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Title: **Entrepreneurial opportunity identification for de-carbonisation and zero-emission in the NSR**

Semester: **Fourth**

Semester theme:

Thesis

Project period:

01.02.2021-03.06.2021

ECTS:30

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Number printed: []
Pieces Pages: [60]
Pages Appendix: [21]
Enclosures: []

SYNOPSIS:

The shipping industry is one of the largest and fastest growing sources of global carbon dioxide (CO2), nitrogen oxides (NOx), and Sulphur oxides (SOx) emissions, putting decarbonization and zero emission ships on the political agenda. Decarbonizing and zero emission is a necessity for sustainable blue growth. This research as a sub project in the PERISCOPE project, has answered the research questions using the Concept mapping, AHP, Thematic analysis and Structural Analysis and has also achieved the research objectives. Based on the research objectives, this research has formulated an applicable framework for screening venturing ideas and improved the existing knowledge in the field of entrepreneurship, while neither such framework nor their priorities are in the literature review. The research identified 15 entrepreneurial opportunities for decarbonizing and zero emission and introduced them to entrepreneurs, investors, and other actors in the NSR. Understanding how each opportunity is plausible is an arguably necessary for entrepreneurship. Deeper understanding of affecting variables for each opportunity and identification of the strategic variables, is a base for future entrepreneurships in the NSR.

By signing this document, each member of the group confirms participation on equal terms in the process of writing the project. Thus, each member of the group is responsible for the all contents in the project.

AARHUS BSS DEPARTMENT OF MANAGEMENT AARHUS UNIVERSITY

PERISCOPE

Interreg North Sea Region
European Regional Development Fund

EUROPEAN UNION

Acknowledgments

I would like to express my utmost gratitude to my supervisor Professor Dr. Harry Boer for the dedicated time, advice and support given throughout the whole period. He was always available over email and Skype calls to discuss and give important feedback.

I would also like to thank Dr. Matthew Jon Spaniol in department of management at Aarhus BSS for his professional knowledge, experience, support, and positive attitude. His door was always open whenever I faced difficulties or needed any help.

Many thanks to my colleagues in the periscope project at Aarhus BSS Aarhus University, Matt Evans, Akhim, Farhad and Kristian for their support.

Hamidreza

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Resumé (Abstract)

The shipping industry is one of the largest and fastest growing sources of global carbon dioxide (CO2), nitrogen oxides (NOx), and sulphur oxides (SOx) emissions, putting decarbonization and zero emission ships on the political agenda. Decarbonizing and zero emission is a necessity for sustainable blue growth. Entrepreneurs by utilizing of their ingenuity can identify venturing ideas and analyse them to identify entrepreneurial opportunities and establish new markets. The markets that can work non-stop while helping to decarbonizing and zero emissions. But how can such opportunities be identified, be made and profitable? Who should it service? Existing knowledge does not answer these questions precisely. Researcher addresses this gap and systematically identified the entrepreneurial opportunities for decarbonization and zero emission in the NSR. In this research, as a sub-project in the PERISCOPE project, the researcher aims to: Formulate an applicable framework for screening venturing ideas in the NSR. Introduce entrepreneurial opportunities for decarbonizing and zero emission to investors. And provide a base for a strategic foresight to manage strategic decisions for decarbonizing and zero emission in the NSR.

For achieving the first objective, the researcher answered 2 research questions:

1. What are venturing idea for decarbonizing and zero emission and their clustering in the NSR?
2. What are venturing idea screening criteria in the NSR and how are their priority?

In answering question one, the literature review showed (Chapter2), there are 57 venturing ideas for decarbonizing and zero emission in the NSR. A concept mapping analysis by Concept System software with 15 participants and a fit stress value showed 32 out of 57 venturing idea are more plausible. The participants, then, clustered 32 venturing idea into 3 clusters: Infrastructural, shipbuilding and technological venturing ideas.

In answering question two, brainstorming and AHP analysis by Expert Choice software were used. This analysis showed 4 venturing ideas screening criteria:

1. Feasibility.
2. The ability to solve emission problem and meet need to decarbonize and zero emission in the NSR.
3. Creating value for the NSR.
4. Commercially availability time.

With answering these questions, the researcher formulated an applicable framework for screening venturing ideas and improved the existing knowledge in the field of entrepreneurship, while neither such framework nor their priorities are in the literature review.

For achieving the second objective, the researcher answered 2 following research questions:

3- When the venturing ideas for decarbonizing and zero emission will be realized?

4. What are Entrepreneurial opportunities for decarbonizing and zero emission in the NSR in each cluster?

In answering question three, a modified Delphi approach was used. The results showed Commercially availability time for all 32 identified venturing ideas.

In answering question four, the author used GAHP. To identify entrepreneurial opportunities, the researcher asked 10 experts to complete 12 AHP questionnaires. Based on Expert Choice software outputs and 2 consensus interviews following entrepreneurial opportunities were identified in the NSR.

1- Infrastructural entrepreneurial opportunities: This cluster includes microgrids at large ports, prolonging life and re-purposing O&G assets, wind park repurposing, fully electric fish farm and offshore vessel charging stations.
2- Shipbuilding entrepreneurial opportunities: This cluster includes Exhaust scrubber, Solar-powered charging vessel, Renewable methanol vessels,100% Renewable energy vessels and Tide-powered hydrogen vessels.
3- Technological entrepreneurial opportunities: This cluster includes Charging at offshore wind parks/farms, Virtual arrival agreements, AI for cargo stowage, International MRV monitoring and Offshore maintenance drones.

For achieving the third objective, the researcher answered 2 following research questions:

5. What are the variables affecting realization of these opportunities?
6. Which variables are the key (Strategic) variables?

In answering question five, the author performed an inductive qualitative data analysis using MAXQDA V.18 and applied Kappa Coefficient and Stress Value for trustworthiness. In result 79 different variables (codes) identified and clustered in 5 themes for the 15 opportunities. The themes are political, economic, social, technological, and environmental.

In answering question six, Structural Analysis by Micmac software was used. This analysis showed 36 out of 79 identified variables are strategic (key) variables, because those are controllable by the system and have an acceptable impact on the system.

Answering these questions created a deeper understanding of affecting variables for each opportunity. Identification of the strategic variables is a base for future entrepreneurships in the NSR.

Recommendations for each cluster in the chapter 5 are applicational approaches for decarbonizing and zero emission in the NSR.

Chapter 1 Introduction

1.1 Introduction

The blue economy represents roughly 5.4 million jobs and generates a gross benefit of almost €500 billion a year (Paulauskas, 2018). Maritime industries, such as aquaculture, are moving further offshore to take advantage of the vast space of the ocean, and moving further offshore requires access to consistent, reliable power untethered to land-based power grids (LiVecchi et al. 2019). Oceanographic research and national security missions increasingly rely on autonomous sensor navigation and unmanned vessels and drones that need to function with limited human intervention—pushing further offshore and staying on missions longer—that challenge contemporary techniques of energy generation, storage, transfer, logistics and reliable remote recharging. The development of large-scale activities offshore creates new opportunities for innovative and sustainable business models (LiVecchi et al. 2019).

The North Sea Region (NSR) is a crucial area for Europe's Blue Economy with marine resources, technologically- advanced industries, major port areas and increased offshore activities. The North Sea has played a vital role in the development of the economies around it – supplying food, energy, and transportation routes. It is also a popular tourism and recreation area, as well as a nature reserve. (WEC, 2017). Due to global drivers, the wider maritime, marine, and offshore economies are exposed to profound challenges with some industries undergoing significant changes, including increased production, as well as stagnation and decrease of production - the NSR is experiencing a period of considerable restructuring (Northsearegion.eu).

Figure 1-1: North Sea region

Source: (Northsearegion.eu)

These new cross-border and cross-sectorial prospects generate new challenges that require entrepreneurship because entrepreneurship plays an important role in fostering economic growth, job creation and innovation to a nation and a transnational region. According to Shane and Venkataraman (2010), "entrepreneurship is concerned with the discovery and exploitation of profitable opportunities". Profit is thus being created by the entrepreneur only because of the discovery, identification or creation of the opportunity and acting upon it. Opportunity identification is the process through which ideas for potentially profitable new business ventures are identified (Baron & Ensley 2006). In the other words, Opportunity identification is "perceiving a possibility for new profit potential through (a) the founding and formation of a new venture, or (b) the significant improvement of an existing venture" (Singh et al. 1999, 658).

The PERISCOPE project that financed by the south Norway European office is an important project for managing of these challenges. This project is structured following the triple helix innovation setup. In the setup Aarhus University, or rather the Strategic Foresight Research Network (SFRN) constitutes the academic circle. Aarhus University's task is to provide a holistic approach for networked industry foresight. The PERISCOPE benefit is to have state-of-the-art industry foresight tools to predict the future of the blue market economy.

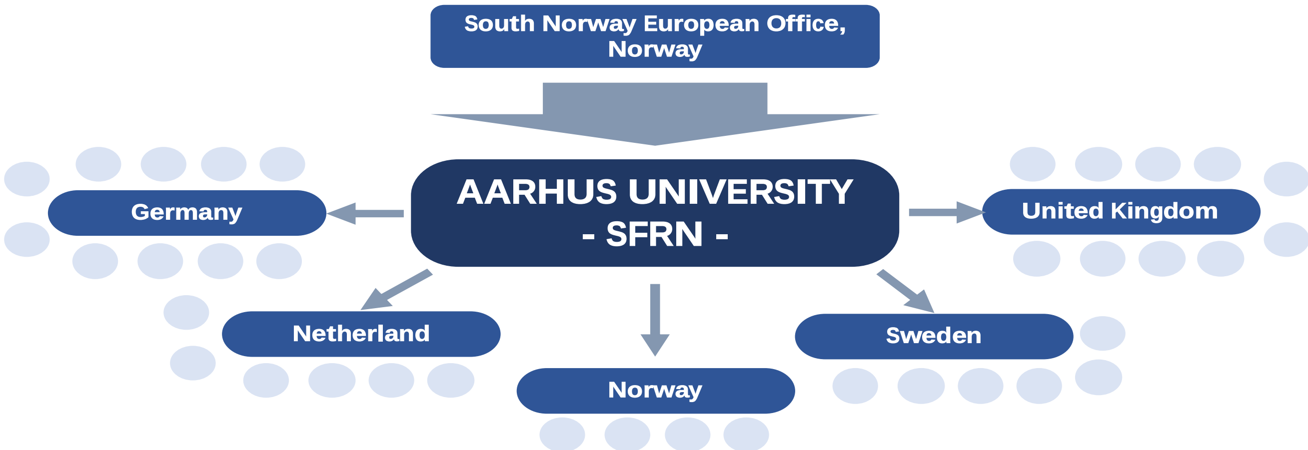

Figure 1-2: Periscope project and NSR

The PERISCOPE aims to support Interreg North Sea's objectives, first and foremost "Thinking growth" by strengthening cross-sector Blue Growth innovation capacity in the NSR by bringing together the players (businesses, entrepreneurs, clusters/networks, researchers, universities, business angels, incubators, investors and funds, customers/users, regional and local authorities and development/business support agencies) for knowledge sharing, acceleration and launch of new innovation-projects for sustainable business development .Identification of entrepreneurial opportunities for decarbonization and zero emission is one of these projects.

In the previous researches in the NSR, the role of entrepreneurship has been neglected or ignored but this research will establish an entrepreneurial discovery process through opportunity identification to reinforce the knowledge base, identify and valorise innovation ideas, and open up a Blue Growth ecosystem to stimulate industry-driven action on the concrete opportunities ahead.

1.2 Problem statement and research questions

The shipping industry is one of the largest and fastest growing sources of global carbon dioxide (CO2), nitrogen oxides (NOx), and sulphur oxides (SOx) emissions, putting opportunity identification for decarbonizing and zero emission ships on the political agenda. In view of climate change and the unsustainable level of greenhouse gas (GHG) emissions and the associated climate impact, the International Maritime Organisation (IMO) continues to contribute to the global fight against climate change, in support of the UN Sustainable Development Goal 13, to take urgent action to combat climate change and its impacts (WEC Netherlands,2017 , OECD,2018 and IMO.org) .Therefore Increasing pressure is on the marine and maritime industry to take more environmentally friendly measure to reduce their carbon footprint by replacing fossil fuels with renewable energy or finding other ways that can help them to attain zero emission. This pressure has posed serious challenges to the North Sea. Researcher addresses this gap and systematically explore the diverse entrepreneurial opportunities that can yield to decarbonization and zero emission. In particular, the author answers the following research questions.

1- What are venturing idea for decarbonizing and zero emission and their clustering in the NSR?
2- What are venturing idea screening criteria in the NSR and how are their priority?
3- When the venturing ideas for decarbonizing and zero emission will be realized?
4. What are Entrepreneurial opportunities for decarbonizing and zero emission in the NSR in each cluster?
5. What are the variables affecting realization of these opportunities?
6. Which variables are the key (Strategic) variables?

1.3 Research objectives

In this study, the researcher aims to:

1. Formulate an applicable framework for screening venturing ideas in the NSR.
2. Introduce entrepreneurial opportunities for decarbonizing and zero emission to investors.
3. Provide a base for a strategic foresight to manage strategic decisions for decarbonizing and zero emission in the NSR.

1.4 Thesis Structure

In the "Introduction" chapter the author discusses the background and problem formulation of the study together with the research questions that this report aims to answer.

Chapter two is dedicated to "Literature review". This chapter presents a broad literature review on the theories underlying the thesis: Entrepreneurship, opportunity, entrepreneurial opportunity definitions, opportunity identification models, entrepreneurial opportunity evaluation criteria and a deep dive in potential opportunities in the NSR. In the last section of this chapter, operationalization variables and concepts were presented. The next chapter is called "Methodology", where the used research methods, data collection and data analysis methods are described.

Chapter four is where the author analysis the data. In the fifth chapter the author answers the research questions possessed in the beginning and draws a concluding remark in the end of this chapter and provides recommendations.

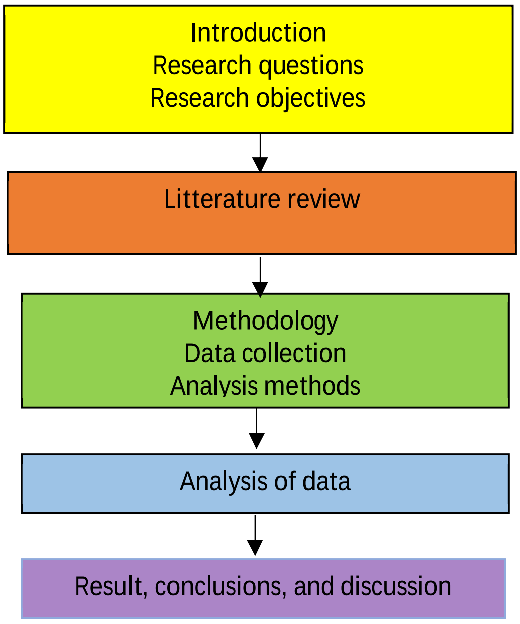

Figure 1.3: Thesis structure

Chapter 2 Literature review

This chapter discusses the core constructs of the research. The first section focuses on the theories underlying the thesis. The second section focuses on the decarbonizing and zero emission and their importance in the NSR and the third section is a deep dive in potential opportunities (Venturing ideas) in the NSR. The fourth section presents operationalization variables and concepts.

2.1 The theories underlying this thesis

The thesis title is "Entrepreneurial opportunity identification for de-carbonisation and zero-emission", therefore entrepreneurship, opportunity, entrepreneurial opportunity, opportunity identification and entrepreneurial opportunity evaluation criteria are the theories related to this title; but only some of these theories can be underlying of this thesis.

Innovation and Entrepreneurship has proven to be the most successful way to address problems and create both economic and social opportunity. Innovation is applying creativity to come up with a unique idea or solution. Entrepreneurship, by contrast, is applying the innovation to bring the ideas to life. (Sandberg,2015).

There are a lot of definitions of **entrepreneurship** in the literature (such as Stevenson,1990; Venkataraman,1997; Timmons,1999; Shane and Venkataraman,2000; Johson,2001; Stevenson,2001; and Kuratko and Morris,2002). The entrepreneurship definition of Shane and Venkataraman (2000) is one of underlying theory of this thesis:

"Entrepreneurship is 'an activity that involves the discovery, evaluation and exploitation of opportunities to introduce new goods and services, ways of organizing, markets, processes, and raw materials through organizing efforts that previously had not existed." (Shane and Venkataraman,2000)

The central key term in entrepreneurship definitions is the opportunity. The notion of opportunities is central to understanding economic transformation, and the concept of ''opportunities'' has been extensively used to explore different aspects of innovation, entrepreneurship, and industrial dynamics (Holmen et.al,2007).

There are also a lot of definitions of **opportunity** in the literature (such as Krueger 1993 and 1998; Timmons,1997; Ardichvili, et.al,2003; Baron and Shane,2005; Short et.al,2010; and Ding,2019). The opportunity definition of Baron and Shane, (2005) is another underlying theory of this thesis:

"A potential factor in creating something new that comes from changing circumstances." (Baron and Shane, 2005).

Entrepreneurial opportunity is one of the vital elements of entrepreneurial behaviour and is one of the central concepts of entrepreneurship definition has been mentioned in much research in the field of entrepreneurship and it is called as the heart and critical attribute of entrepreneurship. (Tumasjan & Braun,2012; Tang et al,2012; Lehner & Kansikas, 2012, Vaghely,2008). Different authors provided different definitions of entrepreneurial opportunity (such as Shane and Venkataraman,2000; Eckhardt and Shane,2003; Gonzalez and Solis,2011; Zoltan, McMullen, and Plummer,2007; Autio,2015; Laverty and Little,2020). The entrepreneurial opportunities definition of Shane and Venkataraman (2000) is another underlying theory of this thesis:

"Entrepreneurial opportunities are those situations in which new goods, services, raw materials, and organizing methods can be introduced and sold at greater than their costs of production" (Shane and Venkataraman,2000).

Opportunity identification is recognized as one of the most important abilities of successful entrepreneurs. Rapidly changing world, the ever-changing business environment, globalization, and the dynamics of the markets make the pursuit of new entrepreneurial opportunities a necessity (Munger, Purdy & Artz 2002). There are several definitions of opportunity identification (such as Hills,1995; Singh et al.,1999; Sarasvathy et al,2003; Baron and Ensley,2006; Barringer and Ireland,2007; Ozgen and Baron,2007 and Corbett,2007). The opportunity identification definition of Singh et al., (1999) and Sarasvathy et al. (2003) are other underlying theories of this thesis:

"Perceiving a possibility for new profit potential through (a) the founding and formation of a new venture, or (b) the significant improvement of an existing venture" (Singh et al., 1999).

Opportunity identification is an activity that evaluates and prioritizes business ideas and selects the best opportunity from among the ideas. (Sarasvathy et al,2003).

There are also several models for opportunity identification in the entrepreneurial literature (such as: Morison model ,1997; Singh et al. model ,1999; Ardichvili et. al model 2003; Gundry & Kichul ,2006; Ozgen and Baron model ,2007; Lumpkin et.al model ,2004; Hajizadeh and Zali model ,2016; and Filser et. al model 2020).

Filser et. al model 2020 is another underlying theory of this thesis which shows Personal factors such as prior knowledge, experience, cognitive processes, personality traits and genetics, environmental factors such as networks, Technology, demographic change, market conditions, and organizational aspects such as potential financial reward, entrepreneurial culture, decision making processes, organizational learning, and information sourcing, all influencing opportunity identification (Filser et.al 2020) .

Various frameworks and criteria have been proposed by entrepreneurship researchers to **evaluate entrepreneurial opportunities**. Table 2.1 shows categorization of entrepreneurial opportunities evaluation criteria. This table has sent to experts to identify idea screening criteria. (See 1.2, 4.2 and 5.2).

Combining different underlying theory of entrepreneurship, opportunity, entrepreneurial opportunity, and opportunity identification processes, in this research a process of entrepreneurial opportunity identification is defined as a discovery or a creation of a new entrepreneurial opportunity through following steps:

1.Identification of venture ideas in the NSR

The author has identified 57 venturing ideas (potential opportunities) for decarbonizing and zero emission in the NSR by a deep dive in 110 maritime reports, 50 websites and 40 articles. (See 2.7, table 2.2 and 4.1).

2. Venturing Idea screening with the criteria that will determine by experts (see 4.2) to identify entrepreneurial opportunities. (See 4.4)

3.Decide about how to start a new venture. (See 4.5 and 4.6).

The research has adapted Filse et. al model for statistical sampling and opportunity identification. Based on this model, the researcher identified an initial sample of experts who have the necessary knowledge, expertise, and experience in the field of research. The researcher then accessed the experts using the snowball sampling method. (See 3.3)

Table 2.1 Entrepreneurial opportunity evaluation criteria

Evaluation criteria category	Items	Authors
Economic and financial factors	Total cost, profit, and revenue generation, required investing, Return on investment (ROI), R&D expenditures	Long and McMullan (1984), Timmons (1986), Murnieks et al. (2011), Douglas and Shepherd (2002), Smith et al. (2010), Spinelli and Adams (2012)
Market and industry	Commercially availability time (an accepted practice), Safe market, Market need, Target market, key customers, competitors, market structure, market size, market potential, market capacity, market share attainable, growth rate	Long and McMullan(1984) Timmons(1986),Smith et al. (2010), Murnieks et al.(2011), Spinelli and Adams (2012)
Product or service issues	Available alternative, Novelty, rarity, substitutability, imitability, competitive advantage, product/service life, sustainability, value proposition Creating value for customers	Long and McMullan (1984), Dobbins&Pettman(1998), Wikhan, Shapherd et al. (2013), Williams and Wood (2015), Spinelli and Adams (2012)
Desirability	Ability to solve a problem, Income, risk, work effort, independence, net perquisites	Douglas and Shepherd (2002), Fitzsimmons and Douglas (2011), Haynie et al. (2009)
Feasibility	Financial feasibility, market and industry feasibility, product/service feasibility, practicality feasibility, technical feasibility,	Long and McMullan(1984) ,Dimov (2010), Zahra et al. (2006)
Human capital	Knowledge, skills, education, experience (industry or technical), Compatibility with the power and skills of founders (entrepreneur), entrepreneurial team, intellectual honesty, intellectual capital, learnings, cognitive-metacognitive abilities, social networks, individual characteristics, appropriate management team	Long and McMullan (1984), Wickham (2006), Wood and Williams (2014), Barreto (2012), Grichnik et al. (2010), Dimov (2010), Murnieks et al. (2011), Mitchell and Shepherd (2010)
Environmental factors	Economic, political, social, and cultural or technological environment, environmental uncertainty	Smith et al. (2010), Mitchell and Shepherd (2010), Autio et al. (2013)

2.2. Decarbonizing and zero emission

Ships and large industries of the maritime are responsible for more than 18 percent of some air pollutants (Walker,2019). More than 90 % of global trade is done with ships (Matthias et.al.2009). The total global transport work by ships (in ton miles) has been tripled since the mid-1980s (Smith et al., 2014). Shipping is a major cause of harmful air pollution in Europe and by 2025 shipping emissions of SO_2 and NO_x could exceed the emissions of these pollutants from all other sources in the EU (Airclim. et.al,2016).

Commercial ships burn fuel for energy and emit several types of air pollution as by-products. Ship-source pollutants most closely linked to climate change and public health impacts include carbon dioxide (CO2), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (clearseas.org).

Figure 2.1: ship pollutants

(Source: https://clearseas.org/en/air-pollution)

One large ship can generate about 5,000 tonnes of sulphur oxide (SOx) pollution in a year.70% of all ship emissions are within 400km of land, and In the North Sea, 90% of emissions take place within 90 km from shore (Ågren,2020) .85% of all ship pollution is in the northern hemisphere. Shipping is responsible for 3.5% to 4% of all climate change emissions (Vidal,2009). While pollutant emissions from land-based sources are gradually decreasing, those from shipping show a continuous increase (Figs.2.2 and 2.3). (Airclim. et.al,2016). Under current legislation, it is expected that shipping emission of the SO2 and NOx will increase by 40–50% up to 2020, as compared to 2000. In both cases, by 2020 the emissions from international shipping around Europe are expected to equal or even surpass the total from all land-based sources in the 27 EU member states combined. In the absence of mitigation policies, and innovative solutions, ship emissions could double or even triple by 2050 (Airclim. et.al,2016). Both gases (NOx and SO2) affect adversely on human health and ecosystem (Licki et al,2015).

