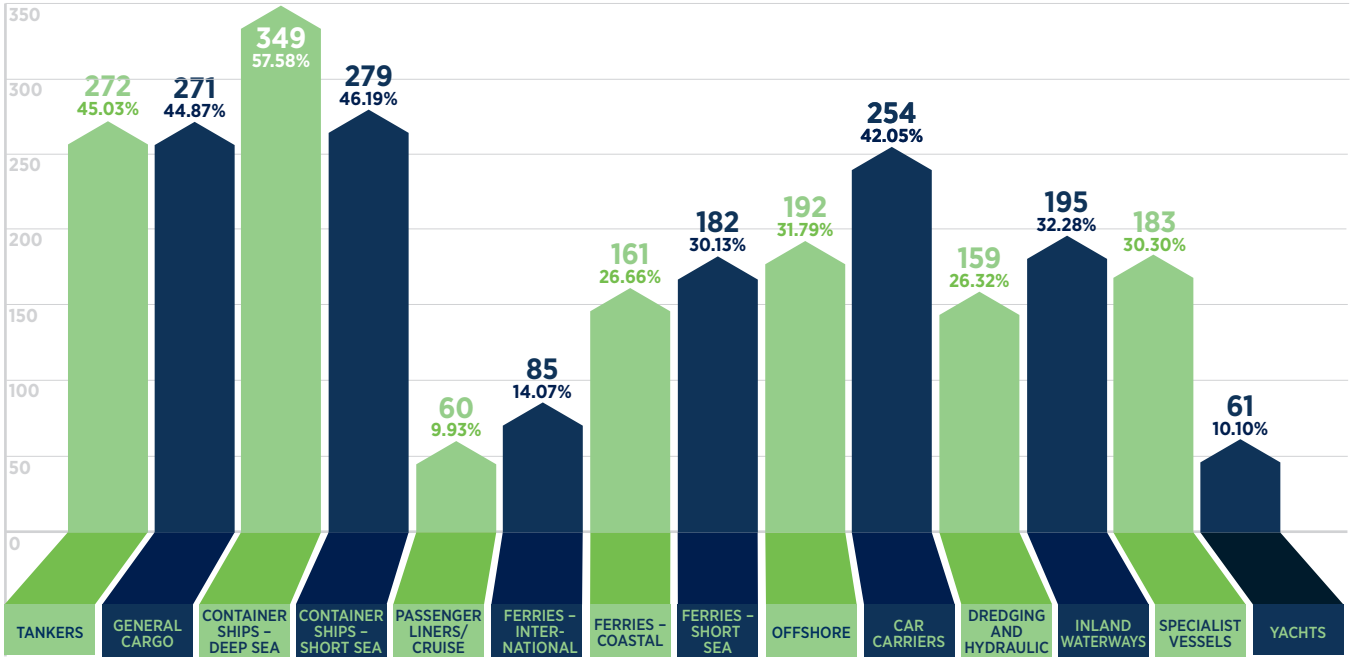


Which industry segments could benefit from automation?

Among the various vessel types, the survey results indicated that cargo transport was the most likely to benefit from remote and autonomous operation. Passenger-carrying vessels (10%) were deemed the least amenable, whereas tankers (45%), general cargo (45%), container ships (both deep sea (58%) and short sea (46%)), car carriers (42%) rated fairly highly as segments that could benefit. Interestingly, 10% of respondents could see potential for remote or autonomous operation in the private yacht market.

> “...a much larger percentage can see the longer term benefits. Furthermore, just under 55% thought that autonomous technology could create cost saving for parts of the industry.”

Which of the following shipping sectors could benefit from the adoption of autonomous operations?

