



**UNIVERSITY
OF TURKU**

Turku School of
Economics

Futures of shipbuilding in the 22nd century

Explorative industry foresight research of the long-range futures for commercial shipbuilding, using elements of OpenAI.

Master's thesis

Futures Studies

Author:

Ludmila Seppälä

Supervisor:

Petri Tapio

14.6.2023

Turku

The originality of this thesis has been checked in accordance with the University of Turku quality assurance system using the Turnitin Originality Check service.

Master's thesis

Subject: Futures Studies

Author: Ludmila Seppälä

Title: Futures of shipbuilding in the 22nd century: Explorative industry foresight research of the long-range futures for commercial shipbuilding, using elements of OpenAI.

Supervisor: Prof. Petri Tapio

Number of pages: 84 pages + appendices 38 pages

Date: 14.6.2023

The shipbuilding industry has historically shaped global trade, logistics, research, and cultural globalization. It was instrumental in exploring and colonizing new continents, thereby significantly shaping our society. Today, it's essential to consider the industry's current transformations and speculate on what shipbuilding might look like in the 22nd century.

This study is dedicated to exploring the possible futures of shipbuilding over a long-range time horizon of 70 -100 years. This thesis applied futures research methods to data collected using OpenAI tools and explored possible transformative pathways within the industry. The research offers potential future scenarios and delineates change pathways from external pressures and internal shifts within the shipbuilding system. Additionally, the study highlights the possible applications and implications of utilizing OpenAI technology in a research context.

The analysis of shipbuilding incorporates the Multi-Level Perspective (MLP) concept, viewing the industry as a system involving ten groups of key actors. This structure guided the data collection process for the input of the research. The primary research process adheres to traditional futures research methods, which include horizon scanning, systems thinking, scenario building, and causal layered analysis (CLA). Furthermore, the methodology was expanded to incorporate AI-assisted techniques. This includes using AI technology for automated data collection and a separate pathway using ChatGPT-4 for computer-generated scenarios and CLA narratives development. The outcomes from both methodologies are compared, and additional literature research about the applicability and implications of using AI in futures studies.

The research has identified critical external drivers of change, originating from fields such as technology, energy, and social development, as well as internal drivers, including biotechnology and diversifying floating structures. The external drivers could influence the future direction of shipbuilding, while the internal factors represent potential changes originating from within the industry. The constructed scenarios are designed to stimulate discussion and provide context for future developmental trajectories of shipbuilding.

Key words: futures of shipbuilding, foresight using OpenAI.

Table of contents

FOREWORD	7
1 INTRODUCTION	9
1.1 Background	10
1.2 Research questions	12
1.3 Research design.....	12
2 CONCEPTUAL FRAMEWORK.....	14
2.1 Multi-level perspective (MLP) framework	14
2.2 MLP and signals classification in horizon scanning	16
2.3 Transitions.....	17
2.3.1 Typology of transitions	18
2.3.2 Types of transitions and types of scenarios in futures studies.....	19
2.4 Broader perspective and deep transitions.....	21
3 METHODOLOGY	24
3.1 Workflow of research steps.....	25
3.2 Input: Environment and Horizon scanning	26
3.3 Analysis: Systems thinking	28
3.4 Prospection: Scenario building	29
3.5 Interpretation: Causal Layered Analysis	30
3.6 Use of OpenAI	31
3.7 Ethical considerations	35
4 DATA COLLECTION AND ANALYSIS.....	37
4.1 Definition of the research focus	37
4.1.1 The subject of the research – commercial shipbuilding	37
4.1.2 The timeline for the research – long-range futures.....	38
4.1.3 The nature of the research – explorative using OpenAI	40
4.1.4 Boundaries of the research.....	40
4.1.5 Mapping system’s structure and dynamics - Data from actor groups for the shipbuilding ecosystem	41
4.2 Data collection	42
4.2.1 Collecting data using Bing and OpenAI	42
4.2.2 Grouping and analyzing data	43
4.3 Data analysis	44

5	RESULTS	46
5.1	The snapshot of the industry at present	46
5.1.1	Additional data for weak signals.....	48
5.1.2	Additional data for wild cards.....	50
5.2	The scenarios for the future of shipbuilding	52
5.2.1	Scenarios for the futures of shipbuilding.....	53
5.2.2	Testing scenarios implications.....	57
5.3	CLA narratives for the scenarios.....	59
5.4	Scenarios and CLA generated by ChatGPT-4.....	61
6	DISCUSSION ABOUT THE MAIN FINDINGS	66
6.1	Discussion about the results	66
6.1.1	Summary snapshot for the current state of shipbuilding	66
6.1.2	Manually developed scenarios and CLA	67
6.1.3	Automatically developed scenarios and CLA.....	68
6.2	Comparison of manually made analysis and result from ChatGPT-4.....	69
6.3	Conclusion about the discussion about the futures of shipbuilding.....	69
6.4	Limitations originating from research design and methods	70
6.5	Findings for the research questions and hypothesizes	71
6.6	Directions for further research	73
7	CONCLUSIONS	76
	REFERENCES.....	77
	REFERENCES FOR ONLINE HORIZON SEARCH SOURCES	82
	APPENDICES	87
	Appendix 1. Data collected step in horizon scanning and summary.	87
	Appendix 2. Data grouped by clusters, topics and relevance.	119

List of figures

Figure 1 MLP framework, adapted from Geels 2002.	15
Figure 2 Futures signals aligning with the MLP concept framework.....	17

Figure 3 Parallels between the typology of transitions in the MLP framework, typology of futures signals, and Dator's Four Futures scenario archetypes.	21
Figure 4 Adapted Generic Foresight Process and methodology of research map on the left side to match with futures studies methods.....	24
Figure 5 An overall workflow of data collection and analysis steps based on the selected methodology.	25
Figure 6 The time horizon for the research and significant time marks from the past.....	39
Figure 7 Main ten groups of actors in the shipbuilding ecosystem	41
Figure 8 Scenarios summary prepared by analyzing the data	53

List of tables

Table 1 Summary of driving forces, based on collected data and categorized by scale in preliminary data analysis using ChatGPT-4.....	47
Table 2 Weak signals found by Bing search using OpenAI	48
Table 3 Wild card events, based on ChatGPT-4 search	51
Table 4 Testing scenarios implications against wild card events	57
Table 5 Scenarios, generated by ChatGPT-4	62
Table 6 CLA analysis, using ChatGPT-4.....	63

Foreword

I started writing this thesis in 2018. My original topic and area of interest revolved around practical strategic foresight applications. I wanted to find a space where I could use my professional expertise to explore a future studies perspective on it. I have over 20 years of experience in IT-related shipbuilding areas, which determined my main focus. Since then, the idea of the thesis evolved gradually around thoughts about the futures of shipbuilding IT systems, a narrow focus on CAD/CAM (Computer-Aided Design and manufacturing) systems and the drawingless building process, business-oriented strategic foresight topics, and similar. Due to personal reasons, I had to postpone my studies until 2022 while keeping the topic in mind and mulling it over with professional shipbuilding activities. During this gap, I collected many industry-related articles and discussions, directly and indirectly, related to the topic. For research purposes, this material was systematized and allocated in the conceptual framework to later serve as a basis for data collection and analysis.

When I wrote this introduction in January 2023, I found myself in a completely changed world. From wild card events in the scenarios anticipated in 2018, a global pandemic and war in Ukraine became a reality in the last two years. It dramatically affected millions of lives, significantly changed our society, triggered profound transitions, and impacted the global economy. A war of aggression started by Russia in Ukraine reshaped European security and policy for the next decades. Something considered a black swan, an event with a significant impact but diminishing probability, became a reality. Witnessing changes of such magnitude is a unique but unfortunate reminder of changes that constantly happen in our world and shape the future. From the comfort thinking of 2018, these tectonic shifts were mere points of possible change, while mainstream business-as-usual scenarios seemed significantly more probable and deserving of attention. This change reflected more attention given to wild card events and provided a fresh influx of updated analytical data for the thesis.

Preparing this thesis, I decided to focus on a significantly broad topic – researching visions and transitions for the shipbuilding industry, considering its global context and interconnected nature. At the same time, the pragmatic strategic foresight approach was replaced by a broader transition exploration with a significantly longer timeline perspective.

In 2023, we are witnessing another tectonic shift that has the potential to revolutionize our lives – OpenAI. Having a limited research capacity, I used available newest IT possibilities (such as OpenAI engines) and tried to keep futures exploration as a primary target mind. OpenAI use was limited to scouting and analyzing the data. This approach added another perspective to the research and opened a discussion about the applicability of such methods and future research methodology.

