The Asian Journal of Shipping and Logistics 38 (2021) 10–18

Contents lists available at ScienceDirect

The Asian Journal of Shipping and Logistics

journal homepage: www.elsevier.com/locate/ajsl

Industrial revolutions and transition of the maritime industry: The case of Seafarer's role in autonomous shipping

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ARTICLE INFO

Article history:
Received 24 September 2021
Accepted 1 November 2021

Keywords:
Industry 4.0
Autonomous shipping
Industry 5.0
Shipping 5.0
Maritime 5.0
Seafarer 5.0
Maritime Education and Training 5.0
(MET 5.0)

ABSTRACT

Digital transformation and automation in the shipping industry is resulting disruptive changes to ship design, operations, and manning that aim to enhance safety, efficiency, and the environmental sustainability of maritime logistics. While there is growing research interest in these areas, examining the role of human element in the new smart shipping context is largely neglected. Through a systematic literature review, this paper aims to explore the multi-dimensional impact of autonomous shipping technology resulting from the application of Industry 4.0 and future industrial revolutions on seafarers. The impacts include the changing role of seafarers on-board and the strategies required to engage seafarers in their transition from traditional shipping to autonomous and smart shipping. The paper concludes that Industry 4.0 is being challenged for its shortfall in recognition of the importance of human role and its intelligence in the expected current industrial revolution. As a result, there is a demand to look further and beyond Industry 4.0 by introducing the next generation of industrial revolution, namely Industry 5.0. This paper suggests that the impact of this revolution in the maritime industry can be defined by concepts such as Maritime 5.0, Shipping 5.0, Seafarer 5.0, Maritime Education and Training 5.0 (MET 5.0).

1. Introduction

The Industry 4.0 digital revolution has been unfolding in the recent decade through the introduction and adoption of Cyber-Physical Systems (CPS), Internet of Things (IoT), Big Data, Artificial Intelligence, Cloud Computing, and automation technologies (Emad et al., 2020; Imran and Kantola, 2018). Digitalisation challenges all industries beyond their limits and constantly requires them to re-evaluate their values and interactions in this changing ecosystem (Heilig, Lalla-Ruiz, & Voß, 2017; Riasanow, Jäntgen, Hermes, Böhm, & Krcmar, 2021). Like other industries, the maritime industry finds itself in a digital transformation by introducing smart and autonomous shipping (Johns, 2018). The shipping industry, as the world's economic engine, is considered one of the four cornerstones of globalisation, with direct impact on global trade (Zaman, Pazouki, Norman, Younessi, & Coleman, 2017; Struck, 2020). The fast-paced introduction of different technologies in the shipping industry is leading the movement toward autonomous ships, provoking a debate on how the maritime industry will be reshaped through digitalisation (Kitada et al., 2018). Consequently, the nature of work and human factors will change in the workplace (Rogers et al., 2019). Likewise, the rapid development of autonomous shipping technology and the gradual change from the experimental stage to the implementation stage may soon negatively impact several areas, including the human element (Chen et al., 2020; Jo & D'Agostini, 2020; Kim, Joung, Jeong, & Park, 2020). Although, there is ample research on technology applied in autonomous shipping, little is undertaken to understand how this trend will affect seafarers and their current and future roles. Thus, the focus of this paper is to provide a comprehensive synthesis and evaluation of literature on the multi-dimensional impacts of autonomous shipping technology resulting from Industry 4.0 and importantly, to identify the challenges of current and future industrial revolutions on seafarers.

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https://doi.org/10.1016/j.ajsl.2021.11.004

Table 1
Systematic literature review process.

Search Engine	Identification	Screening	Eligibility	Included in Final Filter
Scopus	32	25	20	15
Web of Science	43	32	25	17
ScienceDirect	37	30	26	16
Other Academic Search Engine	35	28	23	13
Total Number of Articles in the Final Stage: 61				

2. Methodology

To address the multi-dimensional impact of autonomous shipping technology on seafarers, we used the Systematic Literature Review (SLR) to analyse the current literature. The Systematic Literature Review is a method for classifying relevant articles, analysing, and synthesising results to have a broader insight into the domain (Angreani, Vijaya, & Wicaksono, 2020; Dinter, Tekinerdogan, & Catal, 2021; Zarzuelo, Soeane, & Bermúdez, 2020).