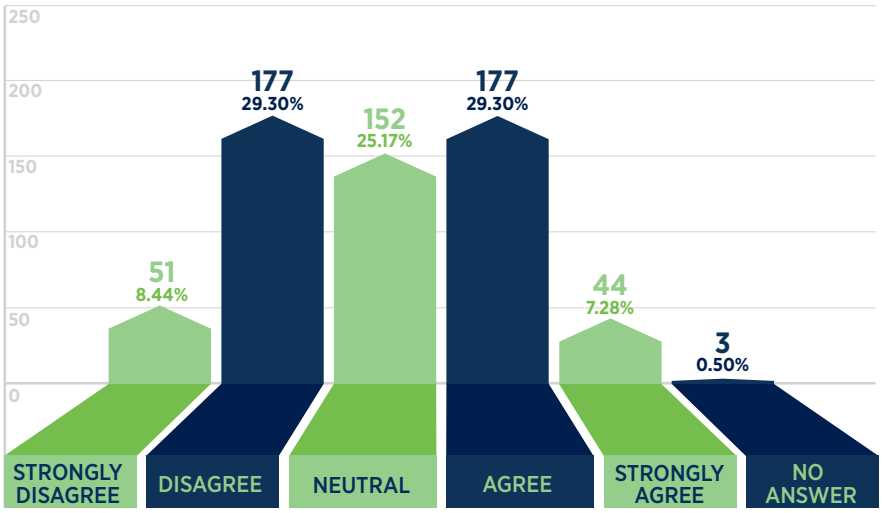


AUTOMATING THE SHIPPING INDUSTRY

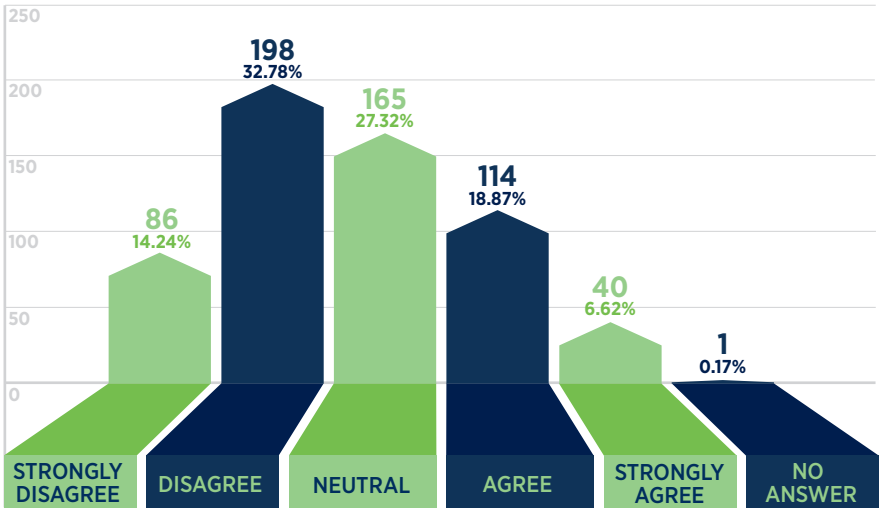
Man and/or machine?

The roundtable panel discussed the value and requirement of the human when considering remote operation and automation.

Replacing human operators on-board ship with machines will create a more efficient industry



Replacing human operators on-board ship with machines will create a safer industry



> “…human error was being used to create a blame culture towards the workforce at sea in being the only real cause of accidents at sea.”

Survey respondents had a mixed view on whether replacing human operators on-board ships with machines (machine mimicking of functions) will actually create a more efficient industry and, somewhat unexpectedly, few agreed it would necessarily create a safer industry.