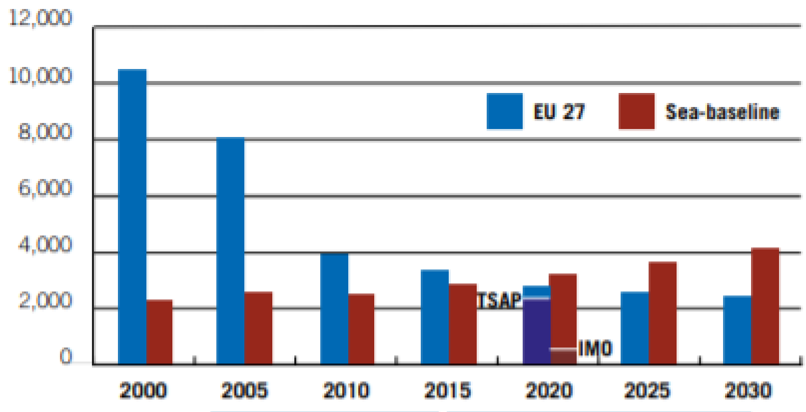

Figure 2.2: Emissions of SO2 2000–2030 (ktonnes)

EU27 = Emissions from land-based sources (incl. domestic shipping)

Sea = Emissions from international shipping in European sea areas

TSAP = Target in line with the EU's Thematic Strategy on Air Pollution

IMO = Expected outcome from implementing the revised IMO MARPOL Annex VI

(source: https://www.cleanshipping.org/Air pollution from ships)

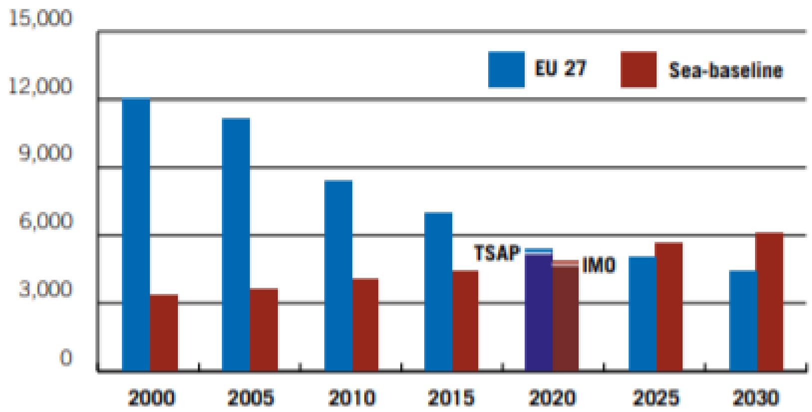

Figure 2.3: Emissions of NOx 2000–2030 (ktonnes)

(source: https://www.cleanshipping.org/Air pollution from ships)

The North Sea is one of the areas with the highest ship densities in the world. Europe's three biggest harbours in Rotterdam, Hamburg, and Antwerp are in the North Sea region. At any time, about 3000 ships are sailing in the North Sea. The steady increase in the number and size of ships leads to an increasing contribution of ships to air pollution in North Sea coastal areas (Matthias et al., 2016). From 1 January 2020, the limit for sulphur in fuel oil used on board ships operating outside designated emission control areas is reduced from 3.50% sulphur by mass (after January 1, 2012) to 0.50% m/m (mass by mass). This will significantly reduce the amount of sulphur oxides emanating from ships and should have major health and environmental benefits for the world, particularly for populations living close to ports and coasts (Schrooten, et al.2009 and IMO 2020).

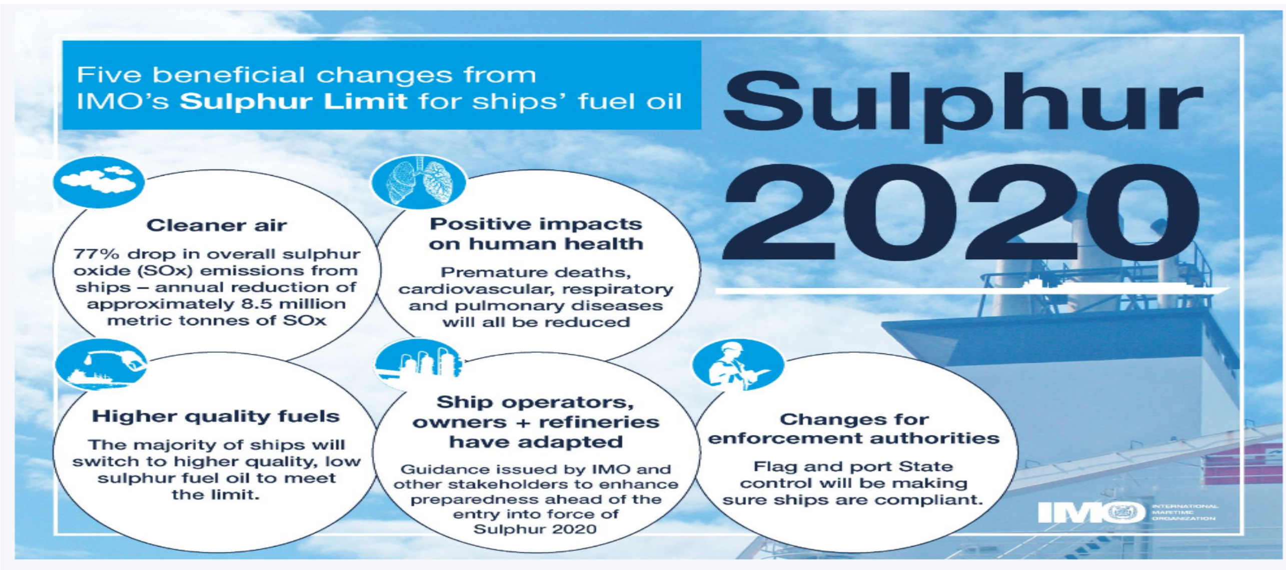

Figure 2.4: Sulphur 2020

(Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx)

Due to the necessity of decarbonizing, zero emission and environmental protection, and improving the blue growth, identification of entrepreneurial opportunity recently captured the imagination of the marine and maritime community.

2.3. Deep dive in potential opportunities in the NSR

The North Sea presents concrete business opportunities for decarbonizing and zero emission, but Timely action is vital, as the required investments have a long technical lifetime. Decisions made today, and in the coming 15 years, will be crucial for progress towards the 2050 CO2 reduction targets. Therefore, identification of these opportunities is very important. (World Energy Council,2017). For this reason, the researcher has tried in the first step to identify all the potential opportunities (Venturing ideas) for decarbonization and zero emissions in the North Sea region.

The author had identified 222 venturing ideas (potential opportunities) for all activity aspects in the NSR by a deep dive in 110 maritime reports, 50 websites and 40 articles during the internship in PERISCOPE project since September to December 2020. (See appendix 1). There are 57 out of 222 initial ideas that are directly or indirectly related to decarbonization and zero emission. Table 2.2 Shows these ideas.

Table 2.2 Initial venturing ideas for decarbonizing and zero emission

Idea	Description	Source
Decommissioning optimization	In the next 7 years, 150 oil and gas platforms are expected to be decommissioned in the North Sea. Annual global spending on decommissioning is set to increase from $2.4bn in 2015 to $13bn per year by 2040. Given the complexity and uniqueness of each removal activity, firms earn new knowledge about environmental hazards on each operation.	World Energy Council Netherlands (2017), Fraser (2016), International Association of Oil & Gas Producers (2017), IHS Markit (2016),Hou et.al (2016)
Prolonging life and re-purposing O&G assets	Perform a technical assessment of the current infrastructure to understand its compatibility for new uses, such as the use of natural gas pipelines for transporting hydrogen, methane, or CO2	World Energy Council Netherlands (2017),
Maritime synergies and spatial planning	Spatial planning is a tool for improving maritime governance in waters of EU countries. Evidence that it could increase the efficiency of licensing offshore activities whilst protecting the marine environment led to the adoption of Directive 2014/89/EU establishing a framework for maritime spatial planning (MSP)	World Energy Council Netherlands and Andrew Sean Merrie (2016)
Electrifying oil and gas platform	By producing clean energy through offshore wind, electrifying oil, and gas platforms (thereby reducing the carbon footprint of O&G production) and using old gas fields for carbon storage, the North Sea could substantially contribute to lowering GHG emissions and other fossil fuel related emissions.	World Energy Council Netherlands (2017),
Smart ships (industry 4.0)	Smart ships are being widely debated as the shipping industry's next technological revolution. In the manufacturing industry, the term 'fourth industrial revolution' describes how 'smart devices will replace the role of humans for the management, optimization and control of machinery. smart ships enable new optimisation of operation, and constantly enhancing design methods that can bring significant energy savings in ships.	Lloyd's register, QinetiQ, and university of Strathclyde (2013), And VTT Technical Research Centre of Finland (2020)

Idea	Description	Source
Sensor for efficient ship	Sensors monitor ships on fuel efficiency. They combine data from different sources to give a full insight into the operations of ships. Data sources include sensor data from ships, position data of ships and data on weather conditions (currents, waves, wind). Combining this data, they give shipowners a (near) real-time overview of his operations. Furthermore, they show deviations from design conditions that impact fuel consumption.	https://angel.co/we4sea-1 https://angel.co/sirenmarine
No-ballast systems	Researchers are investigating a radical new design for cargo ships that would eliminate ballast tanks, the water-filled compartments that enable non-native creatures to sneak into the Great Lakes from overseas.	https://www.sciencedaily.com/releases/2008/03/080326111641.htm
Long-distance power transmission	High voltage DC (HVDC) submarine lines that can transmit electricity for long distances with fewer losses than alternating current, or AC, lines.	https://phys.org/news/2016-09-superconductive-material-long-distance-energy-transmission.html
Ocean vent thermal energy conservation	Hydrothermal vent is a kind of manifestation of geothermal energy on seabed. It produces high temperature fluid through a hole which has a diameter in various range between several inches to tens of meters. Some of them have a thermal power of up to 60 MWt. The technology of hydrothermal vent using ORC method has small impact to the environment. With an output energy as huge as mentioned before, the price of constructing this technology is low considering the empty of cost for drilling as what it should be in conventional exploitation.	Hauerhof (2017) Aryadi et al (2016)
Ocean nanobots	The newly developed nanobots have three key components: a graphene oxide exterior to absorb lead (or another heavy metal); a nickel core that enables researchers to control the nanobots' movement via a magnetic field; and an inner platinum coating that functions as an engine and propels the bots forward via a chemical reaction with hydrogen peroxide. Scientists demonstrating that new microscopic underwater warriors can remove up to 95% of lead in wastewater in just 1 hour.	http://www.businessinsider.com/graphene-based-nanobots-can-suck-pollutants-from-our-oceans-2016-4?r=US&IR=T&IR=T https://www.marketwatch.com/story/nanobots-are-waiting-in-the-wings-to-cure-cancer-and-clean-up-ocean-pollution-2016-06-09
Greener engines	Greener engines that minimise Nitrogen Oxide output and strives to achieve zero Sulphur Oxide output. Aamir Farooq and colleagues from KAUST's Clean Combustion Research Center (CCRC), working with the Fuel Technology Team at Saudi Aramco, used an innovative technique for testing the properties of light naphtha, a fully blended, low-octane, highly paraffinic fuel.	https://phys.org/news/2016-11-technique-foundation-greener-fuels.html https://www.rolls-royce.com/about/our-technology/research/research-programmes/sustainable-and-green-engine-sage-

Idea	Description	Source
		itd.aspx#lean-burn-demonstrator
Advanced ultra-efficient propeller designs	Compared to conventional designs, the Kappel propeller blades offer fuel savings of up to 6 percent. The improvement relates to the blade design alone, not relying on improvements from other components – such as a rudder bulb integrated with propeller and rudder.	https://www.gallois.be/ggmagazine_2012/gg_06_11_2012_254.pdf
Solar cell hybrid system	Solar hybrid power systems are hybrid power systems that combine solar power from a photovoltaic system with another power generating energy source.	Kumar and Garg (2013)
Diversification of the fuel mix	NV sees distillates and LNG becoming more prominent sources in 2030. according to its report, LNG will be generally available in the period 2020-2025 and deep-sea ships will run on distillates, LNG, biofuels, renewable and batteries.	https://www.norwayexports.no/news/green-innovation-in-maritime-technology/
Exhaust scrubber	The solution will remove sulphur and particulates from the exhaust gases of the vessel's main and auxiliary engines and weigh roughly 70 tonnes in equipment plus piping. Bimco reports that 13 percent of the main cargo carrying ship types, approximately 2,600 of the roughly 20,000 commercial cargo-carrying ships, are currently fitted with scrubbers.	https://www.norwayexports.no/news/green-innovation-in-maritime-technology/ https://www.maritime-executive.com/article/scrubber-installations-continue-with-containerships-leading-the-way
Fire Fighter Robots	is an autonomous humanoid robot capable of detecting and suppressing shipboard fires and working shoulder to shoulder with human firefighters using advanced sensors.	https://www.marineinsight.com/future-shipping/5-innovative-robotic-technologies-for-the-maritime-industry/
Prolonging the lifespan of offshore infrastructure	Circular economy as a concept has gained attention worldwide. One strategy for extend the lifetime of wind turbines is the application of different circular economy initiatives being service/maintenance, reuse/redistribution, and remanufacture/refurbishment.	https://www.plateconference.org/routes-extending-lifetime-wind-turbines/
Multi-use platforms	Developing a concept of Multi-use Oceanic Platforms has become one of the EU's most interesting bets to guarantee the use and synergistic exploitation of oceanic resources in a sustainable and eco-friendly manner.	http://www.troposplatform.eu/tropos-european-collaborative-project/What-is-Tropos-for Hansen (2020)
Re-purposing of infrastructure Re-purposing old O&G assets	After oil and gas production has ceased, operators may deem platforms and infrastructure worthless for further use. Nonetheless, those assets could find a new life and be used for the storage of renewable energy, as well as CO2. This would	World Energy Council Netherlands (2017)

Idea	Description	Source
	support the transition to a low carbon energy system in the North Sea.	
Solar desalination	Solar desalination is a technique to desalinate water using solar energy. There are two basic methods of achieving desalination using this technique: direct and indirect. In the direct method, a solar collector is coupled with a distilling mechanism and the process is carried out in one simple cycle. Indirect solar desalination employs two separate systems; a solar collection array, consisting of photovoltaic and/or fluid based thermal collectors, and a separate conventional desalination plant.	https://blog-en.condorchem.com/evaporation-systems-water-desalination/#.YJQKH9Uzapp
Modularized infrastructure	Tenne T presents Hub and Spoke concept for large scale wind energy on the North Sea.	https://www.tennet.eu/our-key-tasks/innovations/north-sea-infrastructure/
Zero-fuel ships	Shipping companies across the world are trying to come up with innovative engineering ideas and green technologies to tackle the stringent regulations about fuel emissions from vessels.Five singular ship concepts which would be zero emission ships are mentioned below: 1. E/S Orcelle 2. Super Eco Ship 2030 3. Container Feeder Vessel ZERO 4. Futureship Zero-Emission Ferry Concept and 5. B9 Cargo Ships	https://www.marineinsight.com/green-shipping/top-5-zero-emission-ship-concepts/ https://www.marineinsight.com/tech/7-technologies-to-reduce-fuel-consumption-of-ships/
3D imaging of cargo stowage areas	Stowage plans, especially in ro-ro bay optimization, can be better balanced "on the fly" to maximize the fuel efficiency and safety on board.	http://www.interschalt.com/fileadmin/user_upload/MACS3_MixStow_Module.pdf
LNG Bunkering infrastructure in the North Sea	Regional strategy to provide infrastructure so as not to overlap or create expensive redundancies.	https://www.dnv.com/maritime/lng/infrastructure.html
The evolving diesel motor	This is for sub-suppliers developing technologies that can be added on or around or within proximity of diesel motors.	Shrinivasa (2012)
Offshore maintenance drones	Offshore platforms sometimes cause environmental pollution. These platforms require regular inspection and maintenance. Drones equipped with tools such as welders and grinders, would provide a safer and cheaper service.	Joshi, D., (2019), Brogaard, R., (2020) Daponte, P et.al (2019)
Composite bulk carrier hull	Fires and explosions have resulted in 112 large vessel losses in the past decade. And have caused a great deal of pollution and emissions. Composite materials, however, are highly resistant to fire compared to wood and steel.	Thomas, G. (2020), Johnson, T., (2018) Håkansson et.al (2017)
Pilot project with clean burning gas carriers	The project has a high level of community benefit, as it can help to start using a fuel associated with significantly less environmental impact than today's alternatives. DME-powered ships have a positive effect on the quality of the dock in local ports as well as being of major importance in a larger climate	https://www.gminsights.com/industry-analysis/dimethyl-ether-dme-market

Idea	Description	Source
	perspective. The EU's goal is to reduce CO2 emissions from maritime transport by 40% (if possible 50%) by 2050 compared with 2005 levels.	
Sensor system for collecting weather and traffic data from ships.	The system will improve the accuracy of weather models and improve weather forecast routing to reduce fuel consumption and risk related to difficult routes and weather conditions.	https://www.ipta.org.uk/news/item/84-reduction-of-ghg-emissions-imo-data-collection-system
100% Renewable energy vessels	Vessels' engines powered by waves. They are hybrid ships that use both waves energy and electrical power provided by solar panels placed on board. In this way they can sail without CO2 emissions and without refuelling. They should be more lightweight than the today ships because they do not need place for fuel or big engines that better exploit the waves power. The technology is already tested and validated; the optimization is still ongoing.	http://www.ouroceanschallenge.org/blue-motion-energy/
Offshore vessel charging stations	Infrastructure of offshore charge points in the open sea fuelled by renewable energy for powering offshore service vessels. A first step is to build electric offshore service vessels. Supply vessels will not need to dock for refuelling, allowing for faster loading times, better air quality in harbours / coastal cities, cost reduction on fuel, and energy gains from moving beyond inefficient diesel engines.	http://www.ouroceanschallenge.org/offshore-charge-points/
50MW floating converter and accumulator	"With a footprint of three soccer fields, energy is harvested from sea water and waves, enough for 150,000 families. Similar output to an offshore wind park, at half the size. 12 pontoons on the lower end of the construction to move along with the waves, generating energy to pump up sea water to a reservoir 50m high. The water flows back to the sea from the reservoir in a continuous way, through a set of hydro turbines. The continuous water flow guarantees a continuous power output."	http://www.ouroceanschallenge.org/floating-cathedral/
Charging at Offshore container terminal	Offshore terminals reroute containers to short sea shippers and provide platforms for renewable ocean energy.	Bebbington, T. (2017) Hansen (2020)
Standardized data scheme for monitoring, verification, and reporting	Standardization for the data format for real-time reporting of fuel type usage and emissions will improve regulatory enforcement practices.	Dennis Mes et.al (2016)
Subsea drone charging platform	The installation of subsea drone charging platforms at offshore wind farms will allow for autonomous subsea drones to undertake maintenance and reduce costs.	Röckmann C. et.al (2017), Measure, (2020) Cherdo. L, (2020)
Wind farms that move autonomously in the ocean	Autonomous roaming wind farms that optimize energy production by moving around in the ocean. They move away by the places without wind to ones windier.	Hill, J. (2018) Equinor (2020) Kinhal, V. (2020)

Idea	Description	Source
(Roaming Autonomous Wind Farms)		
fully electric fish farm	Fish farms, located far out to sea, could go fully electric by using wave energy, and use surplus power to charge the electric vessels that make voyage out to the farm.	Worldfishing & Aquaculture (2014), GoodFishBadFish (2020), Syse, H. L. (2016),
Charging at offshore wind parks/farms	Offshore wind turbines could provide electricity to recharge the battery-equipped vessels that service and maintain them, reducing fuel requirements and emissions	Hansen(2020), Roslyng Olesen, T. (2016), Haynes, J. (2019)
Thermal vent smoke filtering	Hydrothermal vents on the ocean floor can offer an inexhaustible supply of valuable minerals and metals. Plume filtering techniques could environmentally friendly.	Budgen, P. (2017), Hoekstra, C. (2019), O'Kruk, A. (2019),
Microgrids at large ports	Enhanced energy storage and utilization systems at large ports, powered by renewable energy, could play a role in decarbonizing the maritime and transport industries.	Martínez, J., Vazquez, P. & Maldonado, J. (2019), Flaherty, N. (2018), Hosseini, A., Sangsefidi, Y. & Sani, A. (2018)
Solar-powered charging vessel	A network of autonomous solar powered vessels could provide on-call recharging services in route, enabling increased speeds and radius for other electrified vessels.	Hansen(2020), Diamandis, P. H. (2019), Linder, C. (2019),
charging at Thermal-powered platform	A multi-use platform for extracting ocean resources, producing hydrogen, and providing energy for charging of the passing vessels.	Hansen (2020),
Renewable Liquid methanol fuel for vessels	Using methanol produced from natural gas offers reduction of local pollution (NOx, SOx emissions). Methanol produced from renewable sources, can substantially contribute to reducing GHG emissions from shipping.	Chatterton (2020), Advent Technology, (2019),
Tide-powered hydrogen vessels	Hydrogen gas tanks, recharged at tidal power plants, could be swapped on and off medium-sized vessels to help with the greening of the maritime and offshore industries.	Hansen (2020), Giannini, G. (2019), Husseini, T. (2018), Woo, M.J. (2017)
Flying ships	Forcing a layer of air between a ship's hull and the water, improving fuel efficiency, and reducing emissions.	Sinha T. (2019), Raunek (2019), SSPA (2020).
Thermal-powered platform	A multi-use platform for extracting ocean resources, producing hydrogen, and providing a base for detection of illegal fishing by drones, powered by thermal energy	Global Market Insights (2018), PEW Environment Group (2008)
Lightweight containers	Constructing steel containers instead with high-strength lightweight composite materials would allow for higher stacking, lower fuel expenses, and thereby reduce emissions.	Blume Global, (2020), Bison, (2020), Yildiz, T. (2019), Stratiotis, E., (2018)
Ice-class container Vessel	Very large ice-class certified container vessels, sailing through the Arctic's Northern Sea Route and Northwest Passage, would	WorldShipping (2017), Ørsts et.al (2016), Solakivi, et.al (2019),

Idea	Description	Source
	reduce shipping distances by up to 40% and thereby reduce emission.	Lasserre, F. (2014)
Offshore logistics hub	Co-locating a container terminal at an offshore wind energy park would be able to use excess electricity to desalinate water for hydrogen for powering feeder vessels.	Selin, H. & R. Cowing, (2018), Adamopoulos, A., (2019), Spaniol (2020)
Virtual arrival agreements	Ports and shipping companies entering into virtual arrival agreements, enabling ships to arrive at ports just as space is opening, minimizing fuel consumption and thereby reduce emissions.	Napa, (2019), University of Copenhagen, (2019), Karimpour, R, (2018),
Oilfield thermite plug	Offshore oil field decommissioning is done with a seabed cement plug. These crack and oil leaks out. Thermite would be a reliable and long-term solution	Vrålstad, T., Saasen et.al (2019) Kaminski, I. (2017). Wellcem (2017).
International MRV	Ships above 5000 gross tonnes in the EU are required to monitor and report on fuel consumption and emissions. However, there is a lack of transparency and enforcement.	European Commission, (2020), IMO, (2020),
AI for cargo stowage	RoRo vessels carry 234 million tonnes of goods around Europe annually. Artificial intelligence for cargo stowage could limit delays, ensure balance, and lower ballast. And reduce fuel consumption.	Martinez, C. (2020), ECSA (2016), Wathne, E. (2012),
Renewable methanol vessels	Renewable methanol can be produced from renewable electricity. such as wind. Using it as a fuel to power ocean – going vessels would make shipping virtually emission free.	Hobson, C., & Márquez, C. (2018), Advent Technology, (2019),
Wind Park repurposing	Repurposing offshore wind parks' infrastructure by installing wave energy systems would offset the cost of decommissioning and increase renewable energy generation.	World Energy Council (2017) International Renewable Energy Agency (2014),
Carbon Capture and Storage	Carbon capture and storage (CCS) involves capturing carbon dioxide (CO2) emissions, caused by human activities, ideally before they enter the Earth's atmosphere, then transporting and storing them securely in geological sites.	Whitmarsh (2019), IPCC (2005) https://ec.europa.eu/clima/policies/innovation-fund/ccs_en
Seaweed as a biofuel	Seaweed can be used as a biofuel. Seaweed production within offshore windfarms could reduce CO2 emissions by 202 Mt over the period 2020-2050.	World Energy Council (2017)

2.4 operationalization variables and concepts

Based on the research questions and objectives, the theories underlying the thesis, the decarbonizing and zero emission and their importance in the NSR and a deep dive in potential opportunities (Venturing ideas) in the NSR, following variables and concepts have been measured in this thesis. (Table 2.3)

Table 2.3 operationalization variables and concepts

Concept/Variable	Measurement
Venturing ideas	Brainstorming Focus statement: Venturing ideas for decarbonization and zero emission in the NSR. Questions in discussion step: 1.What are plausible ideas? 2. What are duplicate, unrelated, and similar ideas? 3. How is their clustering?
venturing ideas screening criteria	Brainstorming and Analytic Hierarchy Process Focus statement: Criteria for screening ideas to identify entrepreneurial opportunities AHP question: How is priority of these criteria?
Commercially availability time	Modified Delphi method and Online questionnaires Main question: Estimate how many years from now, ……..idea, will become an accepted practice, i.e. commercially available.
Entrepreneurial opportunities	Analytic Hierarchy Process Question: How are pairwise comparisons of venturing ideas with respect to screening criteria and goal (Decarbonization and zero emission).
variables affecting realization of these opportunities	Online questionnaires Open question: What is needed to make this opportunity happen? Thematic analysis questionnaire Question: How is sort of codes for each entrepreneurial opportunity cluster? Please sort a set of codes for each entrepreneurial opportunity cluster based on a corresponding binary symmetric similarity matrix.
Strategic variables	Influence-dependence questionnaire Question: How a variable influences other variables and how other variables influence it? (How likely is it that these two discrete variables influence on one another? Each pair is rated on a scale of 0 to 3.) 0: No influence 1: Weak 2: Moderate influence 3: Strong influence

Chapter 3 methodology

This chapter introduces the research methods and different data gathering techniques used in this project, as to establish the validity of the results generated throughout the project.

3.1 Research method

There are four relevant research methods that has been used within this project; descriptive, applied, mixed and futures research.

Descriptive research is used to describe the characteristics of a population or phenomenon being studied (Mishra and Alok, 2017).