1 Introduction

International waterways connect all continents and most societies in the world. For centuries humankind relied on sea trade and transport, applying the most advanced technology and adapting to changes. Shipbuilding is perhaps one of the oldest industries in human history, enabling Viking seafaring adventures and Columbus explorations. Shipbuilding significantly affected society throughout human history, intertwined society development and globalization, trade enablement, industrialization, and IT advancements with design and innovation.

Many generations of shipbuilders shaped the processes, practices, and the high rate of innovations adopted ahead of any other industry. In the last century, the construction of ships underwent several significant changes that enabled bigger ships to be built in a shorter time. These changes were related to the use of materials, such as welded steel structures and mechanical engineering, as well as ongoing energy transition for new fuel types and longer voyages distances enabled by it. This practical development is an outcome and a reason for global trade development and numerous social changes, such as accessibility of goods from cheaper producers and enablement of remote regions sea exploration, alongside the higher degrees of cultural mix from different regions and wider traveling.

How will the shipbuilding industry and society co-evolution develop in the 22nd century? Will a technological breakthrough cause transitions, or will technology have to catch up and adapt to changing global society – climate, society needs, and business imperatives overall, not only in a selected region? Typically, research in this area falls into one of three categories – focused business strategic research, fueled by commercial imperatives and stretched for 5-10 years, general academic research, aiming to establish the background and find underlying theoretical foundations; or policy-making support.

The present thesis applies futures studies and foresight methodology to explore the futures of commercial shipbuilding in a long-range timeline towards the beginning of the 22nd century. The selected timeline stretches over the horizon of 70-100 years, intending to elaborate on significant shifts in the industry and establish if these shifts are likely to come from inside the industry ecosystem or are more likely to be imposed from larger global systems. Is it possible to expect a similarly significant impact, such as global trade and mobility, as in the previous century? It is explorative research aiming to scout societal

and global natural background complexity. The defined goal of the research is narrow and practical, while concepts and methods are selected from more general academic approaches. The research has certain limitations described in the definition of the research area. Besides the primary goal of answering the question about the future of shipbuilding, it attempts to provide a framework that can be used for applied futures exploration in similar socio-technical areas.

1.1 Background

Sea technology has many applications: growing algae for pharmaceutical and food purposes, fishing, oil and wind fields energy exploitation, shipping, and shipbuilding. Shipbuilding is an industry area often regarded primarily as a technology development and application area. Shipbuilding affects society by directly employing a significant workforce, influencing global trade and mobility, and enabling exploration of sea potential and the blue economy. Mainly being technology and business-driven, it has an artistic part in defining how the floating constructions look and fit in the natural landscape and a timeless question about the interaction of humanity and nature, or more specifically, the sea.

The world's merchant fleet accounts for about 102,000 vessels, with 1450 mGT¹ and roughly 3000 new builds or over 55 mGT yearly (Clarksons Research, 2022). Setting aside navy ships, cruise liners, and other passenger vessels, the shipment of goods by sea accounts for about 80% of global trade (The European Community Shipowners' Associations, 2017). The shipbuilding industry, excluding shipping, equipment manufacturing, and related fields, globally employs nearly 5 million² people, predominantly in coastal areas involved directly in the construction of vessels. Indirect employment, including equipment manufacturers, design, and research fields, can be estimated five times higher. The global shipbuilding market in 2021 is estimated to be about 154 billion U.S. dollars (Statista, 2021), which can be compared to about half of the GDP of a country like Finland. However, a bigger picture would reveal significantly higher numbers for the share of sea technology in the global economy and a directly or indirectly involved population.

¹ mGT – mega Gross Tonn, shipping measure of a ship's internal volume, 1450mGT is equal about 4.5 billion m³

² Estimation based on the data about 285 active shipyards globally in 2021 (Statista, 2021)

Technology historically plays a paramount role in floating constructions. Understanding hydrodynamics in shipbuilding, and owing its success to centuries of experiments, can be compared to its significant role for society in inventing the wheel. Traditionally, shipbuilding rapidly uses all technological innovations ranging from chemical protection of hull structures to fuel cells and electric propulsion. Every vessel encapsulates a significant amount of technology that requires the technological potential to create, operate and maintain. While every subsequent generation of vessels uses new technology, each vessel's life cycle stretches for about 30 years of exploitation. Technology might change significantly during this cycle, calling for upgrade or retrofit projects and large-scale recycling (Bruce, 2021).

The global society and culture were influenced by ships and the ability to travel long-distance by water, which they brought to humankind. Traveling is not a primary reason for shipbuilding, compared with the possibility of transporting freight. However, transporting large quantities of goods influence the globalization of trade, and various exploration missions – Arctic research, sea life observations, and even cruising contribute to cultural evolution. Different purposes of floating constructions, such as primarily ships, are closely intertwined with shipbuilding development. Enabling different types of sea-going vessels have an underlying reason for the need for such vessels, making it impossible to distinguish the reason from the consequence in this case. Ocean and sea surround people and impact their lives directly and indirectly. There are many aspects of the blue economy, which include the influence of changes at sea due to climate change and the human ability to understand and coexist with the sea. However, these are not the focus of the present research, which only considers shipbuilding.

At the beginning of the 21st century, shipbuilding underwent a rapid digital transformation. Unmanned vessels are expected to set off for their first voyages in years, with the first attempts already existing. The restricting environmental regulations push forward innovations in design solutions and technology. At the same time, geopolitical changes and the change of generation of engineers influences the industry. Intensifying technology and innovations face holding due to a lack of skilled workforce, while shipbuilding increasingly shifts to Asian countries and loses its presence in Europe. These changes are visible now, and the immediate effect on the future can be traced with high certainty. These are some of the high-probability developments in the near future, which are evident for people embedded in the industry. This research aims to explore significantly lower

probability events on a longer time horizon. The long-range timeline selected for this research explores the high complexity of low probability ranges, and more extensive scope of possibilities.

Considering the multitude of shipbuilding's impacts and scale, this research aims to provide a structured snapshot of the current status, a systematized set of scenarios and visions based on a socio-technical transition concept, and a possible framework for future uses in similar research.

1.2 Research questions

The nature of futures studies, the subject's complexity, and the above considerations should be considered, while the research focus defines the questions to be explored.

The following research questions are identified:

1. What is the shipbuilding industry's present state from systems thinking perspective?
2. What are possible futures scenarios for the industry in a long-range time horizon?
3. What are the possible main transformations in shipbuilding, and will a technological breakthrough originate from the industry itself, or will technology have to catch up and adapt to changing external systemic shifts?

The selected strategy for answering the research questions includes finding the relevant conceptual framework to identify the industry's primary structure and transition pathways, collecting data for horizon scanning, and analyzing and interpreting the data.

1.3 Research design

This research was designed to have a broad perspective on the selected industry as a system, incorporated into larger societal and technological systems, and having a long time horizon.

It starts with a selected conceptual framework selection, its applicability to the subject, and alignment with the research focus. The conceptual framework – Multi Level Perspective (MLP) helps to select corresponding methods and data collection process design by

identifying main actors and their interaction patterns. It guides the selection of data sources and sets expectations for how scenarios should be built.

The methodology part defines which method of future research will be employed at what stage, how these are aligned, and how the process fits together to be applied to data collection and analysis. The main outline of the research is based on the framework for collecting the input, analyzing it, making prospection, and interpretation. As a foundation for the data collection, main actor groups in shipbuilding are defined based on the MLP framework, which guides the selection of data sources. The horizon scanning method was applied using automated data collection using OpenAI³ elements for collecting and making a primary analysis of the data. For analysis and interpretation of data, systems thinking, scenario building, and causal layered analysis (CLA) methods were employed. An additional arm of research followed the same steps using OpenAI tools to later compare the results with the ones obtained manually. Additionally, the implication of selected methods to obtain results and sets boundaries for the research area are outlined.

The data collection part describes how data was collected and analyzed, what sources were used, and what technology was used for each research step. The data collection for horizon scanning employed a hybrid mode of exploration – a guided use of OpenAI, a novel emerging possibility in futures studies. It enabled significantly higher volumes of information to be processed and automatically summarized. However, it required attention to outlining the data and prompts used and additional methodological grounds for applicability.

The results chapter summarizes the obtained results for each part of the research, and the discussion chapter elaborates on the main findings, answers the research questions, and outlines the possible future research directions.

³ OpenAI refers to technology developed by the company with the same name, the technology is used in ChatGPT-4 tool and Bing search tool.

2 Conceptual framework

The primary approach of this research is based on a multi-level perspective on socio-technical transitions. It incorporates the main requirement for reliable explorative foresight work – a multi-discipline perspective (Bell, 2004) and provides a practical system perspective of large-scale and long-term changes.

This chapter starts with an overview of the Multi Level Perspective (MLP) and the typology of transition processes. Further, future research methodology is added to consideration. The last part presents a more comprehensive perspective, where waves of transitions fit into the historical perspective.

