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Scenario planning for an autonomous future: a comparative analysis of national preparedness relating to maritime policy / legislative frameworks, societal readiness and HR development for autonomous vessel operations

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SCENARIO PLANNING FOR AN AUTONOMOUS FUTURE:

A comparative analysis of national preparedness relating to maritime policy / legislative frameworks, societal readiness and HR development for autonomous vessel operations.

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

(Signature): ………………………..

(Date): 23 September 2019

Supervised by: Professor Michael Ekow Manuel

Supervisor's affiliation World Maritime University

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To God be the Glory! Thank you to my Heavenly Father for ordering my every step.

> *'Now all Glory to God, who is able, through His Mighty Power at work within us, to accomplish infinitely more than we might ask or think' (Ephesians 3:20, New Living Translation).*

Thank you to my awesome family. My parents André and Salomé for raising me with a tenacious spirit. Because of you I am determined, diligent and able to persevere. Thank you for supporting me through the tough times and celebrating with me in the good times. Thank you also to Barry, Sonja, Brian and Emily for reminding me to stay humble and be *ZEF*!

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Abstract

Title of Dissertation: **SCENARIO PLANNING FOR AN AUTONOMOUS FUTURE: A comparative analysis of national preparedness relating to maritime policy/legislative frameworks, societal readiness and HR development for autonomous vessel operations.**

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The Fourth Industrial Revolution (4IR) is considered a disruptive paradigm of innovation, more so in the maritime industry that is traditionally slow to adopt changes. Technological literacy, infrastructure and social acceptance of increased technological advances, and the role of human resources and referred competencies in the evolving technological era are crucial considerations for countries' national preparedness to operationalise autonomous shipping. The 4IR may lead to serious sociological challenges including ethical dilemmas related to the development and implementation of responsible innovations. The lead-time in formulating and implementing policies, and training could result in a situation where the required resources are not available when they are needed. In this study the researcher conducted a systematic literature review to generate four possible scenarios from which to further explore an autonomous future in specific national jurisdictions. Mixed methods enabled the researcher to gain in-depth appreciation of legislative, human resource, and infrastructure preparedness perspectives through questionnaires, interviews and focus group discussions. The resulting analysis was informed by a methodological consideration of various external factors. The findings in this study suggest that countries each have their own motivation for engaging, or not engaging in autonomous shipping discussions and activities; these can be linked to the various external factors unique to each country. A country's maritime transport policy and technological readiness may be of crucial importance in adopting innovative technologies in the maritime industry and in operationalising autonomous shipping, and as such national maritime education and training systems need to be able to anticipate future skills as countries need to be able to adapt to changing requirements. Scenario planning and partnerships are key in meeting needs and growing an economy; close(r) collaboration between government, industry and academia are therefore required to weather the approaching autonomous storm.

KEYWORDS: Autonomous shipping, maritime transport policy, collaboration, maritime clusters, triple helix, digital disruption, systematic literature review, scenario planning

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List of Abbreviations

4IR	Fourth Industrial Revolution
CMTP	Comprehensive Maritime Transport Policy
GMP	Global Maritime Professional
I4.0	Industry 4.0
IAMU	International Association of Maritime Universities
IEB	International Executive Board
IMarEST	Institute of Marine Engineering, Science & Technology
IMO	International Maritime Organization
ITF	International Transport Workers' Federation
MARINA	Maritime Industry Authority
MASS	Maritime Autonomous Surface Ships
MET	Maritime Education and Training
MIDP	Maritime Industry Development Plan
MPA	Maritime and Port Authority of Singapore
MUNIN	Maritime Unmanned Navigation through Intelligence in Networks
NFAS	Norwegian Forum on Autonomous Shipping
PRISMA	Preferred Reporting Items for Systemic Review and Meta-Analysis
R&D	Research & Development
RQ	Research Question(s)
SAMSA	South African Maritime Safety Authority
SDG	Sustainable Development Goals
SLR	Systematic Literature Review
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 as amended
STEM	Science, Technology, Engineering and Mathematics
TETA	Transport Education Training Authority
UN	United Nations
VUCA	Volatile. Uncertain, Complex, Ambiguous
WEF	World Economic Forum
WMU	World Maritime University

1. Introduction

1.1 Background and context

Industry 4.0 (I4.0) as the Fourth Industrial Revolution (4IR) is also known, is impacting many spheres of society and includes operator-less transport systems, 3-D printing and artificial intelligence. Pereira and Romero characterise the 4IR by swift and disturbing modifications comprising “digital manufacturing, network communication, computer and automation technologies” (2017, p. 1208). These industry changes and innovative manufacturing processes will create new jobs (Pereira & Romero, 2017). The maritime industry too is witnessing the effects of this digital disruption. Autonomous ports are already in operation in, among others, Qingdao and Shanghai (CGTN, 2019), Rotterdam (Port of Rotterdam, 2019) and Singapore (PSA, 2019). A regulatory framework for drones in the port of Singapore is being created (Safety4Sea, 2019), and the International Maritime Organization (IMO) is currently conducting a regulatory scoping exercise in preparation of Maritime Autonomous Surface Ships (MASS) (International Maritime Organization [IMO], 2018). Traditional models of doing business as well as for training, recruiting and retaining talent need to change to remain relevant in the 4IR. A major challenge associated with this change is determining the exact future needs that preparations have to be made for.

Autonomous vessels, whether operated with reduced manning or unmanned with remote monitoring/operation or fully autonomous, are receiving attention from different stakeholders in the maritime industry, including policy-makers, manufacturers, academia, and unions. Governments that are actively engaged in this area include Norway[1], Denmark[2], Finland[3], Singapore[4], Republic of Korea[5], Japan[6] and Australia[7].

To date, there are no public international law instruments to regulate autonomous shipping – whether the construction or operation of vessels or relevant training and certification requirements of onboard crew or shore-based operators. There has however already been an international crossing by an Uncrewed Surface Vessel from West Mersey to Oostende (Maritime Training Insights Database [MarTID], 2019), which was made possible through international collaboration (Society of Maritime Industries, 2019). Classification societies have already prepared guidelines and standards in terms of autonomous vessel operation, and as such have each categorized their own levels of autonomy. DNV-GL categorizes degrees of automation separately for navigation and engineering functions (DNV-GL, 2018). Lloyd's Register have conceptualised five levels of automation (Lloyd's Register, 2017). Whilst Bureau Veritas also opted for five levels of autonomy, a distinction is made between the role of the human and the role of the system among the various system functions (Bureau Veritas, 2017).

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[1] Trondheim fjord has been designated the world's first autonomous ships test area through an agreement signed between the Norwegian Maritime Authority and the Norwegian Coastal Administration (Norwegian Maritime Authority, 2016).

[2] Danish Maritime Authority considered the potential for developing autonomous ships in support of, and future competitiveness of Blue Denmark (Technical University of Denmark, 2017).

[3] Finland's maritime industry has increased opportunity to lead digitalisation of maritime transport through exemptions to minimum manning and watchkeeping requirements in vessel automation (Finnish Government, 2018).

[4] Maritime and Ports Authority (MPA) of Singapore focuses R&D on autonomous technologies, intelligent shipping and data analysis (Maritime and Port Authority of Singapore, 2017)

[5] The Republic of Korea has conducted a technology assessment on the introduction and operation of MASS (International Maritime Organization [IMO], 2018).

[6] The goal of the Japanese government is to bring autonomous vessels into service by 2025 and as such it has approved a project to test automated berthing, collision avoidance and remote monitoring systems (Bergman, 2018).

[7] Australian Maritime Safety Authority anticipates the changing role of seafarers and autonomous vessel operations and has drafted a policy on the facilitation thereof (Australian Maritime Safety Authority, 2017).

The effect of MASS on the labour market and seafarer employment has received similar attention from various entities in terms of the impact on future competencies and training requirements. Governments and non-governmental organizations are conducting research in this regard. The International Transport Workers' Federation (ITF) contracted the World Maritime University (WMU) to identify, evaluate and assess the impact of automation on employment, following the introduction of new technologies in the transport sector (World Maritime University [WMU], 2017). This study concluded that on the macro level the introduction of automation would be evolutionary as opposed to radical. It is most likely that automation will least affect the duties executed by highly-skilled individuals, even though skills and tasks may vary from now until 2040 (World Maritime University [WMU], 2019).

The key focus area of the Institute of Marine Engineering, Science and Technology (IMarEST) is to successfully understand the role of the human and how best to optimise human performance (Meadow, Ridgwell, & Kelly, 2018). IMarEST hosted a roundtable discussion during 2018 following a global survey which examined industry perspectives on greater automation. Upon conclusion, it was proposed that a gap analysis be conducted to identify skill-set requirements for the future workforce by projecting towards the year 2040. Another approach to understanding the impact of autonomous shipping included an analysis of the duties, responsibilities and liabilities of the 'Autonomous Ship Controller' in terms of navigation under national and international laws and regulations. The MUNIN[8] Consortium project specifically covered basic legal obligations relating to collision, maintenance, visibility, lookout and watchkeeping (MUNIN, 2018).

Whilst it may take some time to formulate and implement international regulations governing autonomous shipping on the high seas, countries maintain their sovereign right to legislate on this domestically. Further to legislation, factors that are of crucial

[8] Maritime Unmanned Navigation through Intelligence in Networks (MUNIN). This EU-funded research project assessed the feasibility of an unmanned merchant ship from a technical, economic and legal perspective and included the development of a testbed (MUNIN, 2018).

importance in an autonomous future relate to technological literacy of countries, infrastructure and social acceptance of increased technological advances, and the role of human resources and referred competencies in the evolving technological era. The last is the most difficult to determine in the current state of uncertainty: what expertise and competencies will be required to deal with technology twenty to forty years from now?

1.2 Problem statement

Remotely operated or autonomous vessels are anticipated to be sailing in certain sea-areas within the next few years. It is predicted that these vessels may initially be operational on coastal voyages and short sea routes and undertake international voyages by as early as 2030 (United Nations Conference on Trade and Development [UNCTAD], 2018). The introduction of these technically advanced vessels sailing alongside conventional merchant vessels poses a multitude of challenges, relating amongst others to the legal framework, societal acceptance, and available resources – especially human resources and infrastructure. MASS is considered as a disruptive innovation and its introduction will fundamentally change the shipping industry and global maritime transport system (Korea Institute of Marine Science & Technology Promotion, 2018).

While the advancement of technology and increased automation are considered as beneficial by some (International Labour Organization [ILO], 2018), (Geospatial Media and Communications, 2018), the consequences thereof may however also pose challenges. Some (WEF, 2016) (World Bank Group, 2019) consider digitalization a disruption. United Nations (UN) Conference on Trade and Development highlights the disruptive impact of technology on the maritime industry, especially with the many onboard systems and in ports. While technologies including blockchain, drones and autonomous ships may present benefits to the industry, a number of safety, cybersecurity, skill shortages, redundancies and liability issues and concerns arise (UNCTAD, 2018). The World Economic Forum (WEF) has found that the impact of

I4.0 on the employment front will include a mixture of job creation opportunities, job displacements, heightened productivity, and widening skills gaps (WEF, 2016). The redefinition of traditional onboard crew roles vis-à-vis the roles of the emerging shore-based vessel operators and related artificial intelligence remains one of the most important aspects to address in the maritime sector (UNCTAD, 2018). The lead-time in formulating and implementing policies, and training could result in a situation where the required resources are not available when they are needed.

The 4IR may lead to serious sociological challenges including ethical dilemmas related to the development and implementation of responsible innovations. Kravchenko and Kyzymenko (2019) agree that it appears increasingly difficult to outline the philosophical difficulties connected to the formation of a contemporary social order. How does a nation prepare for an autonomous future in vessel operations amidst the many uncertainties that digital disruption brings? It thus becomes necessary to consider different scenarios that may present itself in addressing maritime policy/legislative frameworks to ensure industry readiness and the development of the required human resources.

1.3 Research aims and objectives

The aim of the study is to provide a conceptual framework to assist governments that choose to strategically prepare for autonomous vessel operations through scenario planning.

The objectives of the study include at a national level:

- To generate autonomous vessel scenarios over the short, medium and long term.
- To examine the existing maritime policy/legal framework and determine to what extent it supports the introduction of autonomous vessel operations under the most plausible of these scenarios.

- ⊗ To determine industry readiness to accept increased automation under the most plausible of these scenarios.
- ⊗ To investigate the current maritime curriculum and determine to what extent it supports the introduction of autonomous vessel operations.
- ⊗ To make recommendations in support of governments' preparation for autonomous vessel operations under the most plausible of these scenarios.

1.4 Research questions

The research methodology aimed to answer the following:

Research Question 1:	What are likely scenarios relating to the operationalisation of autonomous shipping?
Research Question 2:	What initiatives, if any, have been taken by each of the jurisdictions to prepare for autonomous shipping according to the most plausible of these scenarios?
Research Question 3:	What are the human resource requirements that need to be addressed to operationalise autonomous shipping for the most plausible of these scenarios in each jurisdiction?
Research Question 4:	How prepared is the maritime industry and society in each jurisdiction to operationalise autonomous shipping under the most plausible of these scenarios?

1.5 Research methodology and methods

One of the most important factors when deciding which research method to use, is the nature of the research (Kitada, 2010). This research deals with emerging technological innovations in the maritime sphere yet to be regulated in an international context. The objectives included generating plausible scenarios to answer specific research questions. As such the researcher deemed a multi-step mixed-methods paradigm appropriate. First, a systematic literature review (SLR) was conducted to generate four autonomous future scenarios from which a comparative analysis in four specific national jurisdictions, could be further explored. This further exploration was undertaken following a qualitative methodology, which included the use of questionnaires, interviews as well as normal and quasi-focus group discussions.

A comprehensive desktop review included national maritime and education policies related to technology and autonomous vessel operations in each of the chosen jurisdictions, and country geopolitical profiles. These jurisdictions were selected based on their active research and development (R&D) involvement in the field of autonomous shipping and digital transformation of the maritime industry in their respective national domains.

Questionnaires were sent to Maritime and Port Authorities, Maritime Education and Training (MET) Institutions, Industry, and Seafarers. Interviews and focus group discussions were arranged with key stakeholders where more in-depth information was required to enable the researcher to answer the research questions.

WMU Research Ethics Committee Protocols were followed, and approval obtained prior to the collection of data.

1.6 Outcomes

Four autonomous future scenarios were generated following a SLR. The research instruments aimed to address specific questions relating to one particular scenario. A questionnaire was designed to inform the researcher of the maritime industry and society's perceived preparedness for autonomous vessel operations, which enabled a comparative analysis of the chosen jurisdictions. More in-depth understanding of the policy amendments and human resource requirements were obtained through semi-structured interviews, as well as normal and quasi-focus group discussions.

1.7 Scope and limitation

The study limited its scope to the national maritime policies and regulations, societal readiness and human resource development of four countries. The study did not consider which curriculum would be most suited to train mariners in future.

1.8 Structure of the dissertation

The literature review focussing on public policy, digital disruption and scenario management is found in Chapter Two. Chapter Three includes the research methodology, stages followed in the systematic literature review (SLR) to generate the scenarios, and an overview of the data collection and data analysis methods. The data analyses and findings are presented in Chapter Four. Chapter Five discusses the research findings. Chapter Six concludes the study, makes recommendations for governments and identifies suggested research areas for future consideration.

