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Delivering Digitalisation and Digital Transformation of Seaports, Shipping and Supply Chains: How Realistic are the Prospects and Opportunities of the 4th Industrial Revolution among Challenges of Climate Change Uncertainty and Other Emergent Risks.

KEYWORDS: Digitisation; 4th Industrial Revolution, maritime technology; risk management, climate change, cybersecurity;

ABSTRACT

In response to existing supply chain and economy challenges for maritime stakeholders; technology and the 4th Industrial Revolution opportunities are emerging. The future of logistics in a digital era, is being radically transformed by new trends, yet few stakeholders have a coherent, comprehensive future vision for their role in it. Increased digital disruption creates new challenges and opportunities. Examples include social media, Drone deliveries, robotic sensors, Internet of Things, Big data and quantum cloud-based storage holograms, augmented and mixed Virtual Reality, digital immersion and sensory isolation from reality, AI, nanotechnology, biotechnology and cybernetics and others reflect just a few trends with possibilities. It includes blockchain technology to reduce physical vulnerability of a single data storage and enhanced cybersecurity This structured literature review and case study seeks to identify and examine these trends, directly applied to maritime supply chains, seaports, shipping and related stakeholders to fundamentally investigate the extent to which these can provide solutions to emerging problems. Or with fears of cybersecurity, mass unemployment, sensory deprivation; increased need and vulnerability of systems to external risk events e.g. electricity and Internet disruptions without sufficient manual redundancy, do they accelerate certain risks and concerns?

Limited research has focused on connecting digitalisation to physical asset protection or risk management. Given high unemployment and poverty, implications of labour-intensive economies of production and consumption, more superfluous employment, automated vessels, systems, risks of mechanisation and social stability, stakeholders need to consider digitalisation risks. Not everything can be resolved by outsourcing and technology assuming customers and employees are all proficient. What are the opportunities? This paper considers the following core research questions as essential to deliver digitisation and digital transformation of maritime supply chains. *KRQI: What are the current and future digitisation and digitalisation trends across seaports, shipping and supply chains? KRQII: To what extent can digitisation and related trends resolve emergent risks such as climate change, marine pollution, cybersecurity, predictive risk management/maintenance, the circular economy, congestion and other stakeholder concerns?*

KRQIII: What are the projected limitations and constraints to digitisation and digital disruption in resolving emergent risks and concerns." It proposes a hypothetical case study example to quantify potential implications of digitisation trends across an entire supply chain. It aims to investigate its technical, economic and eco-sustainable/climate resilient feasibility. This aids stakeholders in determining the extent to which they are or can become aware and prepared.

INTRODUCTION

In an increasingly globalised epoch, digital disruption, vies with restricted access to maritime finance climate change, cybersecurity and sustainability/circular economy including LNG fuel conversion; as competing priorities for ever-shrinking profit margins, constrained resources and attention-spans of maritime sector stakeholders. Without our ocean highways, vessels, seaports; stakeholder and marine ecosystem resources, the infrastructure, superstructure, assets and systems; over 90% of international trade would paralyse. Increasing globalisation has increased greater dependency on the ocean economy, providing livelihoods to over 3 billion people. An increasing percentage reside or depend upon coastal environments, locations, resources and networks, to flourish and exist. In 2015 Earth's oceans were worth over $24 trillion. Formal economic activities are projected to increase from $1.5 trillion in 2010 to over $4.5 trillion by 2030. Through increasing emissions, sea levels, temperatures, ocean acidification; species migration and extinction, storms, droughts, heatwaves, floods, tsunamis, gales, cyclones, bushfires and other risks, climate change increasingly threatens a business as usual scenario future (IPCC 2015). the world economy lost over $2.8 trillion between 1970 and 2014 through climate-related disasters in direct physical infrastructure damage. Each year is expected to cost a minimum of $250-300 billion in further direct economic infrastructure damage, without additional disruption or adaptation costs.

Comparatively few sources have focused on digital disruption and the 4th Industrial Revolution implications across the future of seaports, shipping and maritime supply chain (MSC) stakeholders from a holistic and integrated supply chain perspective. Nor have existing climate change mitigation, adaptation and risk management sources frequently considered employing or utilising technology as an effective series of climateproofing strategies (Dyer 2018). This research's unique contribution is to project a scenario of the extent to which current global digital technologies can potentially assist or hinder effective risk management across an entire maritime supply chain for climate change, sustainability, maintenance and other emerging/historic risks. Its core objective is to consider how realistic are prospects and opportunities of the 4th Industrial Revolution. It aims to provide guidelines to assist stakeholders towards a more practical implementation or delivery of digitisation and digital transformation of seaports, shipping and supply chains.

Intro (2 pages), 1.5 pages -method; 10 LR; 7 results, 1.5 conclusions, 3 references

Section II's Literature Review aims to identify *KRQI: What are the current and future digitisation and digitalisation trends across seaports, shipping and supply chains?* Section III outlines the method of an integrated climate risk-vulnerability and impact cost model and the same maritime supply chain (MSC) model digitally transformed via potential 4th Industrial Revolution

Applications Section IV provides a case study of this hypothetical MSC linked to core risks, disruptive impact costs and aligned constraints/solutions. This paper considers the following core research questions as essential to deliver digitisation and digital transformation of MSCs. *KRQI: What are the current and future digitisation/digitalisation trends across seaports, shipping and supply chains? KRQII: To what extent can digitisation and related trends resolve emergent risks such as climate change, marine pollution, cybersecurity, predictive risk management/maintenance, the circular economy, congestion and other stakeholder concerns? KRQIII: What are the projected limitations and constraints to digitisation and digital disruption in resolving emergent risks and concerns."* Section 5 identifies core research findings and recommendations, study limitations and future research directions. This research provides the first physical evidence-based approach of technology's capacity to resolve common maritime stakeholder challenges or requirements/concerns. Simultaneously this strives towards futureproofing against climate related and other disruption risks and exploiting blue economy emerging opportunities via digitisation trends.

2: Literature Review

Current literature focuses on identifying technology and related applications, along with the importance of integration and collaboration for digitalisation in supply chains (Feibert, Hansen and Jacobsen 2017). Motivations for digital transformation are emphasised as primarily economic, efficiency, customer and competitiveness driven (Nkuna 2017). UNCTAD mentions capacity to achieve the Sustainable Development Goals as another reason to consider embracing technology beyond optimisation and enhancing existing supply chain efficiency/performance, or new possibilities and the final transformation of logistics, trade and economies (UNCTAD 2018). Digital Disruption does have certain advantages. For example in Rotterdam port; a 30 minute reduction in port congestion or time saved a $160 million euros per year including 50 million in reduced port shift time, 7 million in direct incidents and 2 million euros for shipping companies (British Ports Association 2019). APMT operated the first automated terminal in Rotterdam in 2015. Parallel developments in automation and digitalisation technology are occurring across Japan, China, Antwerp London Tilbury Container Terminal, Montreal Port Authority and elsewhere ((Verstraelen 2019; Armin 2019), creating competitive pressures not just cost reduction and enhanced productivity. Reduced crew and reconfigured engine space will provide more cargo space. 3D printing, LNG and technology will require more raw resources and reduced containerised cargo. Digital supply chains will need to be efficient, agile and as flexible as non-digital alternatives to become popular and implemented (PWC 2016).