2.1 Multi-level perspective (MLP) framework

Frank Geels initially developed the multi-level perspective approach in the research articles: (Kemp, 1994), (Rip & Kemp, 1998) (Geels, 2002) and later works (Geels, 2010), (Geels, 2011) and (Geels, 2014). By original design, the framework addresses the socio-technological transitions, focusing on sustainability. However, it was applied to many different systems: energy, transport, urban futures, and more. It constitutes a transition process in three main layers: landscape, regime, and niche.

The landscape layer represents the most stable structure – the existing state of things, and it is a mixture of the political and economic landscape, historically and socially stable way of doing things, and time-proven technology that has been in use for a long time. The regime is a more dynamic layer. It consists of existing practices and the ways of process organization. Niches are the most dynamic places for incubating new ideas and practices (Geels, 2002). Presumably, these appear and frequently disappear, often making little impact on the system as a whole.

The MLP framework is beneficial for futures studies and foresight in industrial transitions as it provides a holistic view of the change process, taking into account the diversity of actors, their roles, and the dynamics of change and innovation (Geels F. W., 2005). By understanding the interactions between these layers, researchers and practitioners can better anticipate and prepare for potential shifts and disruptions in socio-technical systems (Loorbach, 2007).

One of the key strengths of the MLP framework is its ability to account for the complexity of industrial transitions and the co-evolution of technology, society, and policy (Geels & Schot, 2007). This makes MLP particularly relevant for addressing sustainable development challenges and the need for systemic change across various industries (Markard, 2012). Moreover, the MLP framework has been widely applied in futures studies and foresight research, specifically in analyzing and understanding the dynamics of various technological transitions, such as energy systems (Verborg, 2010), transport (Geels F. W., 2012), and urban water management (Brown, 2013). The framework has also been employed in strategic niche management studies, which focus on nurturing radical innovations at the niche level to foster more sustainable transitions (Kemp R. S., 1998).

The MLP is visually presented in Figure 1, adapted from Geels (2002, p 1263) to represent the framework visually. It places niche innovations, socio-technical regimes, and landscapes in the timeline and highlights their interaction dynamic.

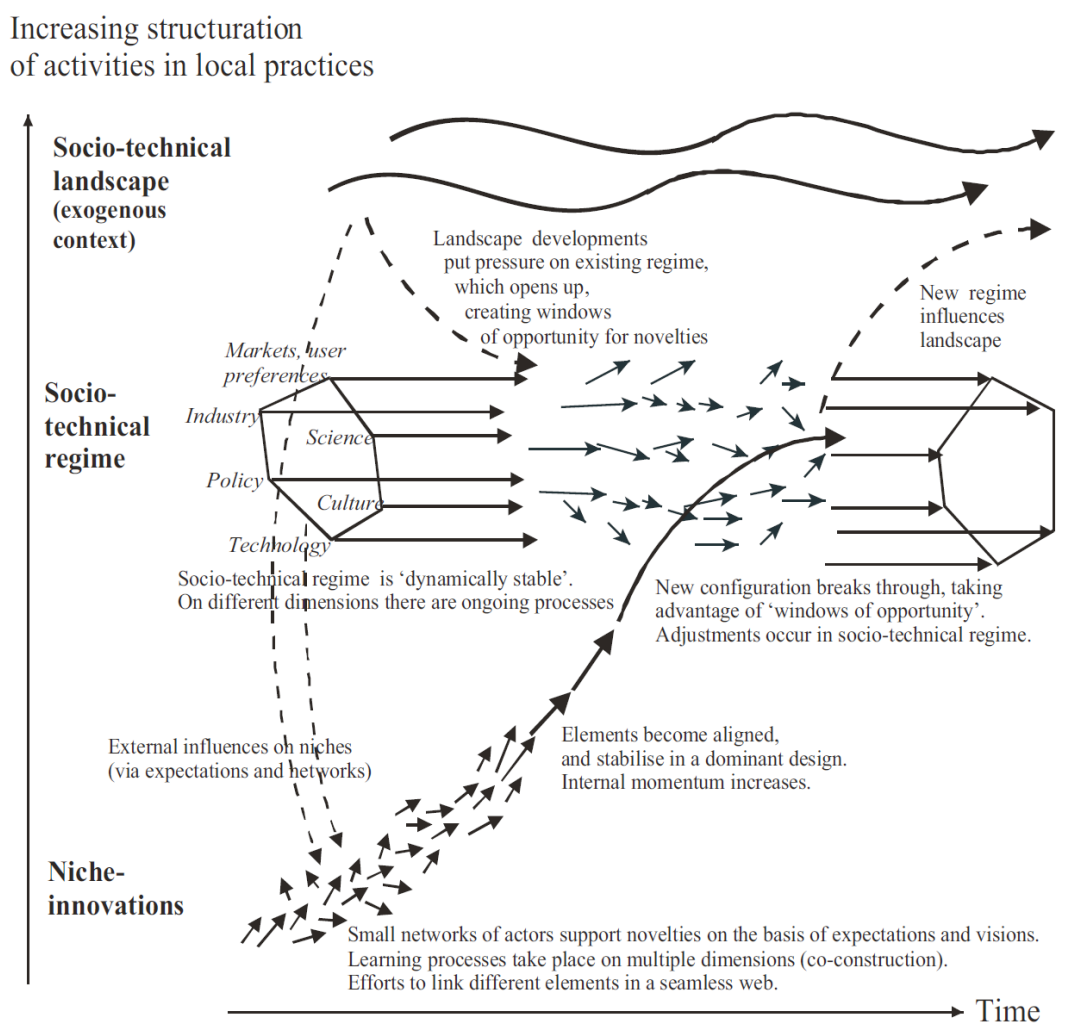


Figure 1 MLP framework, adapted from Geels 2002.

The MLP framework gives a multi-perspective image of the change process, considering the diversity of actors and their roles and dynamics of change and innovation. It provides a holistic view of intertwined actors and their existing and future impact on the system in change over time. The established landscape layer in shipbuilding would represent industry regulators, such as classification societies and partially large shipyards; the regime layer would consist of various naval architecture firms, technology providers, etc., and startups and innovations would represent niches. The borders can not be drawn explicitly; however, the primary type of players can be presented using the framework. The changes on the landscape level mainly originate from the outside of the system. These are, for example, sustainability requirements caused by climate change concerns and imposed on shipbuilding by various policies and governance. Innovations, like new propulsion types or shapes of the hull constructions, can, given sufficient momentum and an opening in the regime cracks, enter the regime level and even become a landscape. For example, this happened with the use of 3D models and CAD/CAM/CAE, which unlocked high levels of complexity in engineering and became a landscape practice from a novel innovation some 30 years back.

This approach makes it possible to make a “map” of existing actors in different levels – landscape, regime, and niches. Such a map of actors for the shipbuilding was created and used for data collection in the “data collection and analysis” part. It represents the system under consideration in the systems thinking method and for analyzing and examining the interconnections between the actors.

2.2 MLP and signals classification in horizon scanning

MLP is generally perceived as a suitable framework for different futures studies and a “system model of how the interaction between multiple analytical levels can influence a development process.” (Vähäkari N., 2020, p. 2). Based on an assumption about the groups of main actors on each layer of the MLP and their role, one can draw a parallel ranking of the futures trends accordingly. While landscape represents the most stable layer, actors are expected to be most sensitive to megatrends type of futures scenarios. At the niche level, it is natural to expect a high concentration of weak signals which would emerge and disappear under pressure from the higher levels. The borders can not be explicitly defined, and the appearance of different types of signals on different levels can not be excluded. However, this comparison appeared helpful for the research, as it presents a possibility to identify and sort signals collected at the stage of horizon scanning.

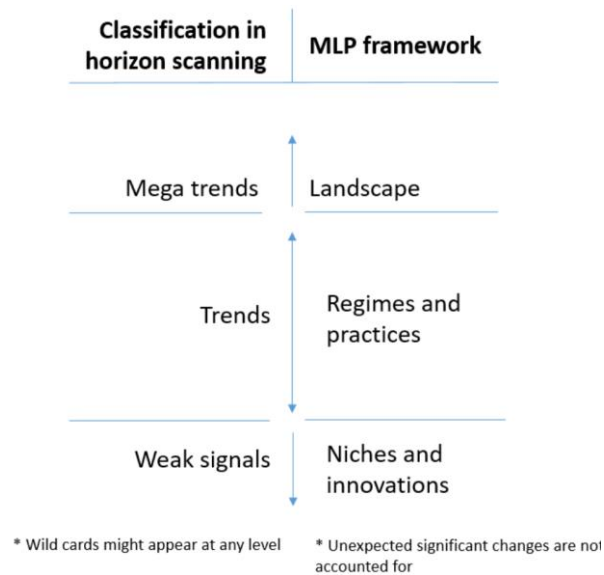


Figure 2 Futures signals aligning with the MLP concept framework

At the stage of collecting signals from a large sample of groups of actors in the selected system, the classification of signals becomes useful. Regarding ideas about futures signals, Naisbitt's discussion centered around monitoring the current landscape for 'signals' of change, which he grouped into broader trends or 'megatrends' (Naisbitt, 1990). He suggested that understanding these trends made anticipating significant shifts in society, the economy, and technology possible. The 'signals' Naisbitt looked for were often manifest in social, economic, and political changes and were drawn from various sources, including newspapers, academic journals, and industry reports.