Applied research is a methodology used to solve a specific, practical issue affecting an individual or group. This scientific method of study and research is used in business, medicine, and education in order to find solutions that may improve health, solve scientific problems or develop new technology (Kothari, 2004). For this project, applied research has been used to identify entrepreneurial opportunities in the NSR and determination of their rating.

Mixed methods research is a methodology used to conduct research that involves collecting, analysing, and integrating quantitative (e.g., experiments, surveys) and qualitative (e.g., focus groups, interviews) research (Clark and Ivankova, 2016). The project has taken advantage of the mixed methods because the data collected is based on both qualitative and quantitative data collection techniques.

Futures research can be defined as a systematic study of possible future events and circumstances. (Sardar,2010). This method has been used to identify when the opportunities will be realized in the future and which strategic variables effect on this realization.

3.2 Data collection

Figure 3.1 describes the methods used for data gathering. As seen in the figure, there are two different sources for data collection: primary and secondary sources.

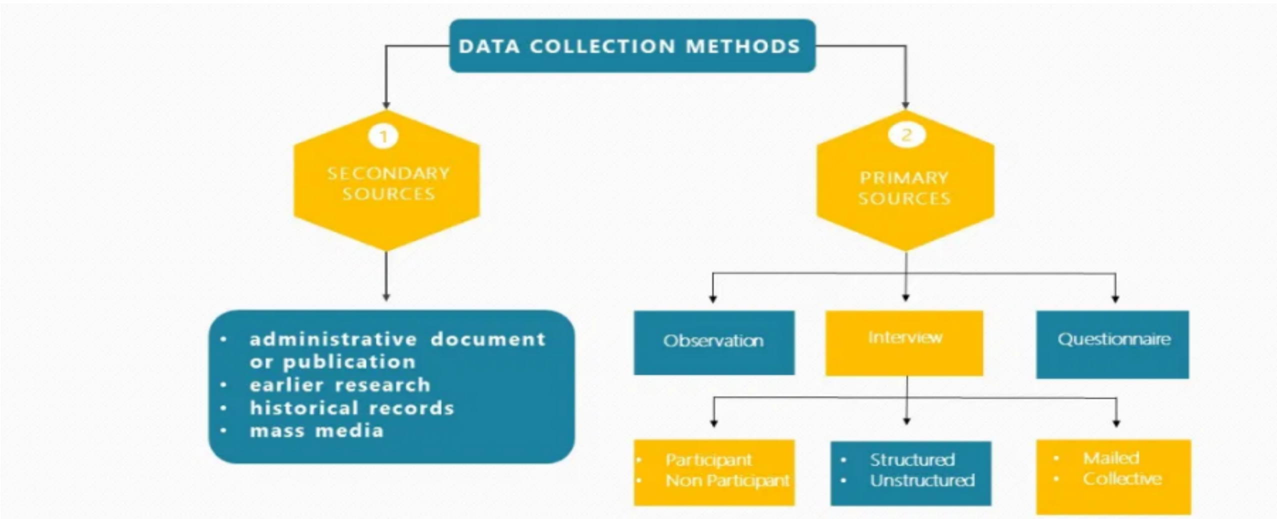

Figure 3.1. Data collection methods

(Source: https://worldsustainable.org/data-collection-tools/)

Data and knowledge used in this report has been collected using a mixture of both data collection methods, field research (Primary sources) and desk research (Secondary sources). The primary data collection methods used in the field research has been interviews, group discussions and questionaries. And the secondary data collection methods used in the desk research has been a deep dive in the literature of entrepreneurial opportunity identification and the potential opportunities for decarbonizing and zero emission in the NSR that have been identified so far. Table 3.1 shows the used data collection methods in this research.

Table 3.1: The used data collection methods

Primary sources	Type	Number	Secondary sources	Number
Miro Brain storming (Venturing ideas)	Concept Mapping	15 experts	Maritime reports	110
Miro Brain storming (Idea screening criteria)	Consensus	10 experts	Articles	50
AHP questionnaires	Matrix	10 Experts	Webpages	40
Periscope questionnaires	Online	Infrastructure 176		
		Shipbuilding 192		
		Technology 144		
AHP questionnaires	Matrix	10 Experts		
Thematic analysis questionnaire	Matrix	12 Experts		
Influence-dependence questionnaire	Matrix	12 Experts		

The research started with a deep dive in potential opportunities (Venturing ideas) in the NSR's literature. 110 maritime reports, 50 papers and 40 web pages were reviewed. 222 venturing ideas were identified. (See appendix 1). 57 out of 222 venturing ideas are directly or indirectly related to decarbonization and zero emission. (See table 2.2). Then the theories underlying the thesis including literature of Entrepreneurship, opportunity, entrepreneurial opportunity definitions, opportunity identification models, entrepreneurial opportunity evaluation criteria were reviewed (chapter 2). Primary data was gathered through 2 virtual brainstorming, AHP questionnaires, Periscope questionnaires, Thematic analysis questionnaire, and influence -dependence questionnaire (Appendix 5). As the above table shows in answering the first research question, 15 experts invited to a Miro brain storming based on Concept Mapping process (see 3.4.1). In answering the second research question, 10 experts were invited to a Miro brain storming. Then they asked to complete an AHP questionnaire to priorate venturing idea screening criteria. In answering the third research question a questionnaire was uploaded for each venturing idea on https://periscope-network.eu/business-opportunities that in total completed by 176,192 and 144 respondents for infrastructural, shipbuilding and technological venturing ideas, respectively. In answering the fourth research question, 10 experts were asked to complete 12 AHP questionnaires to identify entrepreneurial opportunities among of venturing ideas that were previously identified in answer to question one. In answering the fifth research question, 12 experts were asked to answer the Thematic analysis questionnaires and finally in answering the sixth research question, an Influence-dependence questionnaire completed by 12 experts.

3.3. Statistical sampling

For answer to the research questionnaires and participant in the brain storming, statistical samples were selected. Table 3.2 shows sampling methods and number of samples for each interview and questionnaire.

Table 3.2: Sampling methods and number of samples

Collection data tools	Statistical sampling method	Number
The first Miro brain storming	Snowball	15 experts
The second Miro brain storming	Convenience *	10 Experts
AHP questionnaires	Convenience	10 Experts
Periscope questionnaires	Snowball	Infrastructure: 176
		Shipbuilding:192
		Technology:144
AHP questionnaires	Convenience	10Experts
Thematic analysis questionnaire	Convenience	12 Experts
Influence-dependence questionnaire	Convenience	12 Experts

*Due to the COVID19 pandemic

3.4 Data analysing methods.

Researcher addresses research questions by integrating knowledge from decarbonizing and zero emission, venturing ideas and entrepreneurial opportunity identification literature into 5 data analysing methods. (See table 2.3). More specifically, in the first step, Researcher describes key concepts and initial venturing ideas for decarbonizing and zero emission, in the second step, uses concept mapping technique to identify the most likely venturing idea and cluster them. In the third step after a consensus with the experts about venturing ideas screening criteria, researcher uses AHP to rate the criteria, and in the fourth step, uses modified Delphi approach to estimate when venturing ideas will be commercially realized. In the fifth step, AHP analysis determines which venturing ideas based on the criteria can be an entrepreneurial opportunity. Researcher then, in sixth step, uses Qualitative research methodology to clarify the variables affecting realization of the Entrepreneurial opportunities, and the seventh step, uses Structural impact analysis to determine which variables are the strategic variables.

3.4.1 Concept mapping

Concept mapping is an applied procedure, which was developed in the fields of educational, social, cognitive and management science to generate conceptual frameworks based on specific items. It is a stepwise approach in which statements are generated, rated, statistically analysed with several multivariate statistical analysis (multidimensional scaling and hierarchical cluster analysis), and finally interpreted. The method is used to create clarity, develop a model or to specify a conceptual framework. In most studies, the six steps of Trochim (1989) are used to define a framework or to specify a model. (See fig.3.2). (Trochim,1999; Trochim et. al. 2003; Brenan, et al. 2012, Hassanzadeh 2015; Trochim, & Mclinden, 2016).

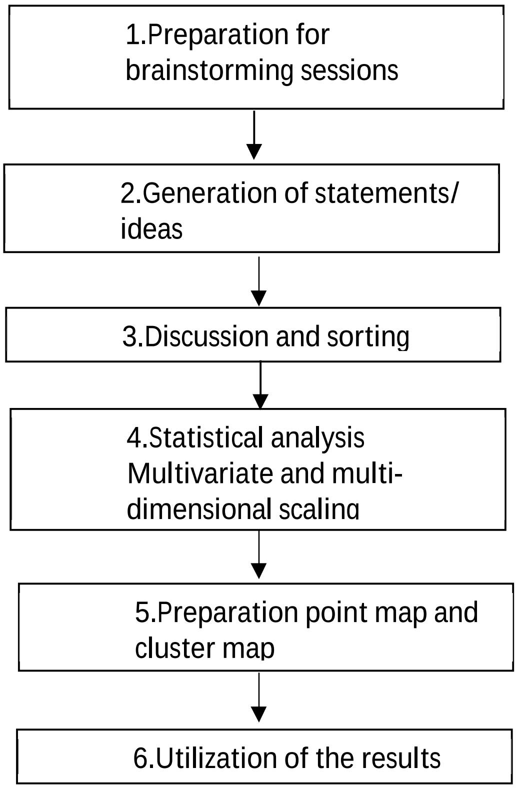

Figure 3.2 Concept mapping process

(Adopted from: Trochim,2016)

3.4.2 Analytic Hierarchy Process (AHP)

Analytic hierarchy process is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or ideas. Thomas L. Saaty in the 1970s developed the AHP technique. (Vargas,2010). The AHP uses alternatives and criteria and structures alternatives within a hierarchy of criteria for evaluation. Through pairwise comparison, AHP elicits ranking preference for alternatives and weighting preference for criteria using a scale from 1 to 9; higher scores indicating greater relative preference (Huang et al., 2011). Table 3.3 shows Saaty's Scale of Relative Importance.

Table 3.3 Saaty's Scale of Relative Importance

Scale	Numerical rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Source:(Saaty,2005)

Consistency Ratio (CR) has an axis role in the AHP and determine whether the decision makers have been consistent in their choices. (Vargas,2010; Teknomo, 2006). The maximum CR can be 10%. (Saaty,2005).

3.4.3 Modified Delphi method

Delphi method was popularized after WWII by the RAND Corporation that worked with the US Department of War to determine when, for example, hydrogen bombs and intercontinental ballistic missile systems would be ready for deployment (Grime and Wright, 2016).

This method is modified for PERISCOPE, rather than ask the probability that a technological capability will be achieved at a future date, the lead question in the survey asks when the use-case vignette will become an accepted practice or viable alternative to the status quo. The time to accepted practice (Commercially available) is drawn from technology diffusion curves, where first iterations have been launched, validated, have received the necessary regulatory permissions to operate. Whereas Delphi surveys seek consensus, this format applies the logic of the wisdom of the crowds (Surowiecki, 2005), where the assumption that the median estimation will outperform the vast majority of individual estimations is made.

3.4.4 Qualitative research

Since the aim of qualitative studies is to provide an accurate description of a real situation, such studies attempt to directly present the opinions of individual participants and to collect data through detailed and in-depth methods (Yıldırım & Şimşek,2008). In qualitative research, a theme (sometimes also termed "category") (Creswell &Poth 2018) is an element of data or sequence of words that can serve as a synoptic. A theme, therefore, is composed of coded data grouped together according to similarities or patterns.

3.4.4.1 Trustworthiness

To ensure the results' trustworthiness, the author applied Kappa Coefficient and Stress Value. The kappa statistic is frequently used to test interrater reliability. The importance of rater reliability lies in the fact that it represents the extent to which the data collected in the study are correct representations of the variables measured. Measurement of the extent to which data collectors (raters) assign the same score to the same variable is called interrater reliability (McHugh,2012). According to Cohen's article, values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement (Cohen,1960). Many texts recommend 80% agreement as the minimum acceptable interrater agreement (McHugh,2012).

To be more confidence of the results, researcher also calculated the stress value. This research involving 12 participants (M=12), each of whom sorted a set of codes for each entrepreneurial opportunity cluster. For each sort, there is a corresponding binary symmetric similarity matrix, SNxN. These are aggregated into the total matrix, TNxN. This total matrix is the input to the Multi-Dimensional Scaling (MDS) analysis, which yields a two-dimensional XNx2 configuration. The Euclidean distances (in two dimensions) between all pairs of statements can be computed directly from the two-dimensional matrix, yielding a distance matrix DNxN where:(Trochim,1993).

$$D_{ij} = \sqrt{(X_{i1} - X_{j1})^2 + (X_{i2} - X_{j2})^2}$$

The stress value indicates the goodness of fit of the configurations, with lower stress values having a better fit. Previous analyses of the stress value suggest that desirable stress value is in a range from 0.155 to 0.352 (Brenan, et al. 2012).

3.4.5 Structural/ cross impact analysis

Cross-impact analysis is the general name given to a family of techniques designed to evaluate changes in the probability of the occurrence of a given set of events consequents on the actual occurrence of one of them (Bañuls, and Turoff,2011). For designing cross impact matrix of the key variables, structural/ cross impact analysis through a panel consisted of 12 experts is used, their aggregated opinions about variables' influences on each other was entered in the matrix. The matrix is analysed by MICMAC software. The Micmac allows participants to see the influence that one variable exercises on another through a third, a fourth, even a fifth. The direct and indirect influences of the variable represent the system the most realistically (Godet,2006).

Chapter 4 Data analysis

The goal of the analysis of data is to create clarity to it and thus produce new information about the researched subject. This chapter answers research questions and provides insights into the future of the decarbonization and zero emission in the NSR.

4.1 Answer Question 1: What are venturing idea for decarbonizing and zero emission and their clustering in the NSR?

Based on the deep dive (See 2.3) initial venturing ideas for decarbonisation and zero emission in the NSR was extracted (Table 2.2). In answer to question 1, the researcher managed a virtual brainstorming by Miro. In the remote brainstorming were 15 participants (See table 4.1) and focus statement was: Venturing ideas for decarbonization and zero emission in the NSR. In the first step, Researcher described key concepts and research objectives, in the second step, shared the initial ideas with participants, and in the third step, Participants expressed their ideas in compliance with the rules of brainstorming and concept mapping (See 3.4.1). Then, in forth step, ideas were discussed. At this step, duplicate and unrelated ideas were removed, similar ideas were merged, and new ideas were added. (Table 4.2). The author, in fifth step, suggested some phrases for clustering, the participants discussed them and reached a consensus on the titles of the clusters., and in the sixth step, each of participant sorted the ideas into the clusters on their own.

For this analysis, The Concept System software was used. Figures 4.1 and 4.2 illustrate the results of the concept mapping.

Table 4.1 Participants' demography

Organization/ Job	Years of experience	Organization/Job	Years of experience
Port of Aarhus	10	Hvide Sande Havn	7
Researcher at Aarhus university	8	MHI vestas offshore	14
Internest France	9	AERSEA AS Norway	7
Maersk	14	Researcher at Aarhus university	15
Researcher at Aarhus university	6	Researcher at Liverpool university	6
Dronequest	5	Ericsson Innovation Hub	11
Northsite	10	Researcher at Aarhus university	8
Stable – drone platform Norway	12		

Table 4.2 Venturing idea for decarbonization and zero emission

Venturing Idea for decarbonization and zero emission	
1. Oil platform decommissioning	17.Solar-powered charging vessel
2.Prolonging life and re-purposing O&G assets (Electrifying oil and gas platform and Carbon Capture and Storage)	18. Composite bulk carrier hull
3. Offshore maintenance drones	19. Renewable methanol vessels
4.Smart ships (industry 04)	20.Tide-powered hydrogen vessels (Charging at tidal plants)
5. Offshore container terminal	21.Flying ships
6.Sensor for efficient ship (Sensor system for collecting weather and traffic data from ships.)	22.Thermal -powered platform
7. Offshore vessel charging stations	23.Lightweight containers
8.Long-distance power transmission	24.Ice-class container vessel
9. 100% Renewable energy vessels	25.Offshore logistics hub
10.Ocean nanobots	26.Virtual arrival agreements
11.Greener engines	27.Oilfield thermite plug
12.Advanced ultra-efficient propeller designs	28.International MRV monitoring
13. Microgrids at large ports	29.AI for cargo stowage (3D imaging of cargo stowage areas)
14. Charging at offshore wind parks/farms	30. Subsea drone charging platform
15.Exhaust scrubber	31.Wind Park repurposing
16. fully electric fish farm	32. Wind farms that move autonomously in the ocean. (Roaming Autonomous Wind Farms)

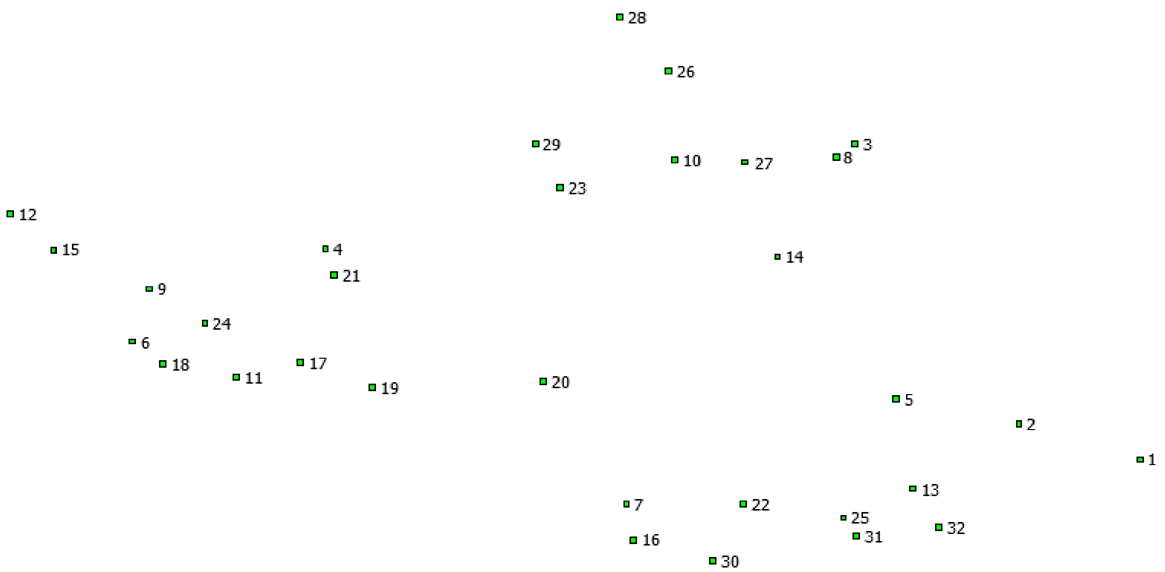

Figure 4.1: Venturing ideas' Point map

Figure 4.2: Venturing ideas' cluster map

The point map (Figure 4.1) and cluster map (Figure 4.2) are the result of multivariate statistical analysis of corresponding binary symmetric similarity matrixes, SNxN. As mentioned in the third chapter, the stress value indicates the goodness of fit of the configurations, with lower stress values having a better fit. Previous analyses of the stress value suggest that desirable stress value is in a range from 0.155 to 0.352 (Brenan, et al. 2012). For this configuration of clusters, the stress value was 0.31, so it fell within the range, suggesting that the clusters in this study have a good fit.

As the above figures show clusters and their related venturing ideas are:

Infrastructure: Decommissioning optimization, Prolonging life and re-purposing O&G assets, Offshore container terminal, Offshore vessel charging stations, Microgrids at large ports, fully electric fish farm, Thermal -powered platform, Offshore logistics hub, Subsea drone charging platform, Wind Park repurposing, Roaming autonomous wind farms.

Shipbuilding: Smart ships (industry 04), Sensor for efficient ship (Sensor system for collecting weather and traffic data from ships.), 100% Renewable energy vessels, Greener engines, Advanced ultra-efficient propeller designs, Exhaust scrubber, Solar-powered charging vessel, Composite bulk carrier hull, Renewable methanol vessels, Tide-powered hydrogen vessels, Flying ships, Ice-class container vessel.

Technology: Offshore maintenance drones, Long-distance power transmission, Ocean nanobots, Charging at offshore wind parks/farms, Lightweight containers, Virtual arrival agreements, Oilfield thermite plug, International MRV monitoring, AI for cargo stowage.

4.2 Answer question 2: What are venturing ideas screening criteria in the NSR and how are their priority?

The literature review showed that there are no clear criteria for screening ideas to identify entrepreneurial opportunities. Therefore, in the second virtual brainstorming, researcher shared table 2.1 with the experts and asked them to discuss how can we identify entrepreneurial opportunities among of the 32 venturing ideas. (See table 4.1) After a scientific and professional discussion, the participants reached a consensus on the following criteria:

1. Creating value for the NSR.
2. The ability to solve emission problem and meet need to decarbonize and zero emission.
3. Commercially availability time.
4. Feasibility

But how is priority of these criteria? To answer this question, the author used GAHP (Group AHP). Figure 4.3 shows Hierarchy tree for priorate of the above criteria.

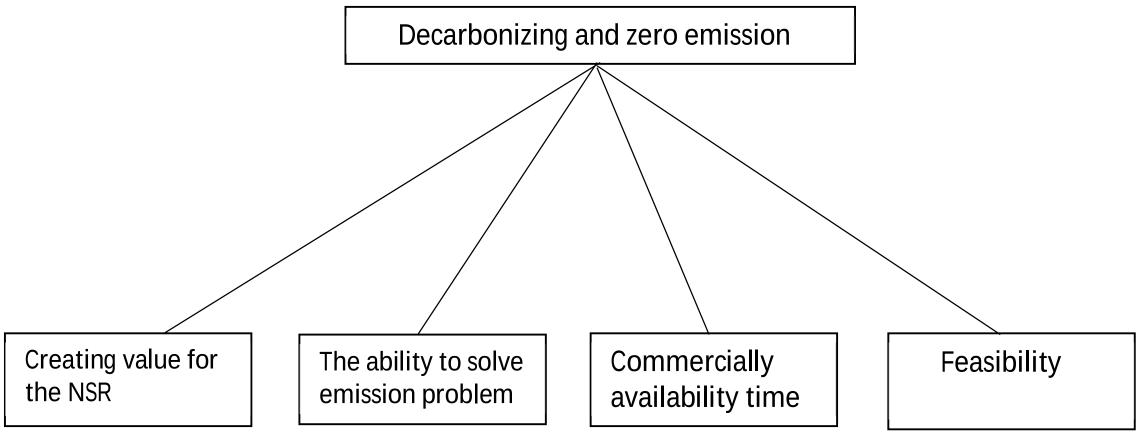

Figure 4.3 Criteria hierarchy tree

Based on the hierarchy tree, researcher formulated an AHP questionnaire (Appendix 2) and asked the experts to priorate the criteria base on the Saaty's scale (See chapter 3).

For this analysis, the expert choice software was used. Figure 4.4 illustrates the results of the AHP analysis.

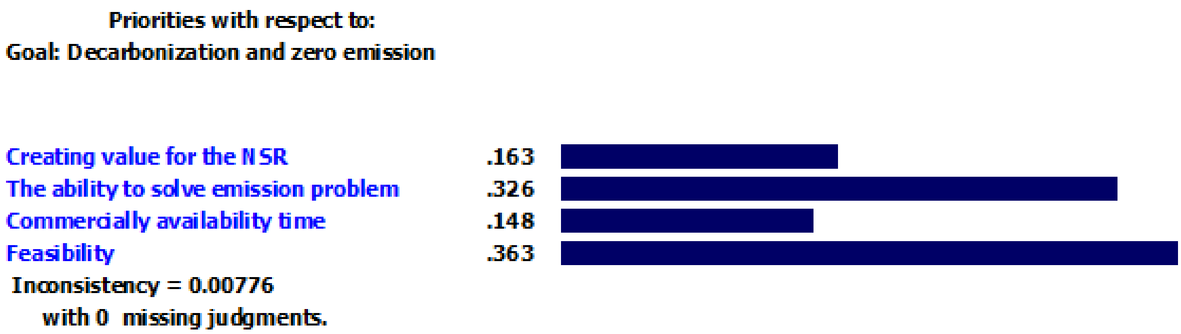

Figure 4.4 Priority of venturing ideas screening criteria

As figure 4.4 shows, criteria "feasibility" and "the ability to solve emission problem" take precedence over criteria "creating value for the NSR" and "commercially availability time" to identification of entrepreneurial opportunity for decarbonization and zero emission.

The inconsistency rate is 0.0078 which is less than 0.1 (See 3.4.2), and shows the inconsistency is acceptable and we do not need to revise the subjective judgment.

In this research feasibility means ensuring an idea is legally and technically feasible as well as economically justifiable. It tells us whether an idea is worth the investment.

The ability to solve emission problem means the idea can meet need to decarbonize and zero emission in the NSR.

Creating value for the NSR means that an idea can help improve people's lives and sustain blue growth in the NSR.

Commercially availability time means when a venturing idea become an accepted practice and available to buy or use within a reasonable time at an ordinary commercial price in the future in the NSR.

Therefore, in this thesis:

Entrepreneurial opportunity = Idea + Feasibility + need + Value +Commercially availability time.

4.3 Answer question 3: When the venturing ideas will be realized?

Each of the 32 venturing ideas were then developed into use-case vignettes. Each of the use-case vignettes was then developed into a survey following the logic of a modified Delphi approach (See 3.4.3). Delphi surveys ask respondents to estimate when venturing ideas will be realized (Commercially available)?

A questionnaire was uploaded for each idea on https://periscope-network.eu/business-opportunities. (See Appendix 3).