2. Literature Review

2.1 Public Policy

Public policy relates to a government's proposed or adopted principle of action in a particular field. Governments have dedicated policies to deal with different subject matters, i.e. transport, education, employment, innovation, science and technology (UNESCO & ILO, 2018). These policies serve as guide for the consistent and uniform administration of the state's mandate, programmes and activities related thereto (Rasmussen, 2016). The policy formulation process involves agenda-setting, the actual formulation of the policy, decision making, implementation and finally evaluation phases, which may lead to the termination or reform of the policy (Manuel, 2018). Collaboration and stakeholder engagement spanning multiple policy spheres throughout the process of generating and implementing an applicable economic development and growth scheme, increases the likelihood of the policy(ies) being successfully implemented and the overall success in terms of reaching intended outcomes (UNESCO & ILO, 2018). These should ideally include a finance arrangement that delivers direct and noticeable benefits to communities, whilst emphasising innovative and future-oriented activities (Fritz & Hanus, 2015).

2.1.1 Maritime policy

Maritime law encompasses different legal systems and frameworks that govern all aspects of shipping and ship operations. These include international law, and regional, national and local rules (Comite Maritime International, 2019).

Maritime policies cover an extensive spectrum requiring deliberations which should ultimately lead to strategic actions being taken. These can range from military to environmental, political, commercial, ports and harbours, production, energy and science, and education (Suárez de Vivero, 2009). The need for an easily monitored, all-encompassing maritime industry policy is not only advantageous (Othman, Bruce, & Hamid, 2011) but a necessity for governance. The formulation of maritime public policies are however considered a challenge due to the large array of topics to be covered. This is intensified when local, national or international domains are not clearly distinguished from a legal, political or territorial perspective (Suárez de Vivero, 2009).

Good governance is said to be:

> …participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and follows the rule of law. It assures that corruption is minimized, the views of minorities are taken into account and that the voices of the most vulnerable in society are heard in decision-making. It is also responsive to the present and future needs of society (Rasmussen, 2016, p. 25).

Collaborative and transparent policy-formulation processes have many benefits. Likewise, strategy-making processes that are transparent and inclusive have the advantage of permitting increased collaboration and deliberation among the maritime society as well as providing increased perceptibility and organisation to external groups. Fritz and Hanus (2015) found transparent collaboration also permits maritime policies to build and offer services to the maritime community, without labouring particular (self)interests. Complementing policies are better able to drive economic growth as is found when governments have established coordination and coherence, rather than in countries where conflicting policies operate in isolation (UNESCO & ILO, 2018).

2.1.2 Collaboration and maritime clusters

In terms of international operationalisation of autonomous shipping, the need for good governance processes concerning decision-making and implementation of MASS is important and should include all stakeholders whether at the national or international levels. A position paper by Comite Maritime International (2019) discusses the host of maritime laws and regulations which are impacted on by the introduction of MASS. Collaboration and the contribution of maritime clusters in the policy-making process may be instrumental as governments choose to prepare (or not) for autonomous shipping operations - whether nationally, regionally or internationally. Maritime clusters are particularly significant, as it has been found that wherever the maritime industry operates, the surrounding region appears to flourish, as result of the multiplier effect (Koliousis, Papadimitriou, Riza, & Stavroulakis, 2017).

Engaging stakeholders in a participatory, consensus-oriented, equitable and inclusive strategy-making process can however be challenging. This can be countered by using key elements of foresight[9] to create networks of knowledgeable stakeholders, who can develop strategic visions and anticipatory intelligence to respond to policy and other challenges (Fritz & Hanus, 2015).

2.2 Digital disruption

Disruptive innovation may be regarded as having positive outcomes. Historically, the first three industrial revolutions have all been viewed as fundamentally altering the conventional industrial methods of its time, the approach to life and civilisation as a whole by applying an innovative approach (Kravchenko & Kyzymenko, 2019). Digital disruption however entails a technologically-generated instability capable of producing industry-level mayhem (Skog, Wimelius, & Sandberg, 2018). The concept of disruption may therefore have a negative connotation. The perceived negativity towards disruption could be linked to the resistance to change, as change is oftentimes

[9] Foresight is a process incorporating systematic and participatory principles to gather future intelligence and formulate a medium-to-long-term vision; aimed to mobilise collaborative actions based on present-day decisions (Fritz & Hanus, 2015)

linked to feelings of discomfort. Industries can however no longer remain inactive as global disruptions like automation, digitalization and artificial intelligence are having a largescale impact on economies, governments and society (World Economic Forum [WEF], 2018). In terms of skills development and future workforce, governments need to take critical and targeted action now to contain ever-growing unemployment and inequality caused by the digital disruption of I4.0 (WEF, 2016).

2.2.1 Digital skills and labour

The latest World Development Report focusses on the shifting landscape of labour as a consequence of I4.0 –

> *'Machines are coming to take our jobs'* has been a concern for hundreds of years - at least since the industrialization of weaving in the early 18th century, which raised productivity and also fears that thousands of workers would be thrown out on the streets. Innovation and technological progress have caused disruption, but they have created more prosperity than they have destroyed. Yet today, we are riding a new wave of uncertainty as the pace of innovation continues to accelerate, and technology affects every part of our lives (World Bank Group, 2019, p. vii).

I4.0 has ethical implications on the labour market. Employment in high-skilled intellectual occupations have grown fastest in developed countries; this is similar for low-skilled vocations that require dexterity. Middle-skilled workers however find themselves with fewer employment opportunities due to automation, which may lead to increased disparity in developed economies (World Bank Group, 2019). Automation and technology are expected to change work processes and the labour force will have to adapt to these changes. The agility of education and training systems to prepare the workforce for newly anticipated roles become paramount in this era of automation and technology. It took decades for industry to develop the training arrangements and establishments required to develop new key skill-sets on a large scale, following previous industrial revolutions (WEF, 2016).

Skills and competencies need to evolve to cope with uncertainty, technological advancements and increased automation. In an attempt to address these skills and competencies, the International Executive Board (IEB) of the International Association of Maritime Universities (IAMU) together with the Nippon Foundation have framed a concept for the Global Maritime Professional (GMP) of the future. The GMP is describes as:

> An individual who is a professional in the maritime industry and who is equipped with all the relevant technical competencies relevant to their specific operational role in the industry and as required by international requirements, with high level academic skills including logical and critical thinking and who – in addition to their technical competency – exhibits a high level of professionalism and ethical behaviour, human relations skills, emotional intelligence and multicultural/diversity awareness and sensitivity. Such an individual exhibits significant leadership skill and is able to optimally work with teams and also take personal initiative. They additionally exhibit a high sense of environmental consciousness and the need for sustainable practices and have an excellent grasp of contemporary issues affecting the maritime industry (International Association of Maritime Universities [IAMU], 2019, p. 4).

The GMP concept was derived from a number of factors including technology, climate change, geopolitical risks, legislative and administrative requirements, increased volatility, uncertainty, complexity and ambiguity (VUCA) and the challenges it bring, and disruptions to the supply and demand of labour from technology (IAMU, 2019). Similarly, Chawla (2015) identified critical future competencies. These include the ability to process large amounts of data from man-machine interfaces, ability to focus on critical issues, ability to work with remote teams, ability to be assertive, ability to understand the limitations and recognize changes of automation, ability to manage change, ability to learn continuously, the ability to cope with increased stress, ability to communicate effectively and the ability to be a leader. Skills development becomes an important enabler in ensuring industry's readiness and society's acceptance of new technology such as automation and autonomous shipping. The accelerating pace of technological change is expected to place considerable pressure on national and global education and training systems in terms of anticipating future skills needs (ILO, 2018).

2.2.2 Societal preparedness for autonomous shipping

Variables that determine the rate at which different regions across the globe will implement innovative and developing technologies include the quality of infrastructure, the efficiency of regulations and organizations, the human capital of a country and its political will to invest in new technologies (WMU, 2019). Much focus is given to remotely controlled and autonomous vessels in terms of R&D, levels of automation, testing systems, and liability and insurance aspects (Singapore Maritime Institute, 2019). The drive for innovation is more often than not linked to sustainability, increased productivity and finding energy efficient solutions. Countries are however not at the same level of advancement in this regard. There is a noticeable difference between developed and developing countries when considering the level of preparedness to accept innovative technologies and automation (ILO, 2018).

Regarding industry's readiness to operationalise autonomous shipping, one needs to consider various external factors such as those included in the common strategic planning tools used in business. PESTELE analyses include insights into political[10],

[10] Political will, government stability, stakeholder engagement

economic[11], social[12], technological[13], environmental[14], legal[15], and ethical[16] factors which may impact on operations. A key focus of the PESTELE analysis is to identify and analyse factors outside the control of an organization which may have some impact on the organization (Team FME, 2019). These factors are unique to particular settings and organizations, and in the case of autonomous shipping, the national jurisdiction, culture and geopolitical context of the country. From an individual country perspective, factors to consider include data infrastructure, frameworks covering both policy and institutions, user adoption level, and industry composition (Geospatial Media and Communications, 2019). The country context will therefore determine the degree of dominance automation has over labour supply and how countries choose to respond, if at all, in this disruptive VUCA environment in which we live (World Bank Group, 2019).

2.3 Scenario management

Some deem I4.0 as an unsupported theory still in its infancy stage. I4.0 is assumed to have no well-defined vision about the latest manufacturing models, nor concerning its implications and consequences (Pereira & Romero, 2017). Others view this digital disruption as one which can be predicted, and which offers companies the opportunity to adequately prepare. Unlike past revolutions, companies can plan for this new industrial paradigm by outlining the best appropriate manufacturing model and preparing the intended solutions to address the challenges (Pereira & Romero, 2017). According to WEF however, the production curve is overwhelmingly uncertain, especially up to the year 2030: governments, industry and academic institutions are under immense pressure to address challenges that may affect innovation, sustainability and employment within a complex and volatile external environment (World Economic Forum [WEF], 2017). We are witnessing the increased likelihood

[11] Blue economy, maritime trade and GDP, infrastructure
[12] Career dispositions, technological savviness, education system
[13] Manufacturing and infrastructure, internet connectivity, technological options
[14] Geographical location, sustainable operations
[15] Regulatory framework
[16] Loss of livelihood due to automation, equal opportunity

of maritime trade patterns being altered globally as a result of the continuing threat of trade wars and inter-country tensions (UNCTAD, 2018).

Scenario planning offers the opportunity to consider how changing social, technological, economic and political factors can lead to multiple futures (Chemarck & Payne, 2005). In their discussion on strategic planning at Royal Dutch/Shell, Schoemaker and Van Der Heijden (1993) highlighted that scenario building is considered an art more than a science and that there are no simple recipes for producing suitable, worthy scenarios. Various researchers refer to how Shell, which is considered an innovator in strategic management, have managed uncertainty and political complexity in the volatile oil and gas industry through planning. Shell's approach is to prepare the 'institutional mind' for many possible futures instead of attempting to predict a single uncertain future. This enables quicker decision-making through having a broader appreciation of the changing external environment (Schoemaker & Van Der Heijden, 1993).

Scenarios have many definitions. WEF refers to scenarios as "compelling, plausible narratives on potential outcomes, which inform the formulation and implementation of strategy, and in doing so enable leaders to anticipate and plan for the future" (WEF, 2017, p.5). The term is used in this work with this definition in view.

3. Research methodology

3.1 Introduction

"A research methodology theorizes the selection of instruments, methods, and procedures of investigation which aim to construct or validate knowledge" (Ramirez, Mukherjee, Vezzoli, & Kramer, 2015, p. 72). In this study the researcher used a systematic literature review (SLR[17]) to generate four scenarios from which to further explore an autonomous future in specific national jurisdictions[18]. A SLR aims to use categorical, organised methods to minimise bias when addressing a specific question through assembling all evidence that meet pre-defined eligibility criteria, and which are believed to offer reproducible results (Higgins & Green, 2011). The researcher deemed scenario planning an appropriate tool for this study given the large amount of uncertainty surrounding autonomous shipping. It has been proposed that the use of scenarios as part of a research methodological framework may increase a study's scope by including the context of uncertainty (Ramirez et al., 2015).

Whilst I4.0 and technological advances such as automation are seen as disrupting the maritime industry, the exact implications and consequences thereof are challenging to predict. Hence the generation of possible scenarios to assist governments in navigating through the uncertainty and strategically prepare for future decision making and policy formulation may be deemed as beneficial. Scenario planning is increasingly being used by governments wishing to legitimise their science, technology and environmental management policy decisions (Duckett, McKee, Sutherland, & Kyle, 2017). Its

[17] The relevance of a systematic literature review and applicability to the social sciences is well established, although it originated/is primarily used in the health and natural sciences (Victor, 2008).
[18] The selection of jurisdictions are discussed in Section 3.4: Selection of jurisdictions and participants

usefulness in presenting various future conditions in environments that are changing too rapidly to predict through strategic planning models is receiving attention (Chermack, 2011). Scenario planning has been used as a policy gap analysis mechanism linking the present and future (Ramirez et el., 2015). Researcher-driven scenario generating methods can be quantitative, qualitative, or mixed (Star, Rowland, Black, & Enquist, 2016).

Following the SLR, the use of other methods in the mixed-methods paradigm aimed to develop a deeper understanding of the research problem by merging the strengths of qualitative and quantitative methods. Mixed methods research is defined as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study” (Johnson & Onwuegbuzie, 2004, p. 17). The researcher was able to take a more pragmatic approach to this study by employing mixed-methods which integrated open-ended (qualitative) and close-ended (quantitative) data collection methods to answer the research questions and include both forms of data analyses (Creswell, 2014). This meant different methods, worldviews, assumptions, data collection formats and analyses all worked together to increase the researcher’s understanding of the problem. Mixed-methods enabled the researcher to obtain a comprehensive appreciation of legislative, societal and human resource development perspectives from key maritime stakeholders in the respective jurisdictions.

Research methods should present the best opportunity to gain useful answers to the research questions (Johnson & Onwuegbuzie, 2004). Figure 1 provides an illustration of the research approach and process. One of the four scenarios were utilised as foundation for creating research instruments to obtain data from each of the respective jurisdictions. Quantitative and qualitative data analysis considered PESTELE factors.

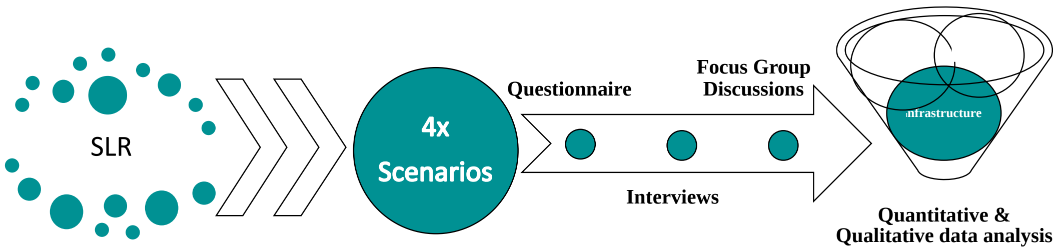

Figure 1. Research approach and process

3.2 Systematic Literature Review: Autonomous Shipping Scenarios

The aim of the systematic review was to ascertain, choose and critically appraise appropriate literature pertaining to a specific question, and to analyse the data collected from the literature that has been reviewed.

> A Systematic Review is a review of a clearly formulated question that uses systematic and reproducible methods to identify, select and critically appraise all relevant research, and to collect and analyse data from the studies that are included in the review (Curtin University, 2019, para.1).

The SLR consisted of key stages which are briefly discussed next.

