Challenges for Developing Navies to Adopt Industry 4.0

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Synopsis

The rapid advancements in microprocessors has enhanced the computational power available on the desk top, enabling a paradigm shift in the way Researchers are handling large amount of data, developing newer algorithms to gain a deeper understanding of the subject matter as well as thinking and performing tasks that could never be imagined by mankind couple of decades ago.

3D additive printing; robotics - soft and hard; increased autonomous operations; Big data analytics; Internet of Things; Cyber Physical Systems; Artificial Intelligence; Machine Learning; Nanotechnology; Augmented and Virtual Reality; Exoskeleton; Cloud computing; Predictive maintenance; Advanced materials etc are the results of exponential rise in computational power, collectively known as Industry 4.0.

Adoption of industry 4.0 across different industrial domains is now encroaching upon design, building, operation and maintenance of both commercial and naval ships.

This paper intends to examine the adoption rate in advanced navies and look at the challenges faced by the developing navies, (especially in the Indian context), in their readiness for industry 4.0. The challenges could be education and training of human resources; industry support; local culture and mindset - within the navy and outside the navy; Cyber Security; Data storage; Data Privacy and confidentiality etc.

Keywords— Industry 4.0, Cyber Physical Systems, Naval Ships, AI/ML, 3D printing, IoT/IIoT.

1. Introduction

1.1 Industrial Revolutions

Industry 4.0 (I4) or fourth industrial revolution is a technology vector which has more than adequately proven its efficacy in industry infusing robust efficiency and creating unforeseen value chains. In the last decade certain elements of digitization and automation has made inroads into the entire gamut of ship design, ship building, maintenance and operations albeit in isolation. I4 has unimaginable potential covering a large umbrella of cyber technologies, sooner the navies adopt it, better it would be for them to maintain the technological superiority. Unlike the earlier revolutions which had distinct phases and finite tempo, the pace of this digital transformation is beyond conceivable belief, as can be seen from the Table 1 below.

The shipbuilding sector has always maintained superiority as compared to other sectors with technologies that were developed during each of these industrial revolutions. It became inherent to this sector perhaps due to the quest for tonnage, speed, propulsion efficiency and safety of the vessels. Correspondingly the naval sector too has been nimble to adopt the waves of modern technologies simply to remain relevant and not redundant in their war fighting capability. The

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chronological evolution depicted at table 1 adequately summarizes this hypothesis.

Industrial Revolution	Year	Approximate Time Period Years	Key Highlights	Warship
First	1765	100	• Iron clad ships • Reciprocating steam engines • Paddle and screw propulsors • Energy source - Fossil fuels • Armament - Guns • Armour – Heavy	 HMS Warrior
Second	1870	60	• Steam turbines • Ships energy sources - Electricity, Oil & Gas • Torpedoes • Heavier guns	 HMS Dreadnought
Third	1969	40	• Electronics • Computing • Communication • High level of automation • Information Technology	 USS Zumwalt
Fourth	2011	20	• Cyber-physical systems. • Autonomous Operations. • Additive manufacturing. • Artificial Intelligence. • Robotics. • Nanotechnology. Quantum computing. Biotechnology. • Internet of Things. • Industrial Internet of Things (IIoT).	 DARPA's Autonomous ship Sea Hunter

Table 1 - Industrial Revolutions

1.2 Maritime Sector

Noting the technical progress across the industries, especially in the commercial sectors, Lloyd's Register (oldest and leading marine classification society), was keen to learn what the future holds for the Marine sector. They commissioned couple of studies concentrating on Global Marine Trends, which has resulted in the publication of the four documents (LR, 2019), Global Marine Trends-2030 (2013), Fuel Trends-2030, (2014), Technology Trends 2030 (2015) & Autonomous Systems 2030 (2016) in association with the industry, research organizations and the academia.

Besides concentrating on Commercial Shipping Sector, Offshore Energy Sector, Oceans Space etc, they examined how the underpinnings of the emerging technologies are shaping the navies of the world.