Major electronic academic databases including Scopus, Web of Science, and ScienceDirect were utilised to identify the relevant articles. Multiple keywords such as Industry 4.0, Shipping 4.0, smart shipping, autonomous shipping, digitalisation, digital transformation, MASS, seafarer, human element, competency, training, education, Industry 5.0, and their synonyms have been used. The results included journal articles, consultants' reports, books, and conference papers.

The combined search results produced 147 articles in the identification stage. The results filtered through the screening and eligibility process including analysing titles, abstracts, conclusions, and the main body to remove the duplicated and ineligible articles. As a result, the total number decreased to 61 articles (Table 1).

Moreover, to better understand the human element in the automation context, the same method has been applied to research in other industries with advanced utilisation of autonomous technologies, mainly in aviation, mining, and road transportation.

According to the result of this systematic categorisation of the human element research in the industry, it is evident that autonomous shipping and Shipping 4.0 is a subset of Industry 4.0. Therefore, in the following section we start with providing a short overview of the current literature on industrial revolutions, by highlighting Industry 4.0 technologies as a key driver of autonomous shipping, digitalisation trend in shipping, and human element in maritime context.

3. Industrial revolution

The first Industrial Revolution began when the steam engine was invented (Rüßmann et al., 2015). Today, the industry has evolved through over four technological and social revolutions that have revolutionised industrial concepts and operation methods (Vinitha et al., 2020). Table 2 depicts the earlier, current, and possible future industrial revolutions' timeline, features, and economic impacts on the industry and workforce.

Based on the scope of this study, this paper focuses on the implementation of Industry 4.0 and its impacts on shipping and seafarers. In addition, the possible features of the next revolution, the Industry 5.0 and its envisaged impact on the maritime industry are discussed. Drawing on this we also introduce the concepts of Maritime 5.0; Shipping 5.0; Seafarer 5.0; and Maritime Education and Training 5.0 (MET 5.0).

Table 3
Industry 4.0 components.

Components	Features
Horizontal Integration	New concept of value chain, new business model, product life cycle enrichment, new control system
Vertical Integration	Supply chain integration, cost reduction, real time data sharing, product's profitability
Engineering Integration	End to end engineering, product's customisation through supportive technologies

Source: Table 3 developed by the authors based on Ghobakhloo (2018), Tay et al. (2018), Ustundag and Cevikcan (2017), Wang et al. (2016)

3.1. Industry 4.0

Humankind has witnessed and experienced the progress of three previous Industrial Revolutions and is now on the way to implement the fourth, referred to as Industry 4.0 (Ling, 2020; Zhou et al., 2015). The term Industry 4.0 was used first in 2011 to highlight German manufacturing competitiveness (Hermann et al., 2015). Hence, in 2013, the German government was the first government that identified Industry 4.0 among ten primary projects of Germany's High-Tech Strategy 2020 Action Plan (Ling, 2020; Schumacher, Erol, & Sihn, 2016). This contemporary era named the Fourth Industrial Revolution age, where Cyber-Physical Systems (CPS) and the Internet of Things (IoT) are the two leading players (Ustundag & Cevikcan, 2017; Yang et al., 2010). Explicitly, Industry 4.0 blurs the lines between the physical, digital, and biological worlds, allowing us to remake the world (Aziz Hussin, 2018; Ciolacu et al., 2019).

Table 3 summarises the three components of Industry 4.0 by highlighting the transformation process within a value chain.

Accordingly, the interconnected technologies of the Fourth Industrial Revolution, which act as a pillar, are summarised in Table 4.

These components and technologies are the basic blocks and fundamental requirements of the Fourth Industrial Revolution, which have exponentially penetrated different industries (Imran and Kantola, 2018). It means organisations need to change their business and operation model based on the Industry 4.0 principles by assessing their virtual and physical infrastructure and adaption policy

Table 2
Industrial revolution.

Industrial Revolution	Timeline	Feature	Economic progress
Industry 1.0	Late 18th -Early19th	Mechanize production, steam engine	Economy 1.0 (the capability of labours and physical fitness)
Industry 2.0	Late 19th -Early 20th	Mass production (Ford's production line), electricity, assembly lines	Economy 2.0 (improving working process through energy resources)
Industry 3.0	Second half of 20th	Information age (computers), automated product	Economy 3.0 (developing performance through fast exchange of information and communication network)
Industry 4.0	Early 21st	ICT Technology, cyber-physical system, Internet of Things, networking	Economy 4.0 (unprecedented change era because of innovative knowledge)
Industry 5.0	Future	Human-robot co-operation, high level of personalisation concept	Economy 5.0 (creating value through competitiveness, creativity, and innovation)

Source: Table 2 developed by the authors based on Aziz Hussin (2018), Baygin et al. (2016), Demir et al. (2019), Emad et al. (2020), Nahavandi (2019), Puncreobutr (2016), Rossi (2018), Sułkowski et al. (2021)

Table 4
Industry 4.0 technologies.