The survey data are analysed to find the median estimation for the venturing idea. Median, rather than the mean (average), is used for this analysis to prevent skewness resulting from outliers. In the following sections, the author analysed the data based on each cluster. Figure 4.5 shows Realizing time for each venturing idea in each cluster.

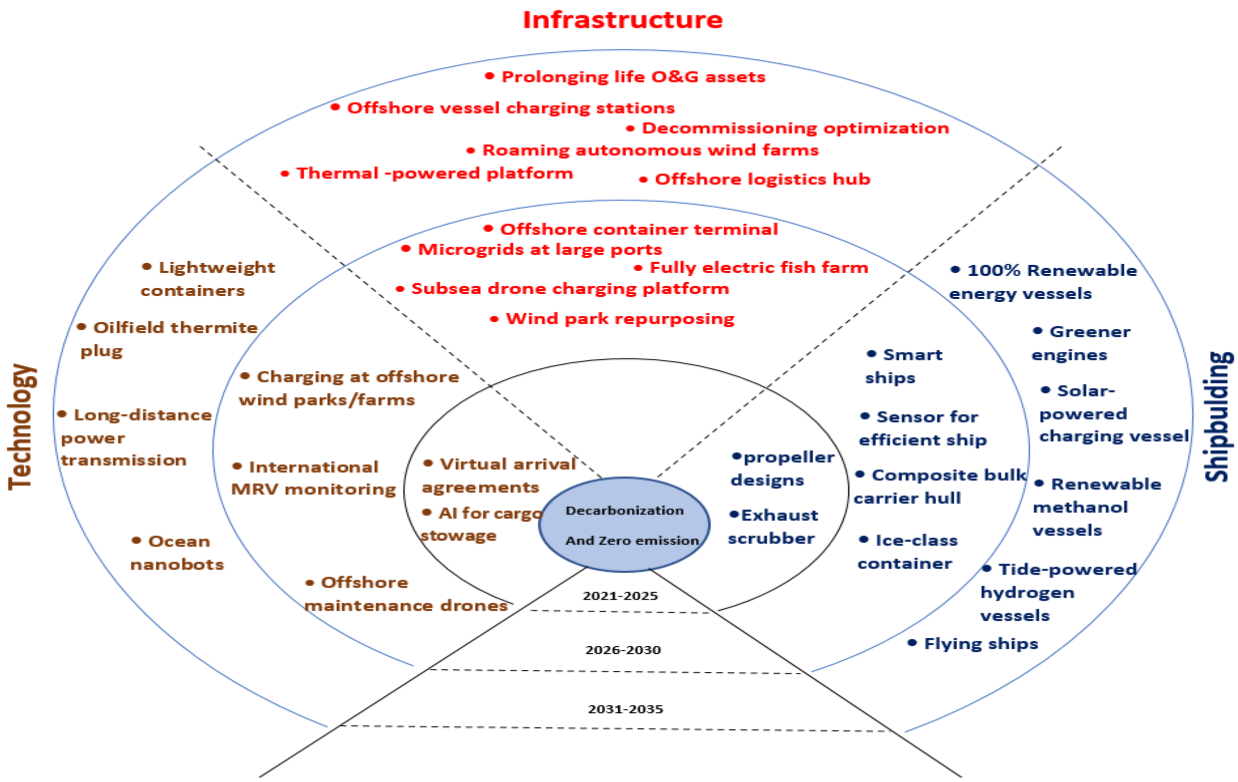

Figure 4.5 Realizing time for each venturing idea in each cluster

4.3.1. Cluster 1: Infrastructure

Figure 4.5 and table 4.3 show predictions for infrastructural venturing ideas according to the median answer by respondents.

When asked for the time to commercially available i.e., accepted practice, the respondents had the options to choose “will never happen”, or “here already”, table 4.3 shows what percentage of respondents have chosen each of these options.

Table 4.3 Predictions for infrastructural venturing ideas (N=176)

Venturing idea	Median (Year)	% Here already	% Never happen
Decommissioning optimization	2032	0	15
Prolonging life and re-purposing O&G assets	2031	5	3
Offshore container terminal	2030	4	19
Offshore vessel charging stations	2031	2	10
Microgrids at large ports	2030	0	0
Fully electric fish farm	2030	0	14
Thermal -powered platform	2035	4	8
Offshore logistics hub	2035	0	5
Subsea drone charging platform	2030	0	4
Wind Park repurposing	2030	9	9
Roaming autonomous wind farms	2033	4	15

4.3.2. Cluster 2: Shipbuilding venturing ideas.

Figure 4.5 and table 4.4 show predictions for shipbuilding venturing ideas according to the median answer by respondents.

When asked for the time to commercially available i.e., accepted practice, the respondents had the options to choose “will never happen”, or “here already”, table 4.4 shows what percentage of respondents have chosen each of these options.

Table 4.4 Predictions for shipbuilding venturing ideas (N=192)

Venturing idea	Median (Year)	% Here already	% Never happen
Smart ships	2028	2	0
Sensor for efficient ship	2029	4	4
100% Renewable energy vessels	2034	3	5
Greener engines	2031	8	6
Advanced ultra-efficient propeller designs	2025	10	0
Exhaust scrubber	2023	20	0
Solar-powered charging vessel	2035	5	10
Composite bulk carrier hull	2029	14	0
Renewable methanol vessels	2031	0	0
Tide-powered hydrogen vessels	2035	6	9
Flying ships	2031	6	6
Ice-class container	2030	0	17

4.3.3. cluster 3: Technological venturing ideas

Figure 4.5 and table 4.5 show predictions for technological venturing ideas according to the median answer by respondents.

When asked for the time to commercially available i.e., accepted practice, the respondents had the option to choose "will never happen", or "here already", table 4.5 shows what percentage of respondents have chosen each of these options.

Table 4.5 Predictions for technological venturing ideas (N=144)

Venturing idea	Median (Year)	% Here already	% Never happen
Offshore maintenance drones	2028	0	0
Long-distance power transmission	2032	1	8
Ocean nanobots	2034	1	10
Charging at offshore wind parks/farms	2027	4	4
Lightweight containers	2030	5	5
Virtual arrival agreements	2025	0	0
Oilfield thermite plug	2030	4	4
International MRV monitoring	2026	8	13
AI for cargo stowage	2025	0	0

4.4 Answer question 4: What are Entrepreneurial opportunities in the NSR in each cluster?

In answer to question 4, the researcher used GAHP. Following sections show entrepreneurial opportunities for decarbonization and zero emission in the NSR.

4.4.1 Infrastructural entrepreneurial opportunities

To identify these opportunities, the researcher asked 10 experts to complete four AHP questionnaires based on the following hierarchy tree.

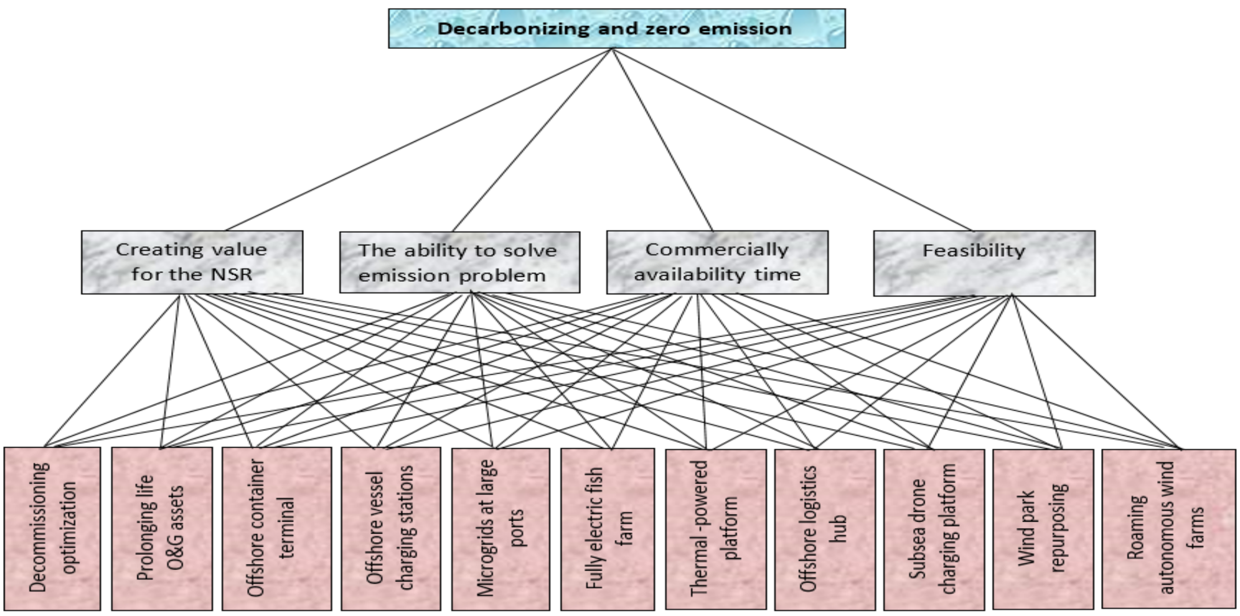

Figure 4.6 Infrastructural cluster hierarchy tree

For this analysis, the expert choice software was used. Figure 4.7 illustrates the results of the AHP analysis.

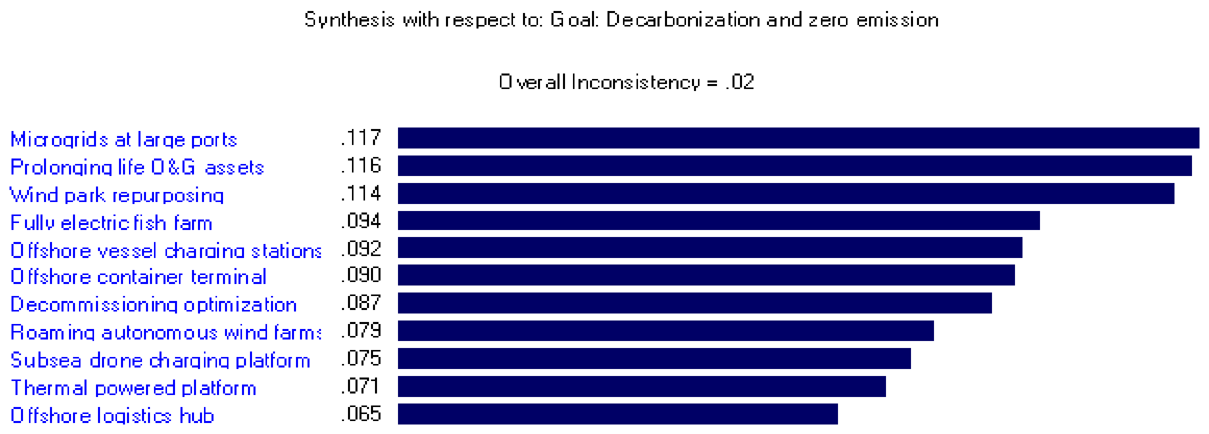

Figure 4.7 Priority of infrastructural venturing ideas based on the screening criteria

The inconsistency rate is 0.02 which is less than 0.1 (See 3.4.2), and shows the inconsistency is acceptable and we do not need to revise the subjective judgment.

The result was sent to the experts; the experts then came together with researcher to discuss again each of the priority. In all, 2 interviews were made, and the following infrastructure entrepreneurial opportunities were identified:1. Microgrids at large ports,2. Prolonging life and re-purposing O&G assets,3. Wind Park repurposing,4. Fully electric fish farm, 5. Offshore vessel charging stations

4.4.2 Shipbuilding entrepreneurial opportunities

To identify these opportunities, the researcher asked experts to complete an AHP questionnaire based on the following hierarchy tree.

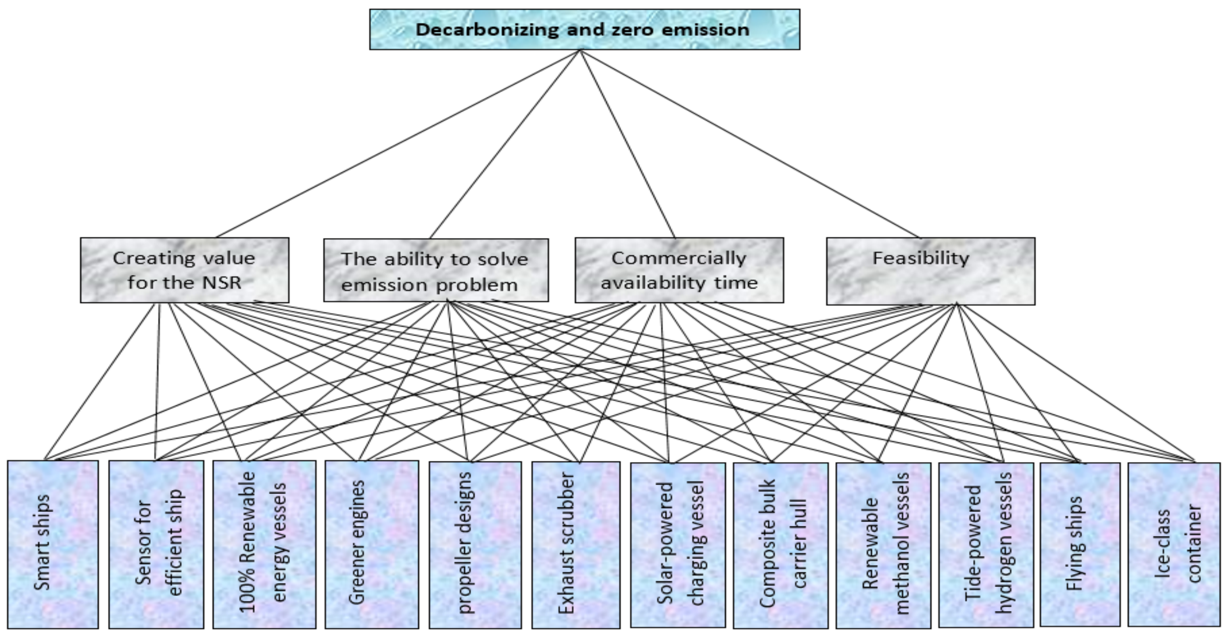

Figure 4.8 Shipbuilding cluster hierarchy tree

For AHP analysis, the expert choice software was used. Figure 4.9 illustrates the results of this analysis.

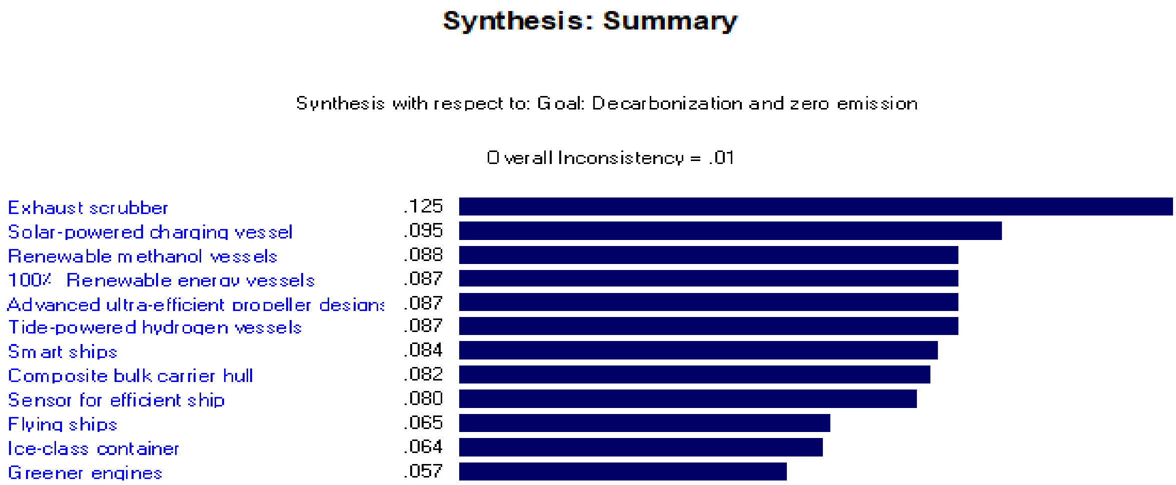

Figure 4.9 Priority of shipbuilding venturing ideas based on the screening criteria

The inconsistency rate is 0.01 which is less than 0.1 (See 3.4.2), and shows the inconsistency is acceptable and we do not need to revise the subjective judgment.

The result was sent to the experts; the experts then came together with researcher to discuss again each of the priority. In all, 2 interviews were made, and the following shipbuilding entrepreneurial opportunities were identified:1. Exhaust scrubber,2. Solar-powered charging vessel, 3. Renewable methanol vessels,4.100% Renewable energy vessels,5. Tide-powered hydrogen vessels

4.4.3 Technology entrepreneurial opportunities

To identify these opportunities, the researcher asked experts to complete four AHP questionnaires based on the following hierarchy tree.

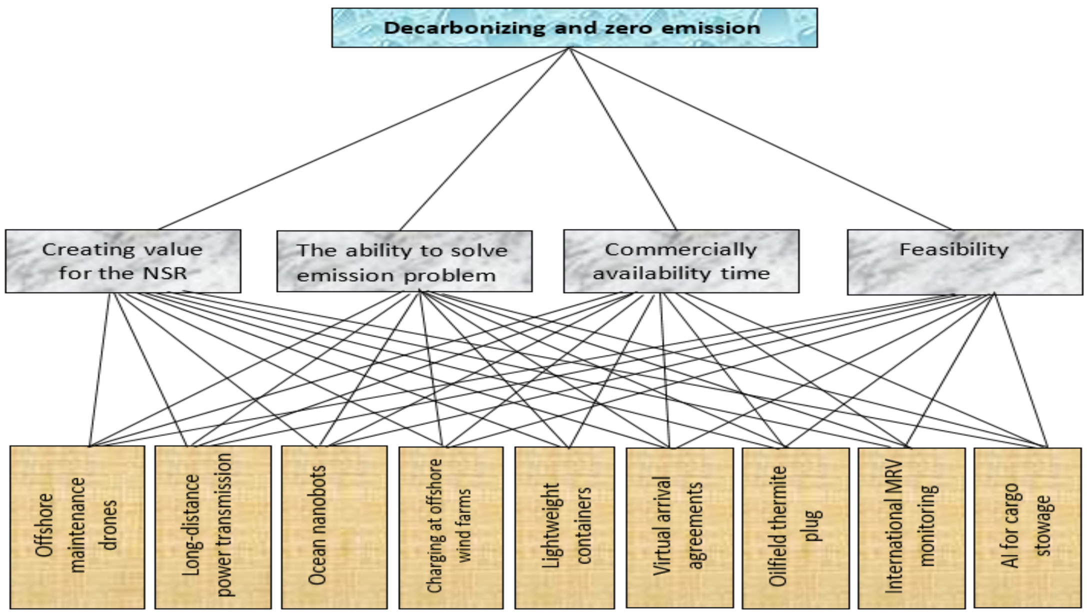

Figure 4.10 Technology cluster hierarchy tree

For AHP analysis, the expert choice software was used. Figure 4.11 illustrates the results of this analysis.

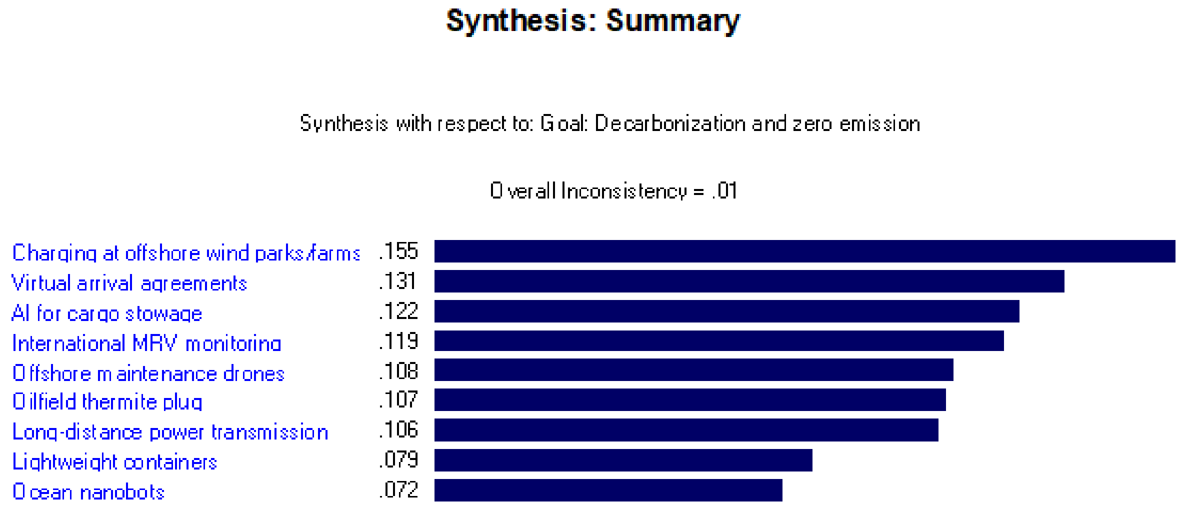

Figure 4.11 Priority of technological venturing ideas based on the screening criteria

The inconsistency rate is 0.01 which is less than 0.1 (See 3.4.2), and shows the inconsistency is acceptable and we do not need to revise the subjective judgment.

The result was sent to the experts; the experts then came together with researcher to discuss again each of the priority. In all, 2 interviews were made, and the following technological entrepreneurial opportunities were identified: 1. Charging at offshore wind parks/farms,2. Virtual arrival agreements,3.AI for cargo stowage,4. International MRV monitoring,5. Offshore maintenance drones.

4.5 Answer question 5: What are the variables affecting realization of these opportunities?

Following the question about the forecast to commercially availability time, the second question in the survey was open-ended, and asked the respondent "what is needed to make this opportunity happen?" For analysing of this question, the author performed an inductive qualitative data analysis using MAXQDA V.18. A four-step strategy was used to qualitatively analyse this data (Tutty, Rothery, & Grinnell, 1996). First step involved identifying codes from the respondents' answers to the open question. In the second step, the codes were sorted and placed in their emergent categories, and the categories were analysed for themes. Then researcher sent the codes and themes to 12 experts in Maritime studies (See appendix 4), the identified themes are:

1.political ,2. Economic,3. Social,4. Technological,5. Environmental

In the third step, the themes were examined for trustworthiness. For this, author applied Kappa Coefficient and Stress Value. (See 3.4.4.1). Table 4.6 shows trustworthiness for each cluster.

In the fourth step, based on trustworthiness of identified codes and themes, the data of the research were analysed using MAXQDA 18 and a diagram was constructed to illustrate the codes and themes found in the data for each cluster. And finally, these themes, related codes, and their frequencies are shown in a table.

Table 4.6: Trustworthiness for entrepreneurial opportunities clusters

Cluster	Kappa Coefficient*	Stress Value**	Result
1.Infrastructural opportunities	91.11	0.248	Perfect agreement/fit
2. Shipbuilding opportunities	93.12	0.267	Perfect agreement/fit
3. Technological opportunities	92.10	0.225	Perfect agreement/fit

* According to Cohen's original article, values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement. (Cohen,1960). Many texts recommend 80% agreement as the minimum acceptable interrater agreement. (McHugh,2012)

** Desirable stress value is in a range from 0.155 to 0.352 (Brenan, et al. 2012).

4.5.1 What are the variables affecting realization of Infrastructural entrepreneurial opportunities?

Table 4.7 shows codes for these opportunities.

Table 4.7: Codes for Infrastructural entrepreneurial opportunities

Code	**All coded segments**	**Code**	**All coded segments**
Environmental management forces	3	Capacity	2
Financially viable	1	Demand	2
Value of product	4	Technology improvement	1
Financial incentives	3	Technology acceptance	4
Cultural shift	1	Cost	11
Collaboration	13	Investment	13
Human factor	2	Legislation	3
Enhance performance	2	Industry regulation	4
Safety	2	Government	13
Environmentally friendly	7	New rules	1
Location planning	4	Government enforcement	5
Installation	5	International laws	1
R&D	5	Monitoring	1
Knowledge	7	Technical aspects	4
Total	124		

As table 4.6 shows, in this research with 12 experts, overall agreement is 91.11% and it means there is almost perfect agreement between the experts. Moreover, for this cluster, the stress value is 0.248, so it fell within the range, suggesting that the themes in this study have a good fit. Figure 4.12 shows Themes and related codes based on MAXQDA analysis.