Out of the 56 critical technologies that were examined that might possibly be developed and implemented by 2030, they selected 18 technologies that they thought would have transformational impact on different sectors. These 18 technologies were sensors, big data analytics, propulsion and powering, advanced materials, smart ship, autonomous systems, advanced manufacturing, sustainable energy generation, shipbuilding, carbon capture and storage, energy management, cyber and electronic warfare, marine biotechnology, human–computer interaction, deep ocean mining, human augmentation, and communication.

One may note from the above that many of them are part of the Industry 4.0 ecosystem as depicted in the Figures below.

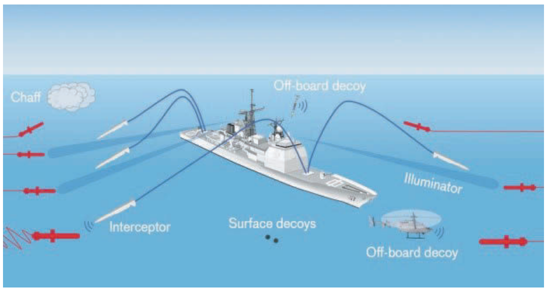

Figure 1 - Artificial Intelligence systems depicting usage of AI in a naval ship's active defence. (*Source* , *Lincoln Lab, MIT, https://www.ll.mit.edu/news /artificial-intelligence -system-helps-navy-select-best-tactics-ship-defense*)

Figure 2 - Illustration of fully autonomous ships based on combination of hyper connectivity, IOT and Big Data Analytics. (*source, https://newsroom.intel.com/news/intel-artificial-intelligence-rolls-royce-push-full-steam-autonomous-shipping/#gs.zkxzd6)*

Figure 3 - Exoskeleton revolutionizes shipyard work flow where workers dressed in wearable robotics transport large sized metal, pipes, plates and other objects. (*Source https://www.newscientist.com/article/mg22329803-900-robotic-suit-gives-shipyard-workers-super-strength/)*

Figure 4 - Augmented reality, simulation of system layout during the design phase. (*Source https://emag.nauticexpo.com/issue11/*

1.3 Navies

The Navy has historically established itself as the national instrument for military and diplomatic engagement. It's but natural for the countries around the globe to therefore empower their Navies by consolidating their assets based on the threat perception and ever changing geopolitical scenarios. In order to maintain the technological superiority and an edge over their adversaries these assets are managed with active collaboration of front-end and back-end specialists to achieve the desired end state of delivering the ordnance where it is due. In a nutshell there is a constant collaborative effort of interdependent and independent stakeholders who enable the war fighting capabilities such as

- Naval platform builders or the shipyards both in the private and public sectors.
- System Integrators for onboard systems, which would include different types of weapon, propulsion, power generation and other auxiliary systems to enable Float, Move and Fight capabilities.
- Original Equipment Manufacturers (OEM), who are also responsible for providing relevant interfaces for the system integrators, shipyards and the operators onboard warships.
- Academia, who are the knowledge generators/providers, at the Universities, Naval Academies (for graduate and higher level education) and Training establishment

(for skill development to maintain industry 4.0 technologies).

It is now felt that each one of them is being directly impacted by the influx of the Industry 4.0 technologies.

The authors opine that all Industry 4.0 technologies may not be applicable to all the stakeholders equally and have drawn up the following table indicating where each technology is more prominently likely to be applied.

Table 2 - Naval Ships Eco System and Industry 4.0

Industry 4.0 Technology	Naval Ship Operations	Naval Ship Designers	Naval Shipbuilders	System Integrators	Original Equipment Manufacturers	Academia
Artificial Intelligence						
Robotics						
Exoskeleton						
IIoT/IoT						
Additive Manufacturing						
Advanced Materials						
Autonomous Systems						
Augmented / Virtual Reality						

2. Industry 4.0 Adoption

2.1 Commercial Sector

Since the formal inception of Industry 4.0 in 2011 (Sharma 2019) wherein it envisions to amalgamate Cyber domain with Physical space thereby creating *cyber-physical systems* to achieve maximum autonomy and efficiency, I4 has proven its efficacy in the modern factories in a short span of less than a decade.