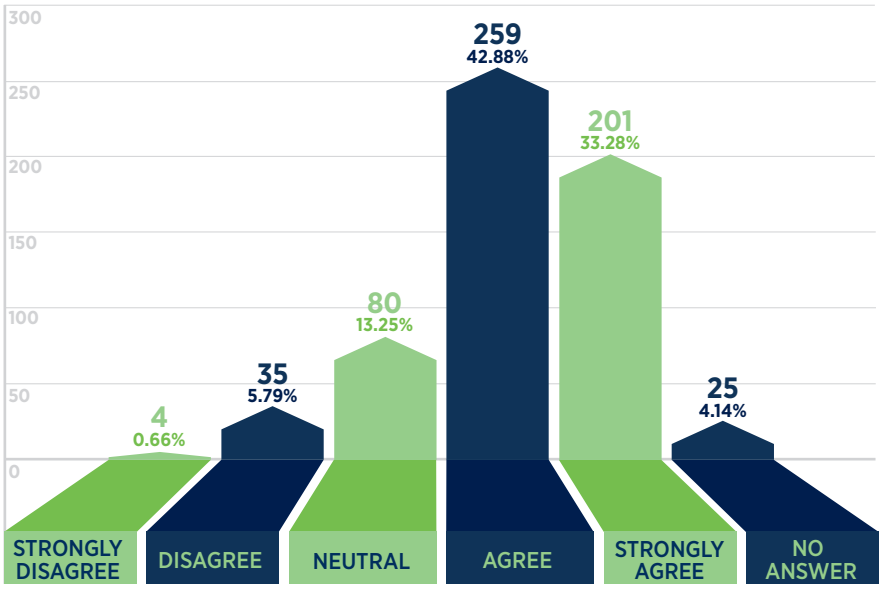
This view was broadly accepted by the panel, though a sector-specific analysis would offer a more illuminating view. For example, in the defence sector, the justification for remote and autonomous operation is to reduce the risk personnel are exposed to, as in the case of minesweeping. In support of a move to remote operation, the panel did suggest that if technology could be developed effectively in a way so that the human acts as the 'parent' and the system/technology acts as the 'child', in support of the human, and that the human could perform at the same level of capability, then what justification would the industry have to continue to send people to sea? This would certainly increase the safety of the mariner, but is separate to the safe operation of the vessel.

A key talking point was in how human error was being used to create a blame culture towards the workforce at sea in being the only real cause of accidents at sea. The panel commented that this is a grey area and that human errors are also the result of poor implementation/introduction/preparation for new technologies.

Debate also considered the scenario of an automated system failing, and the potential consequences of such an occurrence on future adoption. One example shared by the group related to an incident involving a Tesla car that killed its driver when it crashed whilst running on Autopilot[1]. Similarly, an Uber self-driving car that killed a pedestrian also attracted huge public interest[2]. Whilst these two incidents both occurred in the United States of America and are not what the automotive industry wanted to happen, it was felt that it doesn't correlate correctly to the 37,461 fatalities[3] that occurred in other road traffic accidents in 2016 alone. This same debate will have to be quelled in the shipping industry when an incident inevitably happens. However, the consequences of the autonomous car crashing compared to the autonomous ship crashing are somewhat different in magnitude.

The panel recommended that pairing the human and machine effectively to enhance human intelligence and performance rather than replacing the human was an area that should not be overlooked.

Seafarers are worried about the impact of autonomous ships



[1] https://www.theguardian.com/technology/2018/mar/31/tesla-car-crash-autopilot-mountain-view
[2] https://www.theguardian.com/technology/2018/mar/29/uber-settles-with-family-of-woman-killed-by-self-driving-car
[3] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451

AUTOMATING THE SHIPPING INDUSTRY

Societal acceptance?

More than two-thirds of respondents believe seafarers are worried about the impact of autonomous ships. In this respect, the industry should take steps to reassure seafarers that they remain a hugely valuable asset.

The panel discussed the management of change and the messages being delivered to the seafaring community in the drive toward greater automation. It was stressed the industry should take care in how the workforce is communicated to, and that contrary to growing belief otherwise, the workforce is both valued and an essential component of the shipping infrastructure.

There was a recommendation for educational media campaigns to explain the provenance of this technology more clearly to gain greater adoption. The IMarEST MASSSIG will produce an infographic factsheet or Q&A document to help clarify to seafarers the impacts and definitions around this highly misunderstood area of technological development.

Furthermore, in respect of societal acceptance, it should be explained that 'robots' are not a significant threat to employment opportunities. The threat to employment comes about from failing to adapt, through retraining and the assimilation of new skills to perform new functions through continuing professional development.

Finally, the panel discussed wider societal acceptance among the general public and acknowledged that this will be a difficult issue to tackle. Compelling evidence must be brought to bear to reassure the general public that an autonomous cross channel ferry for example is not only as safe, but some orders of magnitude safer than a traditionally manned vessel. A broad level of collaboration will be required to achieve this, but it should be akin to the marketing and educational effort seen across the automotive sector.

> "...not only just as safe, but some orders of magnitude safer."

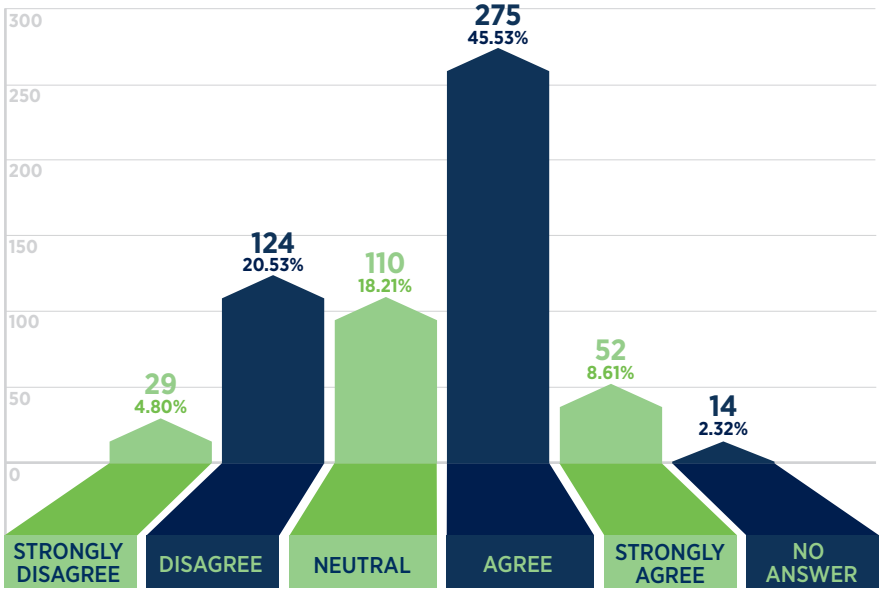
Workforce succession planning

The roundtable discussion then turned to the development of the current seafaring workforce. At the present time, it is believed that it is going to be difficult and therefore unlikely to see fleets remove their deck and engineering officers and ratings.

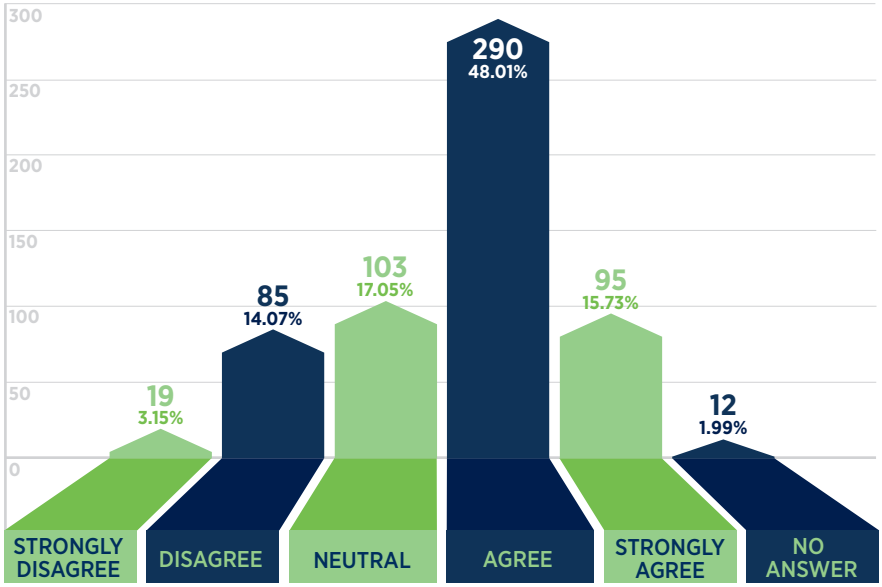
The survey results somewhat disagreed with the panel in this case: more than half of the respondents felt that many on-board roles could be relocated to the shore either now or in the foreseeable future. Nearly two-thirds of survey respondents believed that the current workforce at sea could be trained to handle the remote operation/management of autonomous ships. This view was particularly supported by the panel with significant strength of feeling towards understanding this impending and presumed knowledge gap and filling it. Therefore, from a succession planning perspective, it is recommended that opportunities should be created to train for a shore-based career as well as one at sea.

The panel also recommended that further investigation is carried out into fully understanding how, why, and by whom operational functions are performed on-board, in order to develop a hierarchy of needs. Further, the functional requirements of a vessel should be considered from berth-to-berth including all functions, roles and responsibilities. This would facilitate a road-mapping exercise to determine which functions must be translated to the shore, how they will be performed, and when

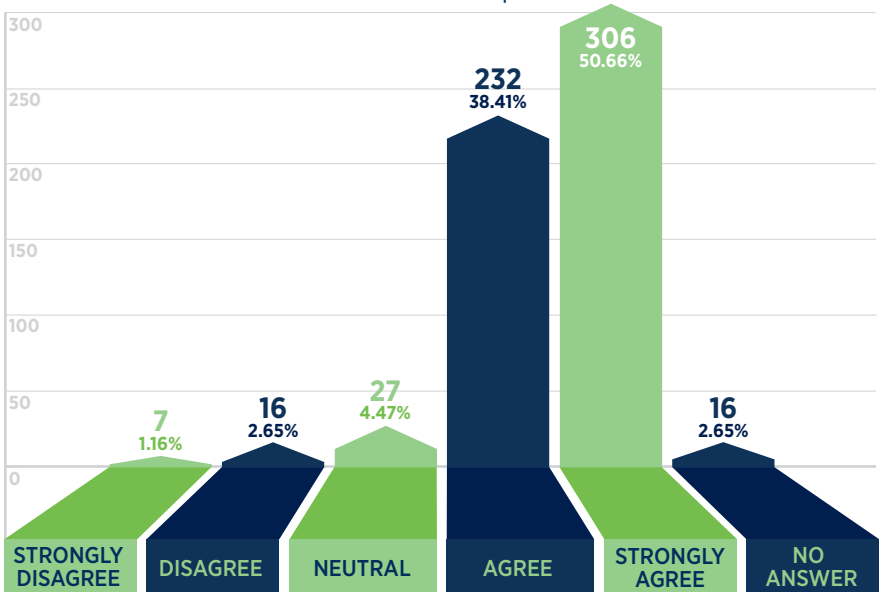
Many on-board roles could be relocated to the shore now or in the foreseeable future



The current workforce at sea could be trained to handle the remote operation of autonomous ships



Current sea and shore-based training will need to change to be ready for the remote operation of autonomous ships



> At the present time, it is believed that it is going to be difficult and therefore unlikely to see fleets remove their deck and engineering officers and ratings.

they will be required. This will provide a richer understanding of the skills shortfalls and inform future training requirements moving forward.

Panel members and survey respondents broadly agreed that current shore-based training will need to adapt if the workforce is to be retained for future succession into these sorts of roles (89%). It was further highlighted in discussion that this succession does not relate to just making 'digital captains' for example. The aim is not to remove particular ranks, rather the challenge is to replace particular on-board functions with remote and autonomous technology.

The panel felt that the navigational-related functions can initially be replaced with smarter technology, which would remove or reduce the paperwork burden for example. It was also suggested that some routine maintenance functions currently performed on-board by the marine engineer could be fulfilled from the shore as long as the correct technology and safeguards were in place.

The roundtable discussion also highlighted the tremendous technological advances that have already been made towards automation. Over the years, many tasks formerly carried out manually have been automated, resulting in a reduction in crew numbers but increased technological know-how among those who remain. That said, the technology, safety/economic/other factors, are still a quantum leap away from autonomy.

AUTOMATING THE SHIPPING INDUSTRY

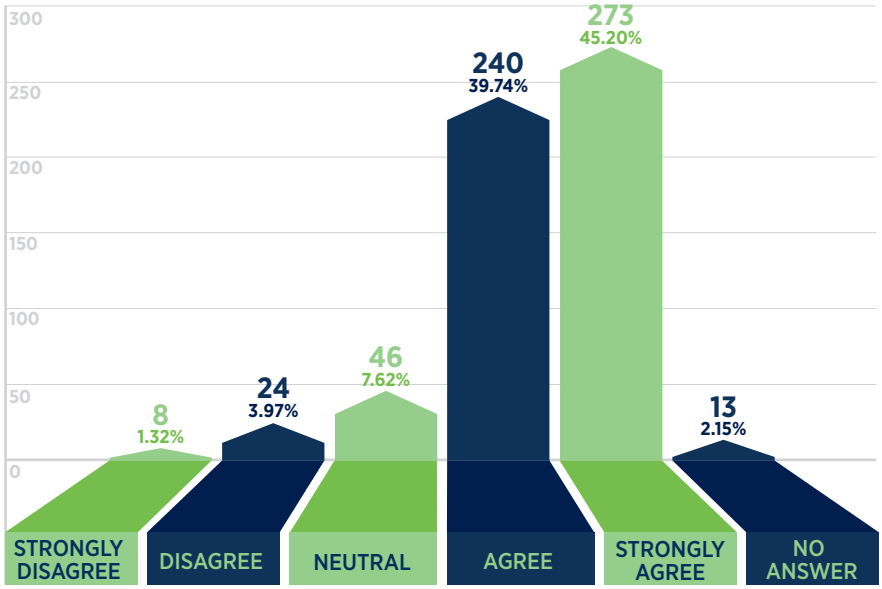
The human element

The consensus was that the future workforce will need to be trained differently, and that, in time talent could be relocated from seafaring roles to shore-based roles as the shipping sector moves more functions in favour of remote and autonomous operation. The survey strongly backed this view with 85% of those surveyed agreeing that seafarer skills will remain an essential component in the long term future of the shipping sector.

Noteworthy, is that the panel agreed for tomorrow's seafarer to be up-skilled it is important for today's professionals to capture the relevant knowledge and skills before and not during the disruption. The panel also felt that the sector would also have to identify the potential knowledge gap due to removal of professionals/functions managed by third-parties, as an outcome of the implementation of autonomous shipping.

We find the response to the final question in our survey to be quite compelling. Asked whether seafarers would remain an essential component of the shipping industry's long term future, 85% believe that to be so. So did our panel.

Seafarers will remain an essential component in the long term future of shipping



CONCLUSION

The focus of this survey and subsequent panel discussion was to gauge sentiment and to seek clarification on a number of pressing issues surrounding the adoption of remote and autonomous technology in the shipping industry. It is very likely that the adoption of remote and autonomous vessels will proceed on a sector by sector basis, but it is still unclear as to the justifications for the business case for each of these sectors in terms of full adoption.

More holistic discussion, data, and collaboration of technology will need to be disclosed and understood in more detail. There needs to be a clear, compelling business and safety cases to show industry that autonomous shipping will help to generate more revenue/reduce costs and make operations safer. This is currently lacking.

These are the first gentle steps in a long and difficult journey to understand the impacts to the industry and answer questions so as to measure the changes required in workforce capability, competency and training requirements to ensure that the human remains highly effective, which sits ironically in the context of the autonomous ship.

Our findings appear to suggest that the human will remain an essential component in the long term future of shipping, even if that future is autonomous. Therefore the next stage of this IMarEST initiative will be to build upon the recommendations in this report, and to understand how we effectively incorporate human performance into the technology of the future. We will also need to understand which human functions to mimic and to what extent. We should not treat automation as the end-goal, instead the priority is to match the best qualities of human performance with the most appropriate complementary technologies.

We will build on these recommendations, later in the year through a series of further engagements and outputs in addition to the artefacts described in the recommendations; we look forward to the challenge.

RECOMMENDATIONS

Our roundtable participants identified the following recommendations from which to support the maritime industry on its journey toward an enhanced cyber-physical future.

AREA	RECOMMENDATION
Societal acceptance	Produce an infographic on what is meant by remote and autonomous shipping for the seafaring community.
	Produce an infographic for the wider public as an educational tool on autonomy in the shipping sector. This will also highlight key facts about the shipping industry with current operations stats (Nm sailed per year compared to tonnage accidents etc.) compared / correlated to road transport sector and the accident / fatality rate etc. to demonstrate the magnitude safety improvements that can be achieved via greater automation
	Reassure seafarers – communicate clearly with industry (particularly seafarers) that robots are not going to take their jobs – people will still be needed in the industry, but roles and responsibilities, along with training will change.
	Create a campaign to support the social acceptance of new technologies for sea and shore based staff
Skills and Education Gaps	Map functions of the digital ship to skills required (research tasks v's functions)
	Develop a framework for training courses aligned to the future roles and functions of sea and shore based operational personnel
	Engage with training providers and share the future skills requirements
	Provide on-the-job training now for seafarers to build cross-skilling opportunities in order to gear up and for future technology changes, helping them to "become relevant"
	Help seafarers to become relevant and maintain up-to-date knowledge to support them in the future
	Capturing knowledge of senior officers on-board is key. Industry should make sure that the knowledge is captured to support the next generation as senior officers and millennials are developing different skill sets.
	Shore-based staff need to have a plan for development as well. With many of the shore-based operational staff being ex-seafarers, they will need to have a succession plan
Roadmap	Develop skills matrix identifying skills/functions of the crew in currency positions, transitional arrangements and arrangement for the next 25 to 30 years.
Industry collaboration	Further develop the detail of the themes that came out of this report, namely: training and education roadmap or framework; the business case for adoption; workforce succession planning (transforming current personnel to be 'automation ready')
	Coordinated discussion required across stakeholders to ensure alignment of messages and input is considered from all, not just the few who are actively pushing this agenda
Engagement with regulators	Engage with regulators to help them to understand the changes in the industry and have a regulatory framework that allows industry to develop with new technologies
Opportunities to practice the 'abnormal'	Engage with industry, regulators and technology providers to allow for systems to be tested in order to practice the abnormal
Seafarer views	What do seafarers see as being the areas to automate – include them as part of the discussion? A survey to seafarers should be conducted

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IMEC Shipping Companies
MASS SIG (IMarEST) Industry
MASS SIG (IMarEST) Industry
Industry MASS SIG (IMarEST) Training and Education
Shipping companies
Industry MASS SIG (IMarEST) Training and Education
Shipping companies
Industry MASS SIG (IMarEST) Training and Education
MASS SIG (IMarEST) Industry Regulators
MASS SIG (IMarEST) Industry
Regulators Industry Government Shipping companies
MASS SIG (IMarEST) Regulators
Technology providers Regulators Shipping companies
Sample taken from shipping companies and associations

Next steps

The panel is keen on setting up a series of events to support the delivery of the recommendations, to ensure that the industry is kept up-to-date with current proceedings, and to benchmark opportunities for the future against the current drivers (industry changes), technologies, business cases and human element agenda. It is envisaged that the programme will culminate in a conference and one-day workshop to be held during Singapore Maritime Week in April 2019. The focus of this initiative is situated in the following aims:

- To understand the tangible benefits to the ship owner, ship operators on a sector by sector basis.
- To capture and to understand the functional requirements of the workforce going forward, including the relationship between man and machine, so as to support the journey into an enhanced cyber-physical future.
- To conduct a gap analysis to identify skillset requirements for the future workforce, projecting towards the year 2040, so as to successfully understand the role of the human and how best to capitalise on human performance.
- To ensure that both existing seafarers and those considering a future career in shipping are not deterred from considering a career at sea and that they are delivered a clear and unambiguous message relating to the many opportunities and benefits from pursuing a career in this sector.

In addition, this discussion dealt with a number of academic research issues, not least social change and the perceived impacts among the workforce and general public. The results in this paper are a summary of the views shared by those attending the discussion to support the implementation and adaption of remote and autonomous operation within the maritime sector and the results of our member survey.

SUPPORT FOR THIS PROJECT

Whilst the IMarEST served as a conduit for gathering the views of the wider maritime sector and bringing together a panel of shipping companies, regulators, technology providers, defence, academia and research groups, it is with the financial support of principal sponsor BMT Defence and Security Limited and additional sponsor Braemar. The project was also supported by the British Chamber of Commerce (Singapore) and the Institution of Mechanical Engineers. The event was held at the A*Star offices who have also supported this activity. Without their support, this activity would not have been possible and the ability to provide a positive discussion to address this key topic has been hugely valuable.

The Autonomous Roundtable Panel

The following organisations and individuals took part in the remote and autonomous roundtable discussion on the 24th April, 2018 at A*Star's executive boardroom in Singapore.

COMPANY
American Bureau of Shipping (ABS)
BMT Defence & Security UK Ltd (Roundtable Co - Chair)
Bernhard Schulte Shipmanagement (S) Pte Ltd
Braemar Technical Services Pte Ltd
DNV GL - Maritime
GC Tankers
IHPC & IMRE
Institute of Marine Engineering, Science & Technology (IMarEST) (Roundtable Co – Chair)
Institute of Materials Research & Engineering (IMRE)/A*Star
Institute of High Performance Computing (IHPC)/A*Star
Institute of High Performance Computing (IHPC)/A*Star
Keppel Offshore & Marine Technology Centre Pte Ltd
Maritime & Port Authority of Singapore (MPA)
Maritime & Port Authority of Singapore (MPA)
Republic of Singapore Navy (RSN)
Republic of Singapore Navy (RSN)
Shell International Trading & Shipping Company Ltd, UK
Singapore Institute of Technology
Solent University, Southampton (Roundtable Chair)
The China Navigation Co Pte Ltd
Technology Centre for Offshore & Marine Singapore (TCOMS)
VTT Technical Research Centre of Finland Ltd
Wärtsilä Ship Design Singapore Pte Ltd
Watson Farley & Williams LLP

The following organisations and individuals observed the discussion:

COMPANY
Institute of Marine Engineering, Science & Technology (IMarEST)
Institute of Marine Engineering, Science & Technology (IMarEST)
Institute of High Performance Computing (IHPC)/A*Star
Institute of High Performance Computing (IHPC)/A*Star
Ink On Paper Communications Pte Ltd
MNEME Works
Maritime & Port Authority of Singapore (MPA)
Maritime & Port Authority of Singapore (MPA)
South African International Maritime Institute

NAME	DESIGNATION
Mr Lui Chih Wei	Principal Engineer, Singapore Engineering Services
Mr Daniel Ridgwell	Principal Combat System Engineer/Autonomous Systems Lead; Co-Chair of the Unmanned Surface Vessels Special Interest Group, IMarEST
Mr Hardy Romahn	Fleet Manager
Mr Graeme N Temple	Managing Director – Marine – Asia Pacific
Ms Rachel Wong	Approval Engineer, Offshore Classification
Mr Mihhail Klaaser	Technical Director
Prof Alfred Huan	Executive Director
Mr David Kelly	Director, Asia Pacific
Dr Lim Yee Fun	Scientist II / Deputy Head, Electronic Materials
Dr Lim Keng Hui	Deputy Executive Director
Dr Lou Jing	Department Director, Fluid Dynamics
Mr Ankit Choudhary	Asst. Programme Manager, Deepwater Technology
Mr Goh Chung Hun	Deputy Director of Shipping
Mr Calvin Lee	Senior Marine Surveyor, Ship Regulation & Development, Shipping Division
LTC Thomas Ong	Head Unmanned/Robotics System, WARCEN
ME6 Jong Sing Peng	Commanding Officer, Underwater Systems School, Naval Military Expert Institute
Mr Rob Whillock	Project Manager, Deepwater, Shipping & Maritime, Technology
Mr Mark Teo	Associate Professor, Engineering Cluster
Gordon Meadow	*As of 31st July 2018 - Gordon Meadow, CEO, SeaBot XR Ltd; Chair of the Marine Autonomous Surface Ships (MASS) Special Interest Group (SIG), IMarEST
Mr Nishant Dhyani	Fleet Efficiency Manager
Prof Allan Magee	Director of Projects
Dr Mikael Wahlström	Senior Scientist, PhD (Soc Psych), Human factors, virtual & augmented reality
Mr David Xu	Sales Manager
Mr Simon Petch	Partner

NAME	DESIGNATION
Mrs Jenny Seow	General Manager, Asia Pacific
Mr Andrew Wong	Partnerships Executive, Asia Pacific
Ms Amy Foo	Director, Industry Development
Mr Lim Sien Koon	Senior Manager
Ms Alicia Tan	Director
Ms Tan Chui Hua	Director
Mr Ang Shao Jie	Manager, Seafarers Management Dept, Shipping Division
Capt Nikhil Kumar	Senior Marine Surveyor, Flag State Control Dept, Shipping Division
Ms Yvette de Klerk	National Cadet Programme Manager

Institute of Marine Engineering, Science & Technology
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