Technologies	Features
Cyber-Physical System (CPS)	Networking system, managing, and monitoring system through computer-based algorithms, a combination of ICT and physical systems, extending the “embedded systems” term
Internet of Things (IoT)	Physical and digital world interaction and connection line, exchanging data through technologies, extending the “embedded systems” term
Cloud Computing	Data management, real-time communication, using enabling technologies
Adaptive Robotics	Smarter products with communication, computing, and autonomy ability, combination of microprocessors and AI
Additive Manufacturing	3D Printing, Computer-Aided Design (CAD), flexible production, decentralisation of production line, low consumption of raw materials, optimised design
Virtualization	Virtual Reality (VR), enriching human’s perception of reality, Augmented Reality (AR), real-world reflection,
Simulation	Simplification, decision making through visualisation, optimisation through real-time data
Big Data and Data Analytics	Big data characteristics (value, volume, velocity, and variety), actionable knowledge through data, data visualisation, decision-making through real-time data
Artificial Intelligence (AI)	Computer development through learning, reasoning, and self-correction areas (simulation of human intelligence), intelligent being,
Cyber Security	Protecting technologies against cyber-attack, information technology security

Source: Table 4 developed by the authors based on Marwedel (2021), Kempler and Mathews (2017), Kok et al. (2009), Mauro et al. (2015), Peng et al. (2020), Sethi and Sarangi (2017), Ustundag and Cevikcan (2017)

(Erol et al., 2016; Ustundag and Cevikcan, 2017). As experienced in the three previous Industrial Revolutions, there is a transitional stage that requires industries to go through a retrofitting process of the current systems for the gradual migration to the future. The retrofitting concept is the gradual improvement of present systems with the new functionalities or technologies (Ehrlich et al., 2015). In this competitive era, the critical element for business improvement depends on the organisation's usage level of Industry 4.0 technologies, which leads to a new value and opportunity (Lee, Cameron, & Hassall, 2019; Johns, 2018).

Currently, to integrate the old and new systems, industries are experiencing the evolutionary migration from Industry 3.0 to Industry 4.0 through digitalisation (Ehrlich et al., 2015; Ghobakhloo, 2018). The maritime industry, like other industries, is embracing Industry 4.0 by adopting new technologies digitalised at different levels (Jo and D'Agostini, 2020). In this respect, the future of shipping is getting shaped through the digitalisation process (Quitzau et al., 2018). In the following section, the digitalisation impacts on the shipping industry are discussed.

3.2. Digitalisation in shipping industry

In the maritime industry, the term shipping refers to the ocean transit of goods by ships (Munim, 2019). The shipping industry is also a synonym for global trade as it is the major player in the trading industry (Struck, 2020). The fact that 90% of global trade moves through the sea, highlighting the shipping industry’s role as a backbone of the world’s economy (Emad et al., 2021). Furthermore, the shipping industry has faced different challenges such as social, climate change, economic, and more importantly, the fast-paced technological development, which requires the industry to be ready to take these challenges as an opportunity rather than a threat (Zaman et al., 2017). Therefore, the new generation of Industry 4.0 technologies, such as autonomous ships, have potential to address the challenges in the maritime domain (Gu et al., 2021).

The digitalisation process in the maritime domain cannot occur overnight. For instance, International Maritime Organisation (IMO) initiated e-Navigation in 2006 to collect, exchange, analyse, and integrate data by electronic means both on-board and on-shore to support human operators however they never fully implemented (Kitada et al., 2018). Moreover, the constant change in the shipping sector due to digitalisation will require modifications in ship’s type and sizes, crew competency, traffic management, transportation routes, and IMO rules and regulation (Baldauf et al., 2018).