The I4 enabled smart production floor employing Internet of Things (IoT), industrial big data, intelligent robotics and industrial automation has resulted in several advantages including overall cost reduction and enhanced productivity besides delighting the customers with the characteristic experience of automation.

In the commercial sector, State-of-the-art 3D modeling virtual reality (VR) software are allowing the 'single truth' simulations to assess interplay of the equipment, spaces and internal structures before they are installed or built, allowing designers to verify and optimize the overall layout of a production floor. It also means that different features, fittings and functions can also be examined in advance to optimize the eventual ergonomics and the actual maintenance envelops.

The concept of *Digital Twin* has been gaining momentum across the sectors wherein the assets are located at remote locations are monitored, maintained and reconfigured in real time. The advanced sensors which are wirelessly hyper networked through the cloud assists in creation of a digital twin at a central location thousands of miles away from the field units. The data streams pertaining to the health of the structure/equipment are converged for a detailed analysis which can then translate into effective predictive maintenance. This concept has been successful in case of remote monitoring of arctic windmill (Tanja 2017) offshore windmill (OE 2018) and health monitoring and maintenance of cargo vessels (Storhaug 2019). This strategy has not only brought down the overall cost but has infused immense efficiency in the life cycle management of the assets.

2.2 Shipbuilding Sector

The shipbuilding sector is inherently in a constant endeavour to lower the ship construction cost, total ownership cost and always desirous of having higher operational availability of platforms in order to remain relevant in the stiff competitive market. The shipyards thus have not shied away from experimenting with the contemporary 'smart' shipyard approaches to avail the opportunities offered by the I4 processes laden with data-rich efficiencies to the design, construct and maintain platforms to meet aforesaid parameters.

The shipbuilding majors like Navantia, BAE Systems and Newport News Shipbuilding (NNS) have been in the forefront of adopting the I4 tenets. Navantia Shipyard, whilst re-orienting protocols inline with the standards of I4, has concluded that a four axis integration mapping would be inevitable for any shipyard. First axis being the digital integration of organizational hierarchy in vertical direction, secondly horizontal integration with OEMs, thirdly integration of the production chain and lastly integration of the skilled personnel (Lana et al 2016).

Some of the leading technology and consulting firms like Siemens, KPMG, BCG, Deloitte (Siemens 2018, Gates 2018, BCG 2017, Renjen 2019) etc too have supported the cause. Collectively it has emerged that the elements of I4 in the shipbuilding domain also known as Shipbuilding 4.0 (S4) has a very wide spread. Consequently the importance of total enterprise collaboration and synchronization through digital connectivity cannot be overlooked and it would be virtually impossible to extract expected benefits and sustain the fourth revolution in the marine sector without addressing the aforesaid aspects.

2.2.1 Hull design optimization

Hull design optimization using virtual prototyping tool which involves evaluation in virtual environment can considerably reduce the design cycle time and present a more optimum design as compared to classical iterative ship design cycle using CFD followed by creation of physical scaled model and towing tank test. The virtualization has not only reduced the overall design time but also has resulted in better design. A reduction of 12 % of hull resistance has been reported (Ang, Goh 2017) by using this very important I4 component during the design phase.

2.2.2 Digital Twins

Digital twins, like in the commercial sector, Figure 5 have many potential applications in ship design, shipboard systems management, operations and maintenance. The hull design developed by virtual means, tested by means of a Digital Twin, have indicated improved efficiency by over 12%. The ships which have implemented wireless sensors on the equipment have reported significant increase in MTBF and reduction in maintenance cost by increasing the MTBO. The I4 designed ships have also reported lower energy consumption when put to sea thereby increasing the overall net profitability.