2.3 Transitions

Creating a static snapshot of the current status of the shipbuilding industry is only one step along the process. Dynamic development of the system constitutes the change and the field of futures research. Geels research provides a perspective on changes happening inside the system, which emerge from within the system itself or under pressure from external systems - "Niche-innovations may breakthrough more widely if external landscape developments create pressures on the regime that lead to cracks, tensions, and windows of opportunity" (Geels, 2010, p. 8).

Transitions represent the impulses for change that can become scenario paths, reflect trends of different magnitudes, and also are linked with types of scenarios. This part outlines the typology of transitions and provides the analogy between the typology of transitions and Dator's scenario archetypes.

2.3.1 Typology of transitions

Multi-level perspective (MLP) on transitions delineates five distinct typologies of transition pathways, which are influenced by the interplay between the three levels of the socio-technical landscape (Geels, 2002). Each pathway illustrates a unique scenario of change based on the degree of landscape pressure and the maturity of niche innovations.

- **Reproduction process:** This transition pathway transpires when there is little external landscape pressure, defined as 'regular change' by Geels and Schot (Geels & Schot, 2007) and Suarez and Oliva (Suarez, 2011). In such a scenario, the existing socio-technical regime maintains its dynamic stability, reproducing itself with little alterations. This means that the established norms, rules, and practices continue to dominate without significant disruptions.
- **Transformation path:** A transformation path occurs when there is moderate landscape pressure, which Suarez and Oliva term as 'disruptive change'. This pressure arises when there are impending changes in the socio-technical landscape, but niche-innovations, or new technological solutions emerging at the fringes, are not yet adequately developed. In response, regime actors, the dominant entities upholding the prevailing regime, adjust the direction of developmental paths and innovation activities.
- **De-alignment and re-alignment path:** This pathway unfolds when landscape change is sudden, divergent, and substantial, characterized as 'avalanche change' (ibid). These escalating regime issues may cause regime actors to lose confidence, triggering a de-alignment and erosion of the regime. If niche-innovations are underdeveloped, no straightforward substitute is available. This scenario opens multiple niche innovations to coexist, vying for attention and resources. Eventually, one niche-innovation outperforms the others, providing the basis for re-aligning a new regime.
- **Technological substitution:** Technological substitution occurs when there is intense landscape pressure — typified by 'specific shock', 'avalanche change', or 'disruptive change' (ibid) — at a time when niche innovations are sufficiently mature. Under these conditions, the developed niche innovations gain momentum and replace the existing regime, leading to a significant shift in the socio-technical landscape.

- Reconfiguration pathway: This pathway involves symbiotic innovations that can co-exist with existing technologies incorporated initially into the regime to address localized issues. These innovations then stimulate further changes in the regime's underlying architecture.

This typology provides a comprehensive framework for understanding the complex dynamics of socio-technical transitions, acknowledging the interdependencies between landscape pressures, regime stability, and the emergence of innovative alternatives. Transitions likely do not happen as isolated events but as a sequence of transition pathways. Furthermore, when landscape pressure manifests as 'disruptive change', a series of transition pathways might ensue, starting with a transformation, followed by a reconfiguration, and possibly culminating in substitution, de-alignment, and re-alignment (Geels & Schot, 2007).

Enforced transitions occur under external influence, and such are transitions targeting sustainability. Sustainability transitions are goal-oriented or target the purpose, while many historical transitions were "emergent" or based on exploring commercial opportunities related to new technologies (Smith, 2005). Sustainable transitions, or often so-called eco-friendly, require additional support from policy or regime and landscape as they often are not cost-beneficial (Geels F. , 2011).

2.3.2 Types of transitions and types of scenarios in futures studies

Comparing the topology of transitions in Geels' multi-level perspective and Jim Dator's archetypes of scenarios allows observing these models' differing approaches to envisage possible future states and similarities in classifying transitions and scenarios. Both approaches explore potential changes and transitions. They do so from different perspectives and with varying levels of detail. Geels' MLP typologies offer a detailed model for understanding transitions within socio-technical systems, while Dator's scenario archetypes offer a broader, more holistic view of potential future developments.

Jim Dator proposed four generic alternative futures or scenario archetypes (Dator, 2009). He suggested that most descriptions of the future could be classified into one of these four categories, which serve as a helpful tool for futures studies and strategic foresight.

Continued Growth: This scenario assumes the future will be a quantitatively expanded or extrapolated version of the present. It posits that current societal values and trends, such as technological progress, economic growth, and increased living standards, will continue to develop and intensify. Essentially, it's the "business as usual" scenario.

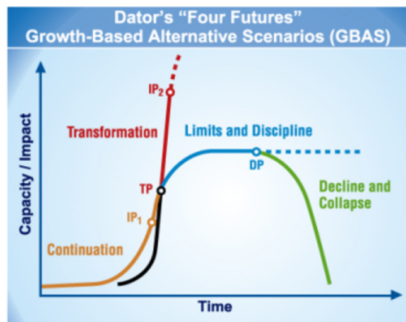
Disciplined Society: This future depicts a world where resources are limited, and growth is not sustainable, requiring society to adopt a disciplined approach to resource usage. It envisions a future where sustainability is prioritized, with society making conscious decisions to limit consumption and population growth to maintain the equilibrium of the global ecosystem.

Collapse: This future is often the result of continued growth or the refusal to adopt the disciplined society model until it's too late. It suggests a decline or a complete breakdown of the current socio-political and ecological system due to environmental disasters, societal unrest, economic crises, or pandemics.

Transformational Change (Ecological/Consciousness Change): This scenario involves fundamental societal changes, often involving new technologies or shifts in consciousness. It includes scenarios where society is drastically altered by technological changes such as artificial intelligence, space travel, or a radical shift in human consciousness or spirituality.

Figure 3 compares the two approaches: previously discussed comparison of the MLP framework and futures signals typology (Figure 2) and stereotypical Dator's scenarios, adapted from Dator, 1979 (Dator, 2009). From this perspective, transformational scenarios are most interesting to explore, as these provide an area of future changes outside of normal development or decline and collapse paths. These types of scenarios were selected for the exploration study of the research.

Typology of transitions and types of scenarios



- *Reproduction process* → • *Continuous growth "Business as usual"*
- *Transformation path*
- *De-alignment and re-alignment path*
- *Technological substitution* → • *Transformation*
- *Reconfiguration pathway*
- *Too solid landscape/regime – no "cracks" to enter/ too weak innovation potential* → • *Limits and discipline*
- *Decline/collapse*

Figure 3 Parallels between the typology of transitions in the MLP framework, typology of futures signals, and Dator's Four Futures scenario archetypes.

2.4 Broader perspective and deep transitions

In addition, the following elements of futures research theories and research complement the main framework: a broader perspective on transitions based on the Techno-economic paradigm (Perez, 2002), (Perez, 2010), (Perez, 2015) and deep transitions perspective (Schot & Kanger, 2018).

The link between technological innovation and long cycles of economic development, theorized by Schumpeter (1939) in his theory of economic development, is common to the most widely accepted theoretical frameworks within long-wave researchers. Kondratieff's (1935) type long-wave patterns and Schumpeter's (1939) clusters of innovation are the constituting elements of the techno-economic paradigm (TEP) shift framework developed by Freeman and Perez (1988), where great surges of development induce socioeconomic transformation effects across all economic activities and provide the key driving force of each long cycle of economic development (Freeman, 2009, and Perez, 2010).

Carlota Perez and Christopher Freeman developed the Techno-Economic Paradigm (TEP) shift framework in 1988. The framework focuses on the cyclicity of technological revolutions and the socioeconomic changes that they cause. According to it, there have been five key techno-economic paradigms in history:

1. The Industrial Revolution (1780s - 1840s)

2. The Age of Steam and Railways (1840s - 1890s)
3. The Age of Steel, Electricity, and Heavy Engineering (1890s - 1940s)
4. The Age of Oil, Automobiles, and Mass Production (1940s - 1980s)
5. The Information and Telecommunications Age (1980s - Present)

These revolutions are driven by a powerful new technological system transforming the economy and society. The techno-economic paradigm shift can be divided into two phases: installation and deployment.