The impact of the Fourth Industrial Revolution in the maritime domain can be seen across the industry including ports, shipping, and their operations and services (Sullivan et al., 2020). The implementation of Industry 4.0 in the maritime industry requires all sectors to connect and grow simultaneously. This can be considered as not a challenge but an opportunity for the maritime domain which requires improved connectivity between ports and ships. This may imply that ships and ports consider the retrofitting process through digitalisation (Quitzau et al., 2018). Thus, more connectivity in the maritime domain will provide more opportunities for autonomous and unmanned ships to be employed in the future and prepare for next industrial revolution, Industry 5.0.

3.3. Industry 5.0

While all industries, including shipping, are embracing and in some cases being forced by competitive pressures to implement Industry 4.0, some industries are already considering the impact of Industry 5.0. As mentioned in the previous section, Industry 4.0’s main focus is digitalisation which adopts smart machines and systems to automatise and exchange data or even control each other without human presence. However, the main focus of Industry 5.0 is to bring back the human’s mind and hand into the industrial framework (Mortson, 2018).

There are different visions and themes regarding Industry 5.0, but the most popular is human-robot cooperation which highlights that humans and machines need to work together. The goal is for humans to bring creativity and innovations and robots as an intelligent system to perform the required task (Demir et al., 2019). “ While the main concern of Industry 4.0 is about automation, Industry 5.0 will be a synergy between humans and autonomous machines” (Nahavandi, 2019, p. 3). Industry 5.0 will position humans back into industrial framework with the focus on human/machine co-operation (Rossi, 2018).

The following section explains autonomous shipping, its level of automation, and explains the trend of automation in other industries.

4. Autonomous and unmanned ship

Sułkowski et al. (2021, p.16) stated that “The future is today, just somewhat further”, which is a relevant perspective for shipping. To be prepared for the future of shipping, there is a crucial need to know about different facets of shipping 4.0 or autonomous and unmanned ships in the Industry 4.0 era. Digitalisation has and will result in a series of changes to ship operations, manning, and automation that collectively will enhance productivity in shipping. Table 5 highlights the ascending flow in ship-related innovations that have led to revolutions in the shipping world.

The pace and extent of implementing Industry 4.0 technologies in Shipping 4.0 employs novel technologies including Artificial Intelligence, automation, remote monitoring, IoT, and innovative

Table 5
Shipping revolution.

Shipping Revolution	Timeline	New Feature in Ship
Shipping 1.0	Around 1800	Steam engines
Shipping 2.0	Around 1910	Diesel engines
Shipping 3.0	Around 1970	Automation and computerised system
Shipping 4.0	Now	Digitalisation in all aspect of shipping

Source: Table 5 developed based on Emad et al. (2020)

propulsion systems (Emad, 2020). Alternatively, the fourth industrial revolution is an enabler for the maritime industry to gradually remove conventional vessels and develop Maritime Autonomous Surface Ships (MASS) (Chae, Kim, & Kim, 2020; Rødseth, Wennersberg, & Nordahl, 2021). MASS will be a prime growth engine for the next-generation of the maritime industry (Jo and D'Agostini, 2020). The autonomous, smart, digital, unmanned, or even connected ships are included in the MASS category (Jo et al., 2020).

4.1. Autonomy taxonomy

"The word "autonomy" is derived from the Greek word "autonomia" which means independent, or more literally, living by one's own laws" (Rødseth and Vagia, 2020, p. 4). In the maritime context, an autonomous ship is relatively a new concept with limited available knowledge about the design and implementation (Rødseth et al., 2021). Therefore, there is a need for more discussion, to determine exactly what type of vessel will be considered an autonomous or unmanned ship (Suri, 2020). Accordingly, different authorities, standards organisations, and class societies like IMO, ISO, Norwegian Forum for Autonomous Ships (NFAS), Bureau Veritas (BV), Lloyd's Register (LR), DNV GL, Class NK, and American Bureau of Shipping (ABS) have their own suggestions for defining an autonomous ship. However, as shipping is an international domain and regulated by internationally accepted legislation and rules, this paper uses the IMO's definition and criteria for autonomous and unmanned ships, which stands out by its broader scope (Rødseth and Nordahl, 2017; Rødseth and Vagia, 2020).

Based on the IMO, "A Maritime Autonomous Surface Ship (MASS) is defined as a ship which, to a varying degree, can operate independently of human interaction." (Rødseth and Vagia, 2020, p. 11). This definition highlighted the human/machine interaction point, so the autonomy level can be classified through the human and machine relationships in operations (Mallam et al., 2020). In other words, the different level of autonomy has shown how the decision-making process will be handed over from the human to the autonomous system (Li and Fung, 2019). Based on this, the IMO devised four degrees of autonomy as depicted in Table 6.