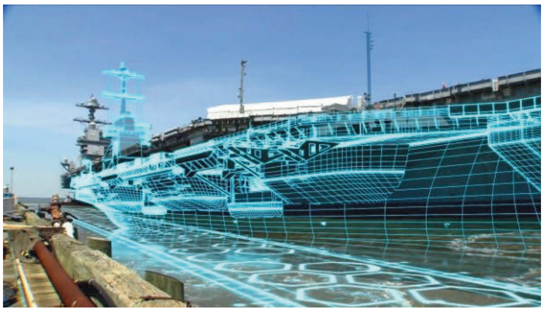

Figure 5. Depiction of digital twin. *Source Newport Sea Shipbuilding*

2.2.3 Government as Stakeholder

Among all the challenges highlighted above, it has also emerged that the Government's role is equally important where in they need to demonstrate both intent and alignment towards I4/S4 implementation, *intent* by promulgating stated national policies and *alignment* by facilitating relevant means and infrastructure to institutionalize S4.

2.3 Naval Sector

Consolidating on the opportunities offered by the tenets of I4, Newport News Shipbuilding (NNS) and Ingalls shipbuilding has taken lead in setting up naval digital shipyard whilst building US Navy's aircraft carriers and other sea going assets (EAP 2018). The design and construction of the upcoming CVN-80 (*USS Enterprise)* would be based on three-dimensional representations only (Eckstein 2016) and earlier the shipyard had introduced digitization of more than 1,000 work packages while building CVN-79. The digital modeling will also be used in the mid life upgradation of the in service ships such as the Nimitz-class carriers. The NNS expects to address several classical and legacy challenges typical of the complex shipbuilding process including the planning and production inefficiencies (EAP 18) by establishing “the single source of truth” for all activities at the shipyard from the lowest denomination to the highest, sourced from a centralized database.

Royal Australian Navy (RAN) too has followed suit with the concept of total digital shipyard for the production of the Hunter Class ASW frigates (NT 2018). In collaboration with BAE systems the future frigate program would be formulated on the Industry 4.0 standards and procedures. The nine platforms would be the first bow-to-stern digitally designed anti-submarine warfare (ASW) warship and the challenges are remain to be seen. The Australian government too has endorsed this I4 based naval shipbuilding strategy (DIIS, 2019).

3.0 Challenges Faced by Developing Navies

Being an emerging technology, not all navies are comfortable with different aspects of Industry 4.0, since many have not really seen/felt the benefits of even a simple AI application of Big Data Analytics. Many in the navies are comfortable with the status-quo wherein the plans and activities flows bi-directionally for manual validation however it is opined by the authors that as the industry matures, more and more navies are likely to feel confident in adopting this new technology. The navies would need to create a roadmap to educate her human resource on the merits of ‘Industry 4.0’ automation and data-exchange revolution that has to an extent matured in the commercial manufacturing industry.

3.1 Legacy mindset.

Often, enthusiasm towards digital technologies is undermined by lack of clarity on its potential and final outcome. Legacy mindset and organisational resistance to change can surely act as a barrier towards I4 implementation. The naval yard’s largely traditional manufacturing mindset can often conflict with new digitally-enabled ways of working. Add to this the shipbuilding industry’s intrinsic characteristics of manufacturing bespoke products in low volumes, long production cycles, high levels of in-production change and customization makes the transition to I4 based organisation a huge challenge (Accenture 2017).

The transformation of traditional mindset where in the procedures and processes are cast in stone in the last two centuries is considered to one of the biggest challenge for any developing nation specially in Indian context. The effort has to be beyond traditional training programs, skill development and education. It has to begin with shaping the perception of the work force towards embracing the digital technologies and perhaps demonstrate it to them the tremendous opportunity it can bring in their work culture and ease of executing their tasks more efficiently.

3.2 Organizational intent.

The Navy as an organization will have to shape the perception of the top management towards induction of I4 technologies gracefully in every domain of ship management. The organizational intent needs to be top down for it to be successful.

