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Toward Future Green Shipping: Resilience and Sustainability Indicators

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Abstract

Shipping companies, ports, governments, and other maritime stakeholders have faced with significant economical, technical, and operational challenges brought about by Climate Change. In response, International Maritime Organization (IMO) have recently set a target to reduce maritime Greenhouse Gases (GHG) emissions by 2050 while at the same time planning toward phasing out GHGs entirely. Nonetheless, to achieve a desired green maritime, the entire maritime community should contribute to decarbonize the logistics system. In this article, we adopted a multidisciplinary methodology for achieving a sustainable maritime logistics to meet the IMO mid-term (2030) and long-term (2050) targets. We defined Climate Change and related consequence damages as the main risks (disturbances), and a resilient shipping as a robust and adaptable system which needs to meet the challenges. This paper proposes a decision-making tool that allows planning and monitoring zero-emission action programs for each contributor. The tool takes into account the dominated development properties such as resilience and sustainability and their interconnection that are specified for maritime industry, while considering the risk and disturbances envisaged for zero-emission future. To monitor and measure the activities, outputs, and benefits, the related Key Performance Indicators (KPI) are defined, adjusted, and then updated by using program/project management framework.

Keywords: Sustainability, Resilient, Shipping, Zero-Emission, Maritime logistics, Green shipping, COVID-19,

1 Introduction

Greenhouse gases (GHG) emissions produced by human activities are considered directly or indirectly responsible for global warming and climate change. As shown in Figure 1, the effects include long-lasting damages to the environment and ecosystems and far-reaching changes to the global economy.

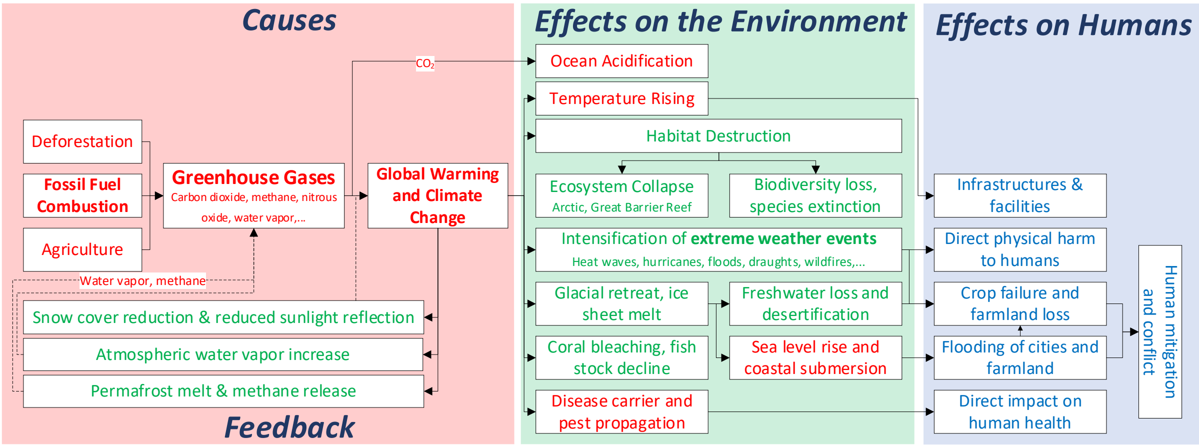

Figure 1, Causes and effects of Global warming and climate change (Poloczanska et al. 2018; Wuebbles et al. 2017)

One of the main contributing human activities to GHG production is the logistics and transportation of goods and passengers. Maritime transportation is responsible for 90% of the global trade and although, it considers being the most efficient mode of transportation nonetheless their sheer volume of activities makes the shipping the most air pollutant of all. Ships represent sources of different substances emitted to the atmosphere. Roughly, 3% of worldwide GHG emissions are generated by marine transportation for example, CO_2 as the major Greenhouse Gas contributing to the global warming. Beside GHG, ships are also the main emitters of SO_X, NO_X and PM in the transport sector. This is mostly because the emission in shipping industry has historically been much less regulated compare to the land transport. Thus, marine engines have consequently been adapted to run on cheaper, lower-quality fuels with much higher pollution capability (IMO 2018a). Investigations show that for example the luxury cruise liner owned by Carnival Corporation & PLC, in 2017 in European seas alone, emitted 10 times more disease-causing SO_X than all of Europe's 260+ million passenger vehicles (Abbasov et al. 2019).

1.1 Global reactions

The UN as the international regulatory authority responded to the GHG and climate change through assigning global goals and international treaties. The United Nations Framework Convention on Climate Change (UNFCCC) in 1992 set limits and had parties agreed to reduce GHG. In 1997, Kyoto Protocol was adopted to extend the treaty's scope. The Paris Agreement adopted in 2015 by Parties of UNFCCC to improve the global response to the hazards of climate change by keeping a global temperature rise well below 2°C above pre-industrial levels. The UN's also adopted Sustainable Goals (Table 1) in 2015, to control, mitigate, decrease, and consequently eliminate GHG emissions by 2030. Some of these goals address industries including shipping regarding their contribution to greenhouse gases emission. Goal 13 – Climate Action – assigned for controlling and reducing GHG emissions agendas (CO_2 → Climate Action). These goals are interconnected, for example, while, in order to achieve Goal 13, contributors should ensue Goals 7 and 9. Furthermore, SO_X & NO_X emissions by ships are one of the main concern of Goals 3 & 14 (SO_X & NO_X → Good Health; Life Bellow Water). IMO, in turn, has stated a substantial cut for vessels operating outside assigned emission control areas to limit Sulphur content of vessels' fuel oil to 0.50% m/m (mass by mass) from 3.50% m/m from 2020(IMO 2020b).On the other hand, ship owners now are paying more for the higher quality fuel (with low Sulphur content), which in turn incentivized investment for the improvement on engine performance. In the current competitive market, owners have developed resistance but unwilling to implement these restricting regulations by IMO.

Table 1: United Nations (UN) sustainable development goals (Desa 2016)

No	Goal	No	Goal
1	No Poverty	10	Reduced Inequality
2	Zero Hunger	11	Sustainable Cities and Communities
3	Good Health and Well-Eating	12	Responsible Consumption and Production
4	Quality Education	13	Climate Action
5	Gender Equality	14	Life Bellow Water
6	Clean Water and Sanitation	15	Life on Land
7	Affordable and Clean Energy	16	Peace, Justice and Strong Institutions
8	Decent Work and Economic Growth	17	Partnerships for the Goas
9	Industry, Innovation and Infrastructure	-	-

Problem: This paper explores fundamental challenges of maritime logistics in contributing to mitigating the climate change. In the one hand, to control climate change, global determination is to reduce GHG and related noxious gases under a sustainable development plan. On the other hand, a maritime logistics including shipping companies should be resilient due to the consequent challenges.

Research Gap: We did extensive literature review on concepts of sustainability, resilience, risks, and climate changes in maritime logistics. Although, there are many studies done in relation to sustainability development and resilient response in maritime industry however, the interconnection and interaction between sustainability and resilient response in the future shipping has not been studied yet. In other words, there is no clear logical pathway for strategic managers to develop a sustainable plan, which includes resilient response. Furthermore, it is required to present a method to identify, update, and trace the indicators that evaluate the outcomes and monitor the benefits.