So far, there are several prototypes of autonomous ships worldwide which have been developed by various countries such as Norway, China, Finland, and the USA through different projects such as MUNIN, YARA Birkeland, ReVolt, AAWA, and AMOS (Li & Fung, 2019; Munim, 2019). Among all mentioned projects, the Advanced Autonomous Waterborne Applications Initiative (AAWA) project is well-known, since this project started bringing major maritime stakeholders like shipbuilding companies, equipment manufacturers, and researchers together through Rolls Royce in order to implement the fully autonomous ship by 2035 (Kim, Joung, Jeong, & Park, 2020; pre, 2017; Walker, 2019). As there are limited examples in the maritime domain on the evolution of automation, this paper examines the progress of automation in other industries in the following section.

4.2. Autonomy in different industries

The pace and extent of automation has motivated different industries to use technology to prepare for a shift to the future global market. Currently, the aviation, mining, nuclear power energy generation, and automotive industries are ahead of the maritime industry due to taking advantage of unmanned units, cars, and aircraft (Li & Fung, 2019; Barabás et al., 2017). The maritime industry can benefit from these industries' experiences, including developing a roadmap, strategy plan, and training programme for the use of autonomous technology in different facets of the maritime industry (Emad et al., 2021).

In the automobile industry, the latest trend is related to autonomous vehicles (AVs), known as driverless cars, which is the result of incorporating the Industry 4.0 technologies such as advanced computation and sensors (Alawadhi et al., 2020). Some companies like Tesla, Google, and Volvo are already started employing driverless cars and trucks in road transport. In this context, some countries are investing in the Industry 4.0; for example, Dubai initiated the world's third-largest automated and driverless metro system (Jacobs, 2018).

The term unmanned aerial vehicle (UAVs) is being used for airborne vehicles without any pilot on board with a long history that goes back to 1818 when an unmanned balloon used for fire rockets (Gu, Goez, Guajardo, & Wallace, 2021; Nisser and Westin, 2006). The use of UAVs is growing exponentially in military services. However, the integration of UAVs into airspaces has brought more opportunities for using drones or pilotless aircraft in civil activities in the areas such as disaster monitoring, traffic monitoring, border surveillance, and search and rescue (Viloria, Solano-Charris, Muñoz-Villamizar, & Montoya-Torres, 2021; Nisser and Westin, 2006).

Autonomation technology has also been used in the mining industry. The autonomous mining systems (AMS) are already deployed and used in Australia and the USA that have automated activities including hauling, drilling, crushing, excavation, and milling (Kansake et al., 2019). Accordingly, autonomous haulage systems (AHS), which are driverless vehicles capable of carrying four hundred tons of ore without human interaction, are a significant advantage of Industry 4.0 in the mining industry (Gaber et al., 2021).

To comprehend the journey to automation, Table 7 shows how utilisation the automation concept began a century ago. During this period, the usage of autonomous units in the aviation, land, and sea transport fleet with the goal of human reduction in systems has gradually increased. Indeed, several autonomous and unmanned ships in the maritime industry are currently in use for short voyages, research purposes, and military activities worldwide (Ahvenjärvi, 2016; AMSA, 2021).

Table 6
Degree of autonomy based on IMO.

Degree	Seafarers on-board/onshore	Feature
Degree 1	On-board	Direct control of ship by crew, presence of some automated operations in ship but crew can take control
Degree 2	On-board and Onshore	Controlling ship from another location, the presence of seafarer on-board to operate ship
Degree 3	Onshore	Controlling ship remotely from another location, No seafarers on-board
Degree 4		Fully autonomous ship, decision making process through ship itself (AI)

Source: Table 6 developed based on Emad et al. (2020), Lee et al. (2019)

Table 7
Start of Automation concept in different industries.

Industry	The first idea of automation / Year
Automobile Industry	1918
Aviation Industry	1914
Mining Industry	1960
Maritime Industry	1967

Source: Table 7 developed by the authors based on Alawadhi et al. (2020), Emad et al. (2020), Kansake et al. (2019), Nisser and Westin (2006)

The current literature shows that research in automation technology in the automotive, aviation, and maritime domains is matured. However, there is a lack of research on the role of the human as a key player in the autonomous operation, which is discussed in the next section from a maritime context.