3.3 Organizational Changes.

Once the I4 enabled changes are adopted within the Navy, the associated organizational changes will also have to be made. There would be requirement for vertical integration as well as horizontal integration. As someone noted - during the periods of changing technology, the victors in international politics are generally those militaries capable of making organizational change to take advantage of the technological change. The connectivity will have to be ubiquitous with the ship builder, ship designer, maintenance yards and the operational authorities.

One will have to go beyond the hype being created with respect to Industry 4.0 based solutions and ensure right resources (people, organizations, processes) and safeguards are put in place. The changes will have to be made at the strategic level as well at the tactical level. The challenge is to create a seamless communication and collaboration structure across all hierarchies. In the present system once the ship is delivered to the navy there is no real time feedback loop to the designer to have an authentic operational and exploitation database to validate efficacy of his Industry 4.0 enabled design.

3.4 Technical Challenges.

Though some of the aspects of industry 4.0 are easier to implement such as IoT; Robotics; Analytical AI solutions (consistent with cognitive intelligence); etc, there are many which are yet to mature fully such as metal 3D printing; autonomous operation (needing advanced level of AI).

Many elements of Industry 4.0 require more research to deal with different technical challenges to be solved and hence are a bit far into the future as on date, unless some new ways of mathematical modeling/mimicking human behavior is discovered. The key is creating a digital thread, a synchronized body of information that encompasses the entire supply chain, and builds into what has been called a 'single version of the truth' that governs everything from conception, design and construction, to upgrades and modifications throughout the vessel's in-service life.

3.5 Human Resources.

Availability of skilled engineers to design systems, leveraging the I4 capabilities as well as autonomous systems is the key to the success of the I4 implementation and sustenance. The I4 awareness and training will have to be imparted at all levels in a continuous and continual manner by each of the stakeholders.

3.6 Ethics.

There is a strong debate in progress on ethical aspects of how far one can depend on AI, especially in the military. Google employees' objection to Project Maven is one such recent example. With the human in the loop alongside autonomous systems, is acceptable for almost all countries, but a fully autonomous system, though a bit far in future as on date is worrying many, since none can foresee the pitfalls of a fully autonomous war fighting machine.

3.7 Local Industry Support

As mentioned above the underlying principle of I4 is single source of truth with ubiquitous collaboration between all the stakeholders including the local industry, therefore there would be a need to invest in I4 technologies by all the players in a manner that the communication in all the axes is seamless.

3.8 Data Storage, Privacy and Confidentiality

Another area of concern is the way Data is stored in the cloud and the access to the sensitive data based on the roles and the responsibilities. The trust in the system will have to be built up where in the access based control has to be clearly demonstrated to all the stakeholders. This aspect would need attention and effort from the top management at all times.

3.9 Cyber Security - Secure communications

The threat in the cyber space is directly proportional to the increase in digitalization of the militaries worldwide. One has seen how viruses/trojans etc have wreaked havoc in the mission critical systems. With the AI enabled adversaries, the cyber intrusions may go unnoticed for a long time, only to be realized when the damage has been done. In order to have an upper hand in this technology war, one will have to invest considerably in AI enabled solutions, so as to be smarter than the adversary, who may be a state or a non state actor. The AI based systems are expected to autonomously protect networks, programs and data from unauthorized access.

3.10 Indian environment- unique challenges

Indian environment has its own challenges as enumerated by Analytics India online magazine (Hebbar 2018)

a) Lack of enabling data ecosystems:
b) Low intensity of Industry 4.0 research
c) Core research in fundamental technologies
d) Transforming core research into market applications
e) Inadequate availability of Industry 4.0 expertise, manpower and skilling opportunities
f) High resource cost and low awareness for adopting industry 4.0 in business processes
g) Unclear privacy, security and ethical regulations
h) Unattractive Intellectual Property regime to incentivize research and adoption of Robotics, AI, ML Big data, 3 D printing, etc.