<u>Stage 1: Planning the review</u>

'*To what degree will technology impact the operationalisation of autonomous shipping?*' This was the SLR question the researcher wanted answered in order to generate autonomous shipping scenarios. Full text literature in the English language were sourced from the online WMU (EBSCO) Library 'Discovery Search' database. Sources included peer reviewed articles, journals, government reports, industry studies, and dissertations/theses. The researcher, in some instances, also considered literature cited within the selected sources for inclusion in the SLR – similar to the snowball sampling technique used in qualitative research.

SmartText Searching included the following key words and phrases: *Fourth Industrial Revolution; autonomous; shipping; maritime*; *automation and jobs*; *autonomous ships*.

Inclusion criteria involved:

- Government reports on autonomous shipping and/or technology
- Industry reports related to autonomous shipping

Exclusion criteria included:

- Literature published before 2015 as its contribution was considered to be significantly reduced due to the fast pace of technological advancements.
- Abstracts that were considered to be not related to the maritime or broader transport industries.

<u>Stage 2: Collecting and evaluating sources</u>

The researcher obtained 36 documents from academic databases and a further 10 sourced online from industry and governments for further review. According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[19] flow diagram, a breakdown of the documents obtained, screened and analysed are presented in Table 1.

[19] Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses. PRISMA focuses on the reporting of reviews evaluating randomized trials but can also be used as a basis for reporting systematic reviews of other types of research, particularly evaluations of interventions (PRISMA-statement, 2019, para. 1).

Table 1. *Systematic Literature Review*

Description	Number
Total number sourced from academic databases	36
Total number sourced from industry	10
Number of duplicates removed	3
Number of records screened	43
Number of records excluded	10
Number of full texts assessed for eligibility	33
Number excluded after full text review	15
Number of studies included	18

Appendix A details the literature considered in the SLR.

Stage 3: Analysis of data

The remaining documents were once again assessed from a content perspective for its suitability in meeting the search criteria. The documents were qualitatively coded according to technology (remote-controlled or autonomous vessel capability), legal (domestic, regional or international operation), timeframe, and human resources by using the Atlas.ti Qualitative Data Analysis[20] software programme. The two most co-occurring codes related to technology and timeframe. The next methodological step was to use the Word Cruncher feature of the Atlas.ti software to highlight the number of specific words relating to the timeframe, technology and area of operation. The results are detailed in Appendix B.

3.3 Scenario building

Key uncertainties identified during the SLR include the regulatory framework, level of technological innovation, and human resource requirements in terms of remotely controlled or autonomous vessels operating in national and international waters. The researcher aimed to address the last of these through the administration of

[20] See https://atlasti.com

questionnaires. The scenarios were temporally separated according to the years 2020, 2025, 2035, and 2040. This based on the literature review and the word count totals as indicated in Appendix B.

The four scenarios generated from the SLR were:

Scenario *"Yankee"*[21]*: Dragging anchor*

In this scenario, it is business as usual as the shipping industry is pushing forward R&D initiatives and experimenting with prototypes to reduce ships' greenhouse gas emissions. The first fully-autonomous ship in the world that emits zero emissions and is fully electrical sets sail in 2020 as an initially manned vessel within the domestic waters of Norway. The size of the world fleet is approximately 97 000[22] vessels and 4025[23] conventional vessels are on order with most vessels having a lifespan of thirty years. Many countries, especially those in the developing world are however lagging behind regarding technological advancements and innovation. In some countries the struggle toward addressing basic human rights, education and employment continue to be prioritised.

Scenario *"Quebec"*[24]*: Manned robots*

It is the year 2025 and the first fully autonomous vessel, the YARA Birkeland has been operating without any crew onboard for three years. Some leading maritime nations have implemented strategies to operationalise autonomous shipping. The international maritime community has implemented transitional arrangements for testing the safety of autonomous vessels on international voyages and their operational integration with conventional ships, especially in regard to compliance with international collision regulations. These vessels are still crewed albeit with the minimum manning onboard

[21] International Code of Signals: Yankee means "I am dragging my anchor" (International Maritime Organization [IMO], 2005).
[22] Clarksons Research (2019).
[23] Clarksons Research (2019).
[24] International Code of Signals: Quebec means "My vessel is 'healthy', and I request free pratique" (IMO, 2005).

reduced to five. Low and mid-level skilled workers have been displaced due to increased autonomation even on conventional ships.

Scenario *"Delta"[25]: Pushing the boundaries*

It is 2035 and there is an increase in the number of maritime nations that have approved unmanned autonomous vessel operations in their domestic waters. Some have bilateral agreements in place to aid regional operation of MASS. Shore control centres are manned by ex-seafarers. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 78) as amended, is undergoing a comprehensive review to include the minimum standards of training, certification and watchkeeping required for shore-based vessel operators. Most of the biggest global ports are fully- or semi-automated and able to berth/unberth autonomous vessels.

Scenario *"Oscar"[26]: Autonomous ghost ship*

The review of STCW 78, as amended, has been completed and the amendments entered into force on 1 January 2040, following the transition period after a diplomatic conference held in Singapore in 2035. The amendments include new competency requirements for shore-based watchkeepers of remote-controlled and unmanned autonomous vessels. Autonomous vessels are operating internationally without crew onboard.

The systematic review suggest a leaning toward the anticipation of autonomous shipping being global by 2040[27]. The researcher therefore limited the scope of this research to Scenario *Delta*. In the *Delta* scenario, countries are pushing the boundaries regarding regional cooperation to test unmanned autonomous vessel operations and

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[25] International Code of Signals: Delta means "Keep clear from me; I am manoeuvring with difficulty" (IMO, 2005).

[26] International Code of Signals: Oscar means "Man* overboard" (IMO, 2005). *Note: The International Code of Signals have not yet amended *man* overboard (MOB) to *person* overboard (POB).

[27] See Appendix B: 2040 and 20 years from now combined to a count of 606, compared to 2030 and 10 years from now (count of 375) and 2035 and 15 years from now (count of 312).

determine the ideal competencies required by watchkeepers of internationally operated unmanned autonomous vessels. The researcher deemed *Delta* the most plausible scenario to further explore countries' readiness, taking into account the lead time to respond in preparation for 2040.

3.4 Selection of jurisdictions and participants

This study followed purposive nonprobability sampling methods. This is the most suited sampling technique when seeking to obtain particular information. In this study it was important to engage with industry experts involved in or impacted by autonomous vessel operations.

Four national jurisdictions were identified based on certain qualifying criteria, which included:

a) Jurisdictions actively engaged in autonomous shipping through R&D, innovation and testing;
b) Jurisdictions forming part of an established /active national Maritime Cluster engaged in autonomous shipping activities;
c) Jurisdictions having considered the changing role of seafarers and future skills required;
d) Jurisdictions actively engaged in discussions relating to MASS at IMO.

The researcher also considered additional factors:

- Maritime nations that may not have met all of the above criteria, but whose governments have a strong focus on developing the Blue Economy;
- Maritime nations who may be severely impacted on socio-economically by autonomous shipping operations;
- Geographical spread to enable deeper insight into regional perspectives; i.e. Europe, Asia, Africa.

The final selection of jurisdictions included Norway[28], Singapore[29], South Africa[30] and Philippines[31].

3.5 Instrumentation and data collection

Further to the SLR, the following instruments were used to answer the research questions[32]:

3.5.1 Questionnaire Instrument

The online questionnaire was generated using Google Forms[33]. The questionnaire consisted of 14 questions in total and aimed to answer research questions 2 to 4. Questions included one 'readiness scale' ranging from 1 to 10 for each key theme and further open-ended questions to offer participants the opportunity to elaborate. The questionnaire was piloted by students completing a Master of Science degree in Maritime Affairs at WMU prior to administering it to the intended participants. Ten responses to the pilot questionnaire were received resulting in no amendments being made.

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[28] The Norwegian Government actively supports R&D in the field of autonomous shipping and the first fully-autonomous, electric and zero-emission ship in the world is about to enter into operation.

[29] Singapore is a big shipping hub in Asia and is actively involved in R&D and innovation, which includes initiatives relating to autonomous ports and autonomous ships.

[30] The South African government-led Operation Phakisa is looking at unlocking the ocean economy and job creation opportunities in the maritime sector. "The oceans have the potential to contribute up to 177 billion rand to the Gross Domestic Product and create just over one million jobs by 2033" (The Presidency Republic of South Africa, 2014). (Retrieved from: https://www.operationphakisa.gov.za/cc/Documents/Open%20Day%20Operation%20Phakisa%20President%20Speech.pdf).

[31] Philippines is the second largest labour supplying country globally: largest supplier for Ratings and second largest for Officers (BIMCO/ISF, 2015).

[32] Research Question 1: What are likely scenarios relating to the operationalisation of autonomous shipping?

Research Question 2: What initiatives, if any, have been taken by each of the jurisdictions to prepare for autonomous shipping according to the most plausible of these scenarios?

Research Question 3: What are the human resource requirements that need to be addressed to operationalise autonomous shipping for the identified scenario in the particular jurisdictions?

Research Question 4: How prepared is the maritime industry and society in each of the particular jurisdictions to operationalise autonomous shipping under the identified scenario?

[33] The researcher ensured that the Google Platform was available in all four selected countries prior to disseminating the questionnaire.

The benefit of using questionnaire-based surveys is that one has the potential to obtain specific data from a large sample in a relatively efficient manner (Creswell, 2014). Using this research method, the researcher targeted individuals representing maritime and port administrations, MET institutions, and seafarers in the particular jurisdictions, in anticipation of comparing the national jurisdictions' individual preparedness and ascertaining which policies, regulations and skills were considered.
A copy of the questionnaire is included in Appendix C.

Questionnaire responses were imported to Atlas.ti Qualitative Data Analysis software for analysis. Obtaining responses however proved to be a major challenge as reflected by the limited number of respondents. To address this limitation (low sample size for the questionnaire) the researcher conducted interviews and focus group discussions with policy-makers and regulators, who also answered questions pertaining to the questionnaire.

3.5.2 Interview Instrument

A semi-structured interview instrument was generated, which consisted of five questions. The approach of purposively choosing participants was to best assist the researcher comprehend the issues confronting the respondents' jurisdictions. Specifically, the interviews were aimed at gaining a deeper understanding of the priority each government is giving towards autonomous shipping, and the regulatory framework and human resource development requirements to operationalise it. As a result, the researcher was able to acquire data presenting deeper insights into the present regulatory framework and government initiatives relating to human resource development and infrastructure of each country.
A copy of the semi-structured interview instrument is included in Appendix D.

3.5.3 Focus group, and quasi-focus group discussions

Focus group discussions were undertaken in South Africa to ascertain what specific action, if any, government and training institutions are taking in preparation of MASS.

The focus group discussions included participants from both the Department of Transport and Department of Environmental Affairs, the latter fulfilling the role of Secretariat for the South African government-led Operation Phakisa Ocean Economy[34] initiative. Other participants were from the South African Maritime Safety Authority (SAMSA) and the Transport Education Training Authority (TETA) as agencies of the Department of Transport and the Department of Higher Education and Training respectively. Four MET institutions as well as a maritime high school were also included in the focus group discussions.

Similar discussions naturally emerged among industry experts and colleagues during students' field study trips to the Maritime Industry Authority (MARINA) and three training institutions in Philippines. These discussions occurred without the overt involvement and facilitation of the researcher. As such, in the context of this research, the Philippine discussions are referred to as quasi-focus group discussions.

All interviews and focus group discussions were transcribed and imported into Atlas.ti for qualitative analysis.

[34] Operation Phakisa focuses on unlocking the ocean economy and creating jobs through skills and capacity building, and R&D and innovation (Department of Environmental Affairs, 2019)

3.6 Data analyses

3.6.1 Qualitative data analysis

The raw data was coded and analysed based on Scenario *"Delta": Pushing the boundaries*[35]. There were 150 codes[36] initially. Following initial analyses, some[37] of the codes were subsequently grouped according to PESTELE factors for further analysis per country. The findings and specific quotations from countries are presented in Chapter 4 and discussed in Chapter 5. The PESTELE code groups are included in Appendix E.

3.6.2 Quantitative data analysis

Once all the documents were coded, statistical data was exported from Atlas.ti to Microsoft Excel and descriptive statistics for each country generated. Preparedness scales based on the responses to questionnaire questions 1[38], 6[39], and 11[40] were prepared according to the code groups: 1-3 (unprepared), 4-7 (moderately prepared), and 8-10 (likely to be prepared). These are presented under key themes in Chapter 4.

Standard normal distribution curves are presented under each of the themes according to the preparedness scales. Each individual country's deviation was standardised through incorporating the global mean[41] and standard deviation (from this mean) of all

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[35] It is 2035 and there is an increase in the number of maritime nations that have approved unmanned autonomous vessel operations in their domestic waters. Some have bilateral agreements in place to facilitate regional operation of unmanned vessels. Shore control centres are manned by ex-seafarers. The STCW 78 as amended is currently undergoing a comprehensive review to include the minimum standards of training, certification and watchkeeping required for shore control vessel operators. Most of the biggest ports in Europe and Asia are fully automated and able to berth/unberth autonomous vessels.

[36] Codes included expertise of respondents, gaps identified, justifications (as follow-up responses to the perceived level of preparedness), skills required, and policy and regulations.

[37] Codes relating to economic, environmental, ethical, political, socio-cultural and technological justifications (as follow-up responses to the perceived level of preparedness), and codes relating to policies and regulations that have been completed, those in process or those required.

[38] Q1: On a scale of 1 (being least) to 10 (being most), how prepared do you think your country is in terms of the regulatory framework and maritime policy to operationalise autonomous shipping in its jurisdiction by 2035?

[39] Q6: On a scale of 1 (being least) to 10 (being most), how likely is it that your country will have the required human resources to operationalise autonomous shipping under its jurisdiction by 2035?

[40] Q11: On a scale of 1 (being least) to 10 (being most), how likely is it that your country will have the required infrastructure to operationalise autonomous shipping under its jurisdiction by 2035?

[41] The global mean refers to the overall mean of the four countries combined.

the participants from the four countries combined. The z-scores[42] for each of the countries are also included. This enabled country comparison between scores that are from different normal distributions by converting the mean to zero (0) (Laerd Statistics, 2019). The closer the z-score is to zero, the closer the country's mean is to the global mean. The z-score indicates the position above ('+') or below ('-') the global mean of the four countries combined, and the amount by which it differs from the global standard deviation.

3.7 Research ethics

When conducting qualitative research, the well-being of the participants is of highest concern. To ensure this, participants gave their informed consent prior to participating in the research and were informed and permitted to revoke their participation at any time.

Approval of the research instruments was obtained from WMU Research Ethics Committee prior to collecting data. An information sheet detailing the research objectives and how information would be protected was shared with all participants.

Data was processed in strict confidence, password protected and saved on an external hard drive. Upon completion of the research, the data was destroyed.

[42] Z-scores are also referred to as standard scores and represent the number of standard deviations from the mean data point (What is a Z-Score?, 2019). Normal distribution scores are standardised to become z-scores in a standard normal curve. This means that the group of data is converted so the mean becomes 0 (zero) and the standard deviation is 1 (one) (Laerd Statistics, 2019).

4. Research Findings

This chapter includes statistical data and transcribed quotations following the data analyses and presents an overview of the findings.

4.1 Quantitative Data: Descriptive Statistics

4.1.1 Total number of research participants

In total this study had 58 participants. The breakdown is found in Table 2.