5. Human element in the autonomous world

The recent development of Industry 4.0 has made a significant change at the level of human and machine work division (Ghobakhloo, 2018). This requires a clear understanding of workers' roles as a major element and resource of each industry (Gilchrist, 2016). At the same time, the lack of a workforce with the new required skill set is considered as one of the socio-economic triggers of Industry 4.0. This highlights the importance of the training of human element in the automation and digitalisation era (Shamim et al., 2016). More broadly, training workers with new digital and soft skillsets is considered a fundamental factor for transitioning society into knowledge-based economies (Beechler and Woodward, 2009). For this reason, as for each of the three previous Industrial Revolutions, Industry 4.0 has developed a new form of education for its workforce. Table 8 illustrates education evolvement through each Industrial Revolution and highlights the relationship between economic demand, industrial revolutions, and education changes.

According to the above Table, any revolution in industry leads to a new educational model. Therefore, within this context, any changes in technology and regulation in shipping will lead to changes in the maritime education and training system (Emad et al., 2020). Thus, the role and responsibility of humans in autonomous shipping, including the changing nature of seafarer competency, should be understood as being relevant to the rapid feasibility of autonomous ship implementation (Mallam et al., 2020). Explicitly, the emerging trend of automation requires seafarers as key drivers of the shipping industry to simultaneously progress during the Industry 4.0 and Industry 5.0 evolution (Lušić et al., 2019).

Considering that shipping is an international industry active in the international domain, any training and competencies for seafarers needs to be standardised and regulated internationally. This is undertaken through STCW (Standards of Training, Certification and Watchkeeping) convention which is developed by IMO as a global authority (IMO, 2020; Sharma et al., 2019). The STCW used the term seafarer for people who work on board ships and engage with activities related to the onboard ship. Likewise, the STCW convention does not have any articles related to autonomous and unmanned ships in its original and amendment versions (Danish, 2017). Moreover, “competencies are skills and abilities; things you can do; acquired through work experience, life experience, study or training” (Prifti et al., 2017, p. 3). Table 9 shows how the concept of seafaring is evolving with each revolution in the industry.

Table 9
Seafarer evolution through time.

Name	Features
Seafarer 1.0	Ship operation through stars, moon, and sun
Seafarer 2.0	Ship operation through advanced celestial navigation
Seafarer 3.0	Ship operation through an automatic and electronic navigation system
Seafarer 4.0 (E-farer / Operator 4.0)	Unmanned and autonomous ship management through digital technologies (digital competencies)

Source: Table 9 developed by the authors based on Erro-Garcés (2021), Jo et al. (2020), Lee C.H (2019)

Although autonomous ship operation eliminated the need for crew presence onboard, the importance of the human element in the system as a whole has not vanished. In contrast, design, building, and testing the technical system of autonomous ships and predicting system behaviours in different operational situations are undertaken by humans. In essence, the role of humans in autonomous systems is shifted to the earlier stages (Ahvenjärvi, 2016). Moreover, the research has shown that human monitoring skills are crucial for automated operations (Karvonen and Martio, 2018). Despite the hype that advancement of autonomous systems in shipping may lead to crew reduction however, research shows that changes to seafarers' roles and responsibilities in the new system will lead to a new breed of seafarers. Seafarer 4.0, as a new group of seafarers, is likely to work onshore and if required onboard ships (Karvonen and Martio, 2018).

While there is a major potential benefit however, the autonomous system brings challenges in the maritime domain, especially for seafarers. The challenges include changing their role with the new requirement for the training for their new position (Kyriakidis et al., 2019; Broek et al., 2020; Karvonen and Martio, 2018). Subsequently, the seafarers' job profile in the traditional work environment will be transformed and requires seafarers to be qualified with a new set of skills and competencies (Prifti et al., 2017).

An autonomous ship needs to be considered as a new concept in the maritime domain and its implementation has the potential to alter all traditional procedures and techniques for design, test, and operation of ships (Oksavik et al., 2020). In other words, the rapid and significant technological advancement in the autonomous world constantly changes and defines the human role in systems with work tasks that require a new set of knowledge, skills, and competencies (Mallam et al., 2020). Additionally, offshore and onshore employment will be impacted as low-skilled workers on-board and

Table 8
Education Movement through Industrial Revolution.