The Government and the private sector in India will have to plan for developing this important human resource and structure the initial curriculum and training to have a large enough pool of such engineers, experts in AI, ML, DL, Robotics, Communications, etc, who could develop Industry 4.0 enabled systems.

4.0 Indian Government/Navy Initiatives

India was one of the top economies of the world from time immemorial, (one of the reasons of attracting so many invaders), until the industrial revolution, when the then rulers did not allow the intelligent, fertile and innovative mind to come forward and be part of that revolution. The effect of the same could be felt even after independence for many years, until the IT revolution where some pride could be restored in the software sector since the beginning of the 21st century.

The Government of the Day did not want to miss out on the Knowledge revolution and rightfully recognized the need for Industry 4.0 in India. Indian Government's seriousness could be gauged from the Indian Prime Minister Narendra Modi speech at the launch of Centre for the Fourth Industrial Revolution — the fourth in the world after San Francisco, Tokyo and Beijing, of the World Economic Forum on 11 Oct 2018, wherein he noted that artificial intelligence, machine learning and internet of things and all the other components of Industry 4.0 will have the ability to transform for the present and future of human life (Hebbar 2018).

The authors are of the view that technologies and the knowledge at this Centre will also help the Naval sector in India, in enhancing their defensive and offensive capabilities.

The Government's think tank Niti Aayog (Kumar 2018) has been tasked to initiate national programmes to direct the Government's effort in the areas of industry 4.0, including research and development of its applications.

Adoption of Industry 4.0 is expected to double the industrial manufacturing by 2022 including the shipping eco system (Kumar 2018). Nomination of Central Manufacturing Technical Institute (CMTI 2018) as Centre of Excellence for Research and development and in Industry 4.0 is a step in right direction.

The Department of Defense Production (DDP) has, in Feb 2018, constituted a task force headed by the Chairman of one of the most respected and reputed company in India, Tata Sons, to study the use of artificial intelligence, which it believes has potential to provide military superiority. The Chairman will lead a 17 member task force, comprising of National Cyber Security Coordinator; representatives of Army, Navy and Air Force; CMD of Bharat Electronics Limited; and many others including representative from Space, Atomic organizations as well as academia.

5.0 Recommendations

The Industry 4.0 penetration into the Indian Navy is miniscule, considering the advancements made by other developed nations and adversaries. The present Government's seriousness can be gauged by the initiatives taken at the topmost level, as mentioned in the earlier section. However, certain recommendations are made in the succeeding paragraphs for the Indian Navy.

5.1 Strategy Document.

The first and the foremost tasks that should be given priority is preparing an Industry 4.0 Strategy document, clearly articulating the vision, mission, objectives and roadmap for the near term and long term goals, by a team drawn from all the stakeholders, especially the end user - Navy.

5.2 Doctrine for AI warfare.

Since there is going to be a paradigm shift in the way future wars are going to be fought once the new technologies are inducted into the military, India needs a new doctrine on the usage of AI/robotics technologies, that will have to flow from the strategy document.

5.3 Available expertise.

Map the available expertise within the country, who are working in Industry 4.0 - AI and supporting fields, at different levels - the individuals, entrepreneurs, startups, MSMEs, Large enterprises, Academia, R & D organisations etc.

5.4 Infrastructure for Data.

The backbone and success of Industry 4.0 is data and the underlying networks. As IoT, AI, robotics applications grow in the Navy, the data storage requirements are going to rise exponentially and hence secure and cyber threat proof systems have to be put in place to store this data at multiple places for redundancy and create robust infrastructure to protect the same. For example, complex neural networks, which are generally data intensive, need to have a vast and flexible storage infrastructure in line with their computing resources. A well thought out and right storage framework is the need of the hour.

5.5 Hardware Solutions.

Whilst the Indian software expertise has achieved remarkable progress, a very strong emphasis has to be put on the hardware as well. The Government's push in terms of appropriate incentives can accelerate the development of hardware in India.