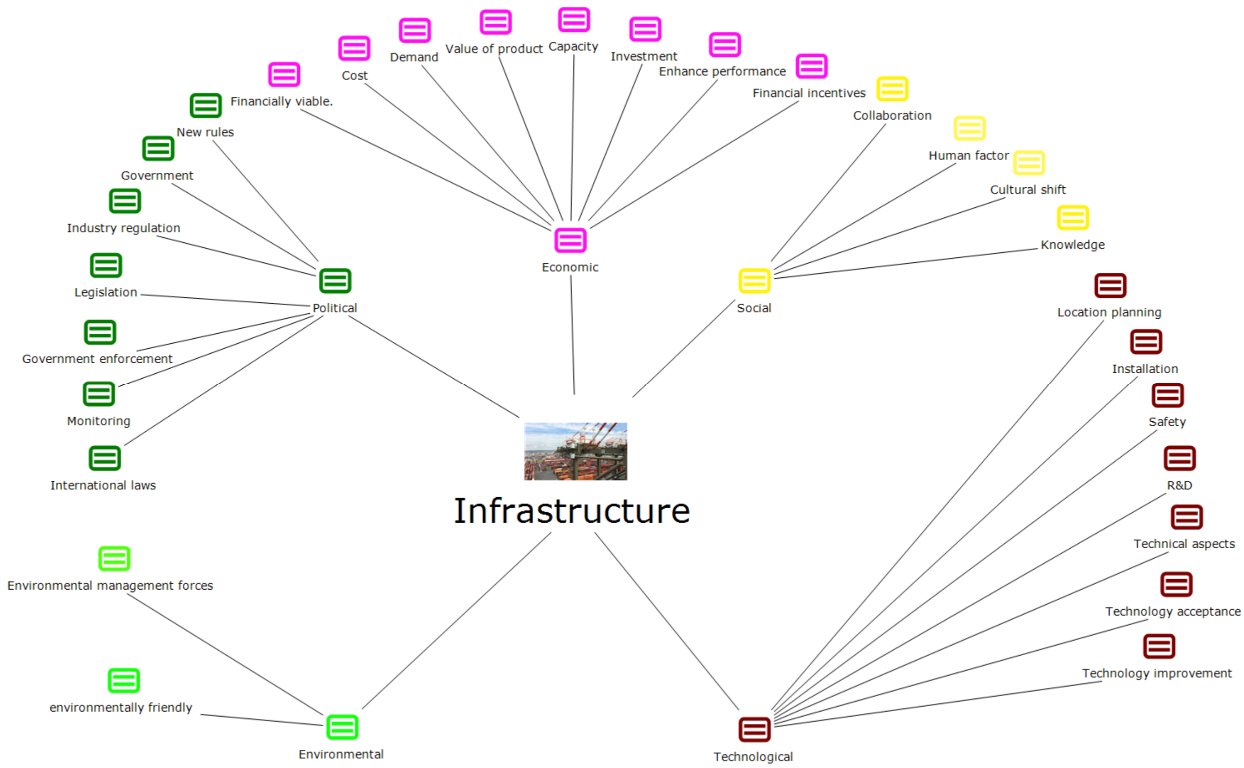

Figure 4.12: Themes and related codes for Infrastructural entrepreneurial opportunities

Themes, related codes, and their frequencies are shown in table 4.8.

Table 4.8: Themes and related codes frequency - Infrastructural entrepreneurial opportunities

Themes	Codes	Frequency
Political (28)	Legislation	3
	Government	13
	New rules	1
	Industry regulation	4
	Government enforcement	5
	Monitoring	1
	International laws	1
Economic (38)	Value of product	4
	Investment	13
	Cost	11
	capacity	2
	Demand	2
	Financially viable	1
	Financial incentives	3
	Enhance performance	2
Social (23)	Knowledge	7
	Collaboration	13
	Cultural shift	1
	Human factor	2
	Technology improvement	1
	R&D	5

Themes	Codes	Frequency
Technological (25)	Technology acceptance	4
	Technical aspects	4
	safety	2
	Location planning	4
	Installation	5
Environmental (10)	Environmentally friendly	7
	Environmental management forces	3

4.5.2 What are the variables affecting realization of shipbuilding entrepreneurial opportunities?

Table 4.9 shows codes for these opportunities.

Table 4.9: Codes for shipbuilding entrepreneurial opportunities

Code	**All coded segments**	**Code**	**All coded segments**
Environmental aspect	2	Renewable Portfolio Standard (RPS)	3
Technical aspects	31	R&D	6
Awareness	5	Financial incentives	4
Risk analysis	2	collaboration	3
Safety	11	Government incentives	10
Environment management	2	Storage technology	4
Demand	3	Dual fuel combustion	2
Investment	18	Energy storage capabilities	11
cost	23	Training of crews	1
Government	13	Economic feasibility study	3
legislation	2	Alteration of ship	5
Process management	3	Renewable energy accessibility	4
New rules	2		
Total	173		

As table 4.6 shows, in this research with 12 experts, overall agreement is 93.12% and it means there is almost perfect agreement between the experts. Moreover, for this cluster, the stress value is 0.267, so it fell within the range, suggesting that the themes in this study have a good fit. Figure 4.13 shows Themes and related codes based on MAXQDA analysis.

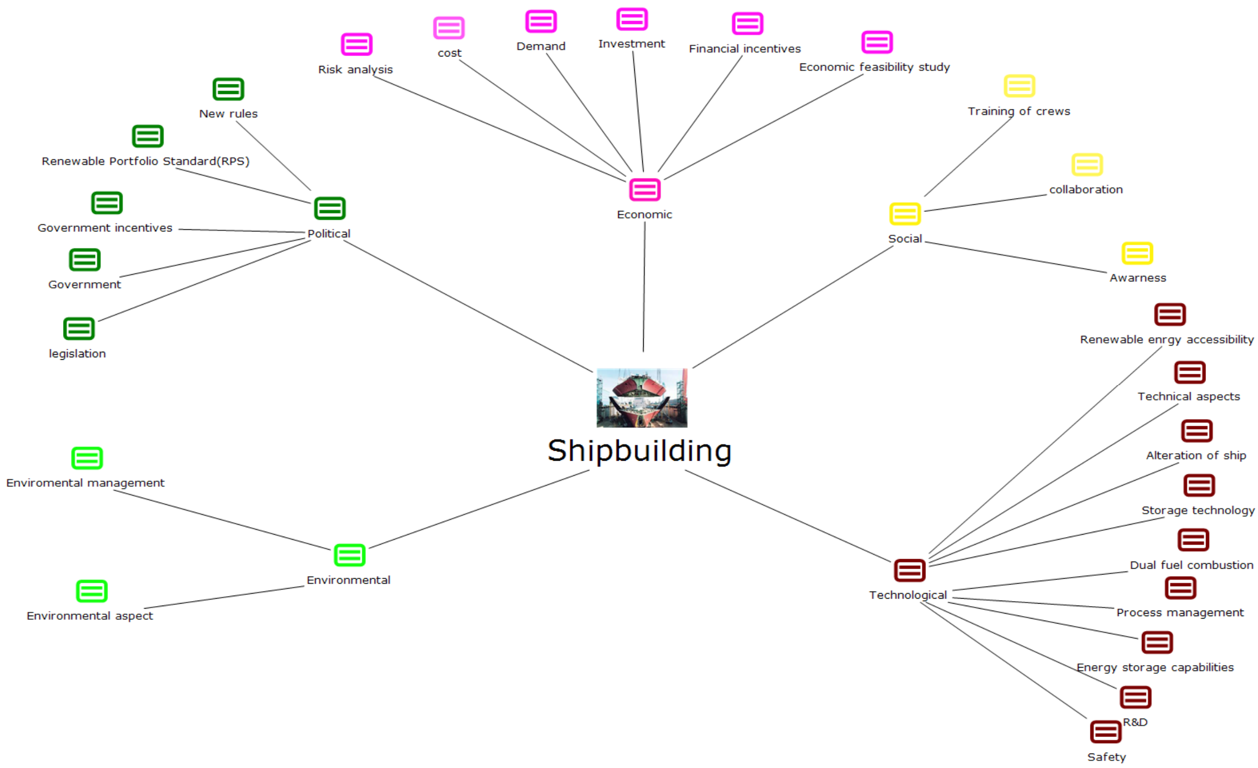

Figure 4.13: Themes and related codes for *shipbuilding entrepreneurial opportunities*

Themes, related codes, and their frequencies are shown in table 4.10.

Table 4.10: Themes and related codes shipbuilding entrepreneurial opportunities

Themes	Codes	Frequency
Political (30)	New rules	2
	Government	13
	Renewable portfolio standard (RPS)	3
	Government incentives	10
	Legislation	2
Economic (53)	Risk analysis	2
	Investment	18
	Cost	23
	Financial incentive	4
	Demand	3
	Economic feasibility study	3
Social (9)	Awareness	5
	Collaboration	3
	Training of crews	1
Technological (77)	Renewable energy accessibility	4
	Technical aspects	31
	Alteration of ship	5
	Storage technology	4
	Dual fuel combustion	2
	Process management	3
	Energy storage capabilities	11

Themes	Codes	Frequency
	R&D	6
	Safety	11
Environmental (4)	Environmental aspect	2
	Environmental management	2

4.5.3. What are the variables affecting realization of technological entrepreneurial opportunities?

Table 4.11 shows codes for these opportunities.

Table 4.11: Codes for technological entrepreneurial opportunities

Code	**All coded segments**	**Code**	**All coded segments**
Environmental aspect	1	General agreement	9
Infrastructure	2	Test of the platform	4
Awareness	2	The NSR regulations	9
Risk analysis	2	Technical aspects	13
Safety	7	Industry 4.0	3
Environmental management	2	Government enforces	5
Financial incentive	2	Communication infrastructure	3
Demand	2	Profit	3
Investment	8	Collaboration	4
Standards	8	Technological advancement	12
Cost	13	R&D	1
Government	3	Financially viable	1
legislation	3	Reliability	1
Total	123		

As table 4.6 shows, in this research with 12 experts, overall agreement is 92.10% and it means there is almost perfect agreement between the experts. Moreover, for this cluster, the stress value is 0.225, so it fell within the range, suggesting that the themes in this study have a good fit. Figure 4.14 shows Themes and related codes based on MAXQDA analysis.

Themes, related codes, and their frequencies are shown in table 4.12.

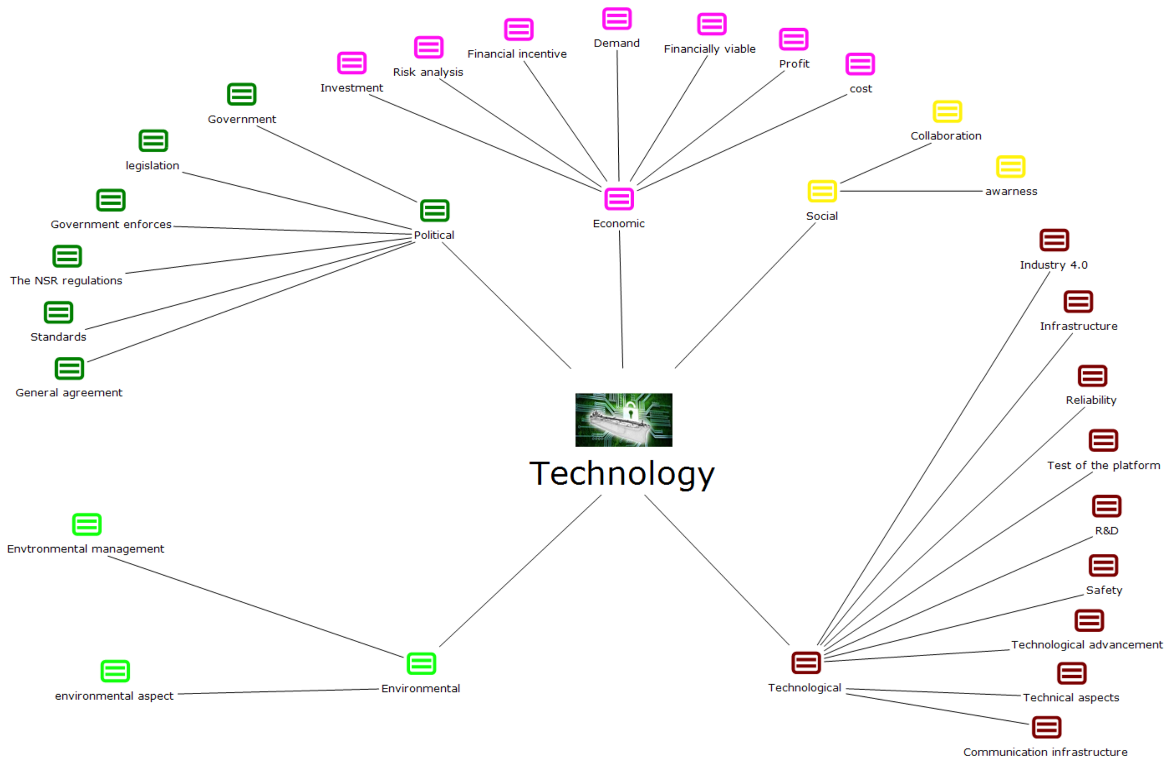

Figure 4.14: Themes and related codes for technological entrepreneurial opportunities

Table 4.12: Themes and related codes frequency – Technological entrepreneurial opportunities

Themes	Codes	Frequency
Political (37)	Government	3
	Legislation	3
	Government enforces	5
	The NSR regulations	9
	Standards	8
	General agreement	9
Economic (31)	Investment	8
	Risk analysis	2
	Financial incentive	2
	Demand	2
	Financially viable	1
	Profit	3
	Cost	13
Social (6)	Collaboration	4
	Awareness	2
Technological (46)	Industry 4.0	3
	Infrastructure	2
	Reliability	1
	Test of the platform	4
	R & D	1
	Safety	7
	Technological advancement	12

Themes	Codes	Frequency
	Technical aspects	13
	Communication infrastructure	3
Environmental (3)	Environmental management	2
	Environmental aspects	1

4.5.4. Answer research question 4- An overall analysis

Table 4.13 shows frequency of initial variables (Codes) for each cluster per themes.

Table 4.13. Frequency of variables(codes) and subcodes for each cluster

Theme	**Infrastructure**	**Shipbuilding**	**Technology**	**Total**
Political	28	30	37	95
Economic	38	53	31	122
Social	23	9	6	38
Technological	25	77	46	148
Environmental	10	4	3	17
Total	124	173	123	420

As the above table shows respondents (See table 4.2) believe Technological, Economic, Political, Social and Environmental variable respectively affecting realization of the entrepreneurial opportunities.

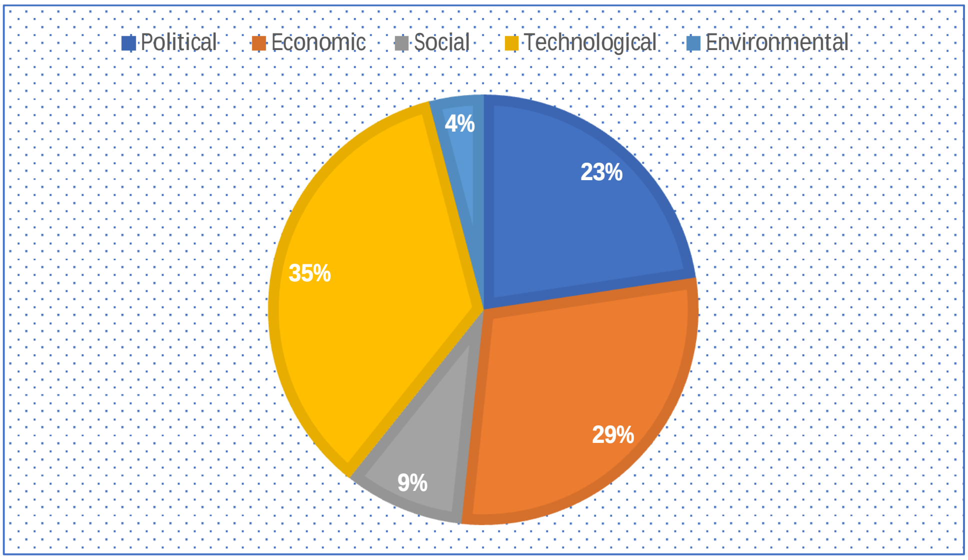

Figure 4.15 Distribution of comments for all entrepreneurial opportunities

The distribution of the comments among the 5 themes is depicted in Figure 4.15 above. This figure shows that only 4% of the comments were related to environmental factors, while only 9% and 23% were related to social and political variables, respectively. This reflects how the respondents to a limited degree consider these variables relevant in the development and implementation of the entrepreneurial opportunities. However, the respondents seem to consider technological and economic variables the main challenges related to these entrepreneurial opportunities, as these make up 35% and 29% respectively, adding up to more than two thirds of all comments. But which variables are the strategic (key) variables? Next section answers this question.

4.6 Answer question 6: Which variables are the strategic (key) variables?

In answer to question 5, the researcher identified 420 initial variables. 341 out of 420 variables were iterative or had similar meanings. By merging these variables, 79 variables (codes) identified and categorized to 5 dimensions (Themes). In answer to sixth question the author wants to reduce the complexity and detecting which are the strategic (key) variables that should be studied first in each opportunity, and then across all opportunities for decarbonizing and zero emission. Structural analysis and MicMac software were used to identify key variables (See 3.4.5). Micmac's object is to identify the most influential variables and more dependent (the key variables), by building a typology of variables in direct and indirect classification. (Godet,2007). For this, an Influence-dependence questionnaire was used (Rabbani, 2012). An Influence-dependence questionnaire shows how a variable influences other variables and how other variables influence it. The questionnaire was then sent to the 12 experts who then completed it for each cluster. In structural analysis, each variable is assessed pairwise with all the other variables. The assessment criteria ask: How likely is it that these two discrete variables influence on one another? Each pair is rated on a scale of 0 to 3.

The structure analysis is completed across all the variables for each cluster. Table 4.14 shows Matrix of Direct Influences (MDI) characteristics. This table presents the number of 0,1,2,3 of the matrix and shows the rate of filling calculated as a ratio between the number of MDI values different from 0 and the total number of elements of the matrix.

Table 4.14 MDI characteristics

Indicator	VALUE Infrastructure	VALUE Shipbuilding	VALUE Technology
Matrix size	28	25	26
Number of iterations	2	2	2
Number of zeros	107	119	83
Number of ones	223	195	155
Number of twos	345	263	374
Number of threes	109	48	64
Total	677	506	593
Fillrate	86.35204%	80.96%	87.72189%

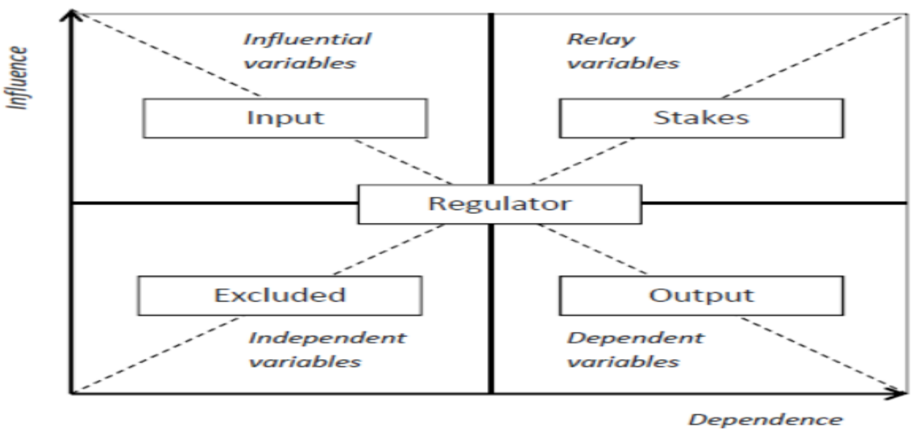

Figure 4.16 variables plane

(Source: Godet 2006)

As figure 4.16 shows, this map consists of 4 sections. The placement of variables in different sections of the map is based on mathematical and quantitative relationships, and the position of the variables within the four sections of the coordinate grid(plane) itself can also indicate the status of the variables in the system (Godet,2006, Rabbani 2012, and Villacotra,2014).

1.Relay variables

Relay variables have the characteristics of being highly influential on other variables and also being highly dependent on other variables. Hence, they relay change and are associated with instability, as any action on or from these variables will lead to a change or reaction on other variables, respectively. Relay variables are the strategic or key variables and are located in the top right corner of the graph (zone 1 of the coordinate plane). The variables situated on or close to the diagonal and allocates a certain degree of leverage depending on the distance to the origin. The further the distance from the center, the higher the leverage or “multiplier effect” and the more strategic the variable is in the system. In turn, the more strategic a variable is, the more receptive it is to influence from other variables, and thus the less stable the variable becomes (Serrano, 2015). These variables can be divided into two categories: Stake (risk) variables and target variables (Godet, 2006; Rabani 2012; Serrano, 2015; Villacotra, 2014).

1.1. Stake (Risk) variables

These variables are located around and above the diagonal line in the top right corner and have a very high capacity to become key variables in the system. Stake (Risk) variables should be carefully analysed and considered when planning intervention (Serrano, 2015).

1.2. Target variables

These variables are located below the north-eastern diagonal area of the plane and represent outcome targets of the system. By manipulating and making changes to these variables, it is possible to achieve system evolution according to its plan and purpose.

2.Influential variables

These variables are variables that have high influence on other variables but are less influenced by other variables themselves (Serrano, 2015). Identifying and manipulating these variables can result in system changes, but are primarily external to the system (Godet, 2006).

3.Dependent variables

These variables are in the bottom right section of the plane and can also be called output variables. These have little influence on the others but are subject to strong pressures themselves.

4. Independent variables

These variables have low influence and low dependence and are in the bottom left part of the plane. Due to the nature of system instability, it seems that some of these variables are excluded variables and should therefore be referred to as independent excluded variables.

4.6.1. Key variables for Infrastructural entrepreneurial opportunities

As table 4.7 shows there are 28 variables that affecting realization of Infrastructural entrepreneurial opportunities. The structure analysis is completed across all the variables.

As table 4.14 shows Matrix size for first cluster is 28*28 and its fillrate with 2 iterations is 86.35%.
which shows that the variables have a large and scattered influence on each other, and the state of the system is unstable. 107 of the matrix cells (matrix relationships) are zero, which means that these factors

have not influenced each other. On the other hand, the matrix based on statistical indicators with 2 iterations converge towards 100% stability, which indicates the high validity of the matrix. (See table 4.15).

Table 4.15 MDI stability- Infrastructural entrepreneurial opportunities

Iteration	Influence	Dependence
1	99 %	95 %
2	100 %	100 %

Figure 4.17 shows direct influence/dependence map. In the analysis of the map, the following variables can be identified in the system.

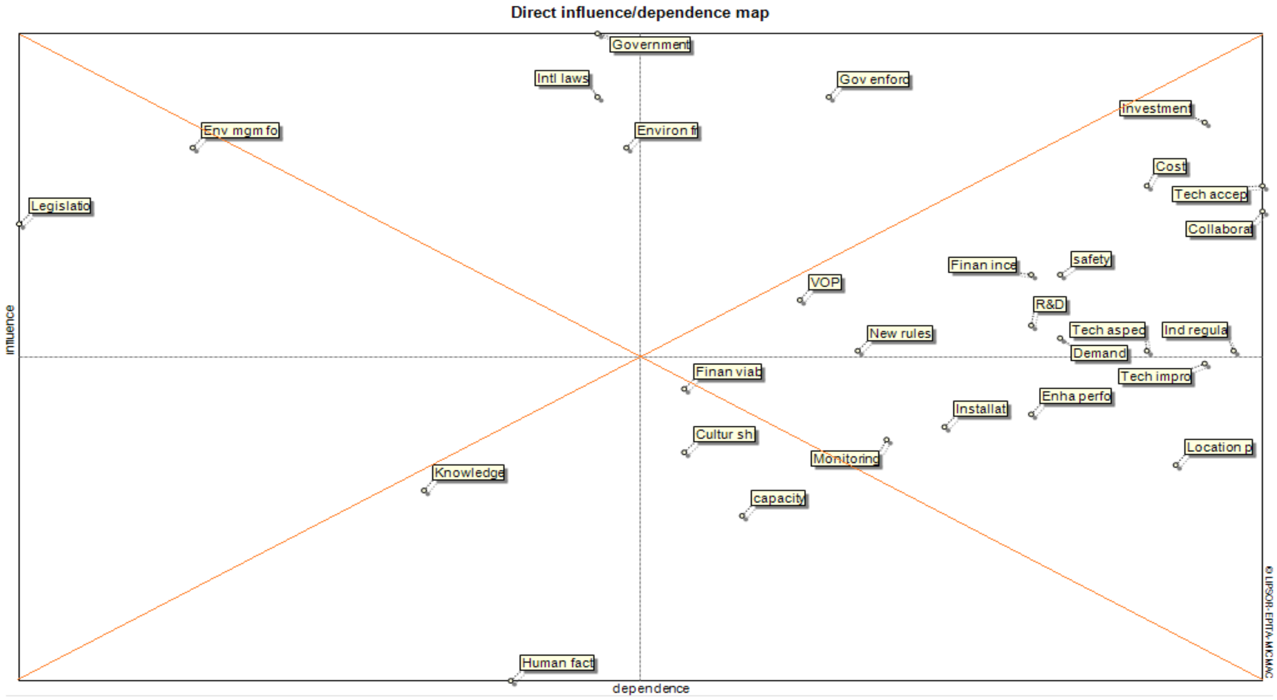

Figure 4.17: Direct influence/dependence map for Infrastructural entrepreneurial opportunities

Table 4.16: Variable types for Infrastructural entrepreneurial opportunities

Themes	Variables	Type
Political	Legislation	Influential
	Government	Influential
	New rules	Relay-Target
	Industry regulation	Relay-Target
	Government enforcement	Relay-Risk
	Monitoring	Dependent
	International laws	Influential
Economic	Value of product	Relay-Target
	Investment	Relay-Target
	Cost	Relay-Target
	capacity	Dependent
	Demand	Relay-Target
	Financially viable	Dependent
	Financial incentives	Relay-Target
	Enhance performance	Dependent

Themes	Variables	Type
Social	Knowledge	Independent
	Collaboration	Relay-Target
	Cultural shift	Dependent
	Human factor	Independent
Technological	Technology improvement	Dependent
	R&D	Relay-Target
	Technology acceptance	Relay-Target
	Technical aspects	Relay-Target
	safety	Relay-Target
	Location planning	Dependent
	Installation	Dependent
Environmental	Environmentally friendly	Influential
	Environmental management forces	Influential

As figure 4.17 and table 4.16 show key variables affecting realization of Infrastructural entrepreneurial opportunities are:

New rules, Industry regulation, Government enforcement, Value of product, Investment, Cost, Demand, Financial incentives, Collaboration, R&D, Technology acceptance, Technical aspects, safety.