Education	Industrial Revolution	Feature
Education 1.0	Industry 1.0	Direct response to agricultural society, dictated education method, no technology presence
Education 2.0	Industry 2.0	Direct response to Industrial society, licensed teachers, the presence of technology in classroom
Education 3.0	Industry 3.0	Direct response to technology and globalisation, self-learning support, using social media in teaching process, knowledge generation by students
Education 4.0	Industry 4.0	Direct response to digitalisation, lifelong learning, E-learning, B-learning, teachers as a facilitator, non-conventional assessment, project-based learning

Source: Table 8 developed by the authors based on Aziz Hussin (2018), Fisk (2017), Harkins (2008), Ling (2020), Puncreobutr (2016)

Table 10
Potential training for Industry 4.0 and Autonomous ships.

New requirements in education concept	Industry 4.0	Autonomous ship operation
Educational and teaching content	Data and computing technologies, data modelling and big data, data analytics, cloud computing, machine learning, innovation, and entrepreneurship, learning to learn	Cognitive skills, communication skills, operational and technical skills, STEM knowledge, leadership skills, mathematics knowledge and programming
Learning technologies	Virtual labs and Augmented Reality (AR), gamification, learning analytics, e-learning	Simulator, 3D simulation and gamification, B-learning, VR, AR
Working in interdisciplinary teams	Requirements for interdisciplinary thinking and doing interdisciplinary task in interdisciplinary teams	Personalised training, digital competences

Source: Table 10 developed by the authors based on Emad et al. (2021), Kozák et al. (2018), Ling (2020), Ustundag and Cevikcan (2017)

offshore may be replaced with autonomous systems and professional operators in shore control centre (SCC) (Streng and Kuipers, 2020).

Research suggests that the shipping industry will need crew who can use ICT technologies and have good teamwork and leadership skills (Belev and Daskalov, 2019). Moreover, there is a claim that future seafarers may never go to sea but instead receive training of ship operations remotely through simulator exercises or shoreside centres (Wahlströma et al., 2015). However, researchers have emphasised that the role of seafarers in bridge and engine rooms will shift into the shore-based control centre operator where the decision-making process is required through real-time data by the remote operators (Lee C.H, 2019). Accordingly, to have an insight toward the employment landscape in Shipping 4.0 as a subset of Industry 4.0, Table 10 shows the significant shift in educational requirements needed for future workers and seafarers to become digital natives in their field of activity (Shahroom and Hussin, 2018).

The above table emphasises how Industry 4.0 educational requirements may translate into the maritime industry. Fig. 1 illustrates the time span of industrial revolutions, which demonstrates the prominent point that the time-lapse between industrial revolutions were about a century; however, it took about 40 years for Industry 3.0 to lose its place to Industry 4.0. It is expected that Industry 5.0 finds its relevancy in an even shorter period (Demir et al., 2019; Senčila and Kalvaitienė, 2019).

Although the full implementation of Industry 4.0 is yet to come, some progressive industries have started to feel its shortcomings. Industry 4.0 fails to recognise the role of the human as a key element of the industrial systems. For that reason, Industry 5.0 is introduced to address this shortage. In other words, Industry 5.0 embraces the human as the prime driver (Rada, 2017). Drawing on this concept we envision the maritime industry will need to embrace the change and evolve toward Industry 5.0 by moving toward Maritime 5.0 including Shipping 5.0, and Seafarer 5.0, Maritime Education and Training 5.0 (MET 5.0).

6. Result and conclusion

The present study confirms that technological developments from Industry 4.0 have changed the operational concept and services in all industries, including the maritime industry. Indeed, the Industry 4.0 trend in the shipping industry was introduced by autonomous shipping. Subsequently, the emerging automation pattern in shipping industries has brought different positive and negative challenges that may become a significant issue for seafarers licensed through the current STCW for the existing ships. Thus, this paper provides an overview of the existing literature by highlighting Industry 4.0 technologies that have penetrated other industries through digitalisation. The paper also focused on the human element in autonomous shipping, new roles, responsibilities, and reskilling process of future seafarers which so far have been neglected.