5.6 Human Resources.

In this new domain of Industry 4.0, not very many military personnel have yet been exposed to this new technology or educated or trained. In addition to investing in infrastructure, Navy will also have to focus on getting the right people such as Robotic engineers, additive manufacturing specialists, data analysts, data engineers and researchers. They hold the key to their success in Industry 4.0 domain.

5.7 Identification of Industry 4.0 Applications.

At a time when AI and automation cover so many different applications, it can be difficult to **know where to focus.**

The experts opine to invest in AI capabilities for tasks with rules or patterns that are predictable and difficult to disrupt. This will give more confidence amongst users. The tasks/processes which are rule based, but performed manually within the defense environment may be taken up first, as the chances of success are large. With success acting as a catalyst, it will encourage users to seek solutions to more complex problems as well.

The tasks with indescribable or unpredictable rules could be taken up late.

5.8 Human in the loop.

Whilst there are still debates ongoing about whether to make weapons systems fully autonomous or keep humans in the loop, in a military environment where there are no runners up, the author is of the view that initially, it is essential to have human in the AI loop where routine number crunching is preformed with AI that supports quicker decision making by the human in the loop, especially in the unpredictable world.

5.9 Industry 4.0 Training.

As India is on a mission to embrace Industry 4.0 as quickly as possible and with anyone and everyone talking about Industry 4.0, it is important for the Naval personnel to have an understanding of AI, ML , Robotics etc. The depth and breadth of such an understanding will vary, depending on the person's hierarchy, and his involvement with Industry 4.0 enabled products/systems - at design, operational or maintenance level. Appropriate training modules could be embedded in different courses all over the training institute.

5.10 Robotics.

AI is the most essential element in autonomous robots which are vehicles for AI to function/perform efficiently. This field also requires equal, if not more attention, so as to draw the full benefits of AI. It is finally the robotic soldier that is going to face the bullet in the battlefield and if a nation has built this capability, it will save precious human lives.

6.0 Conclusion

The fourth industrial revolution is here to stay and the paper examined the evolution and adoption of Industry 4.0 and its impact on the maritime sector in general and naval sector in particular. With that backdrop the paper looked at the challenges faced by the developing navies, (especially in the Indian context), and made certain tangible recommendations.

It is opined by the authors that the most viable model to embrace Industry 4.0 would be a calibrated transition approach where in the developing navy would ease into the digital ecosystem gracefully and incorporate the lessons learned in a step by step manner. The real success would be when the top management as well as the lower echelons is equally amenable to the transformation, if this is not the case then one can expect less than favorable outcomes.

7.0 References

Accenture. 2017. Maritime in the new., Accenture report. London. on 2019 Aug 10]. https://www.accenture .com/t20180209t060907z__w__/in-en/_acnmedia/pdf-71/accenture-digital-shipbuilder-pov.pdf.

Ang, Goh et al. Energy efficient through Life Smart Design, Manufacturing and Operation of Ships in an Industry 4.0 Environment. 2017. [accessed on 2019 Jun 01]. *Energies* vol 10, issue 5. http://eprints.gla.ac.uk/140487/

[BCG] Boston Consultancy Group. Embracing Industry 4.0 and Rediscovering Growth. 2017. Boston USA: BCG Report. [accessed on 2019 May 25]. https://www.bcg.com/en-in/capabilities/operations/embracing-industry-4.0-rediscovering-growth.aspx.

[CMTI] Central manufacturing technology institute. Smart manufacturing demo and development cell. [accessed on 2019 Aug 10]. http://cmti-india.net/?q=smddc

[DIIS] Deptt of industry innovation and science, Autralian Govt. 2019. Industry 4.0. Australia. [accessed on 02 Jun 19] https://www.industry.gov.au/funding-and-incentives/manufacturing/industry-40,

EAP. 2018. Huntington ingalls transforming the shipyard. [accessed on 2019 Jul 18]. https://digital.hbs. edu/platform-digit /submission/Huntington -ingalls-transforming-the-shipyard.