What will this Digital Age mean? Stakeholders radically require alignment to digitisation consequences. It means identifying what their requirements and expectations are, as in Table I and how best to resolve them. To address KRQI: "*What are the current and future digitisation and digitalisation trends across seaports, shipping and supply chains?"* this means determining what are these phenomena, how will it affect us and future of global maritime business. It means interconnected Smart Ports and supply chains (Royal Haskoning DHV 2017); PWC 2016; Deloitte Port Services 2017; Sanchez-Gonzales et. al 2019). It means how to process high volumes of information rapidly to extract necessary information, being updated to new events, news and threats or factors affecting performance as they develop (BNV 2017; CGM-CMA 2017; Europort Daily News 2017; Smith 2018). Warehouses and many other supply chain stages can become even more automated, enhancing efficiency, reducing congestion and adverse externality costs. Digitalisation of logistics includes using chatbots to provide customer service. Cryptocurrency offers more flexibility in payments. Greater emphasis is placed on customised experiences, eCommerce and 3D printing; introducing reverse logistics in a circular economy. It includes beyond simply assuming only basic website access and partial transmission of data in a Port Community System or Electronic Data Interchange for submitting information. Marketing and networking become increasingly important.

Table I: Aggregated Digitisation and Maritime Supply Chain Stakeholder Requirements

Expectations of a Digitisation Provider	Commercial/Community Expectations
Provide sufficient information	Availability
To Consistently update information	Promptness/swiftness of services/infrastructure
Security	Allocative/Productive Efficiency
Cost Competitive	Functions are modernized as much as possible
Productive/Efficient – swift and accurate processing	Direct service/transport connections exist
Reliable/frequent functions of sufficient quality	Productive, trained labour responsive to needs
Satisfying unusual requests – altering schedules/ flexible to changing circumstances	Sufficient Capacity exists Efficient – utilises capacity/economies of scale
Sufficient quantity of functions exists	Commercially profitable
It satisfies marginal caller requirements	Equitable in satisfying the user pays principle
It avoids delays/strikes etc	Minimises negative externality/congestion costs

Digitisation trends in logistics and MSC has only emerged as a research trend since around 2009. An early study focused on technology and supply chain risk management via sensor-based telematics (Skorna, Wagner and Bode 2009). It identified 7,284 insurance claim causes from risk events, dominated by crime, cargo rough handling and environment/climate as most frequent risks. Technology was identified with potential to enable cargo tracking and tracing, condition monitoring and communication enhanced via information sharing. As with other sources; true impact can be measured by how much difference adding technology makes to core performance indicators. In one shipping line the source argued sensors were present for reefer cargo to regulate temperature. Sensors reduced waste by 50% and ruined goods by 36%. Digitisation of shipping currently emphasises the most significant benefits as enhanced efficiency via automation, organisation and integration of people, vessels and shore operations globally (Ando 2017). This is often applied to the Internet of Things, divided into operational or physical and information technology. It requires the capacity to process "Big Data," often stored not only on individual computers but via an online "Cloud" or series of "Clouds" remotely. The aim remains to minimise disruption time, maintenance and fuel or energy inefficiency costs via enhanced remote sensors. This can extend to risk events via greater sensory awareness and ability to diagnose or forecast potential risks along with asset lifespan available as affirmed in Section IV. Examples can assist vessel warehouse and shore logistics cleaning, upgrades, coordination of cargo operations, improved safety and optimised performance, whilst simultaneously reducing adverse externality/environmental costs.

The 2016 World Economic Forum viewed digitisation benefits as worth US 1.5 trillion by 2025, with predictive analytics swiftly accelerating in usage to assess market demand, supply, bookings, vessel deployment, routes and management. It argues benefits of electric battery port equipment and vehicles; telematics for fuel, health and safety management plus dynamic scheduling (International Transport Forum 2019). The EU have created a harmonised electronic cargo declaration and e-Manifest. Singapore, Rotterdam and other ports have devised a Port Community Management System to try and coordinate a single source for data submission to save time, resources and physical paper risks. Blockchains, telematics and the Internet of Things provide the need for reduced paperwork, optimised vessel and berth usage and reduced idle-deadweight capacity across intermodal transport. MSC's may gain from greater use of e-ecommerce platforms and digital container tracking platforms. One case study focuses on blockchains to ensure commercial smart contracts, protect documents and offer flexible payment options via cryptocurrency (Manzano-Salmeron and Manzano-Agugliaro 2019). It reduces congestion and cybersecurity risks with less altered or lost data, reduced fraud and greater traceability. Blockchain can aid consumers to identify origin and more product information for ethical consumption; digital signature security, data transparency, verify smart contracts and property rights (DHL Trend Research 2018). It can aid customs, many of which are still operating manually globally. One prototype application included protecting information among a pharmaceutical supply chain with over 1500 transactions per second and over 7 billion unique serial numbers. It reduces each supply chains' waiting time via instant confirmation of arrival. Yet not all stakeholders have access to the needed resources.

More academic institutions such as NHH in Bergen and even the International Association of Maritime Economists are focusing more on digitisation and modern technology's potential for MSC's although not in this study's research gap of climate change and other emergent risk management. Existing research focuses primarily on identifying specific technology applications and implications for MSC's rather than specifically targeting climate change and other risk management processes. Business operations will change via "Smart Ships" "Smart Fleets" and integrated "Smart Global Logistics" (Stopford 2016). This could mean using mobile apps to reduce need for access to higher level computing systems for greater flexibility. Technology provides feedback loops -continuous learning and responding of supply chain staff. Smart Ships include greater automation and connectivity of various components. Smart fleet includes being easier to coordinate a series of vessels, crew and operations simultaneously. One study investigating 15 technology trends focused on Northwest European MSCs (Carlan et al. 2018). Each digital technology involved was assessed for specific criteria including feasibility, progress in implementation, data type, stakeholders and potential benefits. Examples include trade facilitation via increased cargo monitoring/traceability via a Data Hub. Enhanced information/movement of documents and communication is facilitated via blockchain, a Port Pass, Xynaps and optical character recognition. Digital financial innovations include a smart letter of credit, essDocs and

Bolero technology applications. The aim is to reduce risks of losing or misinterpreting documents, enhance cargo safety and security, ensure greater asset utilisation and risk management.

Table II: Northwest Europe MSC Digital Technology Applications

Product	Purpose/Use	Supply Chain Stages	Status, Data Collected
Antwerp Port Community System -Enhance competitiveness	EDI equivalent, centralise port functions	Port/Logistics/Shipping Aids customs declarations	Implemented, Collects Cargo/Nautical information
Nxt-Port -operations performance and information dashboard	Data sharing among port users	Port/Logistics/Shipping	Initiating -creates value added data, integrates truck, cargo, nautical data
Cargo Stream -increase vehicle fill rates bundled with shippers	Cargo data integration, reduce pollution, congestion	All MSC stakeholders	Initiating, Collects transport tariffs, cargo and truck information
Depot X Platform -reuse import containers for export/inland on a user pays principle.	Optimisation of cargo equipment, reduce congestion/ waiting	Logistics, Shipping	Implemented -collects cargo information
Euro-Trans-Con -exchange container rides to reload empty ones, share data	Communication and data sharing, reduce emissions	Logistics	Initiating -single truck appointment system, Collect truck/cargo data
Temperature Tracking Sensors -digital tachographs	Cargo preservation, emissions reduction	Logistics, Shipping	Implemented -cargo information integration
Optical Character Recognition	Reduce costs and paperwork	Logistics, Shipping	Initiating -collects cargo/container information
Xynaps -cloud based logistics data sharing platform	Share information, transparency, security	All	Initiating -digital signatures for documents
Blockchain	Reduce intermediaries	All but freight forwarders /importers, Exporters	Cargo, payment, documents Initiating
Port Pass	Security -simplify import/export process	All	Initiating -cargo information, tariffs, logistics data

Source: Adapted from Carian et. al 2018.

MSC case studies are primarily restricted to shipping rather than the entire supply chain system or individual stages ((Aro and Heiskari 2017). Project examples include Rolls Royce, MUNIN, REVOLT and the Yara Birkelund. Rolls Royce are focusing on remote operated vessel technology initially with systems risk monitoring to eventual navigation and engine movement. The EU MUNIN project aimed for a similar vessel on deep-sea voyages controlled by land to configure fuel efficiently and claiming greater social benefits for shore-based crew. It estimated savings of $7,000,000 over a vessel's average 25 year lifespan, reduced collision and fire risks. REVOLT provides a DNV GL battery powered vessel without any seafarers necessary for coastal shipping, forecasting 31,500,000 euros saved in 34 years. The Yara Birkelund is a Norwegian 100-150 TEU, electric battery powered autonomous container vessel to replace 40,000 equivalent truck journeys. Continuous voyages without maintenance and frequent hazard exposure provides current technological limits. Yet as Section III will emphasise, all MSC stages can be transformed by various trends. 3D printing will influence industry, from product design to sourcing, production, distribution and end of life/recycling; creating higher demand for raw materials but fewer for finished/assembled goods (Moavenzadeh 2015). It will involve customisation and print to orders without moulds, casting and machining, faster and no inventory costs but with higher fabrication costs. Cloud computing via a shared economy reduces the need for hosting one's own system. Autonomous vehicles and drones will create more flexible deliveries.

Drones are frequently perceived as more cost-effective to build, purchase and operate than piloted technology and vessels. As economies of scale and production develop, drones are estimated to become even cheaper and profitable to users; providing more flexible deliveries. Drones are considered to save maintenance, operating and risk monitoring costs for oil/gas pipelines, surveys and other underwater assets. It can aid renewable and other energy and plumbing/sewerage networks. Financially, they can investigate mineral/other resources and aid in insurance risk. Drones are perceived as quieter, less emissions intensive and producing fewer environmental costs than heavier, manned equivalents. Environmental and research advantages will enable greater monitoring of pollution, climate and ecosystem conditions for continuous risk assessment and awareness, improving responsiveness and adaptability to climate change and other emergent risks. It improves ecological awareness and responses to sustainable ocean resource management. China has realised economic sovereignty of the future can only be ascertained and secured through investing in intelligence, surveillance and reconnaissance (ISR) capability with drones. This provides martial security and research advantages simultaneously. Its Undersea Great Wall Project aims to provide a state integrated sensor and vessel subsurface oceanographic observation network, capable of recording data including drones. It includes sensor nodes, ground stations, drones, ROV's, satellites, patrol vessels, underwater working stations and seismic monitoring system.

The Japanese government and NYK shipping line collaborated on a 2016-2020 project to digitally augment vessel safety via autonomous collision avoidance and navigation (Arno 2018). It included remote sensors of propulsive efficiency, cargo crane conditions and structural monitoring with engine damage prevention systems and a multi-layered Doppler log. Technology needs to link more to real time climate and environment risk monitoring to satellites and meteorology agencies. All vessel components including engines need continuous diagnostic sensors. Other proclaimed digitisation benefits are enhanced safety via fewer collisions and making operations less labour intensive for crew, reducing existing crew fatigue but more controversially leading to fewer crew required. It also provides greater component redundancy against climate damaged systems. Contemporary research claims greater situational awareness but provides limited conclusive evidence. Capacity for onshore support is not always practical for immediate responses.

Certain nations are seeking to embrace the 4th Industrial Revolution and a technology future for the maritime sector/ocean economy. The UK government proposes needing smart ports, research clusters and a continuously updated and educated workforce/maritime vocational awareness to remain globally competitive, more eco-sustainable and consider increasing population/migration growth pressures. It argues the need for an autonomous vessel policy and other regulations plus support for unmanned shipping prototypes such as SEA-KIT unmanned vessel. Technology can aid pressure for security, customs and law enforcement, safety and risk monitoring. It mentions the need for an updated, retooled, aware and prepared maritime labour force with new skills and experiences; addressing high staff turnover and continuous learning or professional development. It highlights the risk of over 1.6 million seafarers with existing low labour costs that could be automated but over 7 billion people with only finite reabsorption capacity into other formal sector employment of comparable or higher worth. It targets 0 emissions shipping as a goal by 2050 following Japan's testing of a 0 emissions solar sailed vessel. It formed a UK pilot National Maritime Single Window as a single point Electronic Data Interchange. It concedes with concern however, that many technology types are still in prototype development phase, yet to prove themselves over a longer timeframe. Its future vision is for more prosperous and efficient MSC's, interconnected by the Internet of Things, powered by marine renewable energy, high automation a greater use of more resilient composites/nano and biotechnology materials to enhance vessel performance and sustainability.

The Philippines 4th Industrial Revolution approach is to identify the need for more coordinated research and development, education, finance and policies to benefit from technology ((Dadios et al 2018). The source estimated potential of $1.7 trillion arose from the Internet since inception. 1 trillion devices could be connected by the Internet of Things, a 300% increase from 2013-2018 alone. It is becoming more economical with 80-90% decline in sensor costs. 3D domestic printer costs have decreased 90% in 4 years. The actual costs and benefits of these digital technology trends has yet to be calculated for MSC operations, performance and risk management. Examples include drones, automation, mobile apps, AI, IOT, blockchain, Big Data, robotic, nanomaterials, 3D printing, biotechnology, additive manufacturing and neurotech, cloud computing, energy storage, synthetic biology and cryptocurrencies. It estimated these technologies via prescriptive and predictive analytics should follow pervasiveness, continuously improve in performance over time and spawn innovations continuously as a catalyst. As seen in case studies for AT+T, Deutsche Telekom, EIT Climate, T Mobile and Verizon (GESI 2019); digitisation can aid communication and information sharing; providing more capacity for humans to prioritise limited attention, time and resources via monitoring and evaluation. For example, only 2 people are needed at Canada Dock Liverpool steel terminal. Dover's Blip-Track can monitor nearby traffic to reduce congestion and logistics waiting times (UK Department of Transport 2019).

Digitisation will focus on capacity optimisation and performance management significantly reducing the number of MSC stages and operators by 2030 (Danish Ship Finance and Rainmaking 2018). The source tracks 36 digital start-up business models focused mostly on providing increased traceability/transparency and risk monitoring ((Danish Ship Finance and Rainmaking 2018). Tech companies such as Google, Amazon, Facebook, Tesla, Huawei and Tencent will require fewer, larger vessels and seek to acquire their own vessels for greater supply chain integration, sustainability and influence/reliability. They will enjoy first move advantages due to greater technological familiarity and literacy. Algorithms will be more accurately able to recalibrate changing cargoes and stakeholder requirements. Shipowners remain vulnerable to other transport types and security over data ownership. Digitisation has potential to aid MSC small and medium enterprise stakeholders as sharing in greater benefits from increased collaboration, risk management, finances, data sharing and interaction (Mafini and Muposhi 2017). One survey example involving 243 Gauteng South Africa participants discovered the extent to which risk and communication aid risk management and risk management aided financial performance, given technology. However, this will require greater cooperation, coordination and a degree of trust. The need to retain competitive advantage will require digital transformation and interaction with people -staff, customers, suppliers and others to be continuously updating, training, available and engaging with progressively shorter attention spans. It means opening up to a changing workforce, considering Toffler's Future Shock as to how adaptable and aware we to this changing pace of digital disruption and how can we survive.

The future of the global logistics industry under technology has been depicted under various scenarios (PWC 2016) to exploit recent technology trends, facing new competitors and changing customer expectations. Customers want free or cheaper shipping costs, care more about customisation and more diverse, smaller shipments. -sharing economy and collaboration. Stakeholders act autonomous of conventional shippers/logistics. Identified risks exist over data privacy/security, lack of digital standards and norms, slow infrastructure growth, scarce human resource talent, uncertain long-term profitability of investing in new technology and IP losses to competitors etc. One company predicted 100-300 billion euros to Europe from standardisation and embracing technology (Reed Smith 2019). It conducted a digitisation survey -67% Europe, 0% non-Sub-Saharan Africa, 2% Oceania; 10% North America; dominated by owners and professional services. 40% favoured big data analytics, 20% blockchain and 40% environment/emissions technology as most significant concerns. Many favoured automation to ensure availability at ports, reduced voyage/port lag times, fuel, climate, repairs and other costs. Invested technology primarily focused mostly on IMO Sulphur cap target compliance rather than digitisation trends, i.e. via scrubbers etc. Only 5% found digitisation to be the greatest challenge,18.3% stagnant demand, 15% fuel emissions and 6.7% cybercrime.

More research is focusing on the human element and adapting to technology/digitisation connecting with existing systems (Laskarides 2018). There will be a need for fewer crew but more shore based. Roles include new career roles of solution designers, VR trainer developers; infrastructure architects, AI and machine learning operators; drone manager, new marine engineer and big data analyst. Swifter, more predictable decision making will be vital for effective risk management. The 4th IR and labour will create uncertain shifts in employment across all industries from technological disruption enhancing productivity and output (NEDLAC 2019). It will require continuously changing work and education for digital literacy and fluency. Improve quality of jobs and life, provide employment for the more skilled/flexible. Even those sceptical, slow or unable to adapt will be pressurised by those that are not, increasingly favouring technology, finite resource's population pressure and needing to reduce emergent risks/potential disruption costs. Online freight platforms and vessels as "Uber of the Seas" may eventually use technology as able to respond to shippers' more immediate needs. Fewer intermediaries and humans will remain employed.

Blockchain and other risk diagnostics can aid the insurance sector -pricing, risk management and efficiency, at the expense of needing fewer intermediaries

What does it mean to the future of employers and productivity with sensors monitoring health, habits and behaviour, high information processing and increased needs to be flexible yet sensory deprived from the real world? Companies and individuals will need a workforce that can master IT, adapt, become proactive, procreate -programming and updating information continuously; flexible working arrangements as people expect virtually immediate responsiveness and accessibility. With more usage of technology, however companies will be able to focus more on quality, customised logistics and personal customer service eco-sustainability, reducing waste, pollution, carbon footprint offsetting and corporate social responsibility. This proposal will demonstrate how digitalisation and the 4th Industrial Revolution can assist in reducing these. Technology can assist in minimising inefficiency, relapse and human error, yet it will need humans to retain flexibility and oversight functional capacity. Most technology is only as good as the utiliser. It can reduce congestion, waste, inefficiency, low productivity, maintenance and other costs. Increasing pressure exists to succeed and be hyper-competitive, if companies fail to embrace it, higher probabilities exist they will perish or incur astronomical costs, whether from the threat of digital disruption, climate change uncertainty, marine pollution, human apathy or other factors. It includes moving beyond basic automation to more sophisticated, real time proactive and predictive heuristics for customer service, maintenance, risk monitoring and management. Sensors can monitor and track changing risks and locations, to inform stakeholders.

Few consider how people respond, their perceptions and awareness to digital transformation across an entire maritime supply chain. Current operators have indicated problems with technology however as operators need real time updated data concerning equipment information, congestion and delays, access to weather data; the need for a single data submission system rather than acting in silos and the issues of system interoperability. However, regulatory uncertainty, limited access to finance and human resource areas remain further impediments. Along with LNG, few ports and shipyards in developing nations present the capacity to participate in the Internet of Things, big data and other digitalisation initiatives, causing congestion and other disruption costs. Nor will they have the capacity for the intermediate future to service technical glitches and automation requirements, when issues arise and lacking the trained crew/cybersecurity protection and other concerns, often ignored by existing marketing publicists and other pro-digitisation advocates.

Digitisation sources endorse technology as enhancing efficiency, lowering time and cost via information sharing although issues of integrating diverse MSC stages, technologies and stakeholders presents challenges along with policy uncertainty, needing sufficient awareness and adaptation training (International Transport Forum 2018; UK Department of Transport 2019). Persuading stakeholders to voluntarily cooperate can be complicated. Data ownership, access and risk exposure presents further vulnerabilities. However, certain challenges exist towards delivering digitisation, its potential benefits and risk management capacities. There is a significant reluctance of maritime industry to embrace technology due to risks of high initial investment or sunk costs as barriers to entry; need for training, and low profit margins. Others incorporate issues of insurance and finance gaps; compatibility with existing systems; ensuring system familiarisation and ease of use. Port community systems depend on “Big Data” to be collected, analysed and communicate. Existing data often lacks consistency and common standards. Data still needs updates, coordination, cooperation and flexibility to address unforeseen risk events. Other issues exist including challenges of data privacy, effective results visualisation, ensuring reliability and accuracy and processing data along with issues of data inconsistencies and uncertainty (Dadios et al. 2018).

Disadvantages for drones and autonomous vessels include uncertain probabilities and natures of accidents, collisions, explosions, lithium ion battery range and aerial, surface plus undersea risks. Various technical and legal problems remain with this emergent area for autonomous shipping and vehicles including the unreliability or challenges with introducing the technology itself, the need for continuous updates and international legal restrictions against voyages outside of territorial waters, unless with a crew (Aro and Heiskari 2017). Autonomous vessels are also limited in the degrees of freedom they can flexibly turn. Battery costs depend on maintenance, repair and support.. Drone operation still remain vulnerable to climate and marine environmental challenges but unlike manned vessels, repairs and operations; become far more arduous to adapt from the event. Many commercially available drones operate at slow speeds and ranges. Drones threaten physical and psychological threats; risks of insufficient data storage and cybersecurity, can be intrusive, infringing upon personal liberties whether buzzing vocally or quietly unobtrusive with stealth capacity. humans are necessary to actually act as a deterrent, solicit an arrest or take action. Coordination with other agents can be trysting and ineffective. Even where drones are used; they have been challenged in courts.

Current research focuses predominately on technology in the context of resolving and being vulnerable to cybersecurity risk. It ranked second highest among logistics and shipping risks in 2018 but only 15th in 2013 (Tam 2013). In 2015 cybersecurity incidents lasted 205 days on average. In 2018 this decreased to 140 days (ICS 2018). Cybersecurity investment ensures fewer human risks; reduce accommodation requirements whilst increasing cargo hold capacity Cargo and passenger/crew management, bridge, navigation, communication, propulsion and machinery, hull stress monitoring systems are all vulnerable targets. Technology enables proactive risk management for maintenance, engine, cargo and voyage performance. Various risk determinants are also identified including the presence of multiple MSC stakeholders involved, weak IT investment measures, remote monitored equipment, crew usage of unsecure networks and system/component availability. It lists core vulnerable systems and technologies including satellite communication, wireless networks, ECDIS, GMDSS, voyage data recorders, AIS, Shipboard Security Alarm Systems and Bridge Navigational Watch Alarm System as among several vulnerable technology systems. Vessel cybersecurity guidelines point to high vulnerability by crew and passengers to vessels navigation, cargo tracking, AIS, satellite communications and radar (ICS 2018). Risk of GPS spoofing example of a Texas yacht with a $3000 customised device. Example 2 hacked a banana reefer vessel -to hide a drugs consignment shipment, using a wireless bridge from the port. The source indicates the need for skills, trained staff, processes, awareness and continuous assessment.

Maritime cybersecurity risks focus on distinguishing between OT and IT GPS spoofing and jamming, with vessel components as seperated systems throughout its lifespan (Lagouvardou 2018) but moving towards integration across MSCs. Hyundai -Integrated Smart Ship Solution - navigation by real time data. IMO guidelines -ISPS and ISM Codes are revised recently to avoid maritime cyber risks of safety, security and operational failures (Tam 2019). ICS guidelines for cybersecurity risk management via awarenness and continuous feedback focus specifically on shipping threats including internal software failure and external attacks, needing to identify human responsibilities and vulnerability of cyber-physical systems. Challenges remain in identifying vulnerability; ensuring secure relationships annd data protection throughout suppy chain. Examples include false ship appointments, electronic wire fraud, ransomware, hacking malware, phishing, water holing, scanning, social engineering, brute force and ultimately denial of services, spear-phishing and subverting the supply chain indirectly, delaying operations, aiding in crew kidnapping and other emergent risks needing to be managed if digitisation is to represent the future of MSCs. The method proposes modifying risk management to identify threats then vulnerabilities; assess risk exposure; develop protection and detection measures, establish contingency plans and recover from cybersecurity incidents. One source provided a survey of 55 participants and 22 questions related to cybersecurity and related risks. 80% expressed concern over crew training standards; 56% cybercrime; 50% environmental; 38% piracy. 60% considered duplicates/archives as precautions; 58% firewalls; 48% external risk monitoring as solutions and 42% restricting personnel access to senior/trained operators only. For marine cyber risks, few report incidents, thus limited data and risk event specific, making it challenging to generate reliable, consistent data trends. Certain systems have similar probability of risk failure whether manned or unmanned -i.e. navigation/communication -but there is no one to repair it for malfunctioning devices, with a challenge for risks such as fire as well. It needs to be compatible with labour unions and laws, safety and personal liability, currently conditional upon having a shipboard captain.

Few technology sources focus on how MSC stakeholders can become more efficient and pre-empt climate change risks via mitigation, eco-sustainability, waste minimisation and the circular economy. Marine renewable examples for shipping include waves and wind (soft, fixed and kite sails, wind turbines and fletter rotors). Marine renewable energy includes ocean, offshore wind, solar, tidal, current, thermal energy, salinity gradient technology, current and wave; challenge of transmission, storage and robust infrastructure/services (Commonwealth Secretariat 2016), These include biofuels, LNG, hydrogen fuel cells and solar photovoltaics. These sources identify renewable energy sources for shipping and shoreside supply chain operations but do not link to digitisation trends so stakeholders can correlate energy/fuel consumption into emissions abatement, carbon footprints and enhance performance (International Renewable Energy Agency 2015). The Internet of Things, AI and remote sensor telematics can link these processes. Rotor technology achieved 60% fuel savings, sail technology 20-25%% fuel savings, recovering costs within 2 years of operation. Technology can therefore assist the IMO compulsory Ship Energy Efficiency Management Plans via sensors, blockchain, telematics and the Internet of Things. However, securing access to finance remains as a concern as well as the fiscal and pragmatic decision to consider a retrofit versus new construction design in response to the IMO 2020 Sulphur cap emission requirement. Issues of ensuring adequate fuel/energy components at bunkerage and shipyards globally present implementation challenges globally but assists finance challenges.

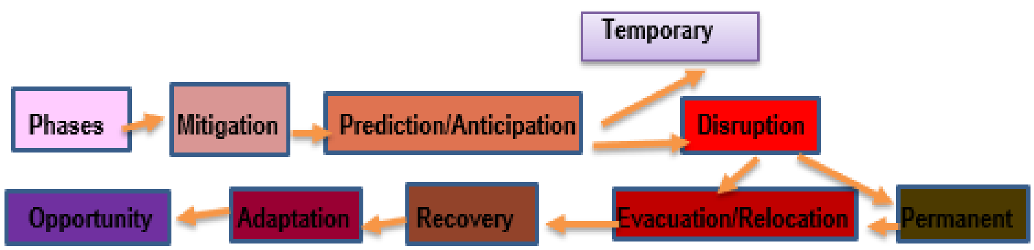
Very few sources focus specifically on linking digitisation and the 4th IR for greater eco-sustainability (PWC 2016). These primarily target urban settlements. A 2017 UN report mentioned nearly 50 million tons of global e-waste, could be recycled into an extra 55 billion euros. Yet digitisation technology could produce a virtual or mixed reality as a digital twin to simulate a real object to assess potential climate change implications, reduce vulnerability, enhance resilience optimise performance, lower cost and reduce resources required. It can assist in training and minimise disruption risk. It mentions assuring eco-sustainability via life cycle assessments for port equipment testing -eco-sustainability and reducing terminal congestion/ improving integrated planning via simulation models to assist stakeholders in actions (Jahn, Kersten and Ringle 2019). Delivering the digitisation of seaports, shipping and MSC stakeholders will necessitate using the full potential of technical progress, realigning priorities to maximise emergent areas from 3D printers to self-healing concrete, other biotechnology forms and biomimicry for repairs, It will mean considering trends from robotics, telematics and proactive risk management, whilst simultaneously acclimatising people, assets, processes, ecosystems, finances and resources as priorities.

Existing research and stakeholders currently neglect the potential of digital disruption to resolve climate change, marine waste, pollution, and sustainability challenges, as this research's unique conceptual contribution (Ernest and Young 2017; Fruth and Teuteberg, 2017; Berenborg 2018). With low probability, high impact Black Swan events creating catastrophic impacts, the need for innovative solutions will become more urgent. As crew become fewer and vessels/trade flows become more cyber-connected yet cyber-dependent, requiring predictive maintenance, pre-emptive risk management and remote control/telematics, challenging during piracy and natural disaster events. This proposal seeks to investigate how technology through the 4th Industrial Revolution could assist in ensuring eco-sustainable and climate-resilient assets, infrastructure, people, processes, protected information and services. The circular economy should in theory reduce resources utilised as well (ABB 2019). How many maritime stakeholders will react and will embracing digitalisation bring benefits to those who invest in it expensively, given the risks of asymmetrical information, moral hazard and lack of first mover advantage/high lifecycle costs of maritime assets and infrastructure (Jahn and Saxe 2017). Risks also exist in ensuring sufficient people provide information openly, technology is transferred and systems are interoperable across divergent stakeholders and their requirements (Lloyd's List 2017; Inkinen, Helminen and Saarikoski, 2019). Technology also must reduce risk of human factors e.g. ennui, fatigue, poor training, stress, negligence as susceptible when adapting behaviour.

3: Method

In response to section II's identified research gap; this section's prime objective proposes existing risk management frameworks and climate change method approaches can be restructured to incorporate digitisation and other emergent technology trends as proactive risk management. This can subsequently be redirected towards achieving sustainable blue economy requirements compatible with varying stakeholder requirements (Table I), and World Bank Sustainable Finance Principles. To devise an effective method this exploratory research counsels forming an integrated climate change risk-vulnerability and impact cost management model (Figure II) as identified in previous research (Dyer 2018) prior to subsequently connecting to emerging digital technology applications to assist maritime supply chain stakeholders against climate change and other potential risks. To adjust to climate change uncertainty; this model proposes the introduced digital trend/technology is subject to a risk analysis including potential impact costs; opportunities, climateproofing mitigation and adaptation strategies. This could consider historic risks, accumulated and projected risks based on various climate scenarios, risk types and time horizons. These could be subsequently adapted to various other emergent risks once successful. The proposed investment, assets, people, systems, ecosystems, technology and location/s could consider digital disruption and various event phases as elucidated in Figure I. Stakeholders may be more convinced through identifying the extent of subsequent vulnerability. After the disruption event; a risk event monitoring and review stage can assess any climateproofed investments against projected existing and accumulated risk.

Figure I: Risk Event Disruption, Impact Cost Phases.



Source: Author.

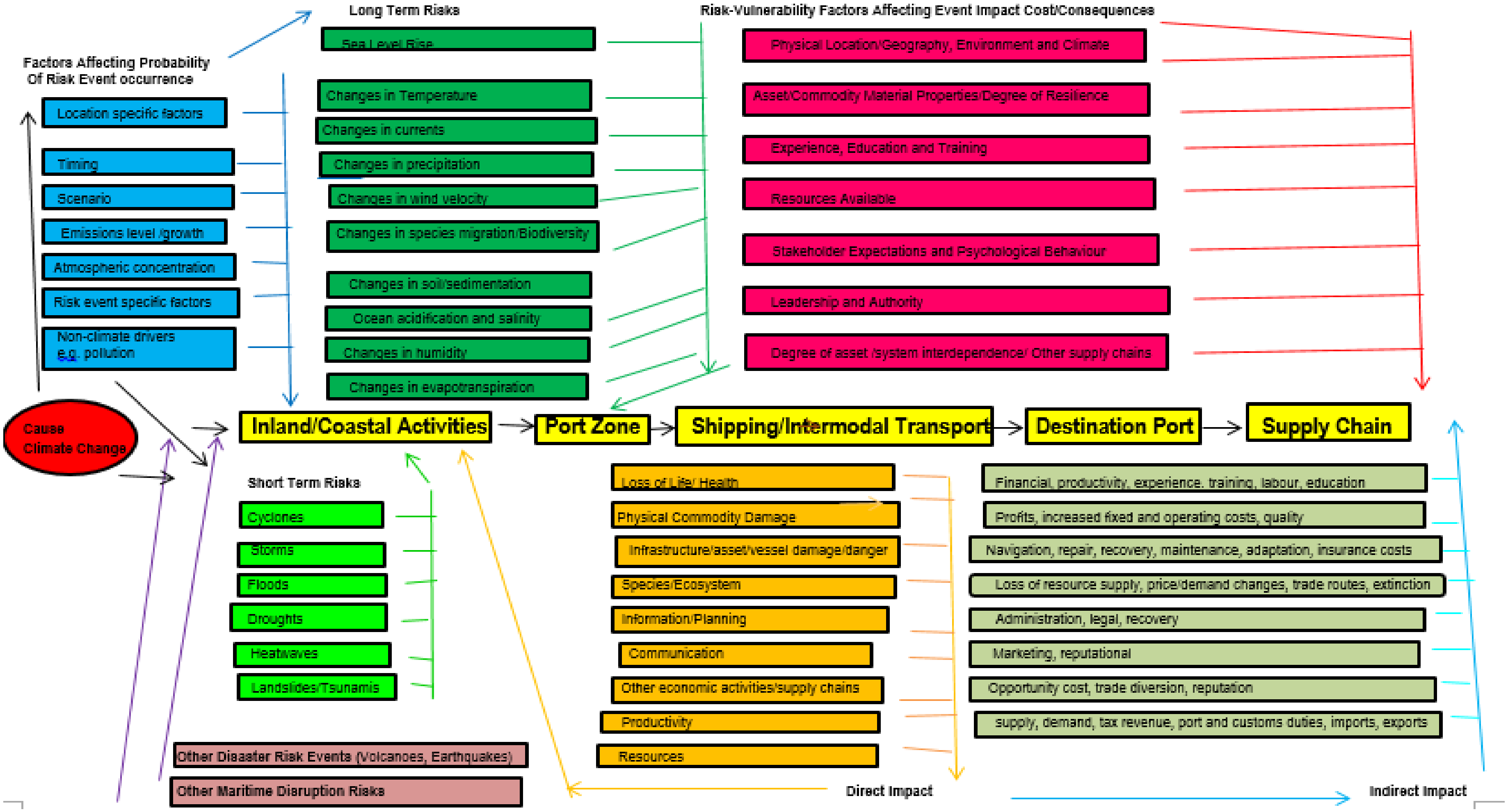
4: Case Study:

Digitisation of maritime supply chains may be one of the only opportunities outside of restricting finance; enforcing education and psychological manipulation to prompt humanity towards resolving emergent risks of climate change, environmental sustainability, security, lack of information sharing/collaboration towards achieving a viable blue economy future. This research subsequently answers KQII in emphasising how specific digitisation trends can target specific risks. As shown in previous research (Dyer 2018), climate change presents significant long-term and short term, risks; factors influencing risks and impact costs that can be integrated with constraints to adaptation and potential solutions into a standardised risk management assessment framework inn Figure I. This framework aims to identify and resolve risks employed for shipping and other MSC stakeholders. This research's conceptual contribution is to emphasise how specific technologies can aid specific stages (Figure III) and impact costs as potential climateproofing adaptation solutions.

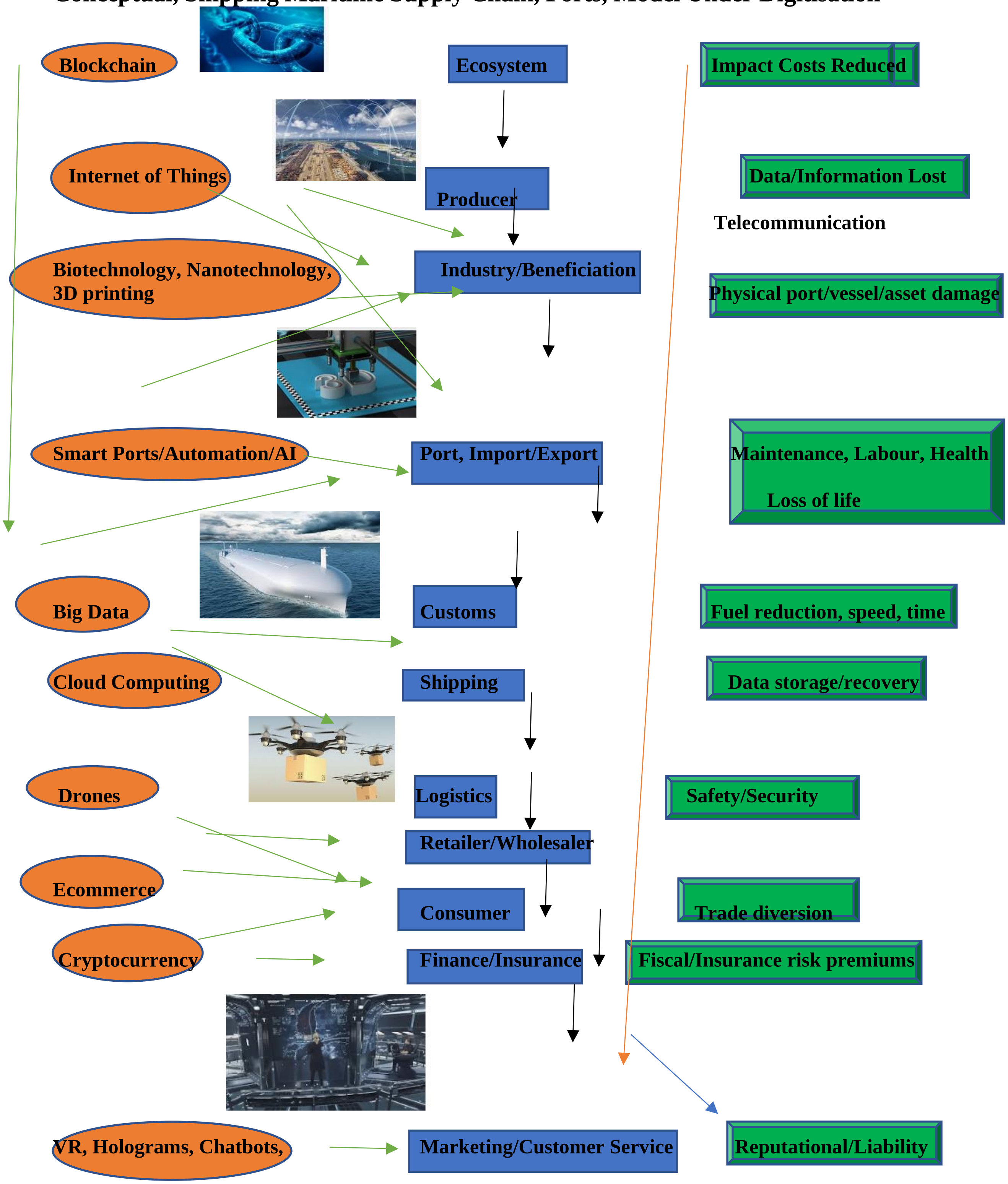
Digitisation's initial prospective benefits are pre-emptive via assisting global trends towards mitigation such as the 2020 IMO Sulphur cap. Sources focusing on maritime transport, MSCS and climate change risk management remain comparatively few and do not frequently mention the capacity of technology to monitor or reduce energy efficiency and emissions (UNCTAD 2009; Dyer 2018). Marine renewable energy can also assist. Sensors connected via the Internet of Things (IOT), automation, telematics and blockchain, along with drones and interconnected smart ports, vessels, warehouses and logistics can optimise performance, minimising fuel, electricity, temperature, water and waste and excess costs. These potentially reduce carbon footprints. It offers opportunities to pre-empt potential climate and environmental risks by more accurate forecasting of storms, floods, cyclones, tsunamis, and other related risk events; improving navigation and external sensory awareness. The costs and benefit implications as to how maritime transport and supply chains could utilise technology to reduce climate change have yet to be empirically calculated. E-commerce and mobile apps may enable vessels as mobile assets to respond directly to consumers, changing routes and cargo operations for spot, time and voyage charters. Banking will receive flexibility if conducted in blockchain and cryptocurrency. For fishing and other marine resources; technology may be able to aid in sourcing primary species as climate change prompts species migration and increases in invasive/alien species -risks to bilge water. During risk events, increased automation reduces pressure on crew and shore-based personnel to make myriad decisions with limited time, energy and attention span to devote to the issue.

Both during an event and subsequent recovery/adaptation; more information can be provided to identify the need for vessel repair/maintenance via telematics. It can either aim for self-repair or provide suggestions. Improved communications via Skype, holograms, chatbots, augmented and mixed virtual reality can improve shore assistance in gaining advice on how best to respond along with the creation of simulations. Virtual simulations and performance models can assist to acclimatise processes, vessels and port/logistics infrastructure, once data is simpler to access and needs to align to user priorities. Technology not only minimises inventory management replacement costs, it aids for replanning voyages, flexible deliveries and reduced inaction/time/opportunity/storage costs for other operators affected within the supply chain. Smart sensors may aid in emissions reduction and reduced usage of scarce resources. The insurance and banking sectors may be able to determine risk more accurately via improved vessel resilience and design. Vessels will no longer have to wait for help from passing vessels or shipyards/ports. Cloud based computing data and blockchains ensures that shipowners, charterers and crew/captains do not have to be concerned with losing physical information during any catastrophe. Even if the incident provides a shipwreck, a real time information feed will be able to locate the vessel for salvage/recovery most often and propose the most effective solutions. 3D printing of component and advanced biomaterials/nano-materials will not only aid in more climate-resilient ports and vessels but assist crew/vessels/operators to provide even more capable and specialised repairs prior to a shipyard for more urgent maintenance/faults. Examples of nanomaterials include graphenes, fullerenes, nanoparticles and nanozymes to improve vessel resilience, - but also potentially aid with invasive species and biofouling. More resilient vessels may enhance sustainability or the need to reduce acoustic and underwater noise.

Figure II: Conceptual Framework for Integrating Climate Change Risks, Impact Costs and Maritime Supply Chain as an Event Tree



Conceptual, Shipping Maritime Supply Chain, Ports, Model Under Digitisation



Individual technology can aid ports and MSC's against specific risks, re-engineered against projected sea level rise and utilising nano/biotechnology via algae/seaweed and other based processes for more resilient vessels from higher global land, ocean and air surface temperatures. Each technology trend also provides greater capacity for emerging profitable cargo such as for nanomaterials, nano and biotechnology, robotics and customised goods from 3D printing. Effective drone deployment can facilitate governance through overcoming existing infrastructure constraints and failures. In 2015 Rwanda became the first global nation with a civilian Droneport specifically devoted to humanitarian and other logistics from medicine to postal deliveries, electronics and commerce. This could counter poor historic records of postal and other forms of postal delivery for urgent, expensive, fragile and remote destination cargo, if effectively secure against theft, cybersecurity, sabotage and other risks. Drones could resolve poor roads and other infrastructure conditions. In 2016 Rwanda partnered with Zipline drones for medical deliveries and GAVI/Vaccine Alliance for vaccine and medicine delivery to rural clinics. An $800,000 UPS Foundation grant will establish 21 blood transfusing centres. The drone port aims at over 100 deliveries per day for a 120 kilometre radius

Biomaterials can also be utilised including collagen nanofibers extracted from hoki skin for cosmetics and air ventilation filters. Japan produces biogas electrical energy with algae and waste water. Korea use red seaweed. Malaysia and Indonesia devised algal systems via photobioreactors for biofuels, waste water management and CO_2 sequestration. Singapore use sponges to purify wastewater. Macroalgae and seaweed has been suggested for multiple uses including carbon sequestration, energy, food, fertiliser, pharmaceuticals, cosmetics, oxygen production, fertiliser, fish feed, nutrient uptake and other purposes. It can provide biofuel, biodiesel, bioethanol and biomethane. Algae produces up to 10,000 gallons of oil per acre compared to 18 for corn, 48 for soybean, 102 for sunflower and 635 for oil palms. Mussels have also been suggested for nutrient uptake, textiles, energy, feed, fertilisers and nutrients. Reeds have also been suggested not only ecologically but for energy, construction materials, nutrients and effluent/water purification treatment, tourism, boats and protection against coastal erosion. Brazilian microalgae have laboratory evidence for effluent cleaning. Jellyfish also possess biotechnology prospects and are envisioned to multiply under climate change conditions globally.

Implications for emergent risks include reducing the time taken to recover from a risk event from greater blue economy opportunities and increased profit margins for more efficient vessels with greater cargo storage capacity and optimised fuel performance. Other environmental applications for marine biotechnology, drones and robots include coral reef restoration and bioremediation processes for polluted coastlines, oceans, waterways and oil spills via nutrient additions and manipulating of organisms/processes. This risk exceeds over 1.3 million tonnes of marine pollution just from oil spills on average each year. The prime aim is to manipulate at a molecular, cell and organism level to ensure or accelerate biodegradation of polluting particles. This research echoes EU maritime transport policy objectives in emphasising these trends aid with competitiveness, decarbonisation and digitisation via diminishing emission, energy/resource consumption, carbon footprints and emissions. Economically it empowers the green/blue economy via opportunities for logistics and a source of eco-sustainable electricity from marine renewable energy sources, LNG, biofuels and alternatives. Determining the extent to which any of the aforementioned technology trends are worthy of investment will be measured by performance criteria to costs, efficiency, performance, resilience and vulnerability during Figure I risk event phases and the extent to which stakeholder requirements are satisfied for a digitised supply chain under climate change versus one that is not.

However, certain limits and constraints exist towards digitisation and digital disruption in resolving emergent risks and concerns (KRQIII). Digitisation has yet to empirically confirm convincingly itself as a climate change adaptation solution and opportunity. From 2015-2025 the ICT sector is estimated to increase electricity connsumption from 8 to 20% of global electricity by 2025 and 14% of emissions, exceeding transport. By 2021 it forecasts over 21 billion devices are connected via the Internet of Things, each contributing to significant energy requirements. Digitisation may enhance efficiency but presents risks in that ecological scarcity of resources remain. Investment represents a trade-off or opportunity cost as to whether this does effectively aid in risk reduction. Technology may amplify pressure on scarce components needed (ECMAR 2017) if not sustainably and responsibly sourced such as for cobalt, lithium and platinum group metals. Converting logistics into embracing digitisation presents greater risks of electronic waste, increased carbon footprints from processing power and additional emissions contributed to potential climate change (ITU 2019).

Issues exist as to whether digitisation and increased automation will promote or reduce human ability to swiftly respond to risk events. Sensory isolation may replace risks from reduced crew/operator fatigue, pressure and other human errors. No remote operator can react as swiftly as a real time response. Challenges remain in sufficiently upskilling or retraining crew. Implications also exist from having fewer stakeholders/crew costs etc. as to how best to deploy or remove surfeit labour. Questions remain as to whether labour costs will actually be saved in replacing shipboard with shore-based operators. Cybersecurity remains an emergent threat, that previously isolated vessels, trucks, warehouses and equipment assets without any or few connections to land and separated systems did not have to content with. However, automated vessels perceived to be safer from piracy and cybersecurity without the crew element as hostage risks. With maximum storage capacity and little/no room for human occupation; it can maximise profitability, whilst reducing risks of theft, stowaways and other incidents. Stakeholders are highly recommended to consider the characteristics of each technology type and whether they help or hinder proactive risk management along with profit, prosperity and performance. For example, the problem of algorithms is that they do not respond to or have challenges forecasting Black Swan or low probability, high impact events. Technology requires a far higher energy consumption in costs and need for processing power, which is not always deliverable under ocean climate and environment related conditions.

The challenge remains as to how many will react as similar problems still remain for the shipping industry of high oversupply; historically low freight rates; access to finance; few shipyards able to enable upgrades or repairs; lack of economies of scale for most pioneering technology; lack of conclusive historical data and low profit margins. The shipping and road freight logistics industries in particular face significant competition and a lack of first mover advantage. They experience not only asymmetrical information but high moral hazard due to global challenges of ocean governance; vessels and ports have significant lifespans 25-30 years on average which are currently unable or unprepared globally to benefit from technology lacking integration. Technology transfer and system interconnectivity needs to be established for many developing nations; discouraging incentives to adapt. The lack of regulations presents both a risk in terms of legal compliance, tax and other laws that may apply but also a current opportunity in being less regulated. Many operators still need to be able to trust sufficiently to ensure greater cooperation and information sharing. However, vessels do remain as footloose, mobile assets which can benefit from risk disruption provided that supply chains self-determine the extent to which technology can reduce potential waiting times, speed, cost, congestion, inefficiency and other potential costs.

Conclusions

In conclusion, in an increasingly interconnected, globalized and technological world, where perpetual disruption becomes the new norm, it can no longer remain business as usual. Increasing climate change uncertainty and human mobility will require businesses, workforces, customers and all processes from production to consumption to adapt or perish. Simulations and machine-human learning already assist in training. Digital transformation will require the future labour force to be responsive as well. This is the world. This is a new Age of Digital Interconnectivity where technology can solve many historic problems facing our society, environment and economy. Existing research has however failed to consider directly what these trends are, how they will influence not only processes, but changes in trade patterns, businesses, assets, and people via digital transformation. This paper's core aim was to investigate how to benefit from the digitisation and digital transformation of the 4th Industrial Revolution and modern technology specifically for maritime supply chains. It resolved KRQI What are the current and future digitisation and digitalisation trends across seaports, shipping and supply chains?" via a Literature Review and case study for blockchain, AI, IOT, cryptocurrency, additive materials, robotics, telematics, smart ports and others.

Section III outlines the method and Section IV provides a hypothetical maritime supply chain case study under climate change and with digital transformation linked to core risks, disruptive impact costs and aligned constraints/solutions. It aims to provide insight towards resolving KRQII: *To what extent can digitisation and related trends resolve emergent risks such as climate change, marine pollution, cybersecurity, predictive risk management/maintenance, the circular economy, congestion and other stakeholder concerns*? Provided certain risks are managed effectively including generating the energy to power this future from renewable energy, adapting labour via training and utilising technology efficiently, reducing waste and minimising/recycling resources utilised, this research considers realistic the prospects and opportunities of the 4th Industrial Revolution among challenges of climate change uncertainty and other emergent risks. KRQIII: What are the projected limitations and constraints to digitisation and digital disruption in resolving emergent risks and concerns, was answered as it also identified cybersecurity and other emergent risks that may originate, without sufficient precautions.

This research provides the first physical evidence-based approach of technology's capacity to resolve common maritime stakeholder challenges and risks, whilst simultaneously futureproofing and exploiting blue economy emerging opportunities. This paper considers as a future research direction to investigate a hypothetical digitised supply chain such as Maersk and investigate just how feasible the promise of technology can be in direct and indirect response to the above method; proposed risks, impact costs and performance criteria. It considers direct and indirect applications of the more significant 4th Industrial Revolution trends. Unlike other sources which offer a more subjective analysis praising the sole merits of technology, it considers a more objective approach and pragmatic realities of adjusting people, vessels, supply chain processes, businesses and assets to acclimatise to digital disruption. Risks also exist if technology fails. Stakeholders need to consider the extent to which it can assist or hinder issues of climate change, marine waste pollution, energy and fuel efficiency, sustainability and the circular economy; beyond existing challenges of congestion, planning, training and coordination, prioritising finite fiscal, time, attention and other priorities.

How can technology serve us? What can the Fourth Industrial Revolution do for us? What can it mean for us? Can we afford to embrace it? Can we afford to ignore it? Given few counterparts; this research seeks to be among the first to synthesise and correlate digitisation and technology prospects of the 4th Industrial Revolution directly with maritime risk management, emergent risks such as climate change and potential policies. Developing the optimal model for more sustainable ports, and shipping provides more immediate, verifiable evidence for sound investments, futureproofing risks into opportunities against climate change uncertainty and other emergent risks. To assist port/shipping and blue economy stakeholders to ensure a radical, sustainable transformation of maritime logistics, shipping; supply chains, economies and stakeholders progress forward. It presents core catalytic projects and a holistic integrated approach as a prototype at how a marine digitalisation and digital transformation/acclimatisation risk management strategy can significantly mobilise stakeholders and resources to transform a conventional economy. Parallel developments in blue economies, technology and climate change could establish greater security for long-term marine ecosystem survival and interdependent livelihoods. It aims to assist in more effective decision making and implementation of technological trends. Simultaneously a sustainable blue economy aided by investors and other stakeholders becomes more self-sufficient, reducing aid, foreign investment and concerns. It minimises stakeholder inaction, maladaptation and opportunity costs to determine if stakeholders are prepared. Or if not, what will it take?

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