Our contribution: This paper presents a congruous view of interconnection between sustainability development, resilient response and risk management centered on maritime logistics challenges. We then explore related indicators, which allow monitoring, controlling, and measuring achievement of the main targets and sub-targets of plan to mitigate the challenges and then recover the system to regular operation and lifetime. Afterward, the possible methods to mitigate the damages are presented. Subsequently, a tool (flowchart) is generated to show the connection, sequence, and cycles of actions with the goal to have a resilient maritime logistics. The tool guides the stakeholders to contribute the UN's targets while implement rational steps toward a resilient system. Meanwhile, a program management model as a framework is presented to identify, define, update, and trace the indicators. By the conclusion, we could refine our comprehension on a resilient future shipping through the sustainable development toward zero-maritime logistics.

2 Literature review

Climate Change is a multi-dimensional phenomenon which, to mitigate, requires several sustainable development plans to be defined by stakeholders. For maritime logistics, a wise plan is needed not only to limit the pollution, but also to mitigate the resultant disturbances and risks associate with implementing the plan in a resilient response. Studies in this field can be divided in four categories namely; maritime logistics sustainability, zero-emission (green) maritime(Chang and Wang 2012; Lun et al. 2015; Pallis and Vaggelas 2019; Psaraftis 2016; Sadek and Elgohary 2020) (Davarzani et al. 2016), maritime risk assessment, and resilient maritime supply chain for climate change adaptation. Several research such as Rigot-Muller et al. demonstrated optimization methods, for reducing total maritime logistics CO_2 emissions for end-to-end supply chains (Balcombe et al. 2019; Emad, Khabir, and Shahbakhsh 2020; van Ingen and Castro 2017; Ogden 1999; Tomašević, Senjanović, and Tomić 2008). Furthermore, Lai et al. illustrated a conceptual framework for assessing green shipping. They provided several suggestions and stating the conditions under which shipping firms would behave in an environmentally responsible manner (Lai et al. 2011). Among quite a few research, there are some technical papers investigated green technologies and alternative fuels for maritime transportation (Koumentakos 2019). Some researchers concluded that the progress the progress toward being green should follow a sustainable development framework which includes relevant key indicators (Dinwoodie et al. 2012; Halim et al. 2018; Karnauskaitė et al. 2019; Kotrikla 2017; Lai et al. 2019; Lindstad, Asbjørnslett, and Pedersen 2012).

However, considering the magnitude of challenges ahead, there are not many literature focused on providing the proper roadmaps (Abbasov et al. 2018; Halim et al. 2018; Psaraftis 2019; Z. Wan et al. 2018). Although, there a some researches on investigation into quantitative impact of climate change under risk assessment and/or resilience responses, however, not many explained how to identify risks and provide resilience framework (Berle, Asbjørnslett, and Rice 2011; Burroughs and Becker 2020; Chhetri et al. 2020; Gligor et al. 2019; Lam and Bai 2016; Mansouri, Sauser, and Boardman 2009; Nam 2002; Omer et al. 2012; Wilmsmeier 2020; Wu, Santoso, and Roan 2017).

Traditionally, risk management focuses on planning and reducing vulnerabilities; while, resilience management puts additional emphasis on speeding recovery and facilitating adaptation. By this definition, risk management is part of resilience management (Ivanov and Sokolov 2009) . Recently, there is an increasing interest in moving from only focusing on managing risk, to including resilience, and ultimately enabling sustainability. Figure 2 illustrates the three concepts of resilience, sustainability and risk management. The diagram intimates that resilience is focusing on short and at the same time long-term adaptability, while sustainability envisioning a longer term ‘future generations’ stance.

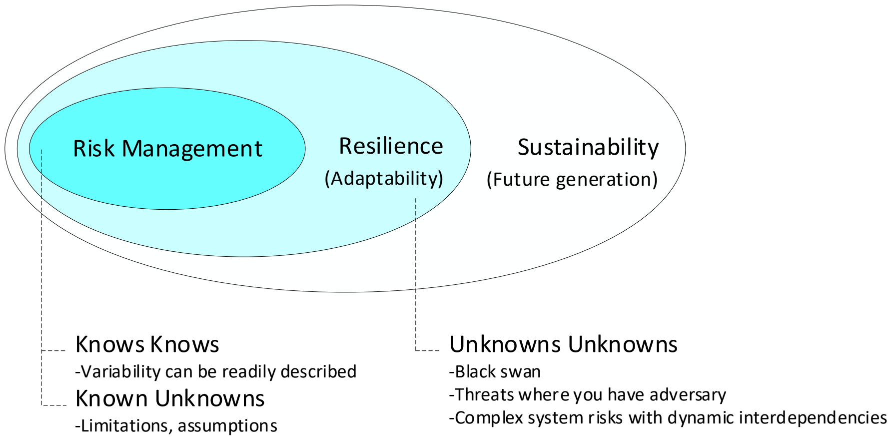

Figure 2. How resilience is related to both risk and sustainability (Berke and Conroy 2000),

The prefer approach to study the suitability of an energy source could be presented in the following items:

- Indicator: a measurable aspect of environmental, technical, economic, or social systems that is useful for monitoring changes in system characteristic.
- Metric: measured values used to assess specific indicators.
- Index is a quantitative aggregation of many indicators that provides a simplified, coherent, multidimensional view of a system (Lespier et al. 2019).

3 Methodology

In order to evaluate the success of an organization or one of its particular activities (such as achieving a specific target, program goal, or products), there is a need to use key performance indicators (KPI) (Fitz-Gibbon 1990). KPIs can reveal the level of success in achieving the set goals while the process is unfolding. Among other methods, the SMART concept (Specific, Measurable, Attainable, Relevant, and Time-bound) has been frequently addressed as the method for setting the ideal goals and to assess the relevance of KPIs of organisations or projects (Doran 1981), and whether they are clear and concrete (Gözaçan and Lafci 2020). SMART requires the objectives to be specific to the target area, easily measurable in different stages to be used as an indicator of progress, attainable and realistic to achieve with available resources in specified time frame. To be effective, management must compile and review the results frequently to ensure that corrective action is taken on any items that are not meeting the established targets. This paper discusses two types of Key Performance Indicators (KPI) i.e. Sustainability indicators and Resilience indicators. To identify, define, update, and trace an indicator and monitor the benefits, there is a need for program management.

The process of climate change adaptation might be considered a project. Projects are defined to solve a problem or achieve a target or certain goal. In the other word, a project is a temporary endeavor undertaken to create a unique product, service, or result (PMI 2017a). In climate adaptation project in a global scale, there are several stakeholders with variety of contribution to the GHG emission. Hence, there is a need to develop various projects with a mutual target. In this case, experts usually define program, a group of related projects, subsidiary programs, and program activities that are managed in a coordinated manner to obtain benefits that otherwise are not available from managing the projects individually (PMI 2017c). Likewise, a portfolio is a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives (PMI 2017b). In brief, climate change or global warming adaptation is a problem, which respectively could be considered to be:

- A project for companies, institutes, (systems) etc.
- A program for leaders (governments, UN, IMO etc.) to mitigate its effects.
- A risk or a strategic objective in a portfolio for investment institutes or governments.