Figure 4.18 shows direct influence graph for all variables in Infrastructural entrepreneurial opportunities.

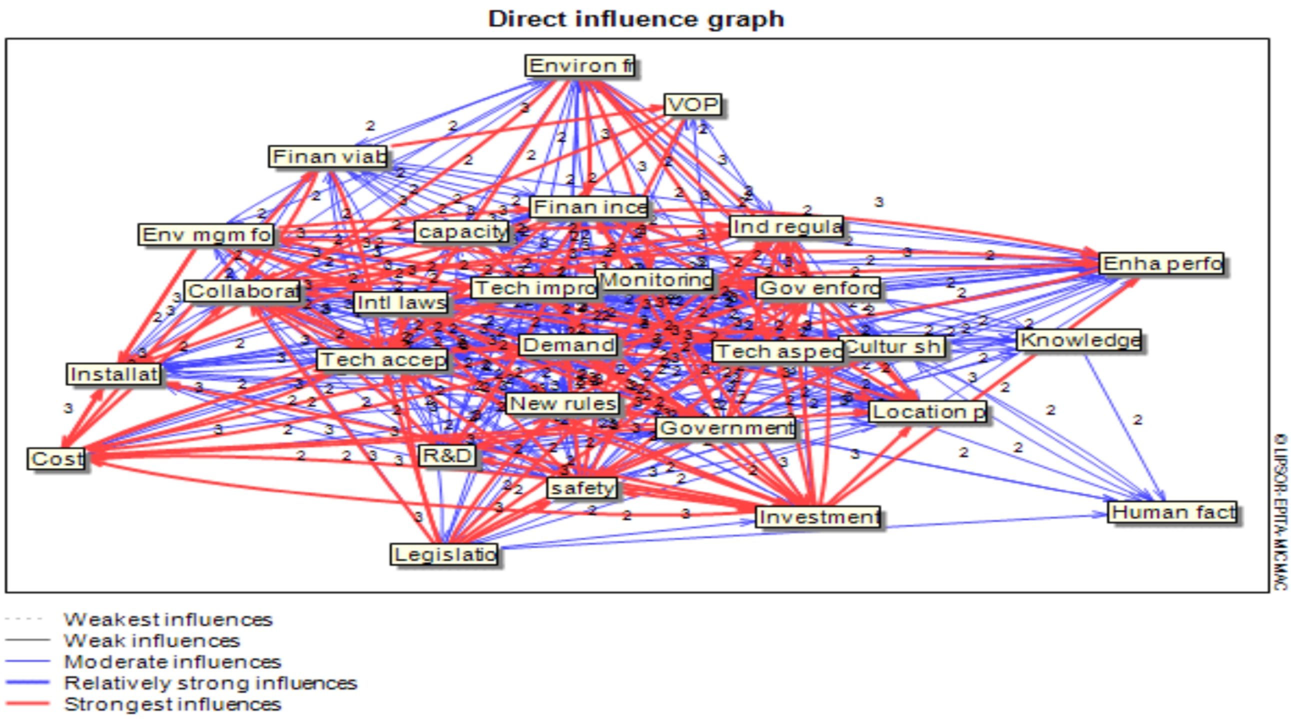

Figure 4.18: Direct influence graph for Infrastructural entrepreneurial opportunities

4.6.2. Key variables for shipbuilding entrepreneurial opportunities

As table 4.9 shows there are 25 variables that affecting realization of shipbuilding entrepreneurial opportunities. The structure analysis is completed across all the variables.

As table 4.14 shows Matrix size for second cluster is 25*25 and its fillrate with 2 iterations is 80.96%. which shows that the variables have a large and scattered influence on each other, and the state of the system is unstable. 119 of the matrix cells (matrix relationships) are zero, which means that these factors have not influenced each other. On the other hand, the matrix based on statistical indicators with 2 iterations converge towards 100% stability, which indicates the high validity of the matrix. (See table 4.17).

Table 4.17 MDI stability- Shipbuilding entrepreneurial opportunities

Iteration	Influence	Dependence
1	96 %	92 %
2	99 %	100 %

Figure 4.19 shows direct influence/dependence map. In the analysis of the map, the following variables can be identified in the system.

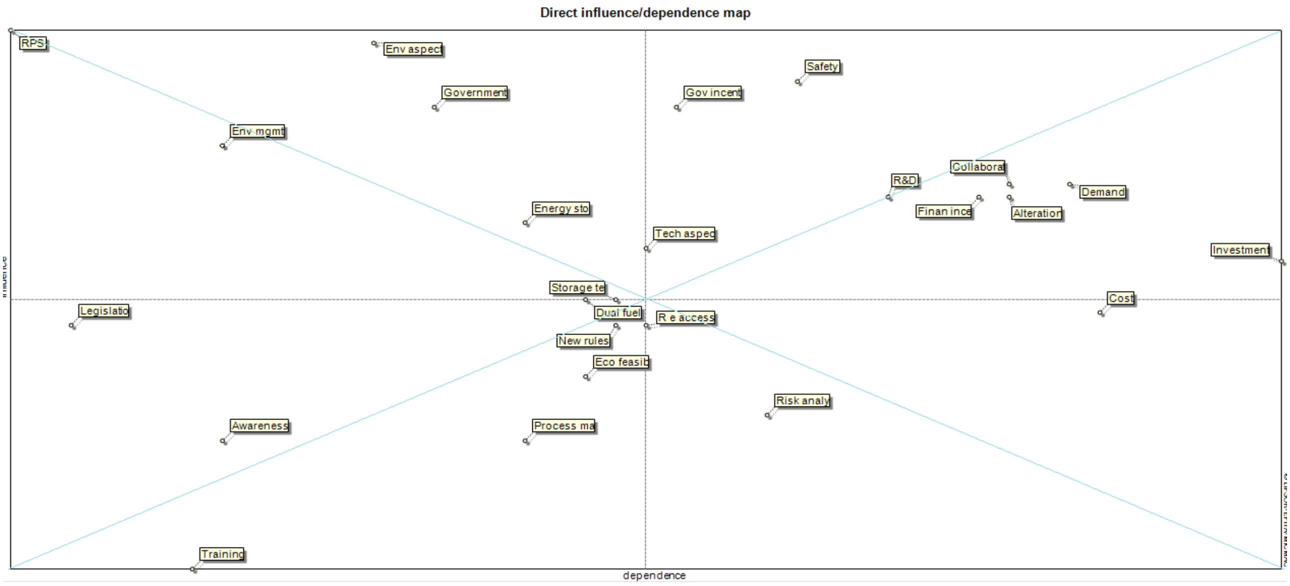

Figure 4.19: Direct influence/dependence map for shipbuilding entrepreneurial opportunities

Table 4.18: Variable types for shipbuilding entrepreneurial opportunities

Themes	Variables	Type
Political	New rules	Independent
	Government	Influential
	Renewable portfolio standard (RPS)	Influential
	Government incentives	Relay-Risk
	Legislation	Independent
Economic	Risk analysis	Dependent
	Investment	Relay-Target
	Cost	Dependent
	Financial incentive	Relay-Target
	Demand	Relay-Target
	Economic feasibility study	Independent
Social	Awareness	Independent
	Collaboration	Relay-Risk
	Training of crews	Independent

Themes	Variables	Type
Technological	Renewable energy accessibility	Dependent
	Technical aspects	Relay-Risk
	Alteration of ship	Relay-Target
	Storage technology	Influential
	Dual fuel combustion	Influential
	Process management	Independent
	Energy storage capabilities	Influential
	R&D	Relay-Target
	Safety	Relay-Risk
Environmental	Environmental aspect	Influential
	Environmental management	Influential

As figure 4.19 and table 4.18 show key variables affecting realization of the shipbuilding entrepreneurial opportunities are:

Government incentives, Investment, Financial incentive, Demand, Collaboration, Technical aspects, Alteration of ship, R&D and Safety.

Figure 4.20 shows direct influence graph for all variables in the shipbuilding entrepreneurial opportunities.

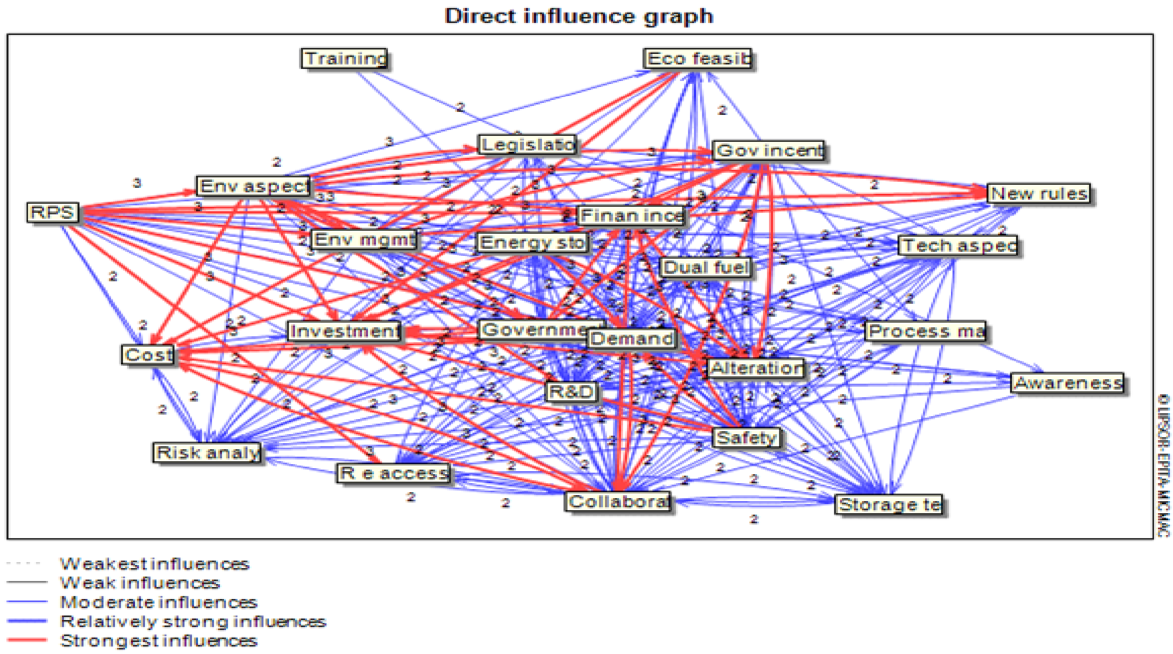

Figure 4.20 Direct influence graph for shipbuilding entrepreneurial opportunities

4.6.3. Key variables for technological entrepreneurial opportunities:

As table 4-11 shows there are 26 variables that affecting realization of the technological entrepreneurial opportunities. The structure analysis is completed across all the variables.

As table 4.14 shows Matrix size for third cluster is 26*26 and its fillrate with 2 iterations is 87.72%. which shows that the variables have a large and scattered influence on each other, and the state of the system is unstable. 83 of the matrix cells (matrix relationships) are zero, which means that these factors have not influenced each other. On the other hand, the matrix based on statistical indicators with 2 iterations converge towards 100% stability, which indicates the high validity of the matrix. (See table 4.19).

Table 4.19 MDI stability- Technological entrepreneurial opportunities

Iteration	Influence	Dependence
1	94 %	95 %
2	100 %	100 %

Figure 4.21 shows direct influence/dependence map. In the analysis of the map, the following variables can be identified in the system.

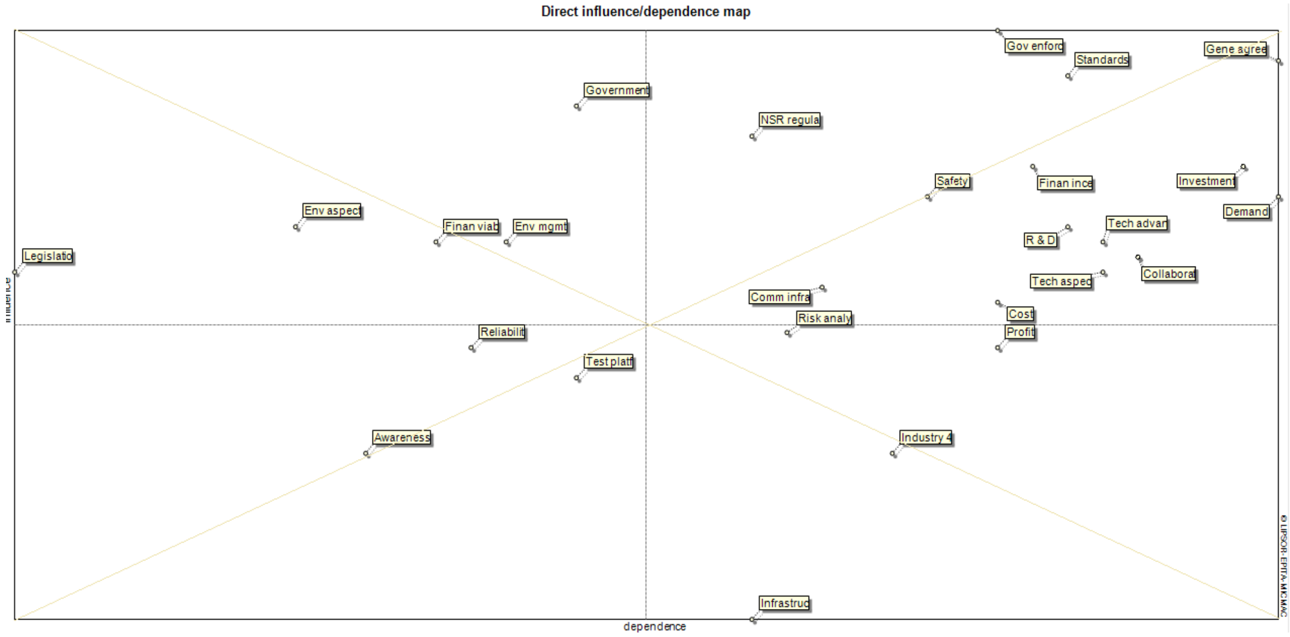

Figure 4.21: Direct influence/dependence map for technological entrepreneurial opportunities

Table 4.20: Variable types in the Technological entrepreneurial opportunities

Themes	Variables	Type
Political	Government	Influential
	Legislation	Influential
	Government enforces	Relay-Risk
	The NSR regulations	Relay-Risk
	Standards	Relay-Risk
	General agreement	Relay-Target
Economic	Investment	Relay-Target
	Risk analysis	Dependent
	Financial incentive	Relay-Target
	Demand	Relay-Target
	Financially viable	Influential
	Profit	Dependent
	Cost	Relay-Target

Themes	Variables	Type
Social	Collaboration	Relay-Target
	Awareness	Independent
Technological	Industry 4.0	Dependent
	Infrastructure	Dependent
	Reliability	Independent
	Test of the platform	Independent
	R & D	Relay-Target
	Safety	Relay-Target
	Technological advancement	Relay-Target
	Technical aspects	Relay-Target
	Communication infrastructure	Relay-Target
Environmental	Environmental management	Influential
	Environmental aspects	Influential

As figure 4.21 and table 4.20 show key variables affecting realization of the technological entrepreneurial opportunities are:

Government enforces, The NSR regulations, Standards, General agreement, Investment, Financial incentive, Demand, Cost, Collaboration, R&D , Safety , Technological advancement , Technical aspects , Communication infrastructure.

Figure 4.22 shows direct influence graph for all variables in the technological entrepreneurial opportunities.

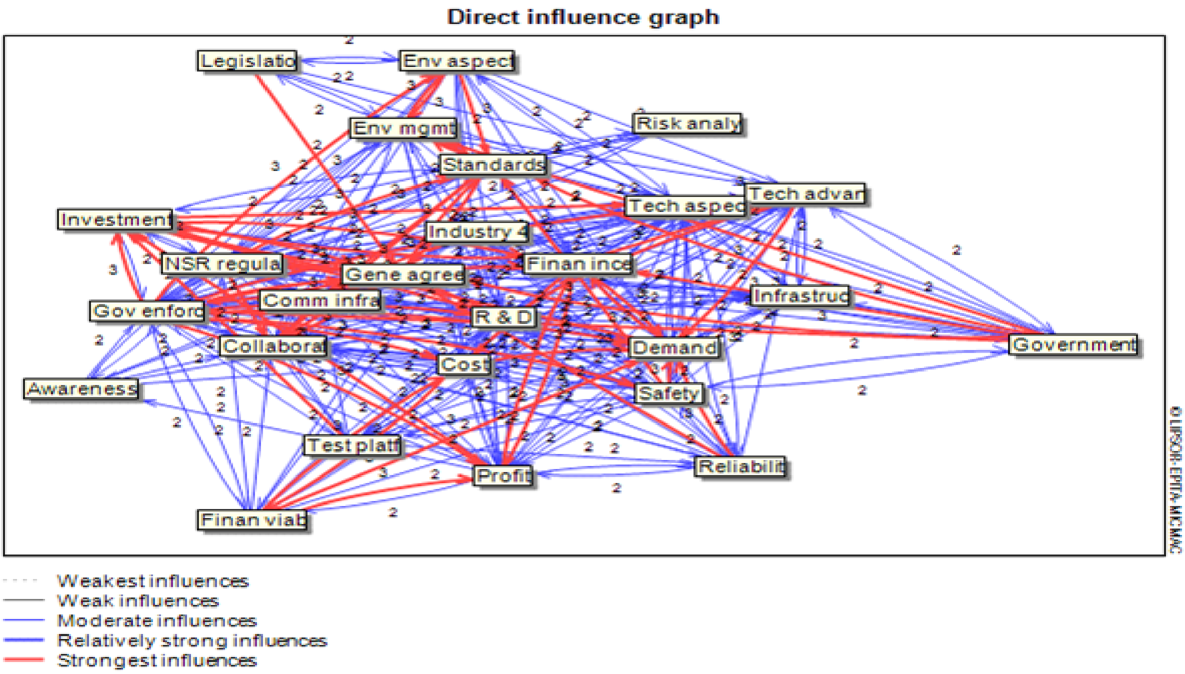

Figure 4.22: Direct influence graph for technological entrepreneurial opportunities

Chapter 5 Results, Discussion, and conclusion

Activities in the North Sea Region are expected to intensify, diversify, and expand further offshore. One way to make use of the increased offshore activities is to decarbonise and zero emission the large industries of the sea, including shipping and service activities. Decarbonizing and zero emission have provided a new context for sustainability and blue growth in the NSR.

Chapter 5 aims to provide summary of key findings, implications, limitations, and recommendations. This chapter focuses on explaining and evaluating what was found in the study and how it relates to literature, and research questions. The research started with a deep dive in potential opportunities (Venturing ideas) in the NSR's literature. 110 maritime reports, 50 papers and 40 web pages were reviewed. 222 venturing ideas were identified. (See Appendix 1). 57 out of 222 venturing ideas were directly or indirectly related to decarbonization and zero emission (See table 2.2). Then literature of entrepreneurship, opportunity, entrepreneurial opportunity definitions, opportunity identification models, entrepreneurial opportunity evaluation criteria were reviewed (Chapter 2). Primary data was gathered through 2 virtual brainstorming, AHP questionnaires, Periscope questionnaires, Thematic analysis questionnaire, and influence -dependence questionnaire (Appendix 2,3,4, and 5).

5.1 Study findings that answer question one: What are venturing idea for decarbonizing and zero emission and their clustering in the NSR?

In answering question one, the literature review showed (Chapter2), there are 57 venturing ideas for decarbonizing and zero emission in the NSR. A concept mapping analysis with 15 participants with a fit stress value showed 32 out of 57 venturing idea are more plausible. The participants, then, clustered 32 venturing idea into 3 clusters:

Infrastructure: Decommissioning optimization, Prolonging life and re-purposing O&G assets, Offshore container terminal, Offshore vessel charging stations, Microgrids at large ports, fully electric fish farm, Thermal -powered platform, Offshore logistics hub, Subsea drone charging platform, Wind park repurposing, Roaming autonomous wind farms.

Shipbuilding: Smart ships (industry 04), Sensor for efficient ship (Sensor system for collecting weather and traffic data from ships.), 100% Renewable energy vessels, Greener engines, Advanced ultra-efficient propeller designs, Exhaust scrubber, Solar-powered charging vessel, Composite bulk carrier hull, Renewable methanol vessels, Tide-powered hydrogen vessels, Flying ships, Ice-class container vessel.

Technology: Offshore maintenance drones, Long-distance power transmission, Ocean nanobots, Charging at offshore wind parks/farms, Lightweight containers, Virtual arrival agreements, Oilfield thermite plug, International MRV monitoring, AI for cargo stowage.

5.2 Study findings that answer question two: What are venturing ideas screening criteria in the NSR and how are their priority?

In answering question two, since the literature review showed that there are no clear criteria for screening ideas to identify entrepreneurial opportunities, the author and 15 experts in a virtual brainstorming by Miro reached a consensus on the following criteria (Table 5.1). The criteria, then, prioritized by AHP with an acceptable inconsistency rate.

5.1 Priority of venturing ideas screening criteria

Priority	venturing ideas screening criteria	Weight
1	Feasibility	0.363
2	The ability to solve emission problem	0.326
3	Creating value for the NSR	0.163
4	Commercially availability time	0.148
Inconsistency rate		0.0078

Based on this result, entrepreneurial opportunity formula in this thesis defined as follow:

Entrepreneurial opportunity = Idea + Feasibility + need + Value +Commercially availability time.

Based on this formula, entrepreneurial opportunities can be identified using MODM (Multi Objective Decision Making), MCDM (Multi Criteria Decision Making) and DEA (Data Envelopment Analysis).

For this, the author used AHP in this study, but researchers in the future research can use other techniques mentioned above.

The use of this formula and AHP required identifying the time of venturing idea realization. Are those already here or be realized in the future? The author has answered this question in the next section.

5.3 Study findings that answer question three: When the venturing ideas will be realized?

Each of the 32 venturing ideas were then developed into use-case vignettes. Each of the use-case vignettes was then developed into a survey following the logic of a modified Delphi approach (See 3.4.3 and 4.3) The survey data are analysed by SPSS to find the median estimation for the venturing ideas. Table 5.2 shows the year estimated for each venturing idea.

5.4 Study findings that answer question four: What are Entrepreneurial opportunities in the NSR in each cluster?

In answering question four, the author used GAHP. To identify entrepreneurial opportunities, the researcher asked 10 experts to complete 12(3 cluster* 4 criteria) AHP questionnaires. Table 5.3 shows the results of AHP analysis based on Expert Choice software outputs and 2 consensus interviews with the experts.

Table 5.2Estimated year for each venturing idea

Cluster	Idea	Estimated year	Cluster	Idea	Estimated year
Infrastructural venturing ideas	Offshore container terminal	2030	Shipbuilding Venturing ideas	Ice-class container	2030
	Microgrids at large ports	2030		Flying ships	2031
	Fully electric fish farm	2030		Renewable methanol vessels	2031
	Subsea drone charging platform	2030		Greener engines	2031
	Wind Park repurposing	2030		100% Renewable energy vessels	2034
	Prolonging life O&G assets	2031		Solar-powered charging vessel	2035
	Offshore vessel charging stations	2031		Tide-powered hydrogen vessels	2035
	Decommissioning optimization	2032	Technological venturing ideas	Virtual arrival agreements	2025
	Roaming autonomous wind farms	2033		AI for cargo stowage	2025
	Thermal -powered platform	2035		Intl. MRV monitoring	2026
	Offshore logistics hub	2035		Charging at offshore wind parks/farms	2027
Shipbuilding Venturing ideas	Exhaust scrubber	2023		Offshore maintenance drones	2028
	Advanced ultra-efficient propeller designs	2025		Lightweight containers	2030
	Smart ships	2028		Oilfield thermite plug	2030
	Sensor for efficient ship	2029		Long-distance power transmission	2032
	Composite bulk carrier hull	2029		Ocean nanobots	2034

As the table 5.2 shows there are 15 entrepreneurial opportunities in the NSR that are feasible, have ability to solve emission problem and meet need to decarbonization, can create value for the NSR and have an acceptable commercially availability time.

Realization of these opportunities is not easy as it seems. Beyond the market problems, there are a host of technological and non-technological challenges. Realizing some of these opportunities requires installing structures on and below the surface of the water and it is costly and dangerous, and operating infrastructure at sea involves challenges different on land, such as the increased effects of harsh weather and sea state conditions, as well as the problems with effects of vibrations on machines and the oxidation and corrosion of both large and small metallic components due to salt as described in detail in the book Rust: The Longest War (Weldman, 2015). Realizing some other requires international agreement, governments collaboration, investment, and new rules.

Therefore, it is necessary to identify the variables affecting realization of these opportunities.

Table 5.3 Entrepreneurial opportunities for decarbonizing and zero emission

Cluster	Entrepreneurial opportunity	weight
Infrastructural venturing ideas	Microgrids at large ports	0.117
	Prolonging life and repurposing O&G assets	0.116
	Wind Park repurposing	0.114
	Fully electric fish farm	0.094
	Offshore vessel charging stations	0.092
Overall inconsistency		**0.02**
Shipbuilding Venturing ideas	Exhaust scrubber	0.125
	Solar-powered charging vessel	0.095
	Renewable methanol vessels	0.088
	100% Renewable energy vessels	0.087
	Tide-powered hydrogen vessels	0.087
Overall inconsistency		**0.01**
Technological venturing ideas	Charging at offshore wind parks/farms	0.155
	Virtual arrival agreements	0.131
	AI for cargo stowage	0.122
	International MRV monitoring	0.119
	Offshore maintenance drones	0.108
Overall inconsistency		**0.01**

5.5 Study findings that answer question five: What are the variables affecting realization of these opportunities?

For analysing of this question, the author performed an inductive qualitative data analysis using MAXQDA V.18 and applied Kappa Coefficient and Stress Value for trustworthiness (chapter 4).