Table 2. *Number of participants per country*

	Questionnaire	Quasi-/Focus Group Discussion	Interview	Total
Norway	4		2	6
Singapore	3		1	4
South Africa	18	14		32
Philippines	12	4		16

4.1.2 Gender profile of research participants

The female representation in this study was 13.8%. Figure 2 gives a per country breakdown, there were eight females in total.

4.1.3 Years served in industry and expertise profile per country

Table 3 includes descriptive statistics relating to the number of years the questionnaire respondents served in industry, this highlights the valuable contribution made by the various subject experts.

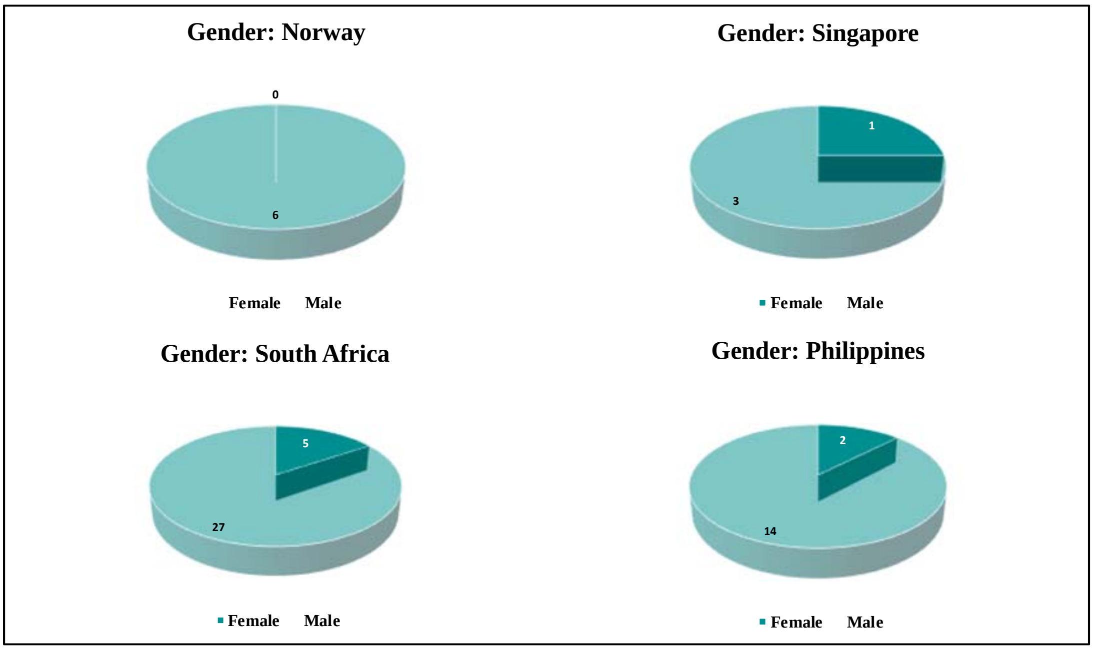

Figure 2. Gender profile of participants

Table 3. *Years served in industry, per country - questionnaire respondents*

	Norway	Singapore	South Africa	Philippines
Mean	25	13	28	26
Min	11	7	5	17
Max	42	24	50	43

The 58 research participants were grouped according to their occupation and expertise. The majority of participants are academics[43], followed by industry[44] and seafarers. Regulators were purposively targeted through interviews and focus group discussions. Figure 3 illustrates the expertise profile of the participants per country.

[43] This group includes maritime specialists, education and training institutions, and researchers.
[44] This group includes consultants and directors, managers, lawyers and fleet personnel assistants.

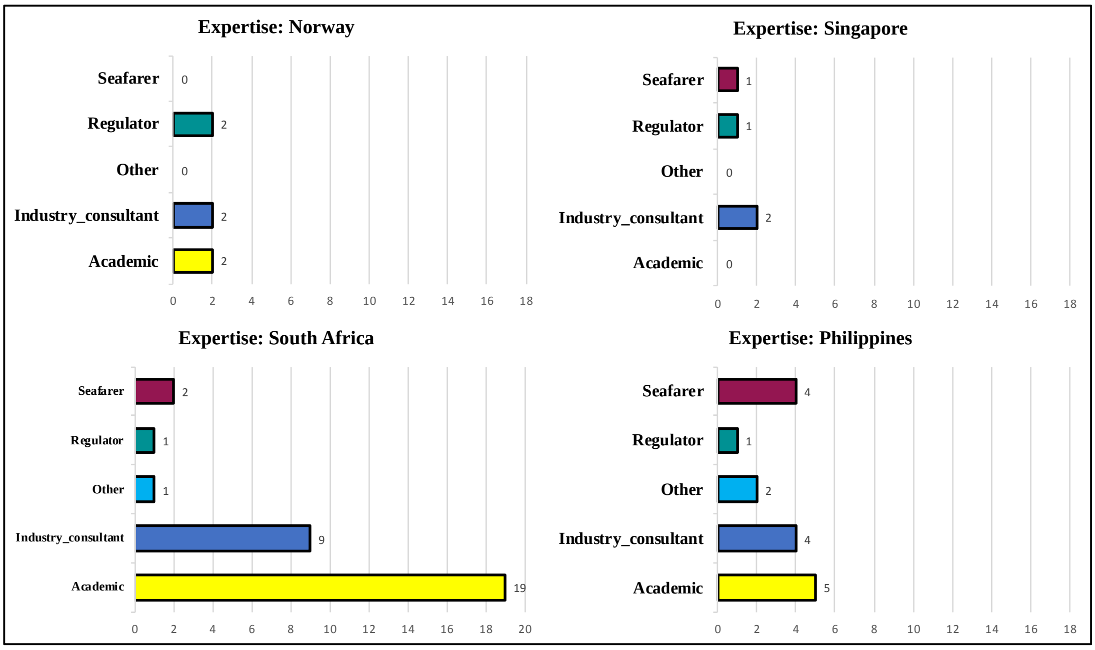

Figure 3. Expertise profile of participants per country

4.2 Qualitative Analysis

This section presents the findings following the qualitative analysis. Quotations are presented in *italics* as follows: Norway (N), Singapore (S), South Africa (SA) and Philippines (P). The selected quotations reflect the general tone of the interviews/focus group discussions. They are reproduced verbatim (no language corrections made).

4.2.1 Norway

It was found that autonomous shipping is high on the agenda of the Norwegian government and there seems to be strong collaboration between regulators, academia and industry through workshops and discussions. There is a dedicated forum - the Norwegian Forum on Autonomous Shipping (NFAS) - working on autonomous shipping. The forum has a number of different working groups.

> *N: "Yeah, any Party of us is actually supporting this, especially because of the sustainability touch that is into it, that is very important. It has really taken off when we started linking it to the sustainability goals"*

N: "There have been a lot of communication from our ministries asking us to look into various issues, and so we have done a lot of studies and the most important thing is probably the national transportation plan"

N: "And already we are working on the regulations..…Like the Vessel Traffic Services, we could do that today the other ones are a little bit more complicated, but still it doesn't hamper us anything"

The Norwegian Maritime Authority and Norwegian Coastal Administration have both visited some educational/training institutions to discuss the future industry outlook. There is also a dedicated government-funded project called *MARKOM2020*[45] looking into future competence requirements.

Currently there are auto-crossing and auto-docking tests being carried out on autonomous ferries, and telecommunication companies like Telenor and Telia are also involved in autonomous shipping projects.

N: "But it is a good question [How likely is it that Norway will have the required infrastructure to operationalize autonomous shipping?], *it is actually one of the things that we are looking into now with the transportation plan, how do we cope with this, we might just end up with a few hubs that could be tailor-made for this type of ships, but we cannot have this everywhere. Where we can have it everywhere is within other segments of shipping, like the ferries, it is a little bit easier to standardise also on that, because we have tools, ferries*

[45] "Markom2020 is a government-funded project comprising the four Nautical Sciences Colleges/Universities in Norway. The objective of Markom2020 is to raise the overall quality of Nautical Science studies in Norway. This project maps the various ways of structuring and modelling nautical science programs by means of indicators identifying the quality of selected Nautical Science study programs worldwide. A total of eight institutions were invited to take part in the mapping: Four in Europe, two in Asia and two in Americas. Data have also been collected from the four Norwegian Nautical Sciences Colleges/Universities in order to make a comparison. The main objective of this mapping is to identify strategic areas of development in nautical BSc programs" (Resnes, Eide, Trovåg, & Jensen, 2017, p. 3).

are actually more regulated by the government, how it should be and connections for charging batteries, and everything"

4.2.2 Singapore

Singapore as a major shipping hub is actively pursuing R&D and technological innovation to operationalise autonomous shipping under its jurisdiction.

> *S: "MPA has already offered grants to companies like Keppel O&M to promote development. There are many others"*

> *S: "Within Singapore, we are actively looking to develop and review our regulatory, legislation and liability framework for Singapore-registered vessels or those operating in the Port of Singapore with different degrees of autonomy while ensuring the alignment with international standards"*

Training is considered essential and as such the MPA has launched the Maritime Innovation Lab to look into future competency requirements.

> *S: "As part of the pilot projects, the ship crew are being trained to operate the autonomous navigation technology onboard tugs. The skills assessment will be part of future deliverables"*

4.2.3 South Africa

Most responses related to government's efforts to alleviate high unemployment as a priority. Governance, policies and the education system were found to be among the challenging areas raised and relate to lack of having the required human resources.

> *SA: "Listen, if you back it up well, we are looking at funding people to get into university, but we have a very poor basic education system. That is how far back I'm going to take it. Basic education, just treating kids right, having*

toilets, those are real concerns. If we get that right it means our university inputs will be at a much higher level"

SA: "Currently, the Maritime Industry in South Africa is as endangered as the Black Rhino. Lack of Administrative cohesion and poor international relations in the public and private sectors are slowly killing off the desire for people to pursue a career in Maritime"

The coastal surveillance and search and rescue facilities, together with government's focus on infrastructure development are however considered by some in a positive light in terms of the country's infrastructure preparedness. Basic infrastructure was however raised as a challenge.

SA: "You are talking to the country that doesn't always have electricity"

4.2.4 Philippines

Responses from Philippines seemed to represent opposing views; some deem the country ready whilst others are of opinion that it is still a long way off.

Having to convince the Maritime Administration to be more flexible in terms of the seafarer education and training curriculum was mentioned by respondents as a challenge and the reason why the country is not yet prepared for the possible change of skillset/competencies required for the operation of future vessels.

P: "There are a lot of forums made by the Philippine government in relation to the higher education, preparing for students in the fourth industrial revolution"

P: "The challenge that we have is that when you want to look at education and training, education and training has to follow a certain framework, and that framework is typically established by governments, and for governments"

Politics, government bureaucracy, the under-development of port operations and insufficient budget allocation to the maritime sector, were cited as reasons why Philippines is not considered as having the required infrastructure to operationalise autonomous shipping.

P: "Zero infrastructure for autonomous shipping"

A summary of the PESTELE analyses and skills identified to operationalise autonomous shipping in each of the jurisdictions follow. In the figures the "positives" reflect code groups relating to proactive initiatives and elements that contribute positively to a country's preparedness. The "negatives" however relate to those code groups that include elements that appear to be a challenge to countries, and negatively impact on a country's ability to proactively respond. The specific elements for each code group are indicated in Appendix E The numbers relate to the number of times the particular codes groups occurred for each country.

'Other' skills included references made to non-technical i.e. soft skills and training on how to handle panic situations. Increased simulation training, situational awareness, artificial intelligence, and zero and low carbon, environmentally friendly energy system competences, were also mentioned as skills required in future.

N: "When it comes to the naval or maritime education, I think there is a lot to learn from the navy still, because we are very focussed on the crises scenarios and making decisions on very little information"

Figures 4 and 5 present the PESTELE findings and required skills for Norway.

> *N: "But what is interesting is this* [autonomous shipping] *is going to come quicker on people than they are actually aware of and I see that now, as Director of the Board of NFAS, we get a lot of information. I cannot mention the companies, but there are big companies that I am speaking with and they are looking seriously into this* [autonomous shipping]*"*

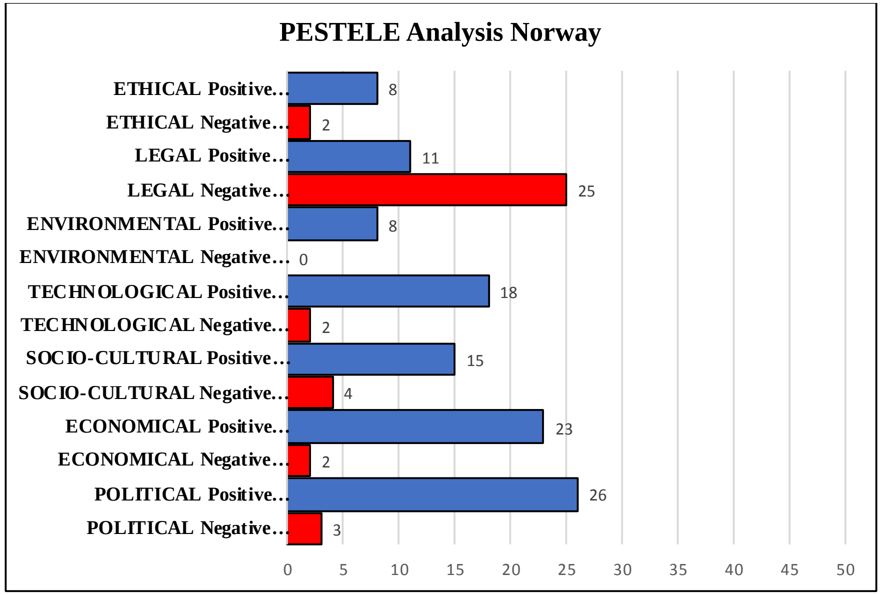

Figure 4. PESTELE analysis: Norway

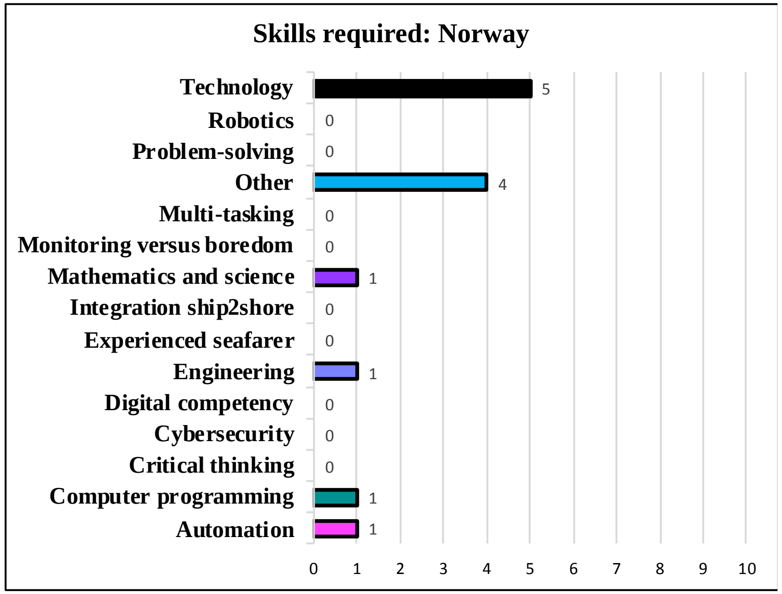

Figure 5. Skills required: Norway

Figures 6 and 7 present the PESTELE findings and required skills for Singapore.