The installation phase involves the introduction and diffusion of new technologies. This period often includes financial speculation and can lead to a financial bubble as investors chase the perceived profits of the new technology. The deployment phase begins after a financial crash and recession when the new technologies are broadly adopted throughout the economy and lead to a period of growth and prosperity.

Perez also highlights that each techno-economic paradigm shift is not only a process of creative destruction but also a process of institutional adjustment. Each new technology creates new winners and losers and challenges existing social norms and regulations. This often leads to social tensions and conflicts that can only be resolved through institutional changes that realign the socio-economic system with the new techno-economic paradigm.

Various scholars and futurists have proposed potential themes for the sixth wave. One notable proposition comes from the work of Paul Mason that the sixth wave could be characterized by the pervasive use of information technology to decentralize and democratize economic production (Mason, 2015). Others suggest that the sixth wave will be driven by resource efficiency and clean technology as society confronts the limits of natural resources and climate change (Moody, 2010) and intelligent technologies and significant advances related to sustainable development and ecological balance triggered at large by climate change (Wilenius, 2018).

The actual form of the sixth wave will depend on a wide range of factors, including technological breakthroughs, socio-economic changes, and policy decisions. Therefore, these predictions provide thought-provoking insights but are inherently uncertain and speculative.

Additionally, the theory of Deep Transitions provides a perspective on the systemic and long-term changes in the socio-technical systems that structure economic and social activity (Schot & Kanger, 2018). It speculates that the shifts in meta-rules, such as resource and energy efficiency, trigger changes in sustainability and inequality, causing socio-technical changes.

These theories and models are a simplification and generalization. However, it might help understand the transitions over the long time horizon and have a similar composition with the MLP framework on a bigger scale selected for this research. Considering MLP on ample time intervals, such as the one selected for the research, it can be expected that there would be one of several high amplitude shifts that would redefine the future of shipbuilding, or at least these can become the main narratives for the scenarios.

3 Methodology

The selected methodology approach for the research is based on the adapted Generic Foresight Process (GFP) developed by Voros and includes a selection of foresight research methods: environment and horizon emerging trends scanning, systems thinking CLA, and scenario building (Voros J. , 2003). The adopted framework and corresponding methodology for each part are presented in Figure 4.

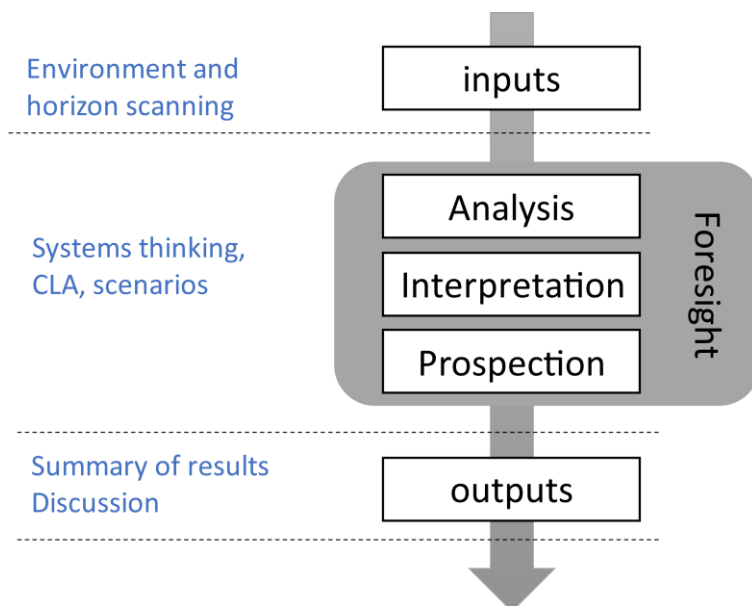


Figure 4 Adapted Generic Foresight Process and methodology of research map on the left side to match with futures studies methods.

In the following chapters, each methodological step is elaborated, and the workflow for the research is presented. In the last part of this chapter, the overall workflow of the research is outlined. Further, the methodology is used to guide data collection and analysis. In the following chapter, the process performed in the study for data collection is described, and its deviation from the standard practices, such as using AI engines, is highlighted where applicable.

3.1 Workflow of research steps

To clarify the research workflow, the steps described in the methodology approach are collected and presented in Figure 5. The main steps, input, analysis, prospection, and interpretation, from the General Foresight Process constitute the body of the research. An additional arm of the research process was made to use data as input for automated processes executed by OpenAI technology elements.

The first two steps, focus and data collection, correspond to the input part of the GFP. The preliminary analysis of collected data and systems thinking methods form the analysis part of the GFP, scenarios – prospection part, and CLA the interpretation.

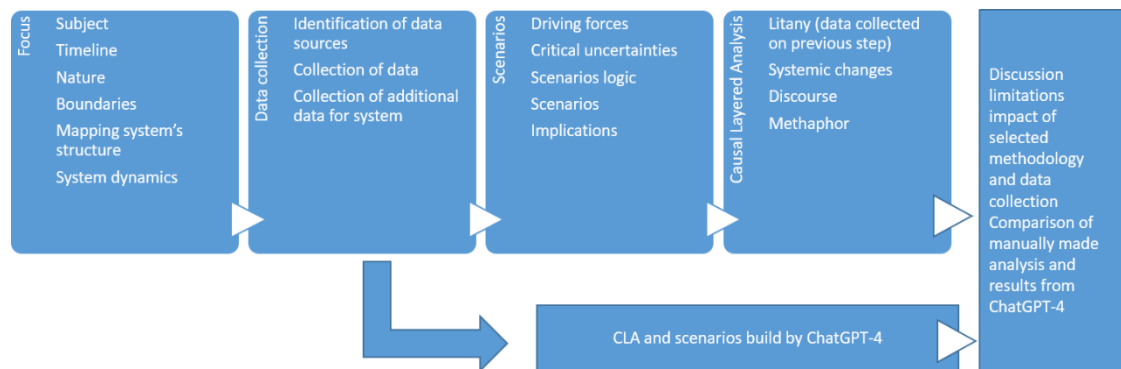


Figure 5 An overall workflow of data collection and analysis steps based on the selected methodology.

The steps taken on every part of the research are described as follows:

- **Focus:** identification of the subject of the research, timeline for the horizon of the future, boundaries of the subject from systems thinking perspective, mapping system structure and dynamics
- **Data collection:** identification of data sources based on the system's structure, collection of data, and collection of additional data
- **Scenarios:** Based on data collected, driving forces are identified along with critical uncertainties and scenarios logic created, which is tested against wild card events
- **CLA:** each scenario narrative is interpreted for four layers: litany, systemic changes, discourse, and metaphor

- Discussion: comparison of the results obtained with manual and automated analysis, discussion about the overall results, summarizing the findings for the research questions, and outlining the limitations.

An additional arm of the research originated from an emerging possibility of using AI engines, such as ChatGPT-4. Data collected in the first two steps were used as input for ChatGPT-4 to generate scenarios and analyze these. The aimed result was to compare the results of such an automated analysis with manually produced results and draw conclusions if such a method can have a potential for future methodology. The resulting comparison and discussion are presented in the results and discussion chapters.

ChatGPT-4 is a novel technology that became publicly available only a few months before this thesis was written. The following chapter discusses additional methodological implications for such automated data collection and handling.

3.2 Input: Environment and Horizon scanning

Collecting the data for futures research is perhaps the most challenging part of the process. The unique nature of the futures is prone to speculations, biases, or even dreams, which affect the selection criteria and might significantly impact the outcome. A typical approach is often inherited from the social studies field and includes interviews, Delphi-type study, or the least structured horizon scanning. The last was selected as the primary method for data collection in this research. Its use and implications are explained in the further chapters.

Environmental and horizon scanning is a method used in futures studies to systematically identify and monitor emerging trends, developments, and events that may influence an organization, sector, or issue (Hiltunen, 2008). By exploring the external environment, this method helps anticipate potential opportunities and challenges, enabling better strategic decision-making and preparedness. Here's a short description of the method:

- Identify the scanning focus: Determine the scope and objectives of the scanning process, which may include specific sectors, geographical areas, or themes relevant to the issue under study (Choo, 2001).
- Gather information: Collect data from various sources, such as news articles, reports, scientific publications, blogs, and social media, to identify emerging

trends, developments, and events (Hiltunen, 2008). Use a combination of manual searches and automated tools or algorithms for efficient scanning (Cinca, 2009).

- **Analyze and synthesize findings:** Review the collected information to identify critical patterns, signals, and potential implications for the issue under study (Schoemaker, 2009). It may involve using qualitative or quantitative analysis techniques, depending on the nature of the data.