Eckstein, Megan. 2016. Huntington ingalls pursuing digital-only blueprints amid navy innovation push. USNI News. [accessed on 01 Jun 19]. http://news.usni.org /2016/02/23/petters-huntington-ingalls-pursuing-digital-only-blueprints-amid-navy-innovation-push.

Gates D, Bremicker M. Beyond the hype: Separating ambition from reality in Industry 4.0. 2017. UK: KPMG Report [accessed on 2019 May 25]. https://home.kpmg/be/en/home/services/advisory/management-consulting/industry-4-0.html.

Hebbar P. 2018. Industry 4.0 Has The Ability To Transform Indian Lives. Delhi, India. [accessed on 2019 Aug 05]. https://www.analyticsindiamag.com/pm-modi-industry-4-0-ai/

Hebbar P. 2018. What Does The Industry Say About NITI Aayog's AI Strategy Report. Delhi, India. [accessed on 2019 Aug 05]. https://www.analyticsindiamag .com/industry-views-niti-aayogs-ai-strategy-report/

Kumar R. 2018. Strategy of new India @ 75. India. GOI, Niti aayog strategy document.

Lamas P, Diego N, Tiago M, Caramés F, Manuel A, Díaz B and Vilar M. 2016. Smart Pipe System for a Shipyard 4.0. Sensors. [accessed on 2019 Jun 10]. https://pdfs.semanticscholar.org/3dab/68b204e6146f3ff017153bcd87ebb6b3b44d.pdf.

LR: Global Marine Trends 2030. 2019. London: Lloyd's Register group; [accessed 2019 May 22]. https://www.lr.org/en /insights/global-marine-trends-2030/

[NT] Naval Technology. 2018. The digital naval shipyard. [accessed on 02 Jun 19]. https://www.naval-technology.com/ features /digital-naval-shipyard/,

[OE] Offshore Engineer. The Digital Twin Evolution for Offshore Wind. 2018. New York USA: AtComedia, Inc, [accessed on 02 Aug 19]. https://www.oedigital.com/news/443249-the-digital-twin-evolution-for-offshore-wind.

Renjen P. How leaders are navigating the Fourth Industrial Revolution. 2019. United States: Deloitte report [accessed on 2019 May 25]. https://www2.deloitte.com/us/en/insights/deloitte-review/issue-22/industry-4-0-technology-manufacturing-evolution.html,)

Sharma AM. 2019. Industrie 4.0. Germany: Federal Ministry for Economic Affairs and Energy, [accessed on 2019 May 10]. https://www.gtai.de/GTAI/Navigation/EN/Invest/I ndustries/Industrie-4-0/Industrie-4-0/industrie-4-0-what-is-it.html#1798432

Siemens. Thinking ahead to the future of industry. 2018. Germany: Siemens report. [accessed on 2019 May 25]. https://new.siemens.com/global/en/company/topic-areas/digital-enterprise.html.

Storhaug G. Digital twins and sensor monitoring. 2019. Oslo, Norway: DNV GL [accessed on 02 Aug 19].available at URL, https://www.dnvgl.com / expert-story/ maritime-impact/Digital-twins-and-sensor-monitoring.html

Tanja R. Digital twin block chain. 2017. Germany: SAP new centre, [accessed on 2019 Aug 02]. https://news.sap.com/2017/05/sapphire-now-digital-twin-blockchain

8.0 Bibliography

https://news.thomasnet.com/featured/exoskeleton-prototypes-sent-to-us-navy-special-command/

https://www.youtube.com/watch? v=Y4Q1 6LB XC9 c&feature=youtu.be

https://www.youtube.com/watch ?v=VMKFzP-wVlY

https://www.sentryo.net/the-4-industrial-revolutions/

Quinn S, ‘Artificial intelligence system helps Navy select the best tactics for ship defense’, available at URL https://www.ll.mit.edu/news/artificial-intelligence-system-helps-navy-select-best-tactics-ship-defense