This paper concludes with several gaps related to seafarers' challenges in the transition to autonomous shipping, including unknown skills, competencies, and characteristics of future seafarers, unidentified training content and facilities, and trainers' skills in Maritime Education and Training Institutions. Thus, according to the

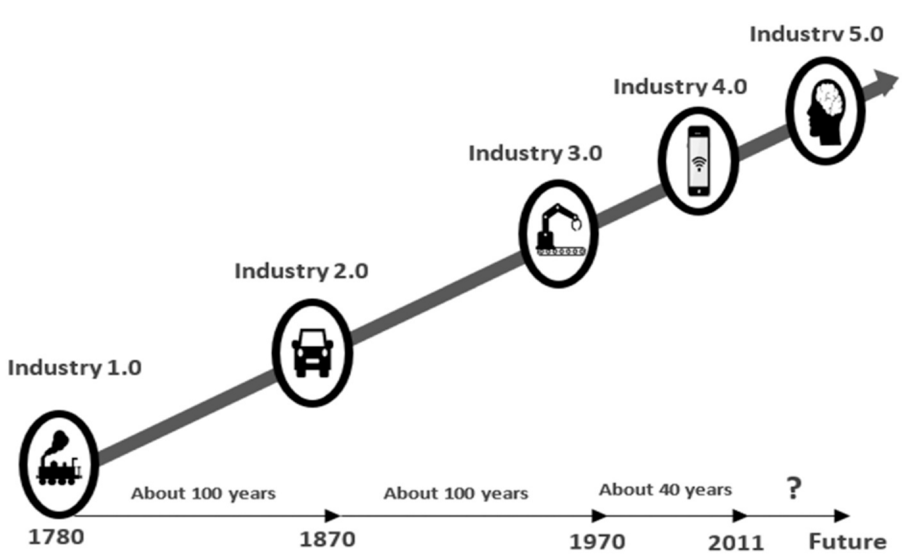

Fig. 1. Industrial Revolution timeline.
Source: Fig. 1 developed based on Demir et al. (2019), Rossi (2018), Vinitha et al. (2020)

Table 11
Definition of Maritime 5.0, Shipping 5.0, Seafarer 5.0, and Maritime Education and Training 5.0 (MET 5.0).

Term	Definition
Maritime 5.0	Collaboration between non-human agents (intelligent agent) and seafarers/maritime operators to perform tasks in all levels of maritime space from design to integrated decision making and operation.
Shipping 5.0	Transformation of smart shipping to intelligent shipping systems with human intelligence at the core.
Seafarer 5.0 (Human intelligent in the system)	Ship management and operation through collaboration with non-human intelligent system.
Maritime Education and Training 5.0 (MET 5.0)	Direct and comprehensive response to the integration of human and non-human agent. Learning to develop core capabilities including teamwork and collaboration with non-human intelligent agent; innovation and creativity as a quick response to dynamic environment in maritime space; and synergistic adaptation to the continuous evolution of technologies.

Source: Table 11 developed by the authors

recent literature to fulfil the gaps, this paper proposes the following questions to lead a future research agenda:

- What are the skills and competencies required for future seafarers?
- What are the characteristics of future seafarers both on-board and onshore?
- What are the effective strategic steps toward full implementation of autonomous ship operation?
- What content, resources, and facilities are required for future seafarers training and education?
- What skills and competencies are required for the future trainer in Maritime Education and Training Institutions?

As discussed, by focusing purely on technology, Industry 4.0 places the human element into the background. The emphasis is to reduce the possibility of human error and mistakes. The lack of human intelligence in the system created challenges that need to be addressed. Industry 5.0 is introduced to fill this gap. Industry 5.0 will bring the human into the foreground by positioning human intelligence as one of the core elements in the system.

Similarly, the Maritime 4.0 is defined as "the integrated implementation of digital processes and technologies in the design, development, construction, operation and service of vessels" (Sullivan et al., 2020, p. 4). To integrate the human intelligence back into the system we define Maritime 5.0 as the collaboration between non-human agents (intelligent agent / AI agent) and humans (seafarers/maritime operators) to perform tasks in all levels of maritime space from design to integrated decision making and operations.

The authors defined the manifestation of Industry 5.0 in the maritime domain through the following terms as indicated in Table 11.

In this context, Maritime 5.0, through educating intelligent seafarers and maritime operators as an early response to a root-cause diagnosis of Maritime 4.0 implementation, has the potential to prevent future obstacles and challenges.

The author's intention is that by introducing novel concepts in Maritime 5.0 will provide a guiding reference that may inspire future researchers to address the seafarers' needs and requirements of autonomous shipping during the transitional stage from current to future industrial revolutions.

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