In total 420 initial variables (codes) identified. 341 out of 420 variables were iterative or had similar meanings. By merging these variables, 79 variables (codes) identified and categorized to 5 dimensions (Themes). Infrastructure, shipbuilding, and technology clusters have 28, 25 and 26 variables, respectively. Among the political variables especially a need for subsidies and support to entrepreneurs are pointed out to make the opportunities possible, as one of the current challenges currently seem to be low costs for fossil fuels. This required political motivation to change but face an uphill battle against entrenched interests in maintaining the status quo. New international law and collaboration of the NSR governments can also help realize these entrepreneurial opportunities. While social pressure to decarbonizing and zero emission is strong, an increase the collaboration between entrepreneurs, shipbuilding companies and governments will facilitate realizing of the opportunities. Among the economic variables the main obstacle is the investment size needed for these opportunities. Profitability of these opportunities is necessary if it is to be a sustainable investment. Financial incentives can encourage entrepreneurs to invest. Meanwhile in technology dimension, concerns over safety and the harsh weather conditions on the North Sea point toward needs for increased automation of operations. Renewable energy accessibility and energy storage capabilities can help to acceptance of the opportunities.

5.6 Study findings that answer question six: Which variables are the key (Strategic)variables?

In answering question six, Structural analysis and Micmac software was used. This analysis enables governments, entrepreneurs, and other key players in the maritime and marine to identify the interactions and mutual dependencies of the variables that influence the future of maritime ecosystem. Structural analysis also helps identify key variables according to their role as a driver or lever and their impact on the system. (Godet 2006).

This analysis showed 36 out of 79 identified variables are strategic (key) variables, because those are controllable by the system and have an acceptable impact on the system. These variables for each cluster are depicted in Figure 5.1 below. 13 out of 28 variables in infrastructure cluster, 9 0ut 0f 25 variables in shipbuilding cluster and 14 out of 26 variables in technology cluster are strategic variables.

Since these variables are the strategic variables any kind of improvement on them can improve other variables and it can help to realization of the opportunities.

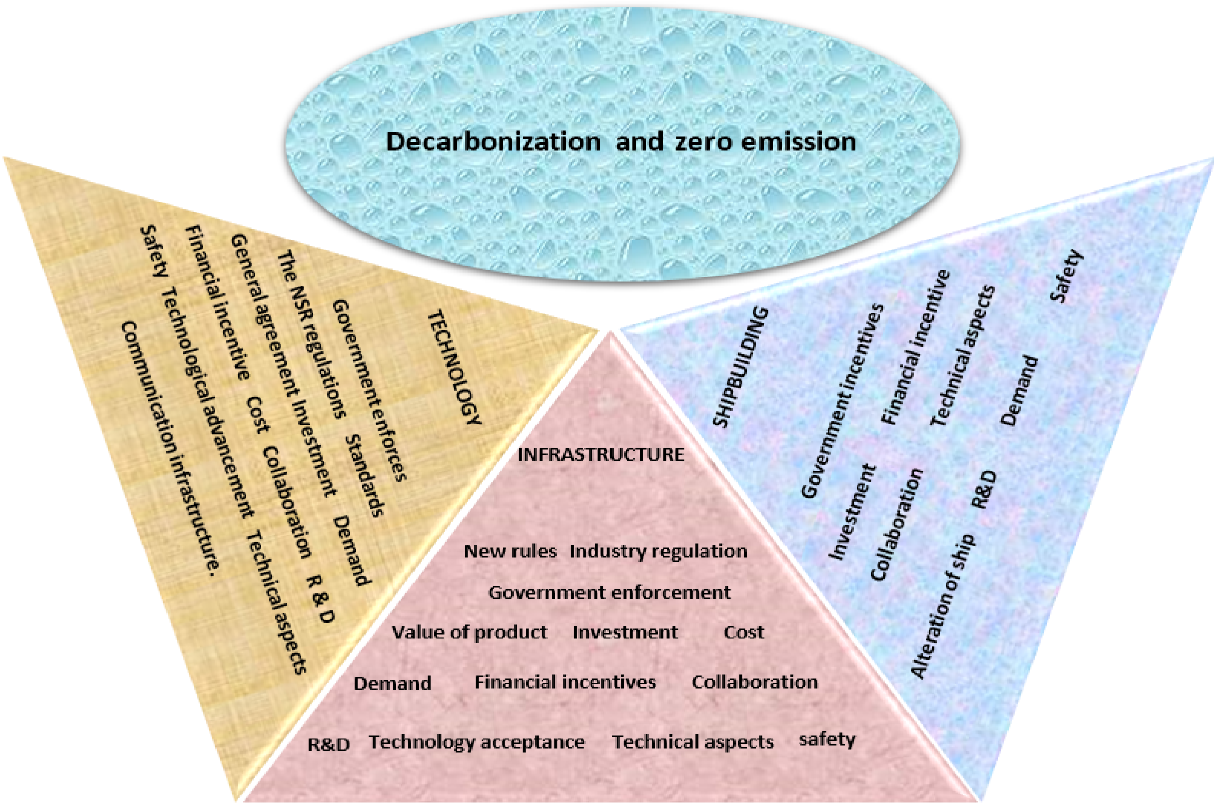

Figure 5.1 Strategic variable affecting realization of the opportunities

As the above figure shows realization of the opportunities requires financial and non-financial support for entrepreneurs. Government enforces and incentives have a vital role in this process. Financial incentives for investment and cost management are very important. Increase collaboration between governments, entrepreneurs, shipbuilding companies and maritime industries in the NSR and attention to technical and safety aspects can lead to the acceptance of new infrastructures, new ships, and new technologies for decarbonization and zero emissions.

5.7 Discussion and recommendation for each cluster

5.7.1 Infrastructural entrepreneurial opportunities

This cluster includes microgrids at large ports, prolonging life and re-purposing O&G assets, wind park repurposing, fully electric fish farm and offshore vessel charging stations.

Ports are the sites of major pollution, where large vessels continue to run their engines even while at berth, and heavy-lifting work is being performed by diesel-powered cranes (Moya et.al 2019 and Villalba et.al 2011). As the maritime industry explores ways to decarbonize, microgrids that at ports can play a supplementary role to existing electric grids with an enhanced energy storage system. The global microgrid market is growing at annual rate of 11.26% and projected to reach $46bn by 2025. (Misra et. Al 2017).

Prolonging the life of an asset means keeping it in production for longer. Electrification is one option which could help achieve this while reducing the CO2 emissions of the oil and gas production itself. The activities to re-purpose and prolong the life of oil and gas platforms represents a new market segment. As such there are no market failures yet. (World Energy Council,2017)

In Europe, 65 offshore wind parks will need to be re-powered, upgraded, or decommissioned, in the next 20 years (OSPAR,2007). The first decommissioning project began in 2016, and in the North Sea alone, decommissioning costs are expected to reach between €80 to €100bn over the next 25-30 years. (World Energy Council,2017). Installing wave energy systems is an opportunity to offset the cost of decommissioning by re-purposing the wind parks' infrastructure. The potential global market for this technology is 500 GW(IRENA,2014), with annual electricity sales of about 50 billion Euros. (IRENA,2014 and EWEA,2011).

Fully electric fish farms, powered by wave energy, might not only produce sufficient energy to power their operations, but even excess energy to power the electric vessels that make the voyage to maintain, stock, and extract fish from the farm (Syse,2016).

In the North Sea, offshore vessel charging stations could be powered by wind energy, where production prices have fallen by 63% in the past six years to 65€/MWh (2018), and have the potential to scale to 2600TWh, making it cheaper than diesel (Orsted, 2017).

The Structural Analysis findings showed that 13 out of 28 identified variables from Thematic analysis are strategic (key) variables. Based on the result of data analysis, policymakers in the NSR should consider following recommendations:

1. Governments/Regulators must provide more strict rulings on decommissioning, prolonging life, and repurposing of existence platforms.
2. Investment from governments in the NSR is needed. Moreover, governmental, and financial incentives are needed for entrepreneurs to invest.
3. Financial incentives whether more tax on the shipping and port companies to deter the use of fossil fuels or even reducing tax in areas where a retrofit happens.
4. Supporting research and development in renewable energy infrastructures.
5. Encourage a collaboration between governments, entrepreneurs, shipbuilding companies and maritime industries in the NSR. Governments must provide incentives for companies for sharing their best practices.
6. The health and safety aspect of all personnel on board whose want to use these infrastructures needs to be considered.

5.7.2 Shipbuilding entrepreneurial opportunities

This cluster includes Exhaust scrubber, Solar-powered charging vessel, Renewable methanol vessels,100% Renewable energy vessels and Tide-powered hydrogen vessels.

An exhaust gas cleaning system (scrubber) is a device installed onboard marine vessels that, quite literally, "scrubs" harmful sulfur oxides from exhaust gases. Scrubbers are also effective in removing black carbon (BC), of particular interest because of the potential impact in Arctic regions. (Maritime Executive,2018 and Muenster, 2019). The expected cost of equipment is between $2 million and $5 million per vessel, with variable labor and installation costs adding significantly to the final price (Muenster, 2019). This can be an attractive investment for entrepreneurs.

Solar-powered vessels will be able to provide charging services that enable increased speeds and radii for other electrified vessels. The lower costs of materials and advanced production techniques makes the price-performance ratio of solar technologies competitive to rival energy sources (University of Toledo,2019).

Renewable methanol is produced from an electrolysis process, powered from a renewable energy source. The process combines hydrogen with CO2 captured from the air or the emissions from an industry, making it carbon neutral (Hobson,2018).

100% Renewable energy vessels powered by waves. They are hybrid ships that use both waves energy and electrical power provided by solar panels placed on board. In this way they can sail without CO2 emissions and without refueling. (OOC,2020).

Tide-powered hydrogen vessels can be electrifying by electricity from tidal. Electricity from tidal is very predictable because it relies on the gravitational pull from the moon, and because the waterways that make good sites for tidal energy are not always easily connected to a mainland electricity grid, producing hydrogen can serve as another way to store the energy (Giannini,2019 and Husseini 2018).

The Structural Analysis findings showed that 9 out of 25 identified variables from Thematic analysis are strategic (key) variables. Based on the result of data analysis, policymakers in the NSR should consider following recommendations:

1. Encourage a collaboration between shipbuilding companies, governments, entrepreneurs, and ports. Governments in the NSR must provide a collaborative framework to manage, focus, develop, and share research and development and leverage best practices in shipbuilding and ship repair.
2. Alteration of ship is very expensive, and governments must provide financial incentives for shipbuilding companies and entrepreneurs that want to help these companies in this process. Governments in the NSR should offer tariffs to companies that switch to renewable energy, to offset the cost of modifying the ship.
3. Invest in alteration of ships, installation of Exhaust scrubber on the existence ships and design future ships.
4. Create demand for renewable energy powered vessels through government incentives or enforces such as emission tax, tax-free or low taxes on maritime transport running with renewable energy.
5. The time to recharge should take no longer than that of the current energy use. Therefore, a technology for shorter recharge time is needed.
6. Ensuring safety on renewable energy powered vessels.

5.7.3 Technological entrepreneurial opportunities

This cluster includes Charging at offshore wind parks/farms, Virtual arrival agreements, AI for cargo stowage , International MRV monitoring and Offshore maintenance drones.

Offshore wind energy is very similar to onshore wind, but with larger blades and turbines. Offshore wind farms are playing an important role as Europe transitions to renewable energy. The European offshore wind market will reach an expected annual capacity of ≈14 GW by 2030 and will require an expansion of the fleet of Service Operation Vessels (SOVs) to maintain them (DNV,2019). According to the Bloomberg New Energy Finance data, the levelized cost of electricity (LCOE) of onshore wind in Europe ranges from 50-65 €/MWh in H1 2018, while offshore wind is on a steady cost reduction pathway with expected costs of 64 €/MWh by 2021 and €60/MWh by 2025. Europe has the potential to realize up to 3,400 TWh of offshore wind energy within its waters in 2030 (windeurope,2020). The research showed this opportunity can be an attractive opportunity for entrepreneur.

When at port, ships keep their auxiliary engines, resulting in unnecessary emission of pollutants and over $18bn in fuel waste (NAPA, 2017). Estimates suggest that an eight-hour stay at port can emit 2.5 tonnes of pollutants. (FathomShipping,2013). Virtual arrival agreements can minimize berthing time for each visit. Access to information about cargo processing progress at ports needs a platform. Designing, running, and managing of this platform can be an attractive opportunity for entrepreneurs.

RoRo (Roll-on/Roll-off) vessels carry 234 million tonnes of goods annually around Europe and is growing at an average rate of 3%. (ECSA ,2016 and European Commission ,2015). The task of the RoRo cargo stowage planner is to limit delays and to ensure a good balance of the cargo onboard for each trip (European Commission ,2015). Suboptimal arrangements are costing shipping companies millions per year, as a more balanced ship will provide fuel (and emissions) savings of up to 2% per trip (Wathne,2012). Artificial Intelligence (AI) offers an algorithmic approach to support stowage optimization, calculating and suggesting options for the stowage planner (Martinez, 2020).

From the 1st of January 2018, ships above 5,000 gross tonnes are required to monitor and report information on fuel consumption and related CO_2 emissions in the EU. (European Commission, 2020). A central data repository must be established to monitor ship performance data base on International MRV monitoring.

Offshore maintenance drones can maintenance and repair difficult-to-reach places. The drones and robotics market are undergoing tremendous growth, with an estimated market forecast to reach $81.4bn by 2022. In the next 3 to 5 years, the oil and gas industry is planning to double its investment portfolio in drones and robotics, from 15% to 28%. (Frost & Sullivan, 2017). Timely repairing of platforms and vessels can help to less emission; and maintenance drones are effective tools for fast repairing.

The Structural Analysis findings showed that 13 out of 26 identified variables from Thematic analysis are strategic (key) variables. Based on the result of data analysis, policymakers in the NSR should consider following recommendations:

1. To make this happen and increase demand, government enforces, and financial incentives need to be in place so that the forecasted reduction in fuel costs, emissions and environmental aspects are not just perceived as morally good but also a financially sound investment.
2. The NSR regulations must facilitate investing on these technologies and increase collaboration between the actors in the maritime and marine. These regulations must also commit maritime industry to using renewable energy rather than just continue polluting the oceans.

3. Support and facilitate general agreement between ship owners, ports, and governments in the NSR.
4. Mange the costs because the cost should not be more than that of the current solutions.
5. International joint industry project that increases the cost of NOT being round the table to drive these technologies.
6. An international consensus on standardizing data, file formats and central warehouses, processes, tools, and technologies are needed.
7. Support of R & D in the NSR for technology advancement.
8. Create and expand a communication infrastructure in the NSR.

5.7 Conclusion

In overall, decarbonizing and zero emission is a necessity for sustainable blue growth. Entrepreneurs by utilizing of their ingenuity can identify venturing ideas and analyze them to identify entrepreneurial opportunities and establish new markets. The markets that can work non-stop while helping to decarbonizing and zero emissions. By identifying entrepreneurial opportunities for decarbonizing and zero emission in the North Sea, this study has effectively helped to shorten the entrepreneurial process and has introduced opportunities for operational investment to the region governments.

The findings of the study show venturing ideas for decarbonizing and zero emission and their clustering in the NSR and venturing ideas screening criteria and their priority. The findings demonstrate how the venturing ideas screening criteria can be applied for identification of the entrepreneurial opportunities and when these opportunities can be realized. However, it is not without challenges. There are political, economic, social, technological, and environmental challenges that must be managed. The study goes further to point out variables that affect realization of the opportunities. Identification of strategic variable by structure analysis provided a base for a strategic foresighting. The research showed Profitability of such opportunities and their effectiveness in decarbonizing and zero emission is necessary if it is to be a sustainable investment. Moreover, financial, and non- financial support for entrepreneurs have a vital role in realization of entrepreneurial opportunities. The findings demonstrated a strategic collaboration between all actors in the NSR (Governments, shipbuilding companies, ports, shipping companies, entrepreneurs, incubators and so on.) is necessary; and government enforces, and incentives can guarantee decarbonization and zero emission. Meanwhile concerns over safety and the harsh weather conditions on the North Sea point toward needs for increased automation of operations. While the technological feasibility is seemingly mature, the political analysis points to a critical issue that remains unaddressed: how will countries share the responsibility of this development?

Based on the research objectives, this research has formulated an applicable framework for screening venturing ideas and improved the existing knowledge in the field of entrepreneurship, while neither such framework nor their priorities are in the literature review. The research identified 15 entrepreneurial opportunities for decarbonizing and zero emission and introduced them to entrepreneurs, investors, and other actors in the NSR. Understanding how each opportunity is plausible is an arguably necessary for entrepreneurship. Deeper understanding of affecting variables for each opportunity and identification of the strategic variables, is a base for future entrepreneurships in the NSR.

Therefor the author's contribution to the literature is twofold. First, by identification of venturing ideas screening criteria and their priorities the author has provided an applicable framework for identification of entrepreneurial opportunities. Therefore, Other researchers in the maritime can use these criteria to identifying entrepreneurial opportunities in the other fields in the NSR. Second, this research created a deeper understanding of affecting variables for each opportunity and identified the strategic variables, which is a base for future entrepreneurships and strategic foresighting in the NSR.

5.8 Limitations

The study is limited by financial resources and time and number of pages constraints. As research was carried out during the COVID-19 pandemic, contribution of some experts was limited. The researcher tried to overcome this limitation with virtual meetings and use of the MIRO. But interactions and consensus between participants were difficult.

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Appendix 1 venturing ideas

Idea	Idea
Decommissioning and building renewable assets	Advanced ultra-efficient propeller designs
Prolonging life and re-purposing O&G assets	Solar cell hybrid system
Maritime synergies and spatial planning	Diversification of the fuel mix
Offshore wind energy	Exhaust scrubber
Electrifying oil and gas platform	Fire Fighter Robots
Seaweed production within offshore wind farms and use them as a biofuel	Robot Ship Inspectors
Big data analytics	Prolonging the lifespan of offshore infrastructure
Autonomous system	Below seabed mineral mapping
Robotics	Drone-driven fish hurding
Smart ships (industry 04)	Ocean vent exploitation
Communications technologies middle of the sea	Subsea wireless communications
Renewable energy for Propulsion and Powering	Multi-use platforms
Intelligence below the surface	Underwater satellite network
Sensor for efficient ship	Re-purposing of infrastructure
No-ballast systems	Protein production
Long-distance power transmission	Anti-fouling into metals
Seabed mega-mining	Iron-fertilization of unproductive dead spots
Ocean vent thermal energy conservation	Construct or repair artificial reefs
Applications of high-resolution seabed imaging	Biomineralization
Self-healing material	Membrane desalination
Subsea gardening	Solar desalination
Deep sea medicine	Hybrid satellite subsea mapping
Pre-catch fish recognition	Offshore platform network
Floating cities	High-speed communication
Underwater cities	Underwater greenhouse
Ocean nanobots	Ocean acidification opportunities
Blockchain for fish catch	Offshore Site Selection for a multi-functional use
Underwater laser scanner	Crab and lobster farming
3D imaging of offshore platforms	Modularized infrastructure
Retrieval and reutilization of plastic	Zero-fuel ships
Floating holiday getaway	3D imaging of cargo stowage areas
Floating housing	Cruise Ship waste processing
Copper recovery from the seabed	LNG Bunkering infrastructure in the North Sea
Cloud of Spares	the evolving diesel motor
Shipmanagement Software Solutions	Recycling of wind farms

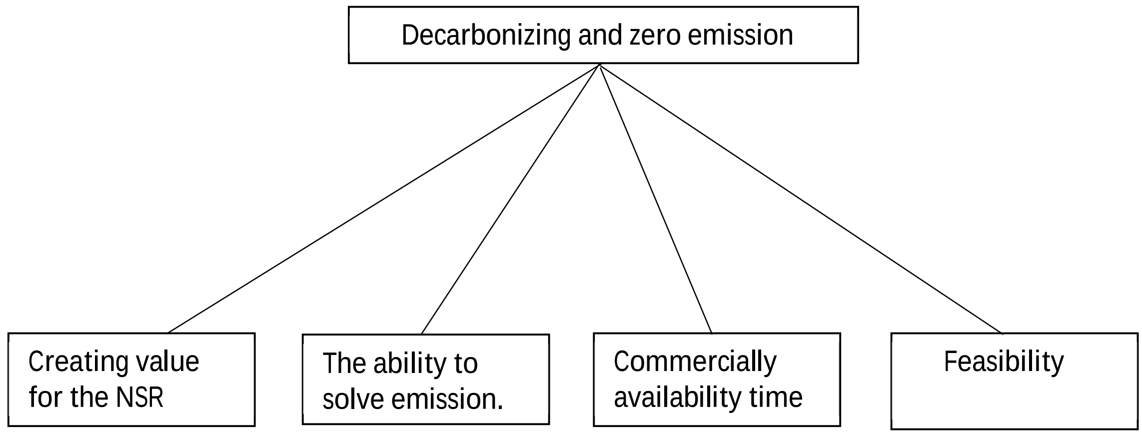
Idea	Idea
Greener engines	Harvesting of wild local macroalgae populations for the food market.
Optimised cooling systems	The nothern sea route (NSR)
Minimal friction hull paint	Autonomous port
Collection of beach-cast macroalgae	Offshore container terminal
Arctic sea ice app	Pre-cooling of containers
UAV for paint inspection	Containers that move autonomously
Flexible underwater pipelines	Under-ice autonomous exploratory vehicles
Laser	Autonomous ship types
AUTONOMOUS/DIGITAL fish farms	Standardized data scheme for monitoring, verification, and reporting
Aquaponics	Policing tax evading shipping
Capture and resale of missing elements.	Lightweight components for the next gen offshore power plants
Identification, collection, and recycling of plastic from the sea	3D printing for on-site repair and re-design of wind turbine components (3D-printed turbine components)
ID system to streamline and enhance quality in fish production	Wave-powered tsunami warning
Locally produced, high quality sustainable farmed fish	Drones de-icing wind turbines
Recording, processing and resale of minerals from the seabed	Subsea robotic maintenance
Pilot project with clean burning gas carriers	Container stacking drones
Sensor system for collecting weather and traffic data from ships.	Underwater cargo hyperloop
Seaweed cultivation within wind farms	Antifouling foil
Floating wind turbines	Subsurface hull laser scanner
100% Renewable energy vessels	Wind park repurposing
Filter pots for hydrothermal vents	Autonomous service vessels
Biodegradable Jelly-bots	Drones for enclosed spaces
Open-sourced and standardized big data platform	Hearing coils on wind blades
Offshore vessel charging stations	Digital vessel twinning
Plastic bubble barrier	Underwater laser pipe cutters
Wave parasite	Offshore wind kite farm
50MW floating converter and accumulator	Drone station at offshore platforms
Mussel shields to protect infrastructure	Offshore container terminal
Polar ice app	Game controller for steering
Autonomus replacement ferry	Smart cabins on cruise ships
Manufacturing as a service: Exploiting digitation	Oilfield thermite plug
Offshore maintenance drones	Subsurface coating reapplication
Deep sea mineral mega-mining	Autonomous offshore service vessels
Offshore sea farming	Very large ice-class container vessel
Smart drone & robotic maintenance	AI for cargo stowage

Idea	Idea
Saltfarming in the North Sea	Environmentally friendly antifouling foil without dry docking
Natural User Interfaces (NUI) in blue industries	fully electric fish farm
Offshore multi-use city tourist park energy hub	Smart buoys for digitalization of ocean weather data
Applications of high-resolution seabed imaging for ecosystem management	Plugging sub sea oilfield with thermite
Under-ice marine spatial planning	Underwater laser scanner for hull corrosion management
Robot retrieval and re-utilization of plastic	Underwater lasers cutter for offshore O&G platform decommissioning
Multidisciplinairy Underwater Recycle & Passenger Transporter (MURP)	Offshore 3D printed wind turbine blades
Modularized offshore platform construction and assembly	Charging at offshore wind parks
Computer-assisted decision verification systems	Thermal vent smoke filtering
Offshore landing strips	Autonomous coast guard platform
Control station in polar region	Solar-powered charging vessel
Polar hotel	charging at Thermal-powered platform
Micro-Service Systems Integration	Renewable Liquid methanol fuel for vessels
Underwater tunnels	Wind turbine blade cleaning by drones(turbine blade cleaning drones)
Wind farms that move autonomously in the ocean (Roaming Autonomous Wind Farms)	3D x-ray container scanner
Offshore incinerator in the "soup"!	Composite material for ship repair
Underwater laser scanner for hull corrosion management	Autonomous underwater vehicle for maintenance operations
Drone & robotic maintenance on offshore platforms (Aerial)	Cruise ship inspection swarms of drones
Sub-sea autonomous robotic maintenance on offshore infrastructure	3D printing of turbine blades
Autonomous drones for inspection of enclosed spaces	Tide-powered hydrogen vessels
Lashing robots	Container lashing drone
Offshore container terminal	3D x-ray container scanner
Oil & gas platforms decommissioning optimization	Ice thickness measurement drones
Offshore wind park repurposing	Charging at wind farms
Screw piles as foundation for offshore installations	Drone stations at wind farms
3D printing	Flying ships
Autonomous Open Ocean Farming	Man overboard rescue drones
Fireproof composite hulls	Thermal -powered platform
document delivery drones	Laser-based navigation
Autonomous bird abatement drones	Underwater data laser
Ice-class container vessel	Thermal vent smoke-filtering
Subsea drone charging platform	Autonomous underwater dredger