Limitations and constraints of this method include the following four implications:

- **Information overload:** The vast amount of available information can be challenging to manage, making it difficult to identify relevant signals and trends amid the noise (Hiltunen, 2008).
- **Subjectivity and bias:** The scanning process may be influenced by the subjective perspectives and biases of the individuals conducting the scanning, which can affect the interpretation and prioritization of findings (Choo, 2001).
- **Limited predictability:** Environmental and horizon scanning cannot predict the future with certainty, and it can be challenging to anticipate the timing, scale, or impact of emerging developments (Voros J. , 2001).
- **Resource constraints:** The scanning process can be time-consuming and resource-intensive, which may limit its feasibility or effectiveness for some organizations or contexts (Schoemaker, 2009).

Environment scanning provides a critical review of the existing situation landscape. In futures studies, obtaining data from the series of workshops (such as in the Delphi study process) or via participatory guided discussions performed in iterative rounds is often considered central. These methods originate from societal studies methodology and are based on a cornerstone assumption that individuals have the most significant impact on societal processes. For this research, the selected approach differs. Considering the industrial changes on a large scale, extended range of time horizon, and intention to identify scenarios, the approach focused on the main groups of actors was selected. When considering changes to happen in the next century in the field where the impact of any single company is irrelevant, it is unlikely to expect the opinion or mindset of single individuals to make an impact. Focusing instead of it on actors from the main layers, as identified in

the multi-level perspective conceptual framework, promises more relevant results. This consideration is in line with the “systemness” challenge – the criticality of considering the “co-influencing of micro and macro layers of reality” (Derbyshire, 2016, p. 47).

3.3 Analysis: Systems thinking

Once the data sample is collected and the main limitations are defined, the first step for analyzing the data will be built on systems thinking principles. It helps to define on a general level the focus of the research and its relations with the broader systems that encapsulate it, such as more extensive societal or technological systems.

The analysis step of the methodology focuses on mapping the linkages between identified elements and identifying critical interdependences, accessing their impact on the possible transitions. Systems thinking is an approach that emphasizes the understanding of complex issues by examining the interconnections, feedback loops, and dynamics between the components of a system (Senge, 1990). Applying systems thinking to futures studies can facilitate the exploration of complex, uncertain, and interconnected issues by considering the relationships between different factors and trends and potential unintended consequences. Below is a description of the main steps of the process:

- **Define the system's boundaries:** Define the scope of the system under study, including its components, stakeholders, and the interactions between them (Meadows, 2008). It involves determining what is inside and outside the system and identifying the relevant time horizon for the futures study.
- **Mapping the system's structure:** Develop a visual representation of the system by mapping its components and their relationships, such as causal loop diagrams or stock and flow diagrams (Sterman, 2000). It helps to identify the key drivers of change, feedback loops, and leverage points within the system.
- **Analyze system dynamics:** Investigate the system's behavior over time by examining the patterns of change, such as growth, decline, oscillation, or chaos (Ford, 2009). It can involve using system dynamics modeling and simulation to explore how different factors and feedback loops interact and affect the system's behavior (Forrester, 1961).

Applying this methodology to the data collected at the “input” step would produce structured information about the research subject and indicate the foundation for prospection and interpretation steps described in the next subchapters.

3.4 Prospection: Scenario building

The data collected for the input and structured in systems thinking manner provide a foundation for prospection. Scenario building was selected as a relatively straightforward and simple-to-execute method for it.

Scenario building is a method in futures studies that facilitates the exploration of alternative futures by constructing plausible and consistent narratives of potential developments (Schwartz, 1991). It helps to think systematically about uncertainties, test assumptions, and consider the implications of different future contexts. The following steps describe the scenario-building method as it is applied:

- **The scope and objectives:** Outline the focus and purpose of the scenario-building exercise, such as identifying key uncertainties, exploring strategic options, or fostering organizational learning (van der Heijden, 1996). The definition of the research area chapter outlined the scope and objectives of the research
- **Driving forces:** Conduct research and engage stakeholders to identify the key factors, trends, and uncertainties that will likely shape the future of the issue under study (Bradfield, 2005). Data collected on the input, analysis, and interpretation steps will be used as input for this stage.
- **Critical uncertainties:** Among the identified driving forces, determine the most critical uncertainties with the greatest potential impact and uncertainty (Ramírez, 2016). These uncertainties will form the basis for constructing different scenarios or the axes for scenarios. Data from the input and analysis stages will be used for this stage.
- **Scenario logics:** Create a set of distinct and plausible scenario logics by combining the critical uncertainties in different ways (Schwartz, 1991). It can be done by using tools such as axes of uncertainty or morphological analysis (Ritchey, 2006). For this research, axes of uncertainty were selected as primary logic.

- **Scenarios:** Flesh out each scenario logic into a coherent narrative that describes a possible future, including key events, developments, and the relationships between driving forces (van Notten, 2003). The narratives should be engaging and easy to understand, to help envision and internalize the possible futures.
- **Implications and strategic options:** Analyze each scenario to identify the implications for the issue under study and explore potential strategies that could be effective across multiple scenarios (Chermack, 2004). Additionally, this step tests scenarios for wild card events to outline the main uncertainties.

An additional consideration is that from the point of view of futures studies, it is considered essential to monitor and update scenarios continuously - regularly review and update the scenarios to account for new information, changing conditions, or shifts in driving forces (van der Heijden, *Scenarios: The Art of Strategic Conversation* (2nd ed.), 2005). However, this step is not feasible as part of the one time research. It would be more beneficial for the continuous foresight efforts perspective.

Once scenarios and main narratives are created, these are interpreted using Causal Layered Analysis, described in the following chapter.

3.5 Interpretation: Causal Layered Analysis

Causal Layered Analysis (CLA) is a futures studies methodology developed by Sohail Inayatullah (Inayatullah S. , 1998), which allows researchers to uncover the deeper layers of meaning and assumptions behind the events and trends they observe. CLA is structured around four layers: litany, social causes, discourse/worldview, and myth/metaphor. Here's a brief description of the main steps involved in CLA:

Litany: The litany is the surface level of the issue under investigation, consisting of visible events, trends, and problems (Inayatullah S. , 1998). This layer usually represents quantitative data and is often presented in media headlines.

Social Causes: The next layer delves into the systemic or structural causes behind the litany. These are the economic, political, and social factors that contribute to the events or trends observed at the litany level (Inayatullah S. , 2004)

Discourse/Worldview: The third layer identifies the dominant discourses or worldviews that shape how the issue is understood and framed. It includes the values, beliefs, and

ideologies that underpin the social causes and drive the actions of individuals and organizations (Riedy, 2008).

Myth/Metaphor: The deepest layer of CLA explores the myths, metaphors, and narratives that underlie the discourses and worldviews. These fundamental stories shape our collective understanding of the issue and guide our actions.

After examining all four layers, insights were gathered to envision alternative futures (Inayatullah S. , 2008). These could involve different combinations of social causes, discourses, and myths, leading to various possible outcomes. The summary of this step would represent the result of the research.

The following subchapter outlines the considerations regarding using OpenAI technology in data collection and analysis.

3.6 Use of OpenAI

In this research, elements of OpenAI were used sparingly, guided by selected methodology, and at the final stage of generating CLA analysis and building scenarios for comparison purposes. A side goal of the research is to address questions about the applicability of such methodology and the possibilities of using it in futures studies.

The concept of AI and related questions, such as “Can computers think?” (Rockwell, 2017), emerged before computers became mainstream around 1950th. The academic discussions about the applicability and implications of AI or Deep Learning started at about the same time, with increased attention from 2000 forward when the use of Big Data came under the spotlight due to increased computational possibilities and the maturity of software to handle it. With the arrival of ChatGPT-4 - a novel possibility for anybody to try, it is a new level of discussion of the possibility of using it for data collection or analysis, especially in future studies.

The use of OpenAI (the technology behind the ChatGPT-4 and technology embedded in the Bing search engine) and other artificial intelligence (AI) technologies in futures research has several methodological implications to consider and an emerging need to develop a robust methodology for these. These implications stem from the nature of AI, its capabilities, limitations, and potential ethical concerns (Makridakis, 2018). By acknowledging and addressing these methodological implications, it is possible to harness AI's

power to enhance future research while minimizing potential pitfalls and ethical concerns (Russell, 2015).

The following characteristics were highlighted in the academic literature regarding the use of AI in the research.

- **Data-driven analysis:** OpenAI and similar AI technologies rely heavily on data for generating insights, predictions, and recommendations (Goodfellow, 2016). Consequently, the quality and representativeness of the data used in training these AI models can significantly impact the research outcomes (O'Neil, 2016). It is desirable to use reliable, diverse, and comprehensive data sources to avoid biases and inaccuracies (Mittelstadt, 2016). For the tools like OpenAI and ChatGPT-4 it is not possible to control or even to list data used for the training of models, unless, it is used in a mode where input is given.
- **Transparency and explainability:** AI models, particularly deep learning models like OpenAI, can be considered "black boxes" due to their complex and non-transparent nature (Castelvecchi, 2016). It can make it challenging for researchers to understand and explain the rationale behind AI-generated outputs (Arrieta, 2020). One should acknowledge these limitations and explore ways to improve the explainability and interpretability of AI-based futures research (Gilpin, 2018). As referred to in the first point, while having reliable information about the model is impossible, limiting the bias by guiding the algorithm or aligning it with the selected methodology is possible. This thesis addresses it by mimicking input on the collected and analyzed data for the automated building of scenarios and CLA.
- **Uncertainty and unpredictability:** While AI technologies have shown remarkable capabilities in various fields, they may not accurately predict future events or trends, especially in cases of significant uncertainty or rapidly changing contexts (Taleb, 2007). Researchers should be cautious about over-relying on AI-generated predictions and consider incorporating multiple perspectives and methods to account for potential uncertainties and unforeseen developments (Miller, 2006). As mentioned in the previous point, this consideration was mitigated by using OpenAI only as a tool alongside the selected research design methodology.
- **Ethical considerations:** The use of AI in futures research raises several ethical concerns, such as data privacy, algorithmic bias, and the potential misuse of AI-

generated insights (Crawford, 2016). Researchers should carefully consider these ethical implications and develop appropriate strategies to address them, such as adopting privacy-preserving data practices, ensuring algorithmic fairness, and promoting responsible AI use (Floridi, 2018). This consideration should be addressed in cases of more extensive or unguided use of OpenAI.

- Integration with other research methods: AI can complement traditional futures research methods by providing data-driven insights, pattern recognition, and scenario generation (Sutskever, 2014). However, AI should not replace human expertise and intuition (Davenport, 2016). Researchers should strive to integrate AI with other research methods and approaches, leveraging the strengths of both human and machine intelligence to produce more robust and reliable futures research outcomes (Clemen, 1999). As explained in the previous parts, these circumstances were explicitly addressed in the research design and methodology selection. For comparison, the second arm of the research provided more free AI-generated outcomes, which were later compared and discussed in the last part of the thesis.
- Continuous learning and adaptation: AI models, including OpenAI, require ongoing training and fine-tuning to stay up-to-date and maintain their relevance and accuracy (LeCun, 2015). Researchers should be prepared to invest time and resources in updating and refining AI models as new data, knowledge, and insights emerge (Mitchell, 2014). The current ChatGPT-4 version's cut-off date for knowledge is September 2021 (OpenAI, 2023). However, the Bing AI search engine, which uses the same technology, allows searching online pages. The last possibility was used for data collection purposes. It is impossible to exclude that the previous prompts influenced the data obtained and that the data would change over time. The prompts are indicated where applicable to address these challenges, and information retrieval data is mentioned. While these are significant considerations, I would like to add that similar can be mentioned for any other research data: information is updated online on websites continuously, people change their views under the influence of many factors, etc. Hence, this appears to have a limited or neglectable impact for future research.

OpenAI and ChatGPT-4 are recent developments that have significant implications for futures studies and the future overall. OpenAI is a research lab that aims to create and ensure the safe and beneficial use of general and superintelligent AI ChatGPT-4 is the

latest version of its large language model, which can generate complex and coherent texts on various topics and tasks, such as writing essays, summarizing articles, composing emails, creating websites, and more. These developments provide an exciting opportunity to simplify laborious tasks and invoke criticism and calls to exercise caution (Future of Life Institute, 2023). Many notorious figures in the IT world signed the letter to pause the development of more potent than ChatGPT-4 AI tools due to high uncertainty and difficulty estimating such technology's impact (ibid).

However, the impacts of using such technology can be positive. Some of the possible positive implications of using OpenAI and ChatGPT-4 for futures studies, summarized by ChatGPT-4, are listed below:

- Enhancing the creativity and diversity of scenario generation by producing novel and plausible narratives of alternative futures based on user inputs or prompts. ChatGPT-4 can also generate scenarios based on images, such as how ports would change if these would adopt smart connection technologies.
- Improving the quality and rigor of scenario analysis by providing relevant and factual information from various sources, such as academic papers, news articles, reports, etc. ChatGPT-4 can also cite its sources and provide references for further reading, making it a valuable co-pilot for the research.
- Facilitating the communication and dissemination of scenarios by generating engaging and accessible texts or visuals for different audiences and purposes, such as reports, presentations, blogs, podcasts, etc. For example, in this thesis, the prompt asked ChatGPT-4 to summarize a scenario in a few sentences and make a CLA analysis for each scenario.

Using OpenAI and ChatGPT-4 for futures studies also poses specific challenges and risks, such as:

- Introducing biases and errors in scenario generation and analysis by relying on incomplete or inaccurate data or reflecting their creators' or users' preferences or agendas. For example, ChatGPT-4 may generate scenarios skewed towards certain regions, cultures, ideologies, or interests, ignoring or misrepresenting important factors or perspectives. ChatGPT-4 may also produce texts or images that

are misleading, false, or even harmful. However, similar possibilities arise from possible lobbying or biases of research participants or data selection.

- Reducing the critical thinking and reflexivity of scenario practitioners and users by replacing human judgment and intuition with automated outputs or creating a false sense of confidence or certainty in the scenarios. For example, users may uncritically accept or adopt the scenarios generated by ChatGPT-4 without questioning their assumptions, implications, or alternatives. Users may also overestimate the validity or reliability of the scenarios based on the apparent sophistication or authority of ChatGPT-4.
- Affecting scenario practice's ethical and social responsibility by raising new dilemmas or issues regarding the ownership, control, use, and impact of AI for futures studies. For example, who is accountable for the quality and consequences of the scenarios? How can the privacy and security and reliability of the data and users be protected? How can the fairness and inclusiveness of the scenarios be ensured?

Therefore, using OpenAI and ChatGPT-4 for futures studies requires careful consideration and evaluation of their potential benefits and drawbacks and their alignment with the values and goals of futures studies. As a secondary goal of this research, it appears essential to carefully outline these considerations, indicating where and how OpenAI was used and listing possible questions for further research.

3.7 Ethical considerations

The use of AI tools in this thesis was conducted in line with the “Guidelines for responsible research” by the Finnish National Board on Research Integrity, reflected in FairUTU ethics guidelines (UTU, 2023), and guidelines for the use of artificial intelligence (UTU, 2023). Concerning these guidelines, the use of tools based on AI is described explicitly in each case it was used, references for the tool are indicated where applicable, and limitations of the results obtained are outlined in each part and the discussion of the results.

In addition to the direct use of the OpenAI elements, this thesis was checked for grammar accuracy with the automated tools – MS Word spell checker and Grammarly⁴.

⁴ AI based grammar check tool: [Free Grammar Checker | Grammarly](#)

4 Data collection and analysis

This chapter describes the data collection and analysis process performed based on the conceptual framework and methodology methods presented in the previous chapters. The chapter is structured in three main parts: definition of the research focus, data collection, and data analysis. The overall process follows the steps presented in Figure 5.

4.1 Definition of the research focus

For achieving tangible results in the research, it is essential to define the area included in the horizon scanning, its borders, and the areas not included. The definition of the research area for this thesis includes three main parts: industry or the subject of the research, a timeline for futures research, and the nature of the study.

The definition of the research area is linked with a discussion of the applicability of the Multi-Level Perspective Framework (Geels, 2010), used for the methodology of the research, in a critique of the framework discussion in “drawing boundaries and defining the topic of analysis” (Geels, 2011, pp. 30-31) and “identifying agency” (ibid) as an integral part of the framework application.

The following parts describe and justify the selection of research focus from the perspectives of subject, timeline, nature, boundaries, and systems thinking approach.

4.1.1 The subject of the research – commercial shipbuilding

This research primarily concentrates on commercial shipbuilding, excluding naval or other marine technological impacts, such as those typically included in the blue economy. Naval activities, being distinctly guided by specific societal, political, and military needs, possess divergent priorities and processes. In most cases, naval shipbuilding is distinct from commercial shipbuilding, with unique shipyards, equipment providers, and other associated processes.

For the purposes of this research, the shipbuilding industry incorporates some aspects of offshore structures, such as jack-up rigs, offshore platforms, and other floating constructs like artificial islands. These floating constructions are typically produced at commercial shipyards and are subject to similar economic, societal, and business influences. This lim-

itation helps define the system within which shipbuilding operates and is further examined in the conceptual framework portion of the thesis, utilizing a systems thinking approach.

Focusing exclusively on one industry allows contextualizing it within global changes while leveraging expertise and experience in the field. It also offers a concentrated perspective on the system directly related to shipbuilding, its interaction with worldwide shifts, and opportunities to identify key players and transition paths. It's crucial to note that the research views shipbuilding as an industrial activity, symbolizing an amalgamation of technology, manufacturing, transportation, societal, and cultural factors.

4.1.2 The timeline for the research – long-range futures

The selected timeline of the research stretches to the 22nd century. It aims for long-range futures over 80-100 years from today without defining a particular year or horizon. This definition challenges a sufficiently open perspective to explore possibly significant shifts. Additionally, it is expected to help avoid biases and ambiguities based on the author's deep connection with today's state of industry knowledge.

Throughout the modern history of shipbuilding, there were the following significant change phases related to technology: the use of iron in shipbuilding, the use of steel, and riveting technology, the introduction of propulsion instead of steam engines, the substitution of rivets with weld hull constructions and use of double bottom technology, and Computer Aided Engineering/Design/Manufacturing (CAE/CAD/CAM⁵) and IT systems driving digitalization. Schematically these are presented in Figure 6.

⁵ Computer Aided Engineering (CAE), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM)

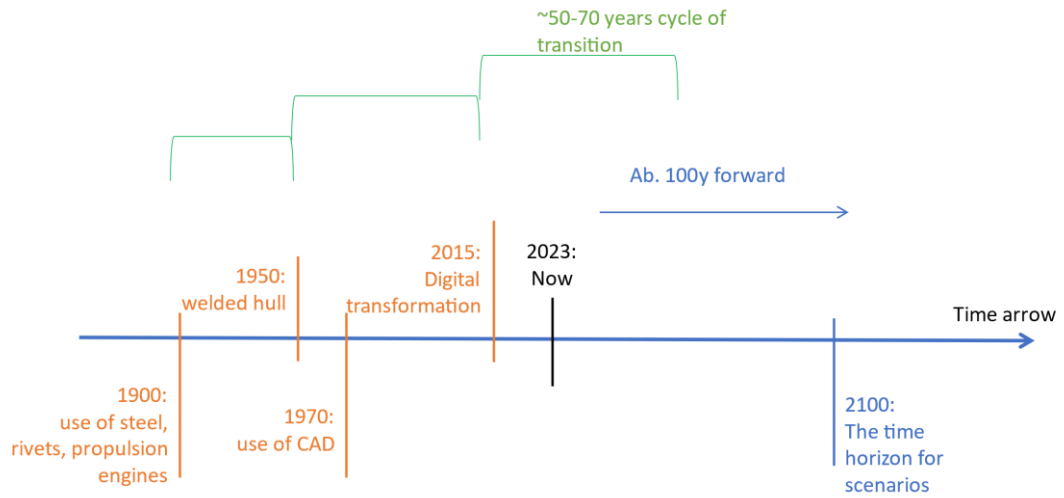


Figure 6 The time horizon for the research and significant time marks from the past

Over the past century, shipbuilding has undergone substantial changes, especially in its societal role, primarily spurred by technological advancements. Several significant milestones in the history of shipbuilding include using steel for hull construction, the shift from rivets to welded hull manufacturing, the advent of Computer Aided Design (CAD) technology, and most recently, digital transformation. These breakthroughs have significantly altered the landscape of shipbuilding.

During this time, shipbuilding has transitioned from a craft reliant on manual labor to a fully-fledged industrial activity. This evolution has led to drastic alterations in ship design and construction, driven by the desire or necessity to create different types of vessels (Bruce, 2021). While identifying the specific actors and interrelationships behind these changes is beyond the scope of this research, it is undeniable that these advancements have fundamentally impacted the industry's trajectory.

An interesting pattern can be discerned from examining historical shifts in shipbuilding: a cycle of significant changes seems to occur every 50-70 years. The most recent active phase of substantial transition in shipbuilding production processes is primarily linked to the introduction of CAD/CAM systems and the broader impacts of digital transformation within the industry. These shifts will likely continue to influence shipbuilding in the foreseeable future, a point that is explored further through the research's conceptual framework and systems thinking perspectives.

Setting a future timeline extending into the 22nd century offers a span of over 100 years, comparable to the previous phase during which significant industry transformations occurred. This timeline is sufficient for forecasting the industry's future, where significant changes in technology and socioeconomic landscapes are anticipated.

4.1.3 The nature of the research – explorative using OpenAI

The primary objective of futures research is exploration. Rather than determining the most likely or preferred scenarios for the future, the thesis aims to sketch out conceivable possibilities. This research adopts an open-minded, visionary outlook bolstered by a long-term research focus, domain expertise, and a forward-thinking approach. Given the defined scope and timelines of the research, its nature encompasses systems thinking, futures research methodologies, innovation, and deep transition theories.

This study's data collection approach is based on horizon scanning using OpenAI technology. It was also used for preliminary data analysis to summarize and categorize collected data. Furthermore, the collected data was used for manual scenario building and CLA and, in a second arm of the research, to analyze with ChatGPT-4. However, as a relatively new tool, questions arise about its applicability and effects on methodology, discussed in Chapter 3.6.

4.1.4 Boundaries of the research

The research subject, timeline, and nature outlined above determine the scope of the system under study. This encompasses the shipbuilding industry and primary stakeholders directly involved in commercial ship construction, including ship design firms, shipyards, classification societies, and IT and technology providers. Additionally, it touches on several adjacent industries, such as IT and digital technology development.

Furthermore, the system exists within broader techno-social, political, and economic systems, including national and international economies, global technology development, and others. Most mega-trends are closely tied to societal development and evolution, and multiple interconnections with other industries are anticipated.

The chosen system for studying shipbuilding is expansive, and the research timeline stretches towards 22nd century. Consequently, immediate, drastic changes are not anticipated. Instead, a slower development trend and extended adaptation period are expected, with wild card events likely having relatively short-term impacts.

4.1.5 Mapping system's structure and dynamics - Data from actor groups for the shipbuilding ecosystem

The data collection's starting point was identifying actors on different layers. Having a conceptual model for this search provided a foundation where search criteria could be set based on a specific group of actors. Understanding the main actors on all ecosystem levels is essential for systematically gathering information. Therefore, before collecting data, a map was made for the main groups of players in the shipbuilding industry and a short overview of the surrounding systems.

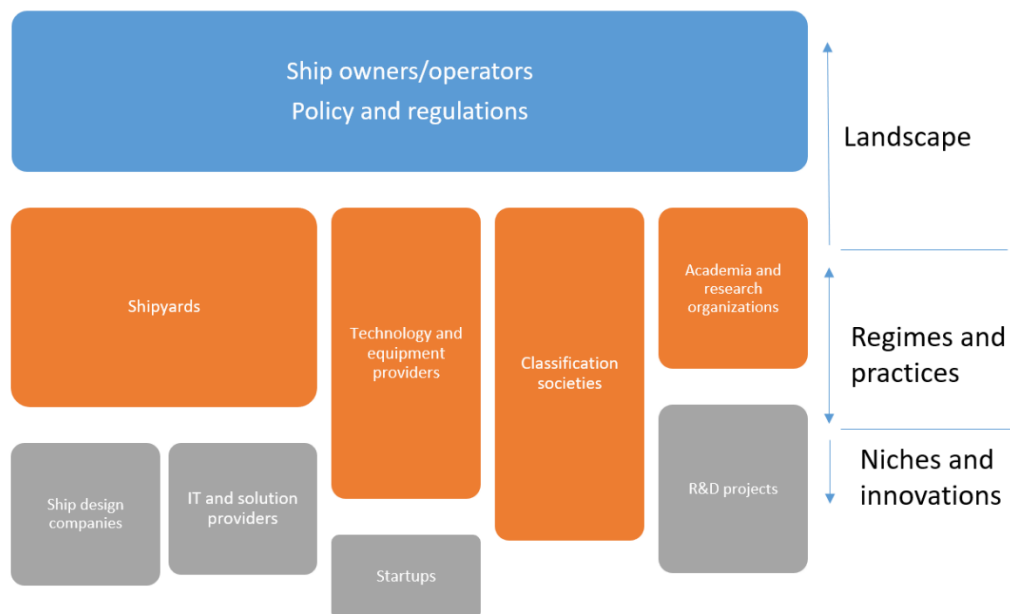


Figure 7 Main ten groups of actors in the shipbuilding ecosystem

Due to the global nature of the shipbuilding industry, it is difficult to estimate the total number of involved actors worldwide, as well as ship owners and operators. These players operate primarily on the business landscape, keeping close relations with policymakers, such as local and national level governments and alliances. Several regulators, such as

IMO and classification societies, act globally in the shipbuilding ecosystem and are visible to identify their positions. The structured map of the actors, presented in Figure 7 aligned with the expected trends, provided a canvas for data collection.

Based on the classification above, the following 10 groups of actors were selected for data collection:

1. Policy and regulations
2. Shipowