Emergent technologies and maritime transport: challenges and opportunities

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ABSTRACT

This paper provides an assessment of autonomous ships taking a contextual approach that goes beyond the traditional focus on technical feasibility. We conceptualise a model for technology adoption that relies on three contextual factors (technical feasibility, human capital and economic benefits) and the enabling environment. We discuss how these factors play a significant role in autonomous ship development, bridging technology and the future of maritime education and training (MET).

By using in-depth interviews with senior maritime stakeholders, we draw a reflection on the future of MET. We argue that technology is creating a challenging environment for institutions and universities to keep the edge on knowledge, but it equally creates the opportunity to rethink programmes and curricula for the seafarer of the future. We conclude by providing guidelines on how MET can be transformed and suggest that university-industry collaboration is key to fostering knowledge creation and transfer that fits its purpose.

1 Introduction

Over the last decades, the maritime sector has seen tremendous changes as a result of the introduction of automation and technology. More recently, the concept of autonomous shipping has raised the interest of the international shipping community leading to a scoping exercise on maritime autonomous surface ships (MASS)[1] at the International Maritime Organization (IMO). Projects such as *YARA Birkeland* in Norway, the world's first fully electric and autonomous container ship under construction, are an example of the need to start to conceptualise how seafaring may change over the next decade or two.

While very often technical feasibility is the main focus of many discussions at the moment, there are a number of other factors that need to be considered. WMU (2019) considers that six main factors that affect the deployment of autonomous ships for commercial purposes. We argue that those six factors can be reduced a simpler model, easing subsequent analysis of technology adoption. Our argument is that technical feasibility, economic benefits and human capital are the main variables determining technology adoption and that the other subset is

[1] MASS is defined as "a ship which, to a varying degree, can operate independent of human interaction." (IMO, 2018).

embedded into the enabling environment that encompasses social acceptance, regulation and governance. And, mutually reinforcing relationship exists between the three factors and the enabling environment. For example, a positive outlook for the three factors is likely to be translated into a positive enabling environment and vice-versa.

The regulatory framework for the operation of autonomous ships is currently under discussion at national and international levels. The regulatory scoping exercise being undertaken at IMO will alone last until 2023. Drafting regulations will take much longer. According to the logic above this is a clear manifestation of the infancy of autonomous ships from a technical feasibility, human capital and economic benefits point of view. In fact, we argue that autonomous ships may not cope with the current business models, as they are thought to be too costly in multiple ways under the current paradigm where seafarers are cost effective. However, research has shown that when labour is scarce and costly, companies are compelled to introduce automation to fulfil their role (Acemoglu and Restrepo 2017). Therefore, careful attention should be taken as specific competencies required to successfully operate the ships of the future, in particular autonomous ships, is not yet available in large numbers. What competencies will be required in the years to come is still subject to debate and by consequence far away from current maritime training and education (MET) systems.

The pace of change in shipping is largely constraint by a large capital investment (Fan and Luo 2013), as shipping remains a capital intensive business. While the pace of technology change is predicted to be slower than other industries (WMU 2019), the change on MET systems is also slow and complex. Therefore, there is an absolute need for starting to rethink MET and the role of MET institution for the next decades. On 15 January 2019 during WMU/ITF report on the future of work, IMO Secretary-General, Mr Kitack Lim, has expressed the need to consider raining and standards aspects of seafarers in an increasingly automated and digital industry. The framework we develop in this article is meant to foster a university-industry dialogue that enables to best adapt MET to a fast-changing landscape.

This paper is organised as follows. In section 2, we developed a theoretical framework while applying to the autonomous ships. Section 3 describes the methodology undertaken. The findings are presented and discussed in section 4, including a reflection on seafaring as a profession in subsection 4.1. Section 5 concludes.

2 Theoretical framework

2.1 Maritime technology: autonomous ships

Ships have been supporting international trade for several centuries, with technology shocks changing shipping operations and crewing. Historical data shows that those changes do not occur overnight but take time to diffuse. For example, the change from steam to combustion engine powered ships took more than a century to surpass 50 per cent in its use and about 180 years to surpass 90 per cent (Comin and Hobijn 2010). While this example illustrates how slow technology can be, historical data also shows that the diffusion process is becoming faster. Current ships are already equipped with a large amount of technology, such as the Autopilot, the Electronic Chart Display and Information System (ECDIS), and dynamic positioning (DP) systems, and modern engine rooms can be frequently unattended. Technological innovation, therefore, is permeating the shipping industry, including those technologies associated with the fourth industrial revolution, at a pace that is predicted to be evolutionary (WMU 2019). Almost every day, the media announces initiatives undertaken by the industry that make use of the fourth industrial revolution related technologies, such as artificial intelligence (AI), internet of things (IoT), advanced robotics or blockchain.

Recently, much attention has been devoted to the concept of autonomous shipping. Projects such as *YARA Birkeland* in Norway, the world's first fully electric and autonomous container ship under construction, have generated enough attention from the maritime community that it has led to the establishment of a Working Group on MASS at the IMO. Currently, guidelines for test trials are being drafted and a regulatory scoping exercise is being conducted. While *YARA Birkeland* might represent a mark in the history of ship operations, its design is far from fitting for current long-distance shipping business models, thus it is not generating much traction among shipowners.

Automation in ships has been around for several decades. In 1964, IMO's (Inter-Governmental Maritime Consultative Organization, IMCO, at the time) VIII Maritime Safety Committee (MSC) under Agenda item 11, the Secretariat has provided several definitions related to automation in ships. This document provides definitions for fully-automated systems, partly-automated systems and remote-control systems for technical systems on-board ships. For example, remote control refers to monitoring and controlling machinery from the navigating bridge. It is clear that the scope of automation in 1964 was very different from the rationale behind the establishment of the MASS Working Group in 2018. Modern ships are becoming digitalised and connected with many automated technical systems, and monitored and optimised by onshore control centres or fleet operations centres which keep the human element in the loop to varying degrees. It is currently highly uncertain how much and to what extent the shipping industry will adopt further automation and autonomy at large. A guiding scale delivered by IMO MSC 100/WP.8 (IMO, 2018) provides a guide to the degrees of autonomy currently being considered at IMO, which we summarise in Table 1. The table shows that under the scoping exercise currently being undertaken at the IMO, Conventions are to be assessed not only for the fully autonomous ship, but also for several partially automated and autonomous ships. Although the aim of the MASS Working Group is mainly to perform a regulatory scoping exercise (RSE), by establishing a scale and definitions for the MASS, the group has contributed to increasing the clarity that is often missing in debates on MASS related subjects (Kitada et al. 2019).

Table 1: IMO MASS degrees of autonomy

Degree of autonomy	**Remote control**	**Seafarers on board**	**Description**
ONE	NO	YES	Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
TWO	YES	YES	Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
THREE	YES	NO	Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
FOUR	-	NO	Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

Notes: Adapted from MSC 100/WP.8, IMO (2018).

For the reasons above mentioned, it is factual that autonomous ships and shipping are an important topic for the maritime community. Despite that, it is very blurry how autonomous shipping will develop. At the current stage, different stakeholders have different views, much influenced by the context in which they belong, a key factor that has often been disregarded by some. We claim precisely that autonomous commercial shipping is mainly a function of an array of contextual factors that need to be in line in order for the technology to be deployed. The underlying hypothesis is that for technology to become widely used, this set of contextual factors needs to be met first, and without the correct alignment of these factors technology will not take over and, therefore, never arrive at a mature state (Gort and Klepper 1982; Ayres 1994).

2.2 A contextual model approach for technology

The literature on the determinants of technology and innovation is vast. Most authors focus on firm-level factors or macroeconomic factors. These studies mainly focus on different industries or the whole economy and are therefore unable to capture the idiosyncrasies from the transport industry, in particular maritime. To fill this gap, we propose a model that takes into account several contextual factors. Our model builds on the model of WMU (2019), which posits six factors that determine the adoption of technology. The contextual model we propose in this paper is based on the same factors but endogenizes parts of it, thus making it more applicable for identifying future opportunities and challenges within the system. The contextual model asserts that technology adoption is determined by three main macro-level pillars. The first is technical feasibility; the invention needs to exist prior to its commercialisation. While its commercialisation is of key importance for its success, the technological invention itself shall not be discouraged, as it is an important piece for its successful commercialisation (Nerkar and Shane 2007). That technological invention results from a highly uncertain process of combination, recombination and integration of individual technologies (Fleming 2001). For example, at the moment, the technologies associated with autonomous ships are not on a readiness level that permits autonomous shipping in commercial operations, especially for deep-sea-going voyages.

The second relates to human capital. Human capital goes beyond the formal knowledge and skills but also encompasses accumulated experiences (Becker 1962) and is of strategic importance for organisations (Wright et al. 2014). Prior research has shown that complementarities between physical capital and human capital are of great importance as they are tightly linked, for example, to industry performance and productivity (Acemoglu and Autor 2011; Fonseca et al. 2018). Naturally, the human capital dimension is closely associated with the labour market and, therefore, subject to the factors affecting it. A close analysis at those is out of the scope of this article.

The third pillar relates to the economic benefits associated with technology. Recent research has shown that wages and investments in automation of tasks depend on the relative prices of capital and wages (Acemoglu and Restrepo 2018), thus making shipowners sensitive to labour costs and capital rents when maximizing their profits and investing in new technology. Currently, the strategies undertaken by most firms in the shipping industry fall under cost advantages rather than differentiation strategies. For autonomous ships to thrive, it is predicted that higher capital cost needs to be compensated by lower operational expenses, either from a fleet or from a supply chain perspective. At this point in time, it is very uncertain whether that is attainable. Some authors have already produced hypothetical cost analyses for autonomous ships (e.g., Kretschmann et al. 2017); however, those remain highly speculative and subject to a high level of uncertainty.

The original model also considers regulation and governance, and social acceptance as key determinants of technology adoption. Conversely, we argue that those factors are underlying factors rather than determinants. The rationale behind this is that the three key factors considered (technical feasibility, economic benefits, human capital) directly influence technology but the underlying factors, that is, regulation, governance and social acceptance, indirectly influence technology through the key factors. The underlying factors are the enabling environment for the three key factors. This logic is illustrated in Figure 1.

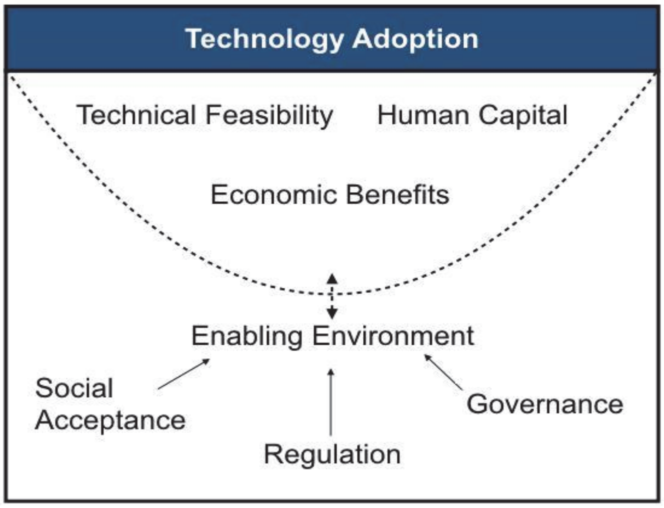

Figure 1: Technology adoption model

3 Methodology

The contextual model of technology adoption described above sets the foundations for our analysis of the current status of technology in maritime transport. We centre our analysis on ships with a varying degree of autonomy. Currently, the information sources for feeding the model are limited. Because of the tacit nature of innovation, much of the information is not codified in the literature but rather scattered in press releases and individual experts' knowledge. Therefore, for our analysis, we rely on in-depth semi-structured interviews with maritime professionals triangulated with a review of press releases and, when available, academic literature. The individual in-depth interviews took place during 2018 and the first half of 2019. While following the guide, the interviewers gave space for the interviewees to express their views in an almost open format. The number of interviewees is 25 senior professionals and stakeholder groups include shipowners, technical developers and experts, seafarers, regulators and classification societies, some from top management of international companies.

All interviews were conducted under strict confidentiality rules and anonymised prior to the analysis. Most stakeholders interviewed are in Europe, the region that has been the most publicly active on autonomous ships, from a technological point of view. The context of the interviews was recorded, or detailed notes were taken, depending on the preference of interlocutors. The qualitative data (transcripts or text-notes) were codified according to the model's variables for analysis. Thus, the findings and reflections of this paper are result of the analysis of the coded interviews triangulated with a review of press releases, academic literature and authors expert knowledge. The framework developed provides the lens through which the analysis was conducted.

4 Findings

4.1 Autonomous ships: technology adoption assessment

The assessment of technology adoption (see Table 2 for the summary), starts with the technology on the market. At the current moment, the adoption of autonomous ships is very limited. The data shows that most projects are in their infancy with limited practical use. The shipowners and operators consulted report limited interest in autonomous shipping but a large interest in making ships smarter, and thus increasing their sophistication not only onboard but also onshore (e.g., by creating fleet control centres). These views are supported by most stakeholders consulted, especially when it comes to seagoing vessels. Autonomous shipping as a concept is currently only relevant for short-distance shipping and coastal trade. Therefore, the overall trend is to focus on already available and upcoming technologies that digitalise and network fleet operations rather than focus on autonomy. An interesting metric that can be used for assessing the diffusion of innovation is the number of producers (Gort and Klepper 1982). Currently, only a few firms are promoting autonomous ships, notably Kongsberg, Rolls-Royce (now part of Kongsberg) and Wärtsilä. This relatively small number of firms is a sign of the infancy of autonomous shipping. However, when it comes to smart shipping, the number of competitors supplying the various related innovations is much larger. The assessment of the status of smart shipping is out of the scope of this paper, yet it is an interesting avenue to be investigated.

Table 2: Technology adoption assessment: autonomous ships

Variable	Trends
Technology adoption	The technology is at its infancy, limited to specific contexts and geographical regions. The lack of firms pursuing autonomous ships' technology is a sign that the innovation is at its first phase.
Enabling environment	Legal and regulatory discussions are at a very early stage. Also, research has been founded by industry and governments to explore and develop autonomous ships but still that it is not enough to come up with a concrete picture about the design of the ships of the future.
Technical feasibility	Partial automation of several systems has been made successful over the last few years. Autonomous ships related R&D projects have been developed but Yara Birkeland is the one that stands out due to its commercial nature. It is thought that several gateway technologies already exist but the integration of all of those in a safe way is still a technical challenge.
Economic benefits	The cost of autonomous ships remains highly uncertain, averting the interest of shipowners in investing in it. It is predicted that autonomous ships will not fit the current business models followed by shipowners and operators, where cost advantages are the underlying strategy followed.
Human capital	Current seafarers are lacking in digital and other skills that are thought to be complementary and fundamental to autonomous ships' operations. Reassessing human capital, general and specific, and changing MET programmes is needed as technology adoption increases.

From a technical point of view, advances have been made toward ship autonomy. Notably, *Yara Birkeland* is taking the lead, not only regarding autonomous navigation but also on automated cargo handling. It is expected that similar projects will emerge in a few years as new projects are being funded. However, concerns regarding safety have been put forward by several stakeholders. These concerns are shared with similar applications in other industries such as autonomous cars, in particular in regard to artificial intelligence-based systems. Most of these systems rely on algorithms that are highly non-transparent, acting as black box models (Samek et al. 2017). These systems can be highly biased, relying on correlations rather can causal links, depending on their training data. It is often impossible to interpret the models which create the question of compliance with regulations and general principles. Currently, research is trying to address this issue by developing strategies for auditing the algorithmic decision-making process behind AI. Advanced techniques are able to do this without violating the secrecy of the algorithmic decision-making processes (Lepri et al. 2018).

The current business model used by firms operating ships is based on economies of scale. As a result, over the last 20 years, the average container ship has grown significantly, by about 153% from 1996 to 2017, to take advantage of a lower average cost due to increased scale (Lian et al. 2019). Some authors have suggested that autonomous ships might not be more costly than conventional ships (e.g., Kretschmann et al. 2017). However, the stakeholders consulted were not optimistic about the introductory cost as more redundancy is required. Adding to that, the research and development (R&D) costs need to be amortised along with the cost of the infrastructure required. It is clear that at the current moment autonomous shipping does not fit the business models for sea-going voyages, a premise that is not foreseeable to change soon. Conversely, it is clear that newbuilds are being equipped with more and more technology that makes the socio-technical system much more sophisticated, digitalised and partially autonomous.

The last component under analysis is the human capital, a key component of a socio-technical system such as a ship. The standardisation of seafarers through IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978, as amended, contributes to a harmonisation of maritime education and training (MET). However, this approach is often criticised by some of the consulted stakeholders as contributing to an education based on minimum standards that has led to a decline in seafarer human capital. Seafarers are currently signalled in the market as having similar qualifications that are often not corresponding to the factual seafaring capabilities, a problem observed in many other labour markets as described by Spence (1973), and which led to Spence winning a Nobel prize. While better signalling might help the employers to hire the right seafarers for the job, this does not solve the root cause of the problem. Most interlocutors that were consulted refer back to proper MET as a tool for solving the problem and providing seafarers with the actual competencies required by shipping companies of today and the future. For most shipowners and operators that were consulted, there a lack of general and specific human capital, which creates a problem for the industry as a whole, including seafarers. As advanced technology becomes pervasive in ships, this lack of human capital is manifested even more than in the past.

Besides the technical development of ships towards automation, a lot of discussions have been started related to autonomous vessels. Numerous research projects are being undertaken in different parts of the world exploring and testing various technical aspects of unmanned and autonomous ships, in close collaboration with the maritime industry and research institutions. One example is the Maritime Unmanned Navigation through Intelligence in Networks project (MUNIN), which was completed in 2015 by a cluster of European maritime stakeholders, aimed mainly to explore the technical, economic, and legal aspects of unmanned ships. Another example is the Advanced Autonomous Waterborne Applications project (AAWA), which has been supported by the Finish Government and led by Academia and industry and completed in 2018. It aims to produce the specification and preliminary designs for the next generation of advanced ship solutions. Remote-controlled and Autonomous Vessels for European and National waters (RAVEN) is a further innovative research project that aims to explore ways to convert an existing ship into an autonomous ship and explores the technical feasibility of its function as well as the infrastructure needed to be operational. Adding to that is the well-known project called Revolt and the Yara Birkeland cited above. DNV GL supported by Transnova, Norway, launched in August 2014 an innovative ship concept for an unmanned, zero-emission, shortsea vessel called the Revolt. This concept was the basis of the conceptualisation of the Yara Birkeland vessel which is expected to begin operations as a fully autonomous ship in the upcoming months.

The international maritime community has also been investing in some research projects related to regulation and policy. Lloyds Register, for example, released in February 2017 a code called “LR Code for Unmanned Marine Systems (UMS)” providing a goal-based framework to ensure the safety and operational requirements for UMS based on a set of performance standards developed to support design innovation. The Maritime Autonomous Systems Working Group (MASRWG) based in the United Kingdom prepared a voluntary Code of Practice in November 2017 for MASS. This code provides necessary practical guidance for the design, construction, and safe operation of autonomous and semi-autonomous vessels under 24m. The ideas in this Code are aligned with another research programme called the Safety and Regulation for European Unmanned Maritime Systems group (SARUMS) part of the European Defence Agency’s UMS (Unmanned Maritime Systems), which has sorted out best practices for unmanned ships including operations, design and regulations. The SARUMS group has members from Belgium, Finland, France, Germany, Netherlands, Italy and Sweden.

In this regard, nine maritime nations (UK, Denmark, Estonia, Finland, Japan, Netherland, Norway, South Korea and the United States) took the initiative in delivering a proposal to the IMO’s Maritime Safety Committee for a “regulatory scoping exercise” to determine the extent to which the existing corpus of IMO regulations are suitable for the introduction of unmanned ships. The proposal paper, submitted to the Maritime Safety Committee session 98 (MSC 98/20/2), was submitted in February 2017 and proposes that the MSC identify IMO regulations which: (a) preclude unmanned operations; (b) have no application to unmanned operations; and (c) do not preclude unmanned operations but may need to be amended in order to ensure that the construction and operation of marine autonomous systems are carried out safely, securely and in an environmentally safe manner.

At its 99th session, MSC at IMO endorsed the preliminary definition of MASS as a ship which, in different levels can operate without human interaction. The framework of the regulatory scoping exercise was approved as a work in progress and concluded the four levels of autonomy that were designated previously in this paper. Further, in its recently concluded 101st MSC session at the IMO, the MSC approved the framework and encouraged countries to participate further in the regulatory scoping exercise (RSE). The Committee also completed and updated the list of statutory IMO instruments provided to address regulatory gaps related to autonomous ships. Moreover, the MASS has developed trial guidelines that aim to be a single document for the use of industry, administrations and relevant stakeholders. It is worth highlighting that discussions about autonomous ships, either among industry or various other stakeholders, are still at an early stage. The development of these discussions depends mainly on social and political acceptance.

4.2 Future of seafaring: a reflection

As mentioned previously, the maritime industry technological transformation in the future has the potential to change the way ships operate. The adoption of innovations in shipping is progressively becoming a reality and is already transforming seafaring as a profession. Some simulations show that the introduction of highly automated ships (IMO MASS autonomy level 2 and above) can lead to a decline in crewing that manifests in reduced global demand for seafarers by about 22% (WMU 2019). However, the same simulations also show that overall demand for seafarers is unlikely to shrink due to a continuing increase in global trade. By 2040, the global demand for seafarers is projected to almost double, despite having some highly automated ships sailing alongside. The ships of 2040 are expected to be more technological, some autonomous, and thus requiring seafarers and onshore operators with different skills, knowledge and expertise than today.

The results of simulations are subject to a high level of uncertainty, which also manifests in uncertainty regarding the extent to which the jobs of seafarers will be affected by technology, especially when most of the seafarers come from developing countries (UNCTAD 2019). Important questions are raised by the maritime community, specifically about how the role of the human element onboard may be affected by technological change. Discussions about the impact of new technologies on seafarers differ between those who take a more cautious approach and are reluctant about the adoption of new technologies on ships and those who are more optimistic about its use and wish to foster and promote it. These views depend on local contexts and economic self-interest. For some, embracing technological change means redefining the professional profile of "*the seafarer*," and seeing it from a completely different perspective by conceptualising the seafarer not only in the classical sense but also as a professional able to perform non-seafaring tasks that emerge due to increased technology use (e.g., working as onshore fleet operations control officers). This view takes the seafarer away from their traditional role towards high-level problem solving and mastering of unusually complex situations, which might create fears among several stakeholders working in the field.

In January 2019, at the launch of the WMU/ITF report: Transport 2040: Automation, Technology and Employment – the Future of Work, the IMO Secretary-General, Mr Kitack Lim, pointed out the need to consider seafarer training and standards aspects as the shipping sector increases levels of automation and digitalisation. The IMO Secretary-General set out subjects that stakeholders at the maritime community have to focus on: "*How will the seafarer of the future manage the challenges related to an increasing level of technology and automation in maritime transport? How will the new technologies impact on the nature of jobs* *in the industry? What standards will seafarers be required to meet with respect to education, training and certification to qualify them for the jobs of the future?*". The importance of the future of seafaring is clear.

In this sense, it is essential to understand which qualifications and skills will be needed in the future. The future of seafarers is promising in the predictions of some (HSBA 2018; WMU 2019), but maritime education and training needs a profound change to adapt to this future. So far, limited literature exists that can provide guidance on shaping MET of the future. The maritime community, including the companies developing and potentially using advanced technologies, have just recently started to brainstorm on the training, skills and motivation for "*the seafarer of the future*".

One of the hardest aspects of professional development of seafarers for the future is to build it on the foundation of the past, but with a vision of what is ahead. A seafarer might need to know the traditional maritime knowledge such as celestial skills, ability to read paper charts, parallel rules, and dividers, while recognizing the clouds, waves, and weather. Traditional maritime knowledge needs to be enhanced with extra knowledge and competencies that enable seafarers to constantly adapt to new and emerging technology. For example, in March 2018, a merchant vessel suddenly and inexplicably lost all connection to GPS on board. The master and officers set out their situation by applying traditional maritime knowledge, common sense and seamanship (S&P Global Platts 2019).

A framework to accomplish this vision can be found in the model of technology adoption described, which can inform the technology-induced gap that needs to be addressed by MET. Furthermore, as frequently referred to by the interlocutors that we consulted, a close consultation between MET institutions and universities, and the rest of the maritime community is needed for building the MET of the future. This logic is illustrated in Figure 2 which bridges the contextual model above explained with future of MET, which we term MET 4.0 in resemblance of the industry 4.0 or fourth industrial revolution.

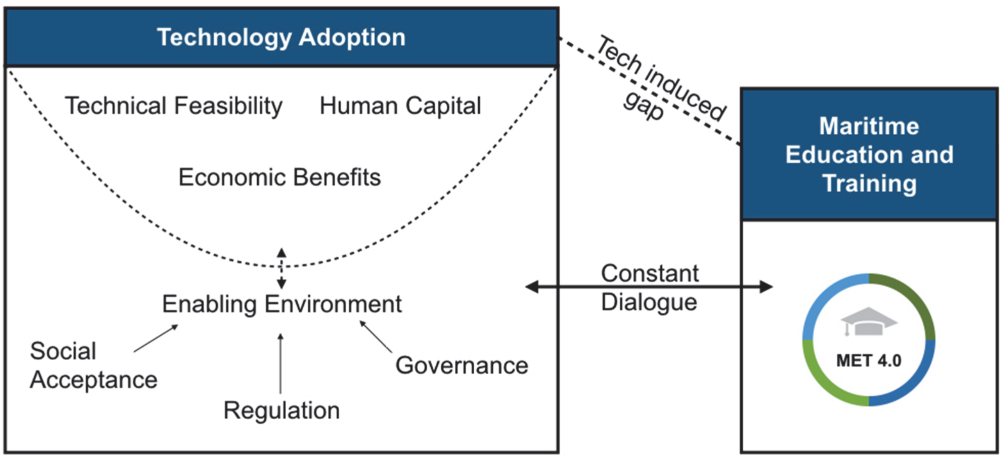

Figure 2: Technology adoption and MET 4.0 - a framework

The future MET or MET 4.0 will not just have elements of classical maritime competencies but also capacitate seafarers to adapt to the fast-changing landscape, while equipping them with competencies that can be used for onshore jobs and even in other industries. According to our interlocutors, some MET institutions are already taking the first steps toward combined MET programmes that provide seafarers with research-based education that combines digital skills (e.g., computer programming), and elements from other specialisations such as engineering, shipping management and logistics. Cross-fertilisation between disciplines capacitates MET students with the tools for tackling problems in a fast-changing landscape as well as providing students with the foundations to successfully benefit from life-long learning.

Universities-industry (U-I) collaboration is also fundamental for translating the needs of the industry into MET programmes. Such collaboration has existed for a long time but not without barriers (Bruneel et al. 2010). However, as technology changes rapidly the pressure on both, industry and universities, builds up and the need for increased collaboration becomes more evident. The pressure for universities to incorporate new knowledge leads to a large burden in establishing solid collaboration that permits universities to remain on the edge of knowledge (Hagen 2002). While research provides some guidance on how to strengthen U-I collaboration (e.g., Ankrah and AL-Tabbaa 2015), the interlocutors that were consulted are still reporting a lack of alignment between MET and the real needs of increasingly complex and digital business.

As technology in the maritime field is advancing, the training methods are slowly starting to change. However, the question remains: *what will be the subjects to be learned in the future and how is this learning going to be delivered?* The answer seems to be the same as to the question: *what will machines and computers be unable to do onboard ships and onshore?* As highlighted in the framework of Figure 2 a gap assessment that is forward-looking is key to ensuring MET is constantly updated to address this. Current intelligent machines have limited capacity to handle all situations, as some may require a complex combination of intuitive reaction, creativity, decision making, social intelligence and complex discernment and manoeuvring that are not reflected in the training data. As written by McKinsey&Company (2017): “Yet machines cannot do everything. To be as productive as it could be, this new automation age will also require a range of human skills in the workplace, from technological expertise to essential social and emotional capabilities.”

With the rapid introduction of technology, seafarers, as many other transport workers are in need of MET that is able to provide them with the tools to master the changing nature of work. These tools come from establishing a close I-U link, and taking onboard classical maritime subjects, complemented with courses in other disciplines as described above. They can provide the foundations that enable the seafarer of the future to be adaptable to a fast-changing working environment. Naturally, this encompasses research-based education on science, technology, engineering, math (STEM) subjects, as well as an emphasis on soft skills. This holistic approach can provide seafarers with the absorptive capacity to benefit from continuous learning, a work value and mindset that both seafarers and stakeholders involved in the maritime sector should always keep in mind.

5 Conclusions

Current maritime rules require ships to be manned. While increasing automation raises questions about the role of the human element in the whole process. Most signals make us believe that the human element will not be taken out of the loop over the next decades. However, the social-technical environment seafarers will operate in the future will change. Therefore, adapting MET to the future is key so that the industry remains at least as efficient and safe as today. Many questions are rising regarding the exact competencies required in the future. To answer these questions, we propose a framework that takes into account not only technology adoption but also the link with its drivers.

Our framework suggest that MET of the future is the result of a continuous scanning for the gaps introduced by technology and that attention is given to the underlying factors of technology: technical aspects, human capital aspects and economic benefit aspects, as well as the enabling environment. By closely monitoring these key factors and developing an efficient and effective interface between MET institutions and universities and the industry, so that future programmes for seafarers encompass, not only classical maritime competences but also enables the maritime professionals to work even in other sectors. A holistic approach is only viable through collaboration and consultation within the maritime community.

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