Idea	Idea
Composite bulk carrier hull	Smart weather buoys
Foldable containers	Lightweight containers
Composite for ship repairs	Microgrids at large ports
Offshore logistics hub	Virtual arrival agreements
Document delivery drones	Multipurpose drones on ships
Autonomous containers	Welding inspection drones
International MRV	Electric pulse fishing
Open weather data platform	
AI for cargo stowage	
Renewable methanol vessels	
seafloor screw piles	

PERISCOPE is supported by the North Sea Region (NSR) EU grant J-No. 32-2-13-17

Appendix 2 AHP questionnaires-Criteria questionnaire



Goal: Decarbonizing And zero emission	Creating value for the NSR	The ability to solve emission.	Commercially availability time	Feasibility
Creating value for the NSR	1			
The ability to solve emission.		1		
Commercially availability time			1	
Feasibility				1

Saaty's Scale of Relative Importance

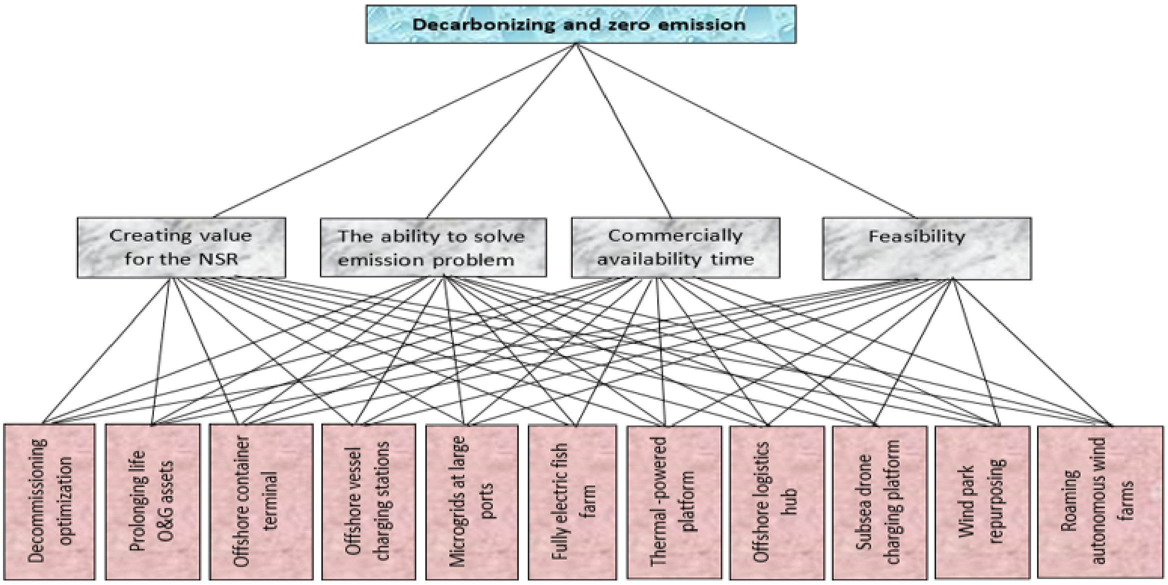
Scale	Numerical rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Source:(Saaty,2005)

PERISCOPE

PERISCOPE is supported by the North Sea Region (NSR) EU grant J-No. 32-2-13-17

Appendix 2 AHP questionnaires-Infrastructural venturing ideas questionnaires



Infrastructural venturing ideas

Saaty's Scale of Relative Importance

Scale	Numerical rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Source:(Saaty,2005)

Creating value for the NSR	Decommissioning optimization	Prolonging life and re-purposing O&G assets	Offshore container terminal	Offshore vessel charging stations	Microgrids at large ports	Fully electric fish farm	Thermal -powered platform	Offshore logistics hub	Subsea drone charging platform	Wind park repurposing	Roaming autonomous wind farms
Decommissioning optimization	1										
Prolonging life and re-purposing O&G assets		1									
Offshore container terminal			1								
Offshore vessel charging stations				1							
Microgrids at large ports					1						
Fully electric fish farm						1					
Thermal -powered platform							1				
Offshore logistics hub								1			
Subsea drone charging platform									1		
Wind park repurposing										1	
Roaming autonomous wind farms											1

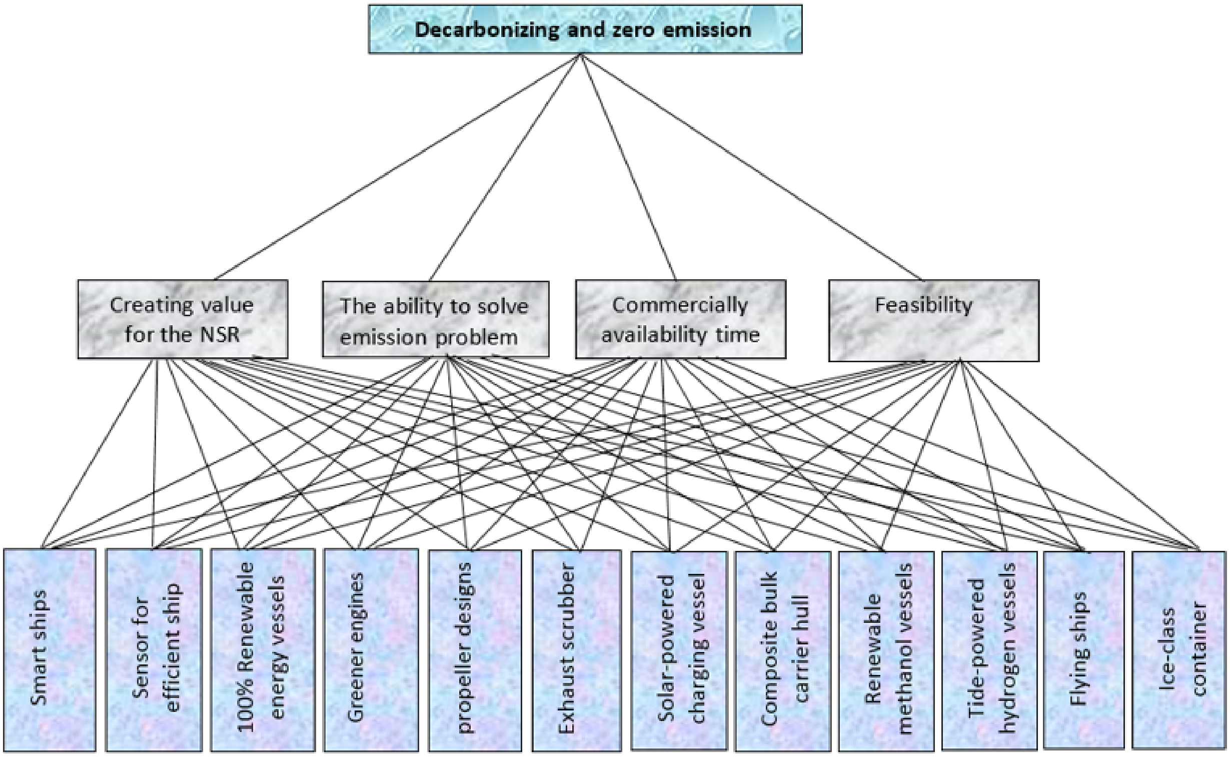
The ability to solve emission problem	Decommissioning optimization	Prolonging life and re-purposing O&G assets	Offshore container terminal	Offshore vessel charging stations	Microgrids at large ports	Fully electric fish farm	Thermal -powered platform	Offshore logistics hub	Subsea drone charging platform	Wind park repurposing	Roaming autonomous wind farms
Decommissioning optimization	1										
Prolonging life and re-purposing O&G assets		1									
Offshore container terminal			1								
Offshore vessel charging stations				1							
Microgrids at large ports					1						
Fully electric fish farm						1					
Thermal -powered platform							1				
Offshore logistics hub								1			
Subsea drone charging platform									1		
Wind park repurposing										1	
Roaming autonomous wind farms											1

Commercially availability time	Decommissioning optimization	Prolonging life and re-purposing O&G assets	Offshore container terminal	Offshore vessel charging stations	Micrograds at large ports	Fully electric fish farm	Thermal -powered platform	Offshore logistics hub	Subsea drone charging platform	Wind park repurposing	Roaming autonomous wind farms
Decommissioning optimization	1										
Prolonging life and re-purposing O&G assets		1									
Offshore container terminal			1								
Offshore vessel charging stations				1							
Micrograds at large ports					1						
Fully electric fish farm						1					
Thermal -powered platform							1				
Offshore logistics hub								1			
Subsea drone charging platform									1		
Wind park repurposing										1	
Roaming autonomous wind farms											1

Idea	Decommissioning optimization	Prolonging life and re-O&G assets	Offshore container terminal	Offshore vessel charging stations	Micrograds at large ports	Fully electric fish farm	Thermal -powered platform	Offshore logistics hub	Subsea drone charging platform	Wind park repurposing	Roaming autonomous wind farms
Commercially availability time	2032	2031	2030	2031	2030	2030	2035	2035	2030	2030	2033

Feasibility	Decommissioning optimization	Prolonging life and re-purposing O&G assets	Offshore container terminal	Offshore vessel charging stations	Micrograds at large ports	Fully electric fish farm	Thermal -powered platform	Offshore logistics hub	Subsea drone charging platform	Wind park repurposing	Roaming autonomous wind farms
Decommissioning optimization	1										
Prolonging life and re-purposing O&G assets		1									
Offshore container terminal			1								
Offshore vessel charging stations				1							
Micrograds at large ports					1						
Fully electric fish farm						1					
Thermal -powered platform							1				
Offshore logistics hub								1			
Subsea drone charging platform									1		
Wind park repurposing										1	
Roaming autonomous wind farms											1

Appendix 2 AHP questionnaires-Shipbuilding venturing ideas questionnaires



Saaty's Scale of Relative Importance

Scale	Numerical rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Source:(Saaty,2005)

Creating value for the NSR	Smart ships	Sensor for efficient ship	100% Renewable energy vessels	Greener engines	Advanced ultra-efficient propeller designs	Exhaust scrubber	Solar-powered charging vessel	Composite bulk carrier hull	Renewable methanol vessels	Tide-powered hydrogen vessels	Flying ships	Ice-class container
Smart ships	1											
Sensor for efficient ship		1										
100% Renewable energy vessels			1									
Greener engines				1								
Advanced ultra-efficient propeller designs					1							
Exhaust scrubber						1						
Solar-powered charging vessel							1					
Composite bulk carrier hull								1				
Renewable methanol vessels									1			
Tide-powered hydrogen vessels										1		
Flying ships											1	
Ice-class container												1

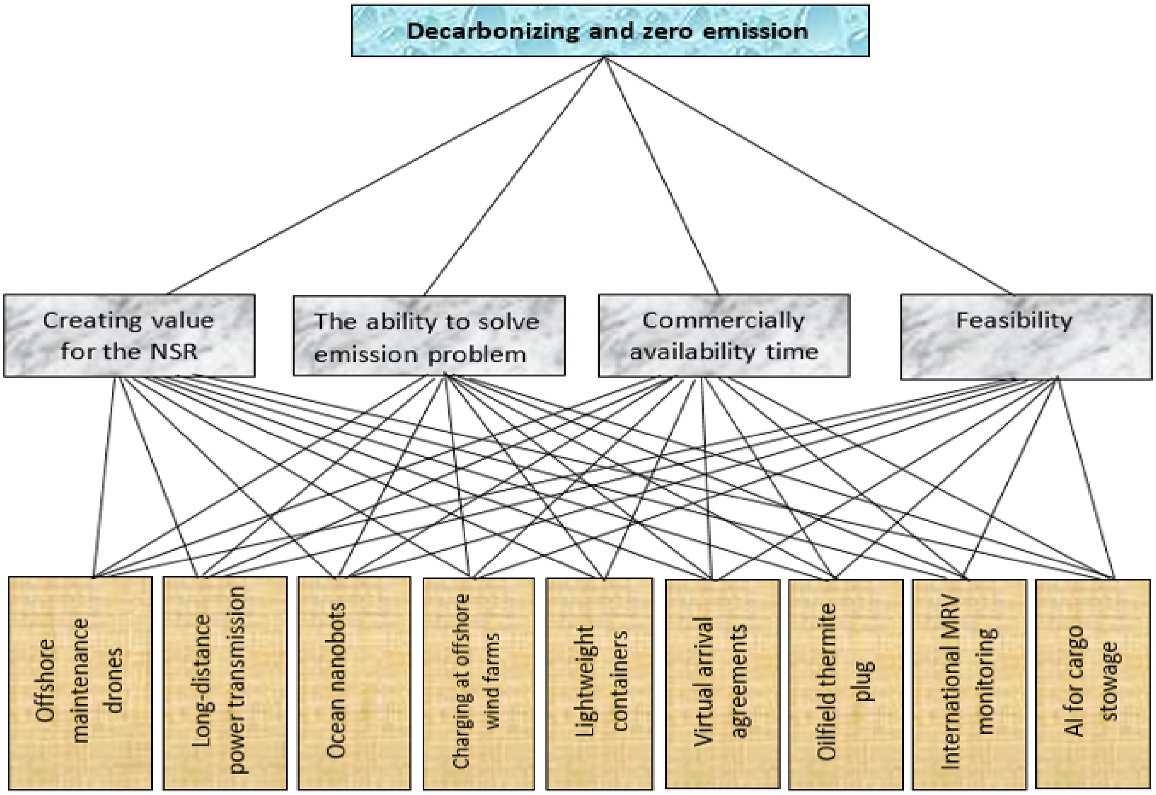
The ability to solve emission problem	Smart ships	Sensor for efficient ship	100% Renewable energy vessels	Greener engines	Advanced ultra-efficient propeller designs	Exhaust scrubber	Solar-powered charging vessel	Composite bulk carrier hull	Renewable methanol vessels	Tide-powered hydrogen vessels	Flying ships	Ice-class container
Smart ships	1											
Sensor for efficient ship		1										
100% Renewable energy vessels			1									
Greener engines				1								
Advanced ultra-efficient propeller designs					1							
Exhaust scrubber						1						
Solar-powered charging vessel							1					
Composite bulk carrier hull								1				
Renewable methanol vessels									1			
Tide-powered hydrogen vessels										1		
Flying ships											1	
Ice-class container												1

Commercially availability time	Smart ships	Sensor for efficient ship	100% Renewable energy vessels	Greener engines	Advanced ultra-efficient propeller designs	Exhaust scrubber	Solar-powered charging vessel	Composite bulk carrier hull	Renewable methanol vessels	Tide-powered hydrogen vessels	Flying ships	Ice-class container
Smart ships	1											
Sensor for efficient ship		1										
100% Renewable energy vessels			1									
Greener engines				1								
Advanced ultra-efficient propeller designs					1							
Exhaust scrubber						1						
Solar-powered charging vessel							1					
Composite bulk carrier hull								1				
Renewable methanol vessels									1			
Tide-powered hydrogen vessels										1		
Flying ships											1	
Ice-class container												1

Idea	Smart ships	Sensor for efficient ship	100% Renewable energy vessels	Greener engines	Advanced ultra-efficient propeller designs	Exhaust scrubber	Solar-powered charging vessel	Composite bulk carrier hull	Renewable methanol vessels	Tide-powered hydrogen vessels	Flying ships	Ice-class container
Commercially availability time	2028	2029	2034	2031	2025	2023	2035	2029	2031	2035	2031	2030

Feasibility	Smart ships	Sensor for efficient ship	100% Renewable energy vessels	Greener engines	Advanced ultra-efficient propeller designs	Exhaust scrubber	Solar-powered charging vessel	Composite bulk carrier hull	Renewable methanol vessels	Tide-powered hydrogen vessels	Flying ships	Ice-class container
Smart ships	1											
Sensor for efficient ship		1										
100% Renewable energy vessels			1									
Greener engines				1								
Advanced ultra-efficient propeller designs					1							
Exhaust scrubber						1						
Solar-powered charging vessel							1					
Composite bulk carrier hull								1				
Renewable methanol vessels									1			
Tide-powered hydrogen vessels										1		
Flying ships											1	
Ice-class container												1

Appendix 2 AHP questionnaires-Technology venturing ideas questionnaires



Technological venturing ideas

Saaty's Scale of Relative Importance

Scale	Numerical rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Source:(Saaty,2005)

Creating value for the NSR	Offshore maintenance drones	Long-distance power transmission	Ocean nanobots	Charging at offshore wind parks/farms	Lightweight containers	Virtual arrival agreements	Oilfield thermite plug	International MRV monitoring	AI for cargo stowage
Offshore maintenance drones	1								
Long-distance power transmission		1							
Ocean nanobots			1						
Charging at offshore wind parks/farms				1					
Lightweight containers					1				
Virtual arrival agreements						1			
Oilfield thermite plug							1		
International MRV monitoring								1	
AI for cargo stowage									1

The ability to solve emission problem	Offshore maintenance drones	Long-distance power transmission	Ocean nanobots	Charging at offshore wind parks/farms	Lightweight containers	Virtual arrival agreements	Oilfield thermite plug	International MRV monitoring	AI for cargo stowage
Offshore maintenance drones	1								
Long-distance power transmission		1							
Ocean nanobots			1						
Charging at offshore wind parks/farms				1					
Lightweight containers					1				
Virtual arrival agreements						1			
Oilfield thermite plug							1		
International MRV monitoring								1	
AI for cargo stowage									1

Commercially availability time	Offshore maintenance drones	Long-distance power transmission	Ocean nanobots	Charging at offshore wind parks/farms	Lightweight containers	Virtual arrival agreements	Oilfield thermite plug	International MRV monitoring	AI for cargo stowage
Offshore maintenance drones	1								
Long-distance power transmission		1							
Ocean nanobots			1						
Charging at offshore wind parks/farms				1					
Lightweight containers					1				
Virtual arrival agreements						1			
Oilfield thermite plug							1		
International MRV monitoring								1	
AI for cargo stowage									1

Idea	Offshore maintenance drones	Long-distance power transmission	Ocean nanobots	Charging at offshore wind parks/farms	Lightweight containers	Virtual arrival agreements	Oilfield thermite plug	International MRV monitoring	AI for cargo stowage
Commercially availability time	2028	2032	2034	2027	2030	2025	2030	2026	2025

Feasibility	Offshore maintenance drones	Long-distance power transmission	Ocean nanobots	Charging at offshore wind parks/farms	Lightweight containers	Virtual arrival agreements	Oilfield thermite plug	International MRV monitoring	AI for cargo stowage
Offshore maintenance drones	1								
Long-distance power transmission		1							
Ocean nanobots			1						
Charging at offshore wind parks/farms				1					
Lightweight containers					1				
Virtual arrival agreements						1			
Oilfield thermite plug							1		
International MRV monitoring								1	
AI for cargo stowage									1

Appendix 3: Samples of Commercially availability time Questionnaire (See all questionnaire in the Periscope website: https://periscope-network.eu/business-opportunities.)

Charging at wind farms

On the sliding scale below, estimate how many years from now, that electric service vessels recharging at offshore wind farms, will become an accepted practice, i.e. commercially available (0= already here).

0 5 10 15 20 25 30

☐ Will never happen

What is needed to make this opportunity happen?

Fully electric fish farm.

On the sliding scale below, please estimate how many years from now, that a fully-electric fish farm, powered by wave energy and capable of charging service vessels, will be installed in the North Sea (0= already here).

0 5 10 15 20 25 30

☐ Will never happen

What is needed to make this opportunity happen?

PERISCOPE is supported by the North Sea Region (NSR) EU grant J-No. 32-2-13-17

Tide-powered hydrogen vessels.

On the sliding scale below, please estimate how many years from now, that hydrogen from tidal plants replaces 1MW diesel vessels powering, will become an accepted practice to, i.e. commercially available (0= already here).

0 5 10 15 20 25 30

☐ Will never happen

What is needed to make this opportunity happen?

Renewable methanol vessels

On the sliding scale below, please estimate how many years from now, that using methanol for ocean going vessels will become an accepted practice, i.e. commercially available. (0= already here).

0 5 10 15 20 25 30

☐ Will never happen

What is needed to make this opportunity happen?

Appendix 4: Thematic Analysis Questionnaires

Infrastructural entrepreneurial opportunities					
Codes	Political	Economic	Social	Technological	Environmental
Environmental management forces					
Financially viable					
Value of product					
Financial incentives					
Cultural shift					
Collaboration					
Human factor					
Enhance performance					
Safety					
Environmentally friendly					
Location planning					
Installation					
R&D					
Knowledge					
Capacity					
Demand					
Technology improvement					
Technology acceptance					
Cost					
Investment					
Legislation					
Industry regulation					
Government					
New rules					
Government enforcement					
International laws					
Monitoring					
Technical aspects					

shipbuilding entrepreneurial opportunities					
Codes	Political	Economic	Social	Technological	Environmental
Environmental aspect					
Technical aspects					
Awareness					
Risk analysis					
Safety					
Environment management					
Demand					
Investment					
cost					
Government					
legislation					
Process management					
New rules					
Renewable Portfolio Standard (RPS)					
R&D					
Financial incentives					
collaboration					
Government incentives					
Storage technology					
Dual fuel combustion					
Energy storage capabilities					
Training of crews					
Economic feasibility study					
Alteration of ship					
Renewable energy accessibility					

Technological entrepreneurial opportunities					
Codes	Political	Economic	Social	Technological	Environmental
Environmental aspect					
Infrastructure					
Awareness					
Risk analysis					
Safety					
Environmental management					
Financial incentive					
Demand					
Investment					
Standards					
Cost					
Government					
legislation					
General agreement					
Test of the platform					
The NSR regulations					
Technical aspects					
Industry 4.0					
Government enforces					
Communication infrastructure					
Profit					
Collaboration					
Technological advancement					
R&D					
Financially viable					
Reliability					

Appendix 5: Structural analysis questionnaires

		Infrastructural entrepreneurial opportunities																											
Themes	Codes	Political							Economic								Social				Technological							Environmental	
		Legislation	Government	New rules	Industry regulation	Government enforcement	Monitoring	International laws	Value of product	Investment	Cost	capacity	Demand	Financially viable	Financial incentives	Enhance performance	Knowledge	Collaboration	Cultural shift	Human factor	Technology improvement	R&D	Technology acceptance	Technical aspects	safety	Location planning	Installation	Environment friendly	Environmental management forces
Political	Legislation																												
	Government																												
	New rules																												
	Industry regulation																												
	Government enforcement																												
	Monitoring																												
	International laws																												
Economic	Value of product																												
	Investment																												
	Cost																												
	capacity																												
	Demand																												
	Financially viable																												
	Financial incentives																												
	Enhance performance																												
Social	Knowledge																												
	Collaboration																												
	Cultural shift																												
	Human factor																												
Technological	Technology improvement																												
	R&D																												
	Technology acceptance																												
	Technical aspects																												
	safety																												
	Location planning																												
	Installation																												
Environmental	Environmentally friendly																												
	Environmental management forces																												

0: No influence
1: Weak
2: Moderate influence
3: Strong influence

0: No influence

1: Weak

2: Moderate influence

3: Strong influence

		Shipbuilding entrepreneurial opportunities																								
Themes		Political					Economic						Social			Technological									Environmental	
	Codes	New rules	Government	Renewable portfolio standard	Government incentives	Legislation	Risk analysis	Investment	Cost	Financial incentive	Demand	Economic feasibility study	Awareness	Collaboration	Training of crews	Renewable energy accessibility	Technical aspects	Alteration of ship	Storage technology	Dual fuel combustion	Process management	Energy storage capabilities	R&D	Safety	Environment aspect	Environmental management
Political	New rules																									
	Government																									
	Renewable portfolio standard (RPS)																									
	Government incentives																									
	Legislation																									
Economic	Risk analysis																									
	Investment																									
	Cost																									
	Financial incentive																									
	Demand																									
	Economic feasibility study																									
Social	Awareness																									
	Collaboration																									
	Training of crews																									
Technological	Renewable energy accessibility																									
	Technical aspects																									
	Alteration of ship																									
	Storage technology																									
	Dual fuel combustion																									
	Process management																									
	Energy storage capabilities																									
	R&D																									
	Safety																									
Environmental	Environmentally aspect																									
	Environmental management																									

0: No influence

1: Weak

2: Moderate influence

3: Strong influence

		Technological entrepreneurial opportunities																									
Themes		Political						Economic							Social		Technological									Environmental	
	Codes	Government	Legislation	Government enforces	The NSR regulations	Standards	General agreement	Investment	Risk analysis	Financial incentive	Demand	Financially viable	Profit	Cost	Collaboration	Awareness	Industry 4.0	Infrastructure	Reliability	Test of the platform	R & D	Safety	Technological advancement	Technical aspects	Communication infrastructure	Environmental management	Environmental aspects
Political	Government																										
	Legislation																										
	Government enforces																										
	The NSR regulations																										
	Standards																										
	General agreement																										
Economic	Investment																										
	Risk analysis																										
	Financial incentive																										
	Demand																										
	Financially viable																										
	Profit																										
	Cost																										
Social	Collaboration																										
	Awareness																										
Technological	Industry 4.0																										
	Infrastructure																										
	Reliability																										
	Test of the platform																										
	R & D																										
	Safety																										
	Technological advancement																										
	Technical aspects																										
	Communication infrastructure																										
Environmental	Environmental management																										
	Environmental aspects																										