This paper aims to provide a framework of KPIs to determine the progression toward success in achieving green shipping including resilient response and sustainability targets, in accordance with SMART criteria for assessing performance. This article provides a tool as a framework that considers the global climate adaptation targets and benefits. Meanwhile, it presents a comprehensive action plan includes risk assessment, resilient response, and sustainability through the planning and developing. The tool helps researchers and managers to infer the indicators in right time and sequence. In line with that, as a big picture, we try to mention the available plans to mitigate and recover the shipping sectors due to climate change challenges. Whereby, the global and some local issues are spread out to help the strategist to adjust the local planning along with the global reactions. Therefore, each section, explores the related concept, then, mentions the available or possible plans.

4 Resilience indicators

Resilience is the ability of a system exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (Hotchkiss and Dane 2019). The main role of a resilient system is to mitigate the exposed risk and try to recover, then adapt to the normal operation level before the risk.

4.1 Maritime logistics risks

There are a number of overviews of risk definitions and approaches to risk analysis in the maritime domain (Goerlandt and Montewka 2015). Furthermore, a risk-based method for safety assessment is developed by IMO titled; Formal Safety Assessment (FSA)(IMO 2018b). Our approach to safety is based on identify the cost-effective risk reduction options. The risks in the maritime logistics depend on variables or factors categorized in five sections as demonstrated in Figure 3.

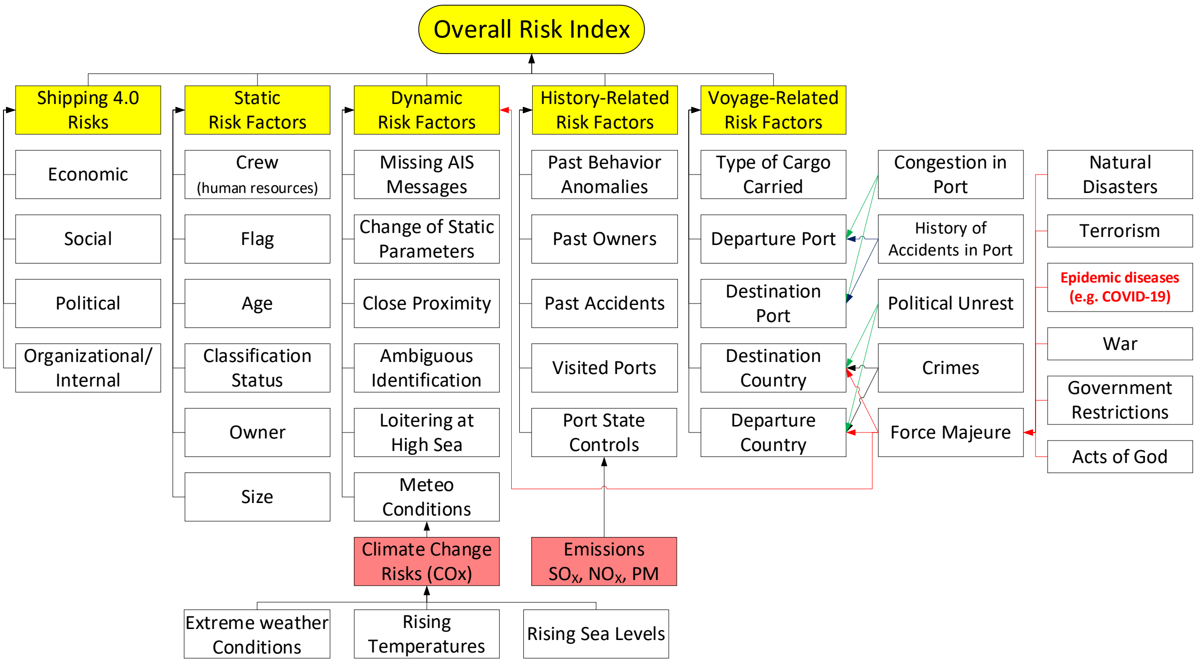

Figure 3: maritime logistics risks (developed based on inputs from BIMCO & (Stróżyna and Abramowicz 2015),(Hunter 2020) frameworks)

The climate adaptation risks and related impacts on maritime logistics and performance indicators are discussed in the next section.

4.2 Contingency plan and reserve

However, it is possible to keep the shipping system in a safe side by insurance cover, but rehabilitation after a tragedy is so solid. In this way, contingency plan and reserve could control the condition. Regarding that, <u>Contingency Reserve</u> is deified as the budgeted resource or scheduled time that are set aside for risks that have been identified and accepted or identified and its **mitigating** responses is developed (PMI 2017c). It will cover the costs and necessary time to handle any accepted risks should they occur and the costs or time of mitigating those risks as needed. Contingency reserves in the budget/schedule may be a percentage of the overall budget/schedule, a fixed amount, or an amount determined based on quantitative analysis. As a project progresses or as more information is received the contingency reserves may be used, reduced, or even eliminated based on if identified risks do or do not occur. The main doubt for shipping companies is the exact value of the required reserve regarding to the climate change challenges. <u>A Contingency Plan</u> is an alternate plan that is developed for those risks that would have a high impact on a project if they were to occur. A contingency plan should include an objective, the circumstances in which the plan will be enacted, the people and resources needed to carry out the plan, and any additional details needed to fully implement the plan. Threat is a risk that would have a negative effect on one of more project objectives. There are a few research on damages of climate change on maritime sectors, hence, evaluating the required plan and reserve is demanded.

Finally, in one hand, contingency plan prepare a strategy to do when a risk happens; in the other hand, the systems should have enough potential to follow up the plan. The potential referred to systems' properties and skills, which are described as resiliency. In next part, this ability is discussed.

4.3 Resilient response

There are three phases over a resilient response as:

- **Preparedness** (anticipation): the system operates in design or normal performance, where both the system capacity and demand are not affected. During this period, system is robust and reliable to small risks and disturbances. A reliable system prepares a contingency plan/reserve for risk days.
- **Mitigation** (absorb, degrade): the system is affected by disturbance and performance decreases. In this phase, system resists against the disturbance and remains robust with the minimum possible vulnerability, while, monitor and control the performance level. There are three critical levels:
  - o Minimum sustainability capacity: In case, system is in a sustainable development pathway; and should recover itself before this level, anyhow.
  - o Minimum required performance to back to the design performance normally
  - o Elasticity/ Threshold level which after that it is not possible to recover the system, and collapses. Survivability is defined commonly in case that the performance level keep on upper threshold level.
- **Recovery** (restore): typically, if system has a contingency plan, or be enough smart and intelligent to develop and imply an in case plan, could rebuild the affected and destructed parts and back to the last functionality. The important characteristic in this phase is the speed of recovery called rapidity (agility)

Furthermore, there are some other terms to describe the characteristics of a resilient system including but not limited to reliability, vulnerability (loss of functionality), rapidity (agility), robustness, redundancy, flexibility etc. as shown in Figure 4.