S: "For vessel operators, the user experience user interface (UXUI) of the autonomous navigation technologies should be intuitive and require minimal re-training. Consequently, this will allow the current crew to be retained and trained on the job to operate the new technology. For autonomous technology developers and research scientists and engineers, the workforce should be trained in competencies such as UXUI design, data analytics, modelling and simulation and artificial intelligence"

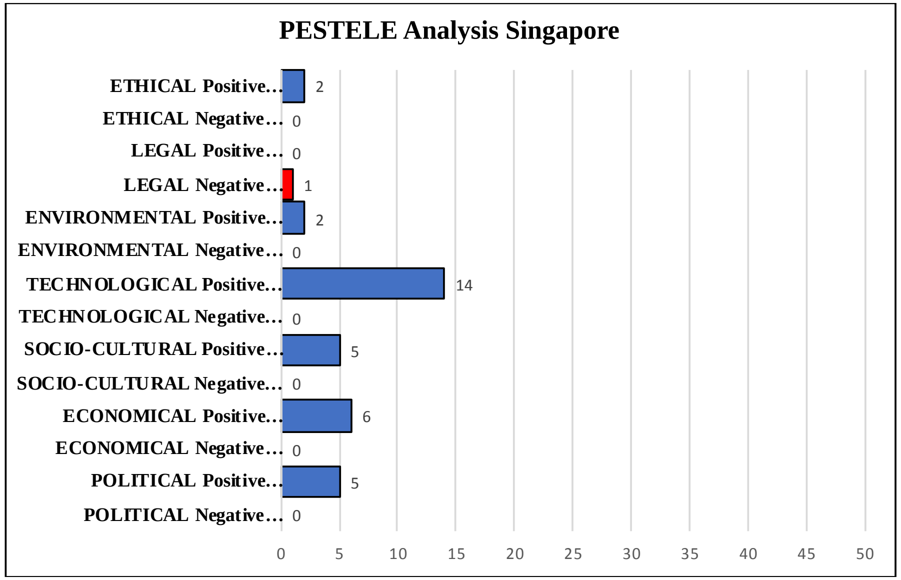

Figure 6. PESTELE analysis: Singapore

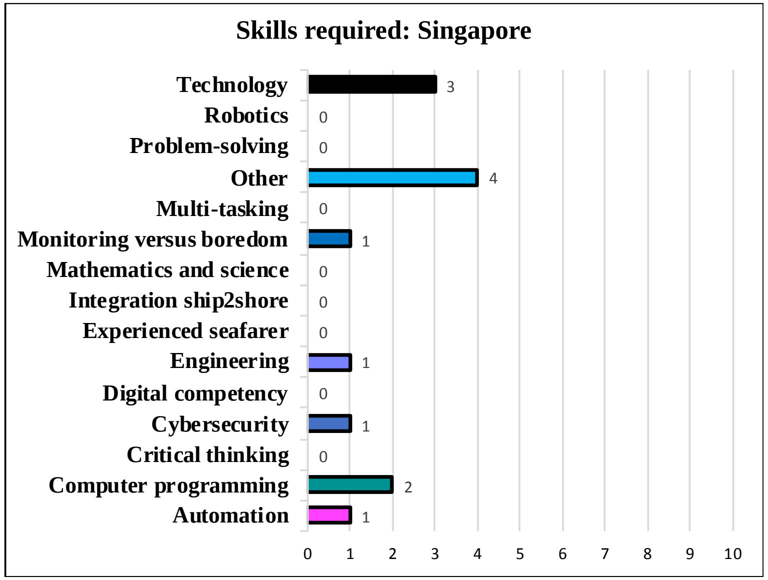

Figure 7. Skills required: Singapore

Figures 8 and 9 present the PESTELE findings and required skills for South Africa.

> *SA: "If you are a Singapore that has got close to zero unemployment then that's* [autonomous shipping] *not an issue for you, but if you are a South Africa whose data has just come out for the first quarter of the year that says you are now at 27.6 % unemployment, of which you are at 55% unemployment of the youth, then you wouldn't want to consider that* [autonomous shipping], *because what that means is that you are letting technology take over the potential job opportunities that could be there"*

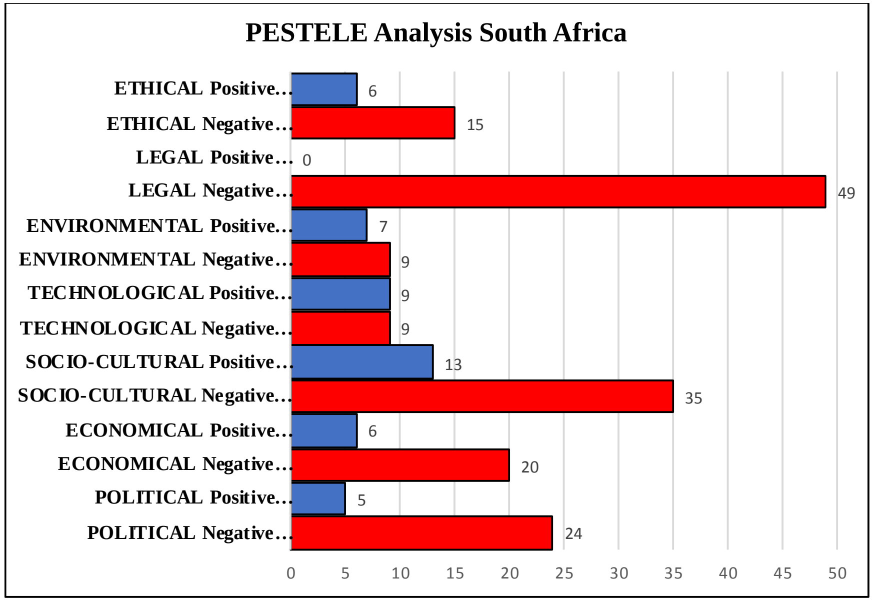

Figure 8. PESTELE analysis: South Africa

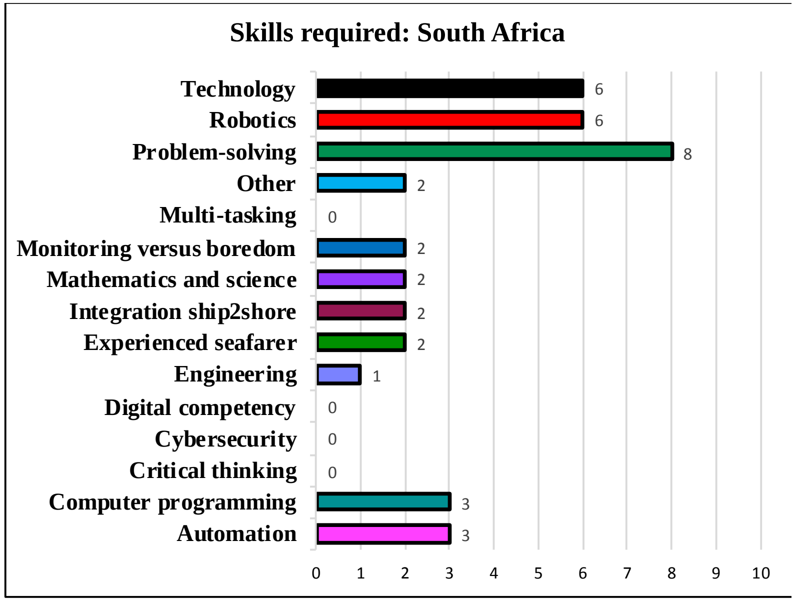

Figure 9. Skills required: South Africa

Figures 10 and 11 present the PESTELE findings and required skills for Philippines

P: "Take an aerial drone. An aerial drone which is pilotless has about 180 people more or less supporting that particular aerial drone in various capacities. So, it's not that we are going to have less people, they just have got to be repurposed"

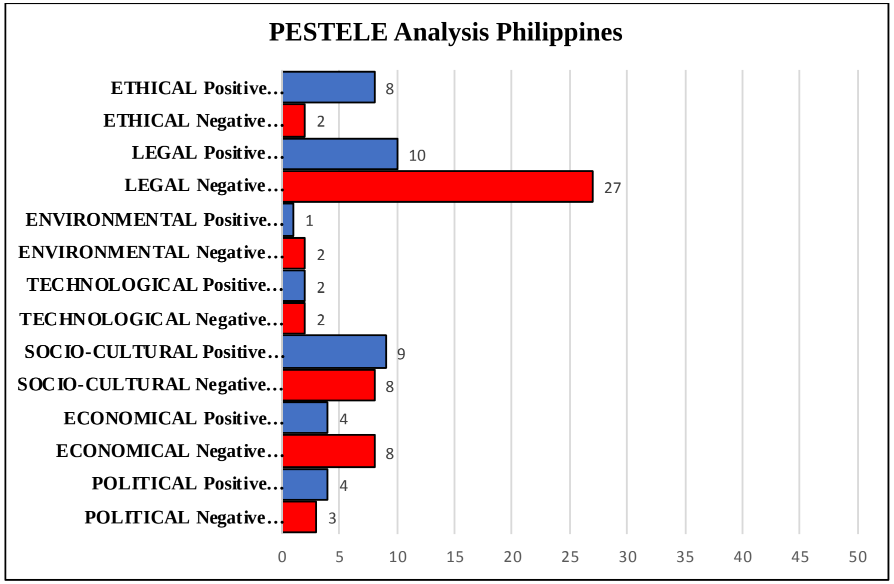

Figure 10. PESTELE analysis: Philippines

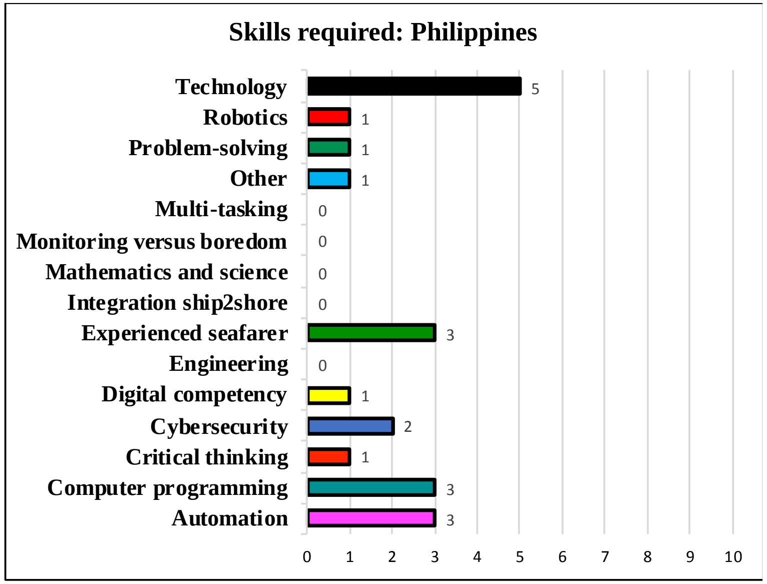

Figure 11. Skills required: Philippines

4.3 Quantitative Analysis: Country preparedness

The quantitative data analysis aimed to answer research question four (RQ4)[46] by looking at the legislative framework, human resource- and infrastructure preparedness of each country. In this context, the country mean, minimum and maximum, and global mean[47] figures mentioned in Tables 4 to 6, are based on a scale of 1 to 10; 1 being the lowest and 10 being the highest. The researcher considered 1-3 as being unprepared, 4-7 related to being moderately prepared, and 8-10 meant a country was likely to be prepared. The standard deviation and perceived level of preparedness per country is also indicated in each of the tables.

The z-scores for each country is indicated in the standard normal distribution curves as follows: Norway (N), Singapore (S), South Africa (SA) and Philippines (P).

4.3.1 Legislative Framework

Questions Q1 to Q5 in the questionnaire dealt with regulations and policies. Table 4 indicates the global mean as 3.25, which suggests that most respondents deem their respective countries as un-prepared in terms of policy and regulations; the global standardised deviation is 2.53. Norway and Singapore’s country means are above the global mean. South Africa and Philippines both have negative z-scores and their country means are lower than the global mean at 1.72 and 3.18 respectively.

[46] RQ4: How prepared is the maritime industry and society in each of the particular jurisdictions to operationalise autonomous shipping under the identified scenario?

[47] The global mean is the mean of the four countries’ scores

The standardised normal distribution curve in Figure 12 illustrates the respective z-scores and global standard deviation per country in terms of the legislative framework.

Table 4. *Descriptive statistics per country – Regulatory preparedness*

	Norway	Singapore	South Africa	Philippines
Country Mean	7.5	7.25	1.72	3.18
Min	6	7	1	1
Max	9	8	1	6
Country Std Dev	1.73	0	1.07	1.99
Global Mean	3.25			
Global Std Dev	2.53			
Z-score	1.68	1.58	-0.6	-0.03
Level of Preparedness	Moderate to Likely	Moderate	Un-prepared	Un-prepared

Note. Based on a scale of 1 to 10 – 1 being lowest and 10 highest

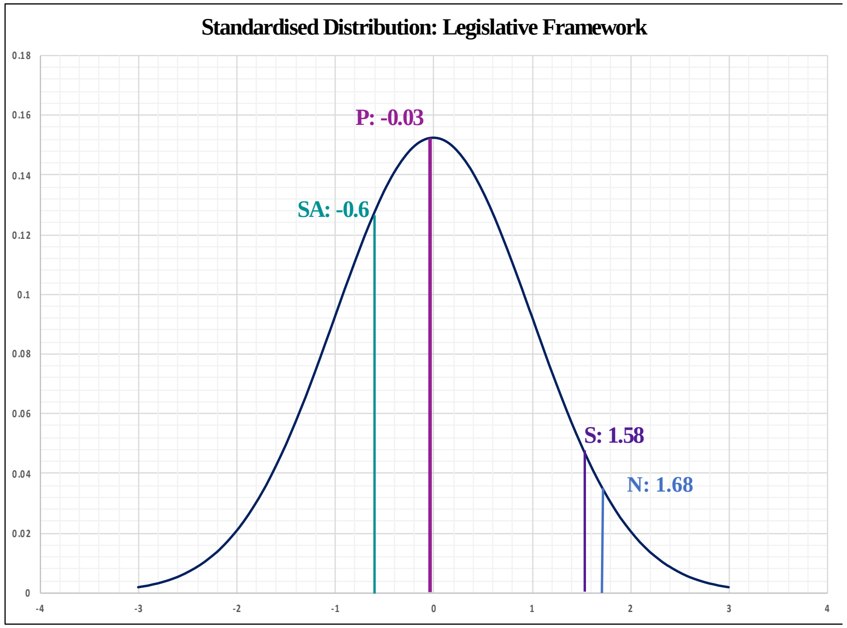

Figure 12. Standard normal distribution: Regulatory preparedness

4.3.2 Human resource preparedness

Questions Q6 to Q10 of the questionnaire considered human resource requirements. Table 5 indicates the global mean as 5.14, which suggests that most respondents deem their respective countries as being moderately-prepared in terms of having the required human resources; the global standardised deviation is 2.83. Norway and Singapore and Philippine's country means are above the global mean. South Africa has negative z-score and the country mean is lower than the global mean at 3.28.

The standardised normal distribution curve in Figure 13 illustrates the respective z-scores per country and standard deviation for each country in terms of HR preparedness.

Table 5. *Descriptive statistics per country – Human resource preparedness*

	Norway	Singapore	South Africa	Philippines
Country Mean	8.75	7.5	3.28	6
Min	8	7	1	2
Max	10	8	7	10
Country Std Dev	0.96	0.58	1.9	2.79
Global Mean	5.14			
Global Std Dev	2.83			
Z-score	1.28	0.84	-0.66	0.31
Level of Preparedness	Likely	Moderate to Likely	Un-prepared to Moderate	Moderate

Note. Based on a scale of 1 to 10 – 1 being lowest and 10 highest

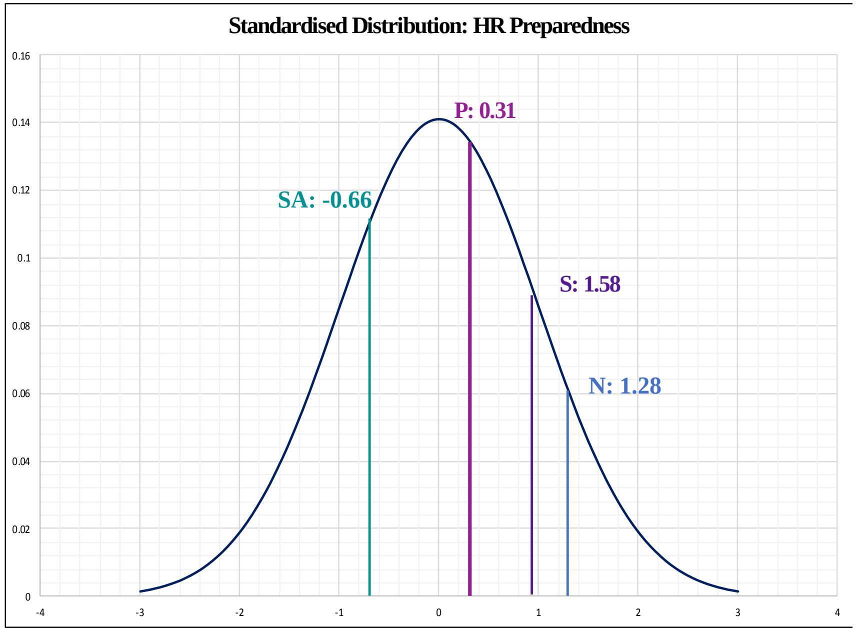

Figure 13. Standard normal distribution: Human resource preparedness

4.3.3 Infrastructure preparedness

Questions Q11 to Q14 of the questionnaire looked at infrastructure readiness. Table 6 lists the statistics in terms of the perceived infrastructure preparedness. South Africa appears least prepared having a negative z-score and mean of 3, which is below the global mean of 4.46. Philippines also has a negative z-score, although the mean of 4.09, is only marginally lower than the global mean. Philippines therefore appears moderately prepared. Norway appears most likely to be prepared, followed by Singapore as reflected by their respective z-scores and respective country means of 9 and 7.5 respectively, which are well above the global mean.

The standardised normal distribution curve in Figure 14 illustrates the respective z-scores and standard deviation per country in terms of infrastructure readiness.

Table 6. *Descriptive statistics per country – Infrastructure preparedness*

	Norway	Singapore	South Africa	Philippines
Country Mean	9	7.5	3	4.09
Min	7	7	1	1
Max	10	8	8	7
Country Std Dev	1.41	0.58	2.17	2.39
Global Mean	4.46			
Global Std Dev	2.9			
Z-score	1.56	1.04	-0.5	-0.13
Level of Preparedness	Likely	Moderate to Likely	Un-prepared	Moderate

Note. Based on a scale of 1 to 10 – 1 being lowest and 10 highest

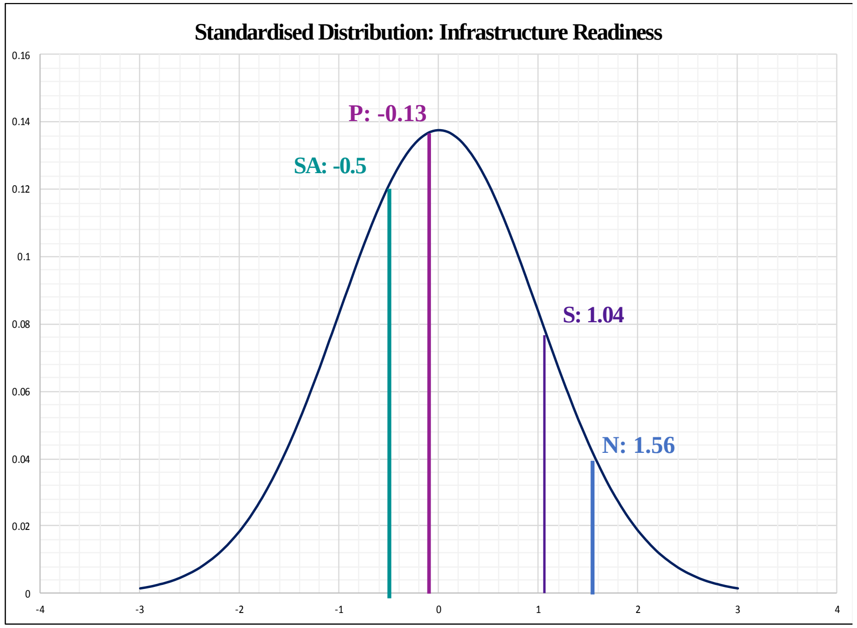

Figure 14. Standard normal distribution: Infrastructure preparedness

5. Discussion of research findings

Three research questions were found to be inter-related as government policies, political will and stakeholder engagement contribute (in part) to the development of human resources and societal acceptance, taking into account the availability of required resources such as infrastructure and facilities. Having the required maritime policies, regulations and human resources in place will in turn determine how prepared the industry is for operationalising autonomous shipping.

Figure 15 illustrates the relationships between PESTELE factors influencing a country's ability to respond to autonomous shipping and includes identified gaps and required skills. The various gaps that have been identified as having an influence on the PESTELE factors are indicated by the red arrows. The yellow arrows indicate that they have an impact on the skills required. Although not indicated in the figure, the PESTELE factors are all inter-related and together determine a country's overall preparedness for autonomous shipping operations.

In this chapter the research findings are discussed according to country preparedness and the implications of the findings in terms of public policy and digital disruption.

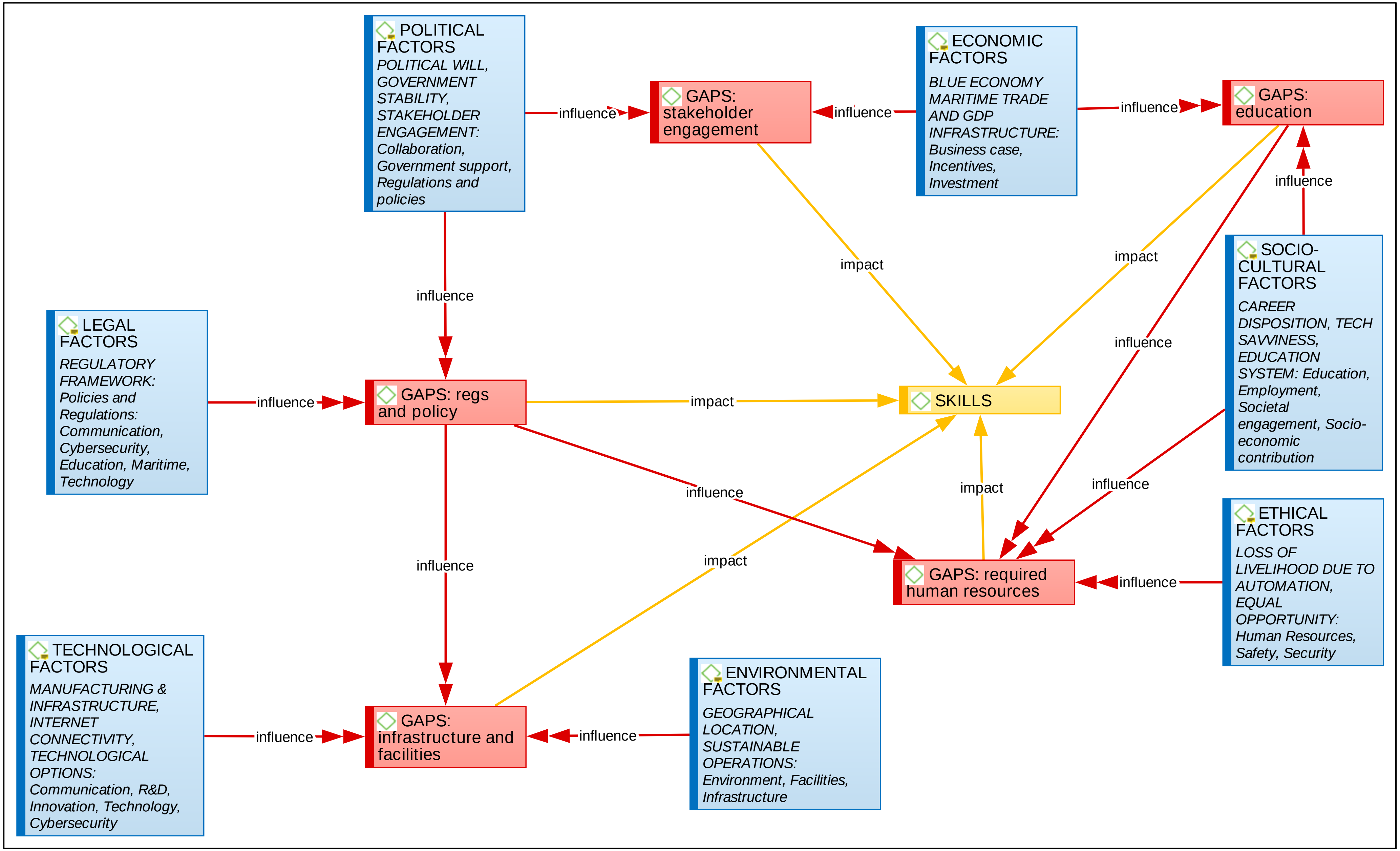

Figure 15. PESTELE Network Relationship, including gaps and skills

5.1 Country preparedness

The findings of this comparative analysis of national preparedness relating to the maritime policy/legislative framework, societal readiness and HR development for autonomous vessel operations indicate that Norway has strong government support in creating an enabling environment conducive to R&D and technological innovation, especially with respect to the UN Sustainable Development Goals (SDGs). Similar government support in fostering innovation exist in Singapore. It was found that Singapore recently launched a Maritime Innovation Lab. This Living Lab has four focus areas as illustrated in Figure 16 including autonomous systems and robotics, smart and innovative infrastructure, data analytics and intelligent systems, and finally safety, security and environment. The purpose of this initiative is to provide a partnership platform for technology and capability development in support of the future Next Generation Port (NGP2030) (Maritime and Port Authority of Singapore, 2019). Initiatives include applications that leverage the Maritime Geospatial Database.

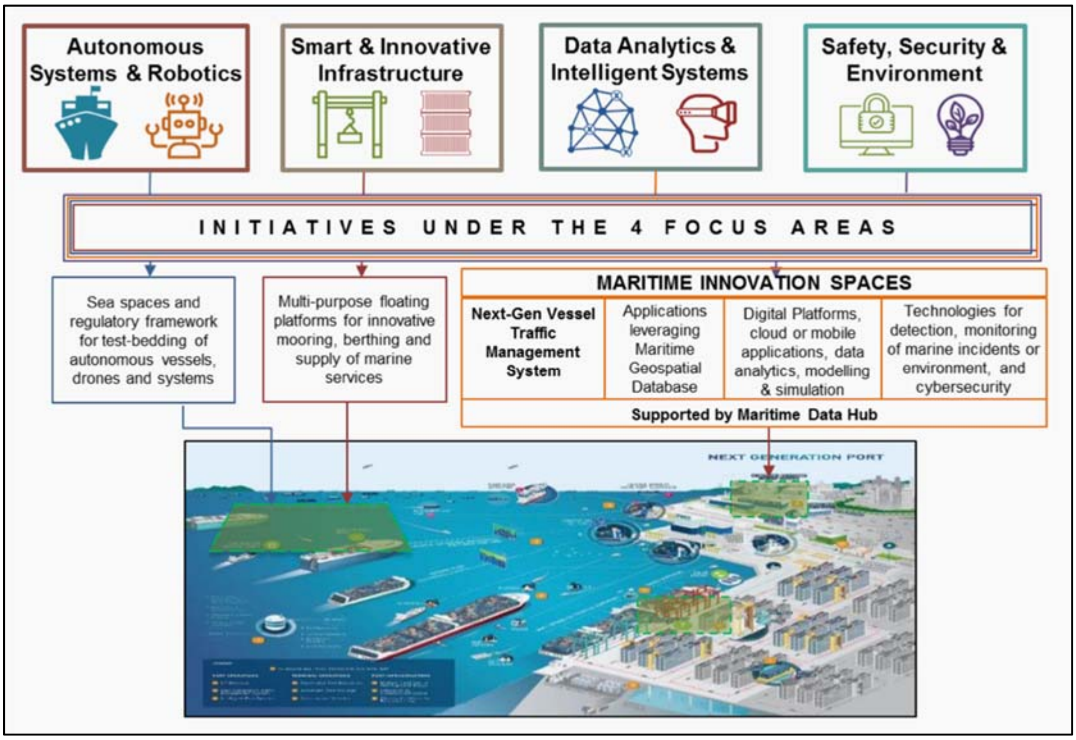

Figure 16. MPA Living Lab focus areas and initiatives
From Maritime Singapore. (2017, September). IMC 2030 Strategic Review. Singapore.

South Africa and Philippines are lagging behind compared to Norway and Singapore as indicated in the research findings presented in Chapter 4. Both countries cited lack of government initiative and the industry having as its main priority compliance to current STCW requirements and remaining on the so-called 'white list[48]'. The challenge was also raised by a respondent from Philippines regarding the country's education framework that requires more flexibility and government's role in establishing that framework. A recent study by the Belgian Development Agency reported concerns raised by the South African maritime industry that it is not geared towards I4.0, noting that legislatively and technologically, the industry is lagging behind (Belgium Development Agency, 2019). This sentiment supports the research findings in this study and in particular as they relate to the skills that have been identified as required.

In the case of South Africa, many schools do not have access to technology or computers and students generally seem to not fare well in science, technology, engineering and mathematics (STEM) subjects - in comparison to students and the education system in Norway.

> *SA: "So I think what schools have got to do if you ask me, is to fix the maths and science problems that we have because that is what is stopping a lot of people. You know these young people are learning and interacting with the world in a way that is very different, and the school system has not kept up. So, we are still teaching in the same way we did a hundred years ago"*

[48] The so-called "White List" refers to Parties of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended, confirmed by the Maritime Safety Committee to have communicated information which demonstrates that full and complete effect is given to the relevant provisions of the Convention (International Maritime Organization [IMO], 2018). Countries prioritise being/remaining on this list as it forms the basis of having certificates issued by the authority, recognised by or under the authority of another Party pursuant of Regulation I/10 of the STCW Convention (International Maritime Organization [IMO], 2017) which permits seafarers serving on foreign-flagged vessels.

N: "…because you see a lot of this is already in the curriculum at school. Look at my kids, they are already programming. They have coding clubs at the library, so they start out when they are like five, six years old; making programmes and when they are like ten, they start with python programming and c-plus and everything"

SA: "We lack the fortitude to drive a change in what we teach our youth. The education system is pushing out painters and domestic workers, not robotics engineers and people with IMAGINATION [capitalisation in original written answer to open-ended question]. *The schooling system kills every shred of imagination"*

It seems however that the government has realised the need to develop post school education and training. It has been reported that some initiatives include addressing the shortfall with regards to STEM subjects, and the development of digital skills capacity (Belgium Development Agency, 2019).

SA: "There is still room for us to encourage our youth to go towards the maritime careers, and even when it evolves, we do think that we will stay ahead of that evolution curve because such is our preparation today"

SA: "The next important driver for change is the MET sector and it is here where I see most change taking place in order for South African seafarers to gain decent work opportunities internationally. The local MET sector needs to step up to the plate and provide appropriate training"

SA: "The future maritime skills development has to be informed by what the maritime economy of the 4IR require. So that would then have an impact on our legislation, it would have an impact on the transfusion of MET itself, it would also impact on the skills and the requirements for future shipping. So, *we want really to use MET as a strengthener of what we want to become in the international maritime sector"*

5.1.1 Public policy and collaboration

Most countries appear not to have all the required regulations in place to operationalise autonomous shipping. The IMO scoping exercise for MASS operations in international waters is ongoing and may shed some light on the state of countries in this respect. Some countries (and organizations) do however have policies and/or strategies that relate to their intention of promoting technological advancement and in particular automation in the transport sector through R&D as is the case in both Norway and Singapore. The difference between countries are evident in this study when considering the proactive approach of Norway, Singapore and (to some extent) Philippines, in exploring different options and proposals to find possible solutions for improved services, efficiency and safety in the transport sector. Reform of existing education policies and curriculum were also found to be an area requiring collaboration. Governments, academia and industry should collaborate to envision what a true 21st century curriculum should entail (WEF, 2016). Fundamental to this foresight is creating a combined vision between stakeholders regarding what the future should look like and a mutual appreciation of the difficulties and required actions to take to accomplish the vision (Fritz & Hanus, 2015). Proactive collaboration and foresight initiatives among stakeholders include:

> *N: "So now, a lot of cities are looking into this* [small autonomous passenger crafts]*, so if there will be one place that they can do it I believe there's at least, I think it's seven or eight cities actually looking into this and more or less working together, or they have started to look at this together"*

> *N: "We haven't made regulations saying or been descriptive saying, like this and this and then you're allowed. We have more or less said okay to the customers. If you have new technology like autonomy come to us with it, and*

we are open to look at it and try to find a way to be able to solve it and to allow it"

N: "I believe that the most important things about making just a few test areas is that you are able to test infrastructure and to have a place where different types of companies come in and say okay this area is here, it is possible and here it will be ships being tested and different types of companies can go together and deal with projects"

P: "We shouldn't wait for it, so a company like ourselves already today is engaged in the different discussions that are happening. We don't have a plan of action yet, but we're engaged in terms of what do we think, when do we think this is going to happen….and as we think of the future, we should imagine what that future will be like and we should try to imagine what we can do in that future, so we can engineer the right solutions"

The sentiments from South Africa are not as proactive.

SA: "Any of that type of innovation is going to come through from the first world countries and filter through to us. Technology is a challenge here"

The 'triple helix' model of university-industry-government interactions are increasingly driving innovation (Etzkowitz, 2003, p. 293). The model distinguishes between the generation of wealth (industry), novelty production (academia) and public control (government) (Leydesdorff & Meyer, 2006, p. 1441). Both Norway and Singapore appear to have incorporated this concept. Government takes on the role of civic businessperson and risk financier, whilst universities are more pre-emptive in knowledge application and in expanding the entrepreneurial input into the creation of academic knowledge. Organizations engage at superior levels of training and in knowledge sharing as they themselves move closer to an academic model by raising their technological level.

In Norway, a comprehensive maritime strategy for research, development and innovation was developed by the maritime actors on behalf of the Norwegian government. The Maritim21 strategy is aimed at contributing to sustainable growth and value creation through linking authorities, the policy instrument, the business community, organizations and research communities (Maritime21, 2019). Similarly, Singapore enjoys strong collaboration between government agencies and administrators, industry and academia. Its strategic geographic port location, rule of law, skills, good infrastructure, and a government that is familiar with business needs are all contributing to its success in terms of maritime-related R&D and innovation (Maritime Singapore, 2017). Maritime Singapore developed five strategies to position itself as an international centre of excellence for connectivity, innovation and talent. The proposed strategies include the expansion and deepening of the maritime cluster, strengthening inter-linkages of maritime clusters and network effects, the development of a maritime innovation ecosystem and promotion of digitalisation, development of human resources that are multi-skilled and have a global mindset, and the establishment of Singapore as a global maritime benchmark holder (Maritime Singapore, 2017).

"In the triple helix model, the knowledge base of the economy is analysed in terms of university-industry-government relations" (Etzkowitz & Leydesdorff, 1998, p. 208). Innovation is thus interactive instead of following the traditional linear model (Etzkowitz, 2003). Knowledge-sharing is an essential element of the triple helix model with the goal of creating niche technological innovations by further developing existing resources. Competition, economic interdependence and collaboration are elements of a knowledge society that require of organizations to operate in a world-wide economy (Van Laar, Van Deursen, Van Dijk, & De Haan, 2017).

N: "Public data is very open. We have a policy that we yeah, just free everything now and digitalise it. But companies, they like to share a lot but of course there are some company secrets, and of course they need that. What we need to find the solution is - how to regulate this, deal with this? Because, keeping some with some secrets that we have these black boxes, that's where the secret is, and how do we test this? There is also an area where we need, there's a gap because we need some standards today. How to test it? We need to develop these scenarios where these black boxes are going to be tested against, to prove that it is safe enough"

Not all countries have embraced the triple helix concept. In South Africa, despite the government-led Operation Phakisa, the country does not have a *national* maritime cluster. Neither does Philippines apparently. South Africa has a Comprehensive Maritime Transport Policy (CMTP) which was launched in 2017 and refers to innovation, research and development and using technology to enhance the industry (Department of Transport, 2017). The policy appears, however, to be somewhat unclear in its implementation, as not all activities and actions are explicitly listed in the implementation timetable.

The 'Philippines: Maritime Industry Development Plan (MIDP) 2019-2028' was launched in December 2018 and includes eight priority programmes. Most relevant to this discussion are the "Development of a Global Maritime Hub" and establishment of a "Maritime Innovation and Knowledge Centre". The plan highlights the role of government in offering significant and impactful assistance to visionaries; investing in the necessary technology, research infrastructure, and R&D researchers; implementing suitable amendments in education, the investment climate, and trade; and removing obstacles and blockages to innovative proposals in governing structures (Maritime Industry Authority [MARINA], 2018).

In the case of South Africa, comprehensive collaboration amongst all stakeholders will prove to be crucial in reaching Operation Phakisa targets, as for the implementation of the CMTP. Similarly, the MIDP in the case of Philippines.

Norway, Singapore and Philippines are actively collaborating nationally, or intending to collaborate with each other and/or with other jurisdictions. This was reflected in the findings, as indicated through action taken.

> *N: "What we are going to cooperate with Singapore very well is a new initiative there, they are establishing. Then we are also working a lot with South Korea and of course the Nordic countries, especially Finland, and we are also helping a lot with Belgium and The Netherlands"*

> *N: "And the EU, they are very interested in starting up now with the cross-border activities, autonomous traffic"*

> *P: "We have just, we've got to add corporate public policy into our whole equation, and the reason for having corporate public policy is the need to be able to talk to governments and relate to governments and engage them to discuss these* [automation, curriculum reform] *important things"*

A supportive government, together with good public policy frameworks allowing for optimal agenda setting, policy formulation through to policy implementation and evaluation (Jann & Wegrich, 2007) are obvious influencing factors for Norway and Singapore's relatively high levels of preparedness to operationalise autonomous shipping. Essential to these policy frameworks in both jurisdictions is the involvement of all key stakeholders through vibrant maritime clusters, in particular government agencies, industry and academia (the triple helix concept). The resulting policies enhance job creation opportunities and facilitate better focussed investments in novel education and training programmes, technological advancements and start-ups in emerging maritime economic sectors (Fritz & Hanus, 2015).

UN SDG 17: *Partnerships for the Goals,* echoes the need for "partnerships among governments, the private sector and civil society to implement a sustainable development agenda – to encourage partnership and highlights the relationships between people, planet, prosperity and peace at the global, regional, national and local levels" (United Nations, 2019, para. 1).

5.1.2 Digital disruption and societal preparedness

Concurrent to this digital disruption are wider socio-economic, environmental, geopolitical and demographic factors that interrelate in different ways, impact one another, and which drive change. Sustainability appear to be a major driving force for some countries in terms of finding more efficient transport solutions, as is the case in Norway and reflected in the country's new draft transportation plan.

> *N: "First of all the short, or coastal shipping, like in Norway I think we have a lot of opportunities around the coast where we can see smaller ships, less than hundred meters going with containers, or bulk, or such things and between the cities and around the coast. And why small, more or less because autonomy maybe isn't the goal in itself, the goal is to have down the emissions and such things and more efficient maritime sector"*

> *N: "It is highly on the agenda to our government actually, and what I'm sitting with in front of me now is, but that's technology in general, but it's been mentioned a lot and I was taking part in this work and we looked at technology for sustainable and freedom of mobility, and it's a very good report"*

Infrastructure, and the required investment that go with it, is an area that may delay a country's readiness to operationalise autonomous shipping.

N: "That is actually the most challenging part of it, because the required infrastructure has a lot to do with the ports; but it is actually the owner of the ports that is responsible for any investment into the port. Every business model is based on predictability. You don't invest in something if you don't know if it's going to be allowed within five years or ten years"

S: "Singapore has identified port connectivity and cybersecurity as key infrastructure and are taking steps to enhance them"

In terms of labour, engagement from governments, industry and education/training institutions is recognised as necessary in reviewing training approaches, methods, content and assessment to ensure industry has the right skills available to respond to global developments, trends and challenges (MarTID, 2019). A study by the International Labour Organization found that new occupations, some job losses, and an alteration in the skills composition will emerge in the quest of transitioning towards an environmentally sustainable economy (ILO, 2018).

Many gaps identified by countries in this study relate to education and human resource challenges, whilst the required skills identified relate to technology, computer programming, automation, cybersecurity and non-technical/affective abilities. These are found to be similar to those identified in IAMU's GMP study. The GMP study categorised the knowledge, skills and attitudes that seafarers require into four sets, namely: foundational knowledge and skills[49], academic skills[50], professional technical skills[51] and professional soft skills[52] (IAMU, 2019).

[49] Mathematics, science, general humanities and social science, computing and informatics, physical and mental fitness

[50] Problem recognition/solving, critical thinking, academic research, contemporary global issues.

[51] Competencies set out in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), including risk assessment and management, job-specific technological awareness, maritime law, policy and governance, logistics and supply chain, and maritime business.

[52] Global technological awareness, leadership, teamwork and discipline, effective interpersonal communication, sustainable development, human resource management, cultural/diversity awareness and sensitivity, progressive mindset and lifelong learning, environmental awareness, sustainability and

N: "The gaps, we have already covered that. When it comes to education there are gaps all over. How is this going to be in future, the education system for this? We need to clarify that. We also need to find all the black swans[53] [sic] with this new technology and the new risks arising when taking this into use"

N: "You have people looking at the human element, but even those studies need to think different, because when you have technology and the human element working together, and we have artificial intelligence and human elements, when they're connecting, how do we deal with that? So, all those studies need to also become different, so there are competencies that we need, but we don't have any studies giving us them today"

The following fundamental skills were identified as drivers of maritime workforce development and the advancement of strategies to address future human resource challenges "for the maritime industry: digital literacy & data analytics, environmental engineering and green technologies, and soft skills" (Maritime Singapore, 2017, p. 28).

Countries and companies are addressing human resource requirements in different ways.

N: "The big focus at the moment in our ministry is qualifications within the Administrations and that is something we're working on, we need to reorganize a little bit to meet the future, but we also need to get people with other education into the Administration"

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stewardship, decision-making and proactivity, mentorship, and professionalism and ethical responsibility

[53] 'Black Swan' refer to an event that has the following three characteristics: it is highly improbable, bears extreme consequences and is only explainable in hindsight (Aven, 2013). Black swans have influenced technology, science, business and culture in the past (Taleb, 2007).

SA: "Even our intern selection this year, which we are currently busy with, we have taken on three now, we are waiting for another four to join, they are all not maritime educators, they are all in artificial intelligence and in big data collection to help us prepare our materials for that"

This chapter included a discussion of the research findings according to the preparedness of each country based on the respective PESTELE analyses of each jurisdiction. The discussion also considered the implications of the findings in terms of public policy and digital disruption – with particular focus on collaboration and required skills.

6. Conclusion and recommendations

This chapter provides a concluding overview of the study by summarising the main areas, providing recommendations in support of governments' preparation for autonomous vessel operations and making suggestions for further research. The focus areas included maritime policy/regulations, human resource development and infrastructure to answer particular research questions.

6.1 Research conclusion

The four possible autonomous shipping scenarios generated are summarised in Table 7.

RQ 1: *What are likely scenarios relating to the operationalisation of autonomous shipping?*

Table 7. *Summary of scenarios*

Scenario	Timeframe	Description
Yankee	2020	Business as usual, autonomous vessel operating with crew onboard in domestic waters
Quebec	2025	Reduced manning on conventional ships, and the first fully autonomous vessel is operating without crew onboard in domestic waters
Delta	2035	Autonomous vessels operating in domestic waters, without crew onboard
Oscar	2040	Autonomous vessels are operating internationally without crew onboard

Note. *Generated following a systematic literature review*

The study then compared the national preparedness of four countries in terms of operationalising autonomous shipping in their respective jurisdictions by 2035 (Scenario *Delta*). Comparable to the WMU report it is found that effective regulations, education and training, and investment into infrastructure are required to introduce automation into the maritime industry. The findings in the current study suggest that countries each have their own motivation for engaging, or not engaging in autonomous shipping discussions and activities. These can be linked to the local context unique to each country, informed by PESTELE factors.

> RQ 2: *What initiatives, if any, have been taken by each of the jurisdictions to prepare for autonomous shipping according to the most plausible of these scenarios?*

The results indicated that no country is fully prepared at this stage to operationalise autonomous shipping, although the governments of Norway and Singapore are prioritising this and therefore they appear to be quite advanced. Developed countries are generally in a stronger position to leverage technological solutions to improve maritime transport and combat climate change. R&D and innovation are used as enablers to effect change and therefore governments create an environment conducive to collaboration amongst all stakeholders through clear policies and strategies. R&D and innovation outputs normally contribute to the country's economic growth, which in turn leads to more funding being made available by these governments towards new R&D projects.

Both South Africa and Philippines seem to be challenged with regards to giving full and complete effect to the STCW Convention, and as such consideration for the 4IR and autonomous shipping are not prioritised, nor is there evidence of any major technological initiatives in terms of sustainability for the maritime transport sector. Should South Africa and Philippines wish to prepare for autonomous shipping operations by 2035, their respective maritime transport policies require updating to reflect this. Likewise, (maritime) education policies and those related to science and technology need to reflect clear strategies of how the country wishes to implement proposed changes to be able to operationalise autonomous shipping in their respective jurisdictions.

> RQ 3: *What are the human resource requirements that need to be developed to operationalise autonomous shipping for the identified scenario in the particular jurisdictions?*

There seems to be uncertainty among respondents relating to exact human resource requirements needed fifteen years from now. Recurring education and training challenges raised include a lack of the desired educational framework and the need to integrate more advanced technology into the MET curriculum, without losing out on the contemporary skills for today's shipping industry. The seafaring skills of today is expected to be in shortage in 2035. A vital element in guaranteeing that the required human resources are available relates to knowledge sharing through collaboration. Government, industry and academia need to ensure the education system produces the required skills needed by industry. The education systems in both Norway and Singapore already incorporate programming and place strong emphasis on STEM subjects. Soft skills including critical thinking, leadership and problem-solving are required by companies and individuals to adapt to the VUCA challenges of the 4IR. South Africa and Philippines need to add subjects like robotics and computer programming to ensure individuals have the technological and digital competencies required, in addition to soft skills.

> RQ 4: *How prepared is the maritime industry and society in each of the particular jurisdictions to operationalise autonomous shipping under the identified scenario?*

Optimal policies and legislation, human resources and infrastructure as well as acceptance from the broader society are all required to enable a country to fully operationalise autonomous shipping. It is however interesting to note that all four countries included responses such as *"I don't know"* or *"I am unsure"* when answering questions related to what action has already been taken. This suggests that communication among key stakeholders and the broader industry could be improved, which could perhaps in turn lead to increased perceived preparedness and acceptance by the industry.

As already highlighted, Norway and Singapore have policies and strategies in place with regards to the promotion and implementation of increased automation in the industry. Solutions to HR development and infrastructure challenges are also actively pursued by both these governments. Philippines and South Africa seem less prepared. The latter is said to be grappling with unemployment whilst both countries face lack of infrastructure and educational challenges.

In conclusion, the overall perceived national preparedness of the countries to operationalise autonomous shipping by 2035 is given in Table 8.

Table 8. *Overall level of preparedness of each country*

	Norway	Singapore	South Africa	Philippines
Regulatory preparedness	7.5	7.25	1.72	3.18
HR preparedness	8.75	7.5	3.28	6
Infrastructure preparedness	9	7.5	3	4.09
Overall preparedness	8.42	7.41	2.67	4.42
Perceived level of preparedness	Likely to be prepared	Moderately to likely prepared	Unprepared	Moderately prepared

Note. Based on a scale of 1 to 10 – 1 being lowest and 10 highest

This overall preparedness per country is based on the combined mean score of the three focus areas per country. The score is based on a scale of 1 to 10; 1 being the lowest and 10 being the highest.

6.2 Contribution to literature

The researcher aimed to demonstrate the utilisation of scenario planning as a mechanism in policy gap analysis to assist governments strategically prepare for an uncertain future by providing a conceptual framework that considers the legislative, human resource, and infrastructure readiness of a country. Scenario planning may be used as an instrument by governments to prepare the maritime industry's mindset for adapting to different possible autonomous futures.

The economic growth of a country is directly impacted on by political factors such as political will, government stability and legal factors which relate to the legislative framework and include policies and regulations. In this context policies can include maritime-, education-, and technology policies. National MET systems need to be able to anticipate future skills to enhance national adaptation to changing requirements. The role of MET as an enabler for national economic development needs to be realised through policies that consider the interest of all stakeholders in an ethical and sustainable manner.

Stakeholder engagement has been identified as a crucial element in advancing any country's position. In the current VUCA environment this is even more so. Close(r) collaboration between government, industry and academia is required to weather the approaching autonomous storm.

6.3 Recommendations

Governments should consider the following in their preparation[54] to operationalise autonomous shipping:

i. Closer collaboration between government, industry and academia to ensure the required skills are identified and readily available;
ii. Establishment of a visible and unequivocal national maritime cluster in South Africa and Philippines to align national policies and education programmes with global and local industry needs and towards achieving the UN SDGs;
iii. Governments, industry and academia should collectively generate different future scenarios through participatory processes and plan autonomous shipping contingencies accordingly;
iv. Develop and communicate clear steps for the implementation of policies, as those found in the CMTP and MIDP.

6.4 Limitations and future research

The scenarios in this study were generated following a systematic literature review which was generalised. Participatory processes may have yielded more probable scenarios for each of the chosen countries and could therefore have resulted in an even more plausible analysis of the preparedness of each country to operationalise autonomous shipping. Future research would benefit from the participation of all key stakeholders in each country when generating country-specific scenarios as well as by using emerging models for scenario planning[55], whilst considering all pertinent aspects that may influence the preparation and operationalisation of autonomous shipping. Particular focus in determining which regulations in each country require amendments

[54] 'Preparation' in this context includes both: Governments that actively choose to take certain action in terms of operationalising autonomous shipping, and those deriving at the conclusion that they choose not to enhance (neither want/need) automation. A government will nevertheless require a rigorous mechanism to 'respond to' the discussion and have a policy framework to support the process of deliberation.
[55] These models use simulation for example.

will also greatly contribute to the discussion of how best countries can respond to autonomous shipping.

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Appendices

Appendix A: Systematic Literature Review

Doc No.	Author(s)	Date	Name	Source
1	Ahvenjärvi, S.	(2016).	The human element and autonomous ships.	*TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 10*(3), 517-521. doi:10.12716/1001.10.03.18
2	Arntz, M., Gregory, T., & Zierahn, U.	(2016).	*The risk of automation for jobs in OECD countries: A comparative analysis*	Éditions OCDE / OECD Publishing. doi:10.1787/5jlz9h56dvq7-en
3	Chwedczuk, M.	(2016).	Analysis of the legal status of unmanned commercial vessels in U.S. admiralty and maritime law.	*Journal of Maritime Law & Commerce, 47*(2), 123-169. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=a9h&AN=115747484&site=ehost-live&authtype=sso&custid=ns056238
4	Cross, J. F., & Meadow, G.	(2017).	Autonomous ships 101.	*Journal of Ocean Technology, 12*(3), 23-27. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=eih&AN=125464354&site=ehost-live&authtype=sso&custid=ns056238
5	Guerra, S.	(2017).	Ready about, here comes AI: Potential maritime law challenges for autonomous shipping.	*University of San Francisco Maritime Law Journal,* , 69. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edshol&AN=edshol.hein.journals.usfm30.10&site=ehost-live&authtype=sso&custid=ns056238
6	Hult, C., Praetorius, G., & Sandberg, C.	(2019).	On the future of maritime transport - discussing terminology and timeframes.	*TransNav: International Journal on Marine Navigation & Safety of Sea Transportation, 13*(2), 269. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edb&AN=137227642&site=ehost-live&authtype=sso&custid=ns056238
7	Komianos, A.	(2018).	The autonomous shipping era. operational, regulatory, and quality challenges.	*TransNav: International Journal on Marine Navigation & Safety of Sea Transportation, 12*(2), 335. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edb&AN=130607129&site=ehost-live&authtype=sso&custid=ns056238

8	Man, Y., Weber, R., Cimbritz, J., Lundh, M., & MacKinnon, S. N.	(2018).	Human factor issues during remote ship monitoring tasks: An ecological lesson for system design in a distributed context.	*International Journal of Industrial Ergonomics*, *68*, 231-244. doi:10.1016/j.ergon.2018.08.005
9	Meadow, G., Ridgwell, D., & Kelly, D.	(2018).	Autonomous Shipping - Putting the Human back in the Headlines.	IMarEST Report, Singapore.
10	Ponce, R.	(2018).	The maritime world enters the fourth industrial revolution: New era requires revolution of data processing, analysis and use.	*Sea Technology*, *59*(2), 10-13. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=eih&AN=128114631&site=ehost-live&authtype=sso&custid=ns056238
11	Pribyl, S. T., & Weigel, A. M.	(2018).	Autonomous vessels: How an emerging disruptive technology is poised to impact the maritime industry much sooner than anticipated.	*RAIL: The Journal of Robotics, Artificial Intelligence & Law*, , 17. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edshol&AN=edshol.hein.journals.rail1.7&site=ehost-live&authtype=sso&custid=ns056238
12	Pritchett, P. W.	(2015).	Ghost ships: Why the law should embrace unmanned vessel technology.	*Tulane Maritime Law Journal*, *40*(1), 197-225. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=a9h&AN=112044981&site=ehost-live&authtype=sso&custid=ns056238
13	Rolls-Royce	(2018).	Rolls-Royce opens autonomous ship R&D centre in Finland.	*Military Technology*, *42*(3), 13. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=a9h&AN=128757285&site=ehost-live&authtype=sso&custid=ns056238
14	Singapore Maritime Institute.	(2019).	Singapore R&D Roadmap 2030: Maritime Transformation.	Retrieved from Singapore Maritime Institute: https://www.maritimeinstitute.sg/roadmap2030/
14	UNCTAD.	(2018).	Review of Maritime Transport.	New York, USA.
15	World Maritime University	(2019).	Transport 2040: Automation, Technology, Employment - The Future of Work	Reports. 58.https://commons.wmu.se/lib_reports/58

16	Wróbel, K., Montewka, J., & Kujala, P.	(2017).	Towards the assessment of potential impact of unmanned vessels on maritime transportation safety.	*Reliability Engineering and System Safety, 165*, 155-169. doi:10.1016/j.ress.2017.03.029
17	Zghyer, R., Ostnes, R., & Halse, K. H.	(2019).	Is full-autonomy the way to go towards maximizing the ocean potentials?	*TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 13*(1), 33-42. doi:10.12716/1001.13.01.02
18	Zhou, X. Y., Liu, Z. J., WU, Z. L., & Wang, F. W.	(2019).	Quantitative processing of situation awareness for autonomous ships navigation.	*TransNav: International Journal on Marine Navigation & Safety of Sea Transportation, 13*(1), 25. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edb&AN=136432916&site=ehost-live&authtype=sso&custid=ns056238

Appendix B: Word Cruncher

Title:	ATLAS.ti - Word Cruncher Results
Project:	MSc Systematic Literature Review Scenario planning
User:	Yvette de Klerk
Date:	19/07/2019

Word	Length	Count	Percent
10	2	300	5.73%
15	2	281	5.36%
20	2	294	5.61%
2020	4	73	1.39%
2025	4	41	0.78%
2030	4	75	1.43%
2035	4	31	0.59%
2040	4	312	5.96%
2050	4	52	0.99%
30	2	213	4.07%
40	2	182	3.47%
ashore	6	18	0.34%
autonomous	10	994	18.97%
coastal	7	42	0.80%
crewless	8	15	0.29%
domestic	8	72	1.37%
ferries	7	33	0.63%
inland	6	58	1.11%
international	13	667	12.73%
manned	6	119	2.27%
national	8	119	2.27%
regional	8	62	1.18%
remote	6	279	5.33%
shore	5	158	3.02%
unmanned	8	721	13.76%
waterways	9	28	0.53%

Appendix C: Questionnaire Instrument

You are invited to participate in this questionnaire which aims to determine how prepared the maritime industry and society in your country is with regards to autonomous vessel operation in the year 2035. It will take approximately 15 minutes to complete. Your participation is completely voluntary and without any payment. Your responses will be treated in the strictest confidence and anonymised. You are welcome to withdraw from the survey at any time. Thank you for your participation.

Name (Optional): ______________________________

Nationality: ______________________________

Organization (Optional): ______________________________

Occupation: ______________________________

Number of years in Industry: ______________________________

Please answer as comprehensively as possible.

Regulatory framework and policy:

1. On a scale of 1 (being least) to 10 (being most), how prepared do you think your country is in terms of the regulatory framework and maritime policy to operationalise autonomous shipping in its jurisdiction by 2035? (Circle relevant number)

1	2	3	4	5	6	7	8	9	10

2. Why do you think this is a fair reflection of your country's readiness for autonomous shipping?
3. What policies and/or regulations relating to autonomous vessel operations are already in place in your country?
4. What additional policies and/or regulations are needed to operationalise autonomous shipping under your country's jurisdiction?

5. What steps if any, are being taken to develop your country's regulatory framework in terms of operationalising autonomous shipping under your country's jurisdiction?

Human Resources:

6. On a scale of 1 (being least) to 10 (being most), how likely is it that your country will have the required human resources to operationalise autonomous shipping under its jurisdiction by 2035? (Circle relevant number)

1	2	3	4	5	6	7	8	9	10

7. Why do you think this is a fair reflection of your country's readiness for autonomous shipping?
8. What additional competencies/skills/occupations you think is necessary to operationalise autonomous shipping operations under your country's jurisdiction?
9. In what way (if applicable) will the competencies required in 2035 differ from what is currently required under the STCW Convention, 1978 as amended (including the Manila amendments) for autonomous shipping?
10. What initiatives if any, are taken to recruit and retain mariners for your country's maritime industry in preparation of autonomous shipping operations in 2035?

Infrastructure:

11. On a scale of 1 (being least) to 10 (being most), how likely is it that your country will have the required infrastructure to operationalise autonomous shipping under its jurisdiction by 2035? (Circle relevant number)

1	2	3	4	5	6	7	8	9	10

12. Why do you think this is a fair reflection of your country's readiness for autonomous shipping?
13. What are the gaps if any, that have been identified as necessary to operationalise autonomous vessel operations in your country?
14. What action if any, is being taken to address your country's infrastructure needs to operationalise autonomous shipping?

Thank you for your participation.

Appendix D: Interview Instrument

You are invited to participate in this interview which aims to determine what changes to existing national maritime policies and regulations, and what human resources need to be developed with regards to autonomous vessel operations under certain scenarios. Your participation is completely voluntary and without any payment. Your responses will be treated in the strictest confidence and anonymised. You are welcome to withdraw from the research at any time. Thank you for your participation.

Name (Optional): ______________________________

Nationality: ______________________________

Organization (Optional): ______________________________

Occupation: ______________________________

Number of years in Industry: ______________________________

1. What policies are required to prepare the maritime industry to remain relevant and competitive considering increased automation on board and remotely controlled/autonomous vessel operations on shore by 2035?
2. What qualifications / competencies do you think industry require for autonomous vessel operations?
3. What changes to the existing education system would be required to attract and train the future workforce entering industry 15 years from now?
4. What qualification / competencies do you think future maritime educators require to prepare graduates for increased automation on board, and shore control operating centres?
5. What other competencies do you foresee being in shortage 15 years from now, considering those entering the maritime job market in 2035 are currently five years old?

Thank you for your participation.

Appendix E: PESTELE Analysis Code Groups

Code groups	Negative codes	Positive codes
Political	Negative collaboration	Positive collaboration
	Negative government	Positive government
	Negative regulation or policy	Positive regulation or policy
Economic	Negative business case	Positive business case
	Negative incentives	Positive incentives
	Negative investment	Positive investment
Socio-cultural	Negative education	Positive education
	Negative employment	Positive employment
	Negative societal engagement	Positive societal engagement
	Negative socio-economic	Positive socio-economic
Technological	Negative communications	Positive communications
	Negative cybersecurity	Positive cybersecurity
	Negative innovation	Positive innovation
	Negative R&D	Positive R&D
	Negative technology	Positive technology
Environmental	Negative environment	Positive environment
	Negative facilities	Positive facilities
	Negative infrastructure	Positive infrastructure
Legal	Policies required communication	Policies in process communication
	Policies required cybersecurity	Policies in process cybersecurity
	Policies required education	Policies in process education
	Policies required maritime	Policies in process maritime
	Policies required technology	Policies in process technology
	Regulations none	Regulations completed
	Regulations required	Regulations in process
Ethical	Negative human resources	Positive human resources
	Negative safety	Positive safety
	Negative security	Positive security