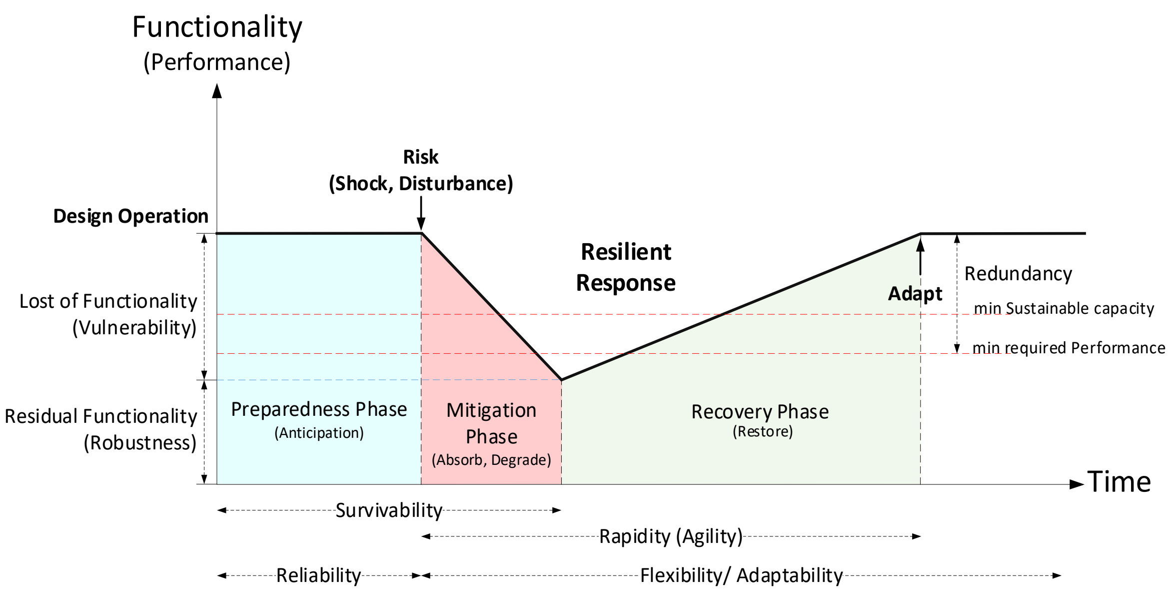

Figure 4: Resilient response of a system (developed based on (Enjalbert et al. 2011; Shafieezadeh and Burden 2014; C. Wan et al. 2018))

The order of adaptability addresses performance into five levels as the following (Figure 5):

1) Adaptive resilient system
2) Engineering resilient system (fully robust behavior)
3) Ecological resilient system with a ductile behavior.
4) Not resilient system while just keep on survive from the disturbance.
5) Fail system while collapse and no performance is expected. System is lost for a poor reaction.

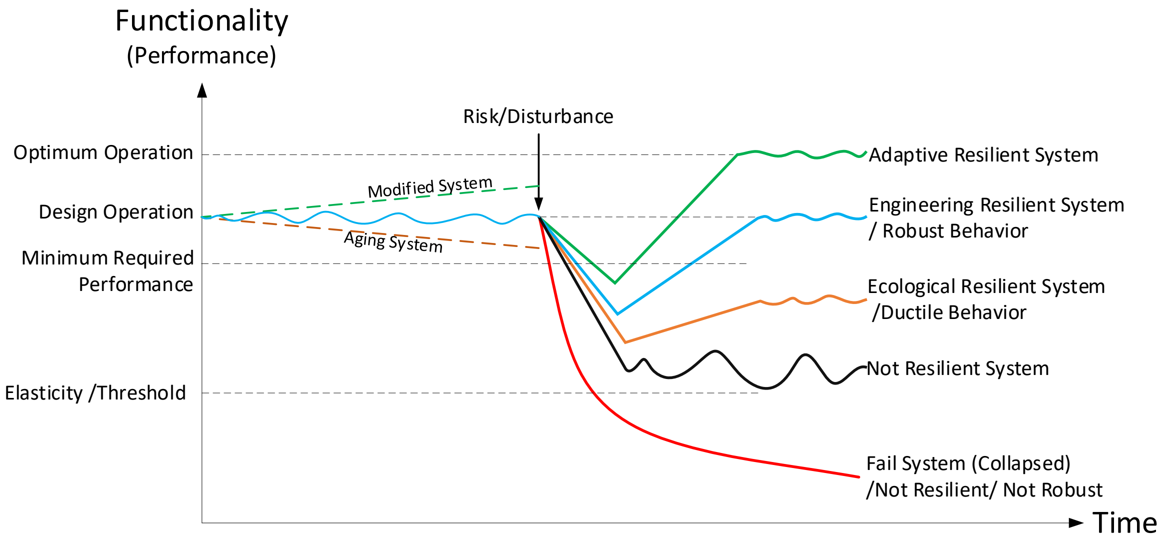

Figure 5: Types of Resilient Systems

In each phase, there are some indicators to monitor and control the characteristics of system and consequently imply the contingency plan, categorized in Figure 6.

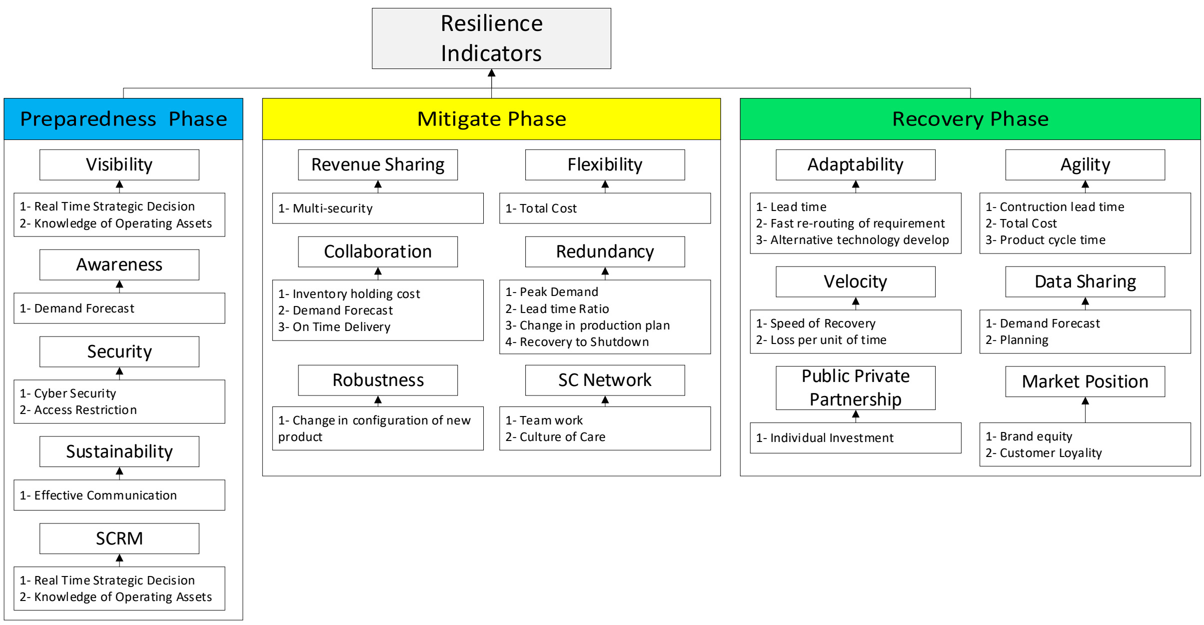

Figure 6: General indicators of resiliency (developed based on (Singh, Soni, and Badhotiya 2019))

4.3.1 Preparedness and mitigation phases

In order to control climate change, United Nation, suggested governments and international associations, committees, organization as the main leaders to define and imply several tasks. Some of them could be sorted as the following terms:

1) Set strategic targets including challenges, and possible benefits,
2) Define goals, their related indicators, and the appropriate phases to meet the goals,
3) Regulating and legislating,
4) Facilitating policy & management,
5) Providing the roadmap to zero-emission (globally- nationally),
6) Coordinating contributors to keep following the rules and roadmaps to achieve the target,
7) Monitoring and measuring the emissions,
8) Technical support,
9) Standardize and classify the related technical issues (design, construction, procurement, construction, operation, maintenance and survey by standard institutes and classification societies,
10) Finance and investment support,
11) financial supports in research and development in order to assess:
12) Economic, environmental and technical issues
13) Risk mitigation measures & Cost assessment
14) Preparing shipping banks for climate change (conducted loans)
15) Infrastructure development to carry out the sustainable supply chain.
16) Social awareness about GHG hazards and encourage using the low-carbon fuels or zero-carbo fuels.

Each item would be exclusive for each country based on available infrastructures, resources, and capacities. This implies that the plan for a country may not be imitated in other countries as it may result in different outcomes. In order to mitigate climate change impacts, United Nation's agencies provided variety of plans that can be considered. For example, International Energy Agency suggestions are summarized in Table 2.

Table 2. Potential mitigation options (UNCTAD 2009)

Scope	Measure	Example
Technology & Energy	• Efficient and lower-emitting propulsion systems • Clean fuels and alternative energy sources • Ship design (structure, hull and machinery) • Emission control technologies (e.g. after exhaust treatment, carbon captures and storage)	• EU and IMO sulfur emission control areas • Solar Sailor 2006 and Skysails 2006 • Switch from diesel to natural gas
Operational	• Speed Reduction • Rout Selection • Monitoring of weather and sailing conditions • Collaboration among ports, carriers, other	• NYK announcement in early 2008 to reduce the speed of all vessels in the fleet by 10% to cut fuel consumption by up to 25% • Vessel sharing agreement between

Scope	Measure	Example
	modes and other players in the supply chain • Cold ironing or onshore power	Maersk MSC and CMA-CGM on Transpacific trade
Market-Based	• Environmentally differentiated rates/dues • Cap and trade • Taxation • Subsidies • Industry-led voluntary schemes	• Fairway dues in Sweden, Green Award Scheme, Green Shipping Bonus, differentiated tonnage tax in Norway • Kyoto CDM and JI • EU ETS and proposed IMERS • Potential global fuel tax • California Air Investment Program • Preferential contracting

In addition, international Maritime Organization (IMO) is a specialized agency of the United Nations responsible for regulating shipping, and plays the main role in leading climate adaptation actions of the maritime sector. Although, the Paris Agreement does not specifically addressed international shipping, but IMO, as the regulatory body for the industry, is committed to reduce GHG emitting by international shipping. In April 2018, IMO agreed to reduce GHG emissions by at least 50% by 2050 compared with the 2008 level, with a target of CO_2 emission intensity reduction for 2030 and 2050. The main framework to control global warming is presented in Table 3.

Table 3. Global Warming control main framework by United Nations ,(IEA 2019a)

Category	**Factor**	**Indicator**	**Criteria**	**Index**
Environment	Air Quality	Produced GHG emission (CO_2)	%50 reduction by 2050 based on 2008	324 million tons by 2050

Currently, there is a considerable cost involves switching from conventional and green energy technologies. This incentivizes the industry for achieving fuel consumption efficiency may lead to low-carbon and/or zero-emission fuels (IEA 2019c). To provide a clear target, IMO's Marine Environment Protection Committee (MEPC) provided a framework for Member States as its initial strategy. This provides the 'levels of ambition' for decreasing GHG in shipping industry, which includes short-term, mid-term and long-term targeted goals. Based on that, IMO launched the following global projects and regulations:

1) GloMEEP Project (The Global Maritime Energy Efficiency Partnerships Project): To carry out energy efficiency measures, and reducing GHG, and identify and develop solutions that can support overcoming barriers to the uptake of energy efficiency technologies and operational measures in the shipping
2) GMN Project (The Global Maritime Energy Efficiency Partnerships Project): To develop

national maritime energy-efficiency policies and measures, promote the uptake of low-carbon technologies and operations in maritime transport, and establish voluntary pilot data-collection and reporting systems.

3) EEDI regulation (Energy Efficiency Design Index), an efficiency standard for new ships,
4) SEEMP regulation (Ship Energy Efficiency Management Plan), improve the fleet energy efficiency, only 1% annually during 2015 and 2025.
5) USD 5 billion (USD 2/ton of marine fuel purchased for consumption by shipping companies worldwide) over a 10-year through International Maritime Research and Development Board (IMRB), to collaborative shipping R&D program to help eliminate CO_2 emissions from international shipping. This program includes the deployment of new zero-carbon technologies and propulsion systems, comprises hydrogen and ammonia, fuel cells, batteries and synthetic fuels produced from renewable energy sources, which be available for large commercial ships (IEA 2019b).

From a regulatory perspective, currently, there are two available schemes in order to track, monitor and report emissions based in transportation sector:

- **IMO DCS** (Data collection system for fuel oil consumption of ships by 2019)
- **EU MRV** (Monitoring, Reporting and Verification of CO_2 emissions from maritime transport by 2018)

At the same time, there are several initiatives require the stakeholders to monitor and report their emissions; for Instance, Port benefit schemes such as the **CSI** (Clean Shipping Index, a tool used by cargo owners to assess the environmental performance of shipping).

Additionally, there are regulatory requirements that drive decarbonization such as the **EEDI** (Energy Efficiency Design Index), the upcoming **EEXI** (Energy Efficiency Existing Ship Index) and **CII** (Carbon Intensity Indicators)(IMO 2020a). There are also industry initiatives such as the Rightship Environmental index - the **EVDI** (Existing Vessel Design Index) – developed by RightShip (Rightship 2014).

4.3.2 Recovery phase

One of the main challenges in maritime logistics is the lack of appropriate consideration for climate changes' impacts on transportation. As the result, there is a lack of proper quantitative risk analysis and vulnerability associated with global climate adaption responses. Each sector of maritime logistics is susceptible to a wide range of loss of functionality if risks are realized. An appropriate effective response to the risk should be arranged based on the following areas of priority:

a) Manage rightly targeted risk and vulnerability based on sufficient data,
b) Perform Quantitative Risk Analysis (QRA) based on empirical data to determine the effects of climatic impacts,
c) Assure that enough funding and appropriate technology are in disposal and there are plan for their adaptation,
d) facilitate cooperation among researchers, scientists, engineers, managers, industry, governments, policy makers and international organization,
e) Clarify the contribution of insurance industry in order to encouraging adaption and further explorations.

Some impacts of the climatic changes cause serious threats to shipping systems are expressed are as the following, explored in Table 4:

1) Rising temperatures
2) Rising sea levels
3) Extreme weather conditions
4) Pandemic diseases

Meanwhile, maritime logistics are prone to known risks but recent pandemic brought a new perspective on this sector's vulnerability to unknown risks. World Health Organization (UN) expressed climate change might indirectly affect the COVID-19 reaction, as it destroys environmental determinants of health, and composes extra stress on health. In general, most appearing infectious diseases, and just about all recent pandemics, wildlife-source, and there is evidence that increasing human pressure on the natural environment impel new diseases growth (WHO. 2020).

Table 4. Select potential climate change impacts and adaptation requirements in transport (adapted from (Becker et al. 2011))

Climate change factor	Potential implications	Adaptation measures
Rising temperatures		
• High temperatures • Melting Ice • Large variations (spatial and temporal) • Frequent freeze and thaw cycles	• Longer shipping season (NSR), new sea route (NWP) • Shorter distance for Asia–Europe Trade and less fuel consumption • Additional support services and navigation aids such as ice-breaking search and rescue • Competition, lower passage tolls and reduced transport costs • New trade, diversion of existing trade, structure and direction of trade (indirectly through impact on agriculture, fishing and energy) • Damage to infrastructure, equipment and cargo • Increased construction and maintenance costs; new ship design and strengthened hulls; environmental, social, ecosystem related and political considerations • Higher energy consumption in ports • Variation in demand for and supply of shipping and port services • Challenge to service reliability	• Heat-resistant construction and materials • Continuous inspection, repair and maintenance • Monitoring of infrastructure temperatures • Reduced cargo loads, speed and frequency of service • Refrigeration, cooling and ventilation systems • Insulation and refrigeration • Modal shift • Transit management scheme and regulation of navigation in northern regions • Ship design, skilled labor and training requirements • Upgrading of infrastructure parameters in UNECE agreements on pan-European rail, road, inland waterway and combined transport networks
Rising sea levels		
• Flooding and inundation • Erosion of coastal	• Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland	• Relocation, redesign and construction of coastal protection schemes (e.g. levees, seawalls,

Climate change factor	Potential implications	Adaptation measures
areas	connections) • Increased construction and maintenance costs, erosion and sedimentation • Relocation and migration of people and business, labor shortage and shipyard closure • Variation in demand for and supply of shipping and port services (e.g. relocating), modal shift • Structure and direction of trade (indirectly through impact on agriculture, fishing, energy) • Challenge to service reliability and reduced dredging, reduced safety and sailing condition	dikes, infrastructure elevation) • Migration • Insurance • Upgrading and/or relocation of transport infrastructure on hinterland connections of seaports
Extreme weather conditions		
• Hurricanes • Storms • Floods • Increased precipitation • Wind	• Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) • Erosion and sedimentation, subsidence and landslide • Damage to infrastructure, equipment, cargo • Relocation and migration of people and business • Labor shortage and shipyard closure • Reduced safety and sailing conditions, challenge to service reliability • Modal shift, variation in demand for and supply of shipping and port services • Change in trade structure and direction	• Integrate emergency evacuation procedures into operations • Set up barriers and protection structures • Relocate infrastructure, ensure the functioning of alternatives routes • Increase monitoring of infrastructure conditions • Restrict development and settlement in low-lying areas • Construct slope-retention structures • Prepare for service delays or cancellations • Strengthen foundations, raising dock and wharf levels • Smart technologies for abnormal events detection • New design for sturdier ship • Upgrading and/or relocation of transport infrastructure on hinterland connections of seaports
Pandemic Diseases		
• e.g. COVID-19	• Affects the safety and health of seafarers and fishers, then restriction on their ability to join their vessels and return home, and the future of their	• Reduced crew with remote support and operation of certain functions • Remote controlled unmanned vessel

Climate change factor	Potential implications	Adaptation measures
	jobs (ILO 2020), • Crew changes may be under significant delays due to travel restriction in different countries, • As a new force majeure situation in charter-parties contracts, • Cargo operations challenges due to terminal, ports may be closed, and subsequently delays for cargo delivery, • Change of vessels' route and/or speed to allow quarantine periods to elapse; • Reduced number of available Pilot during virus infection or, pilots refuse to board the vessel etc. • Active seafarers may become unavailable as they cannot renew their certificates; • Ducking, repair, retrofits, new building, and scraping delays on scheduled times and future contracts, • Bunkering and de-bunkering operation need to have face-to-face conduct, effected by restriction situation. • Charter-parties delay and rising the related costs, • Certificates expire and cannot be renewed, for both crew and ship and related statutory purposes, because of training, survey and inspections limitations. • Formal and informal training is interrupted; • Insurance covers and claims challenges due to delays, • Ports may be unsafe without being declared unsafe in the more traditional sense of the word. • Again, the reason may be actual illness or quarantine denying ships to enter or allow passengers and crew ashore, • Medical handling on board in case of suspect persons, • Off-hire when a vessel is unable to	• Autonomous Shipping • Autonomous Health Care Systems • Restricted health care monitoring

Climate change factor	Potential implications	Adaptation measures
	perform the work under the charter party and time is lost due to COVID-19-related issues,	

5 Sustainability Indicators

Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland 1987). Sustainable energy is clean and can be used over a long period. Generally, sustainable development in the field of energy is a vital element for economic sustainability and national security. Thus, this is increasingly encouraged through governments investment policies (Farah 2015). Moving towards energy sustainability will require changes not only in the way energy is produced and consumed, but in more importantly how it supplied, transported and delivered. Opportunities for improvement on the demand side of the energy equation are as rich and diverse as those on the supply side, and often offer significant economic benefits (Council 2007). The sustainability targets could be categorized into social, environmental, economic, and technical sectors. A compact list of sustainability indicators is listed in Figure 9.

Regarding that, the global indicator framework was developed by the Inter-Agency and Expert Group on sustainable development goals (SDG) Indicators (IAEG-SDGs), and agreed as a practical starting point at the 47th session of the UN Statistical Commission held in March 2016. The report of the Commission, which set the global indicator framework, was then taken note of by ECOSOC at its 70th session in June 2016 (UN. General Assembly 2017).

Furthermore, any development plan to achieve a green maritime should follow and meet the future shipping elements. Nowadays, maritime supply chain and logistics become extraordinary complex and high risk. In order to manage the complexity, the industry approaches digital technologies interaction and cyber-physical systems, which called (4^{th}) fourth industrial revolution includes Shipping 4.0. One of the main particles of Shipping 4.0 is Autonomous or Unmanned Shipping. The conventional propulsion systems use high-carbon fuels. The need for processing of Heavy Fuel Oil (HFO) on board and problems of switching between HFO and lighter marine gasoil (MGO) during port calls in emission control areas (ECA) makes it challenging to use HFO onboard. There is a partially complex fuel processing system associated with HFO, which could be difficult to operate reliably without humans on board unless technology providers develop affordable and reliable technologies. The IMO's requirement for low Sulphur content and development of scrubber and catalyst technology is an example of available solution. An attractive alternative to conventional fuel is the use of LNG and other low-carbon fuels (Rodseth and Burmeister 2015). Furthermore, fuel cells are an attractive alternative, especially for autonomous shipping. Current propulsion systems are not yet suitable for fully autonomous based shipping due to the maintenance demands for human on board. However, fuel cells will be a suitable alternative as no moving parts demands little maintenance with no requirement for on-site human intervention (ABB 2019).

In conclusion, the alternative fuels and technologies are the main chance to zero-emission shipping. Although advanced biofuels, hydrogen, and ammonia are potential low-carbon options to replace conventional fuels however, an important uptake barrier is their high cost compared with conventional fuels. In the cases of ammonia and hydrogen, another barrier is the lack of infrastructure. Hence, the transition should follow in three steps from low cost and avoidable emissions fuels, to high cost and unavoidable emissions fuels (Figure 7).

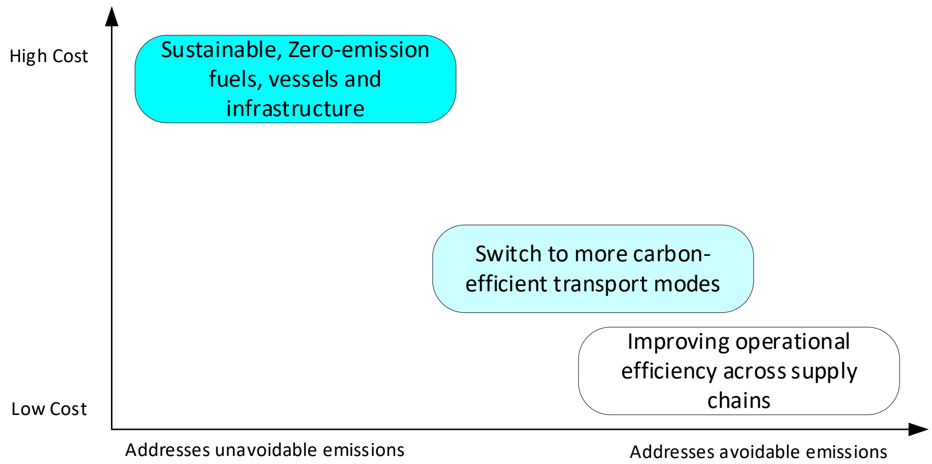

Figure 7. Pathway to clean logistics (Al Saleh and Fries 2020)

To examine, a survey of maritime stakeholders was done in Sweden. The survey ask stakeholders to express the priority of these indicator when selecting the alternative marine fuels (Månsson 2017). The included criteria represent a limited number of sustainability aspects that linked to alternative marine fuels.

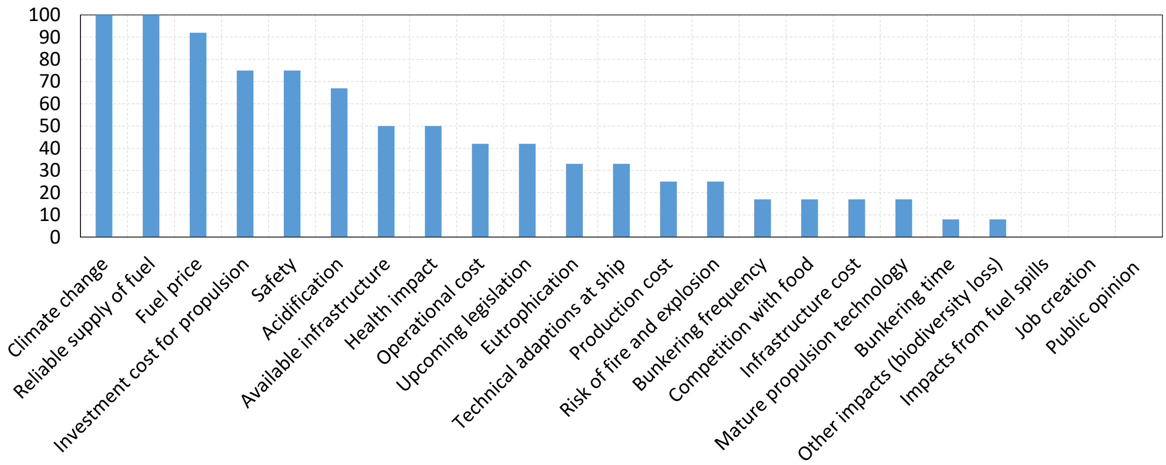

Figure 8: Priority of indicator to select an alternative fuel by stakeholders. source: (Månsson 2017),(Hansson et al. 2019)

The related policies discussed before, in this section, appointed indicators are reviewed as per the Table 5.

Table 5. Targets and related indicators based on Goal 13: Climate Action (adapted based on (UN. General Assembly 2017))

Goal 13: Climate Action	
Targets	Indicators
13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.3. Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies 13.1.1. Number of deaths, missing persons and persons affected by disaster per 100,000 people 13.1.2. Number of countries with national and local disaster risk reduction strategies
13.2. Integrate climate change measures into national policies, strategies and planning	13.2.1. Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other)
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1. Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula 13.3.2. Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions
13.A Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as	13.A.1. Mobilized amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment

Goal 13: Climate Action	
Targets	Indicators
soon as possible	
13.B Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities * Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.	13.B.1. Number of least developed countries and small island developing States that are receiving specialized support, and amount of support, including finance, technology and capacity-building, for mechanisms for raising capacities for effective climate change-related planning and management, including focusing on women, youth and local and marginalized communities
• Alternative fuels,	• **Price**: Accounts for production process, raw materials, market price and the reasoning behind it, current/foreseeable (five years) price/expected price (beyond five years) • **Infrastructure**: Current/future distribution network, bunkering, availability • **Regulations**: Existing/expected regulations, consequences • **Availability**: Current/future production as related to the requirement in shipping • **Environmental Impact**: CO_2, NO_x, SO_x, particulate matter (PM) and others • **Technology**: Availability of current/future technology, foreseeable changes • **CAPEX**: Engines, storage, processing, retrofitting • **OPEX**: Exhaust cleaning, scrubber, additional costs for fuel change

6 Pathway tool

In brief, by understanding the concept resilient and sustainable maritime specifications, and related available plans, it is time to demonstrate the interconnections and interactions. Figure 9 shows a schematic of the interaction and interconnection, explained more in continue.

At the first step, it is important to clarify then categorize the available and possible future effects of climate change in maritime, while, it may not be achievable by one stakeholder. Climate change may affect directly or indirectly a stakeholder. Therefore, all maritime stakeholders should find out type and depth of the effects in own field. For instance, by climate change, in one hand a shipping company faces with more bad weather days, which is a direct effect. In the other hand, in this condition, an insurance company should increase the safe side in charter-party contracts by new terms and conditions, where affected indirectly by climate change. The stakeholder could refuse the risk completely by pay and earn a safe side; or accept the risk; or mitigate the risk. However, the global target is removing all the risks by control the climate change.

In the second step, a given actor identifies the related contribution categories; and then specifies the field of activity based on the available sources. Although, the flowchart does not contain all types of contributors and sources, but presents an appropriate big picture. For example, a shipping company is the first layer face with climate challenges, and the related field of interest is freight and passenger market, ships.

Based on the global target, all contributors should design an own development plan to meet the target. This step needs a comprehensive cooperation between all players. As mentioned in section 2. Methodology, remove the risks of climate change is a program, where a program planner should define several sub-projects and sub-program, and distribute them between players. In this matter, governments and international association design the roadmaps play this role. Hence, each player should align its project with government's one. As illustrated in Figure 7 , it is not possible to achieve the target by one-step, while, needs a beginning, transient, and final period by several project/program.

A contributor should align the own development plan not only with global target, but also with the future shipping requirement, called shipping 4.0. Where, one of the significant components of the future shipping is autonomous shipping needs a green and low process fuels. Regarding that, a technology provider company should attend to design and manufacture an engine working with green and low process fuel, rather than a green and high process fuel. It means the green maritime is woven with shipping 4.0.

By defining the development plans, role and responsibilities should be established for internal and external activity in a company. Some of these responsibilities are demonstrated by upstream organizations, in form of law and statute. For instance, IMO restricted ships to use low Sulphur fuels by 2020. Regarding that, some new responsibilities are defined for governments and bunkering companies to supply the demanded fuels for the vessels.

In the next step, the development plan should be evaluated by a Risk assessment and analysis study, in which developer identifies all risks, their consequences, probability and frequency. Afterward, he evaluates the response of the system, and then proposes the risk plan. In many cases, owners need to know cost-benefit evaluation of the plan. Generally, owners want to spend minimum money with the highest efficiency. After all these steps, whole plan is checked by sustainability indicators. These indicators guarantee the continuously of the plan for a long time with enough and reliable supports.

To have a resilient system (company, organization, association etc.), some properties and specifications should growth gradually in system. It means, a resilient response does not come out from a risk reaction plan and procedure after a risk or disturbance occurs. However, it is possible to evaluate the resilient response against risks and disturbances time by time. It may be required to revise company's structure or attitude in form of transmuting. The above-explained procedure promises the system to meet the challenging target.

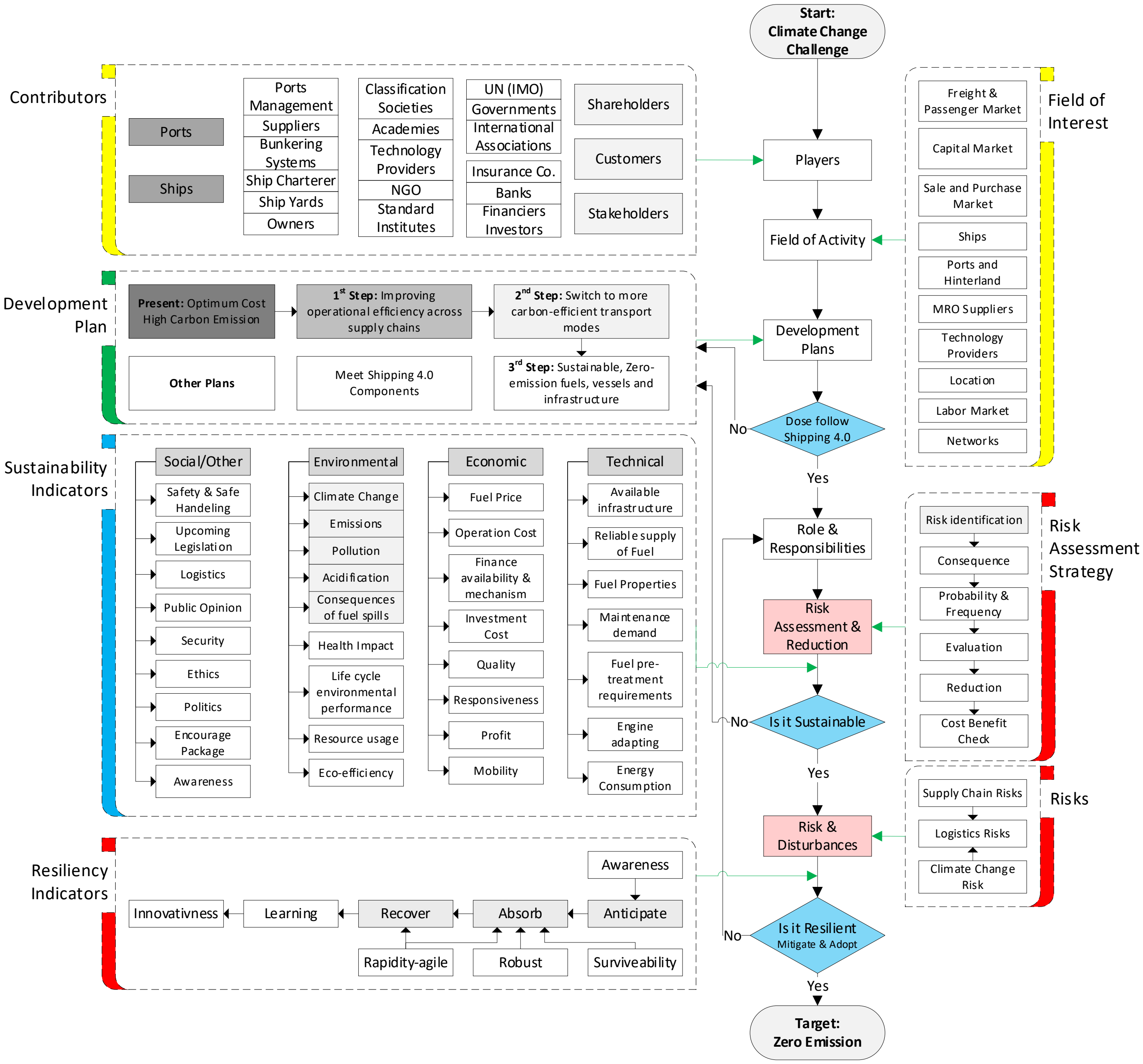

Figure 9. Resilience and sustainable development pathway to zero-emission

7 Conclusion

There were several reason to persuade authors to investigate into zero-emission shipping includes: (1) lack of an action plan framework toward a future target as big as zero-emission shipping, and (2) differences in detonation, management indicators, methodology, and sustainability and resilience domains, (3) vague about correlation and interconnection among risk assessment, resilience response and sustainability development domains. Accordingly, stakeholders were bewildered to contribute clearly in future green shipping with a right role and responsibility. This paper expands the climate change cause and effects on maritime logistics and illustrates a comprehensive view of global plan to monitor and control it. Then, it highlights a main solution pathway framework by term of project/program management based on international standards. Meanwhile, the dominant managerial terms and their interconnections, includes risk assessment and resilience response to impact of climate change, and afterward, sustainability development pathway, are investigated one by one. In order to following, monitoring and measuring the benefits of target by governance roles, the related indicators are presented. These indicators are adjusted for note only zero-emission, but also for future requirement of shipping (Industry 4.0). In conclusion, Figure 9 is presented as a guideline to clarify pathway for each contributor in future shipping, while are following the sustainability and resilience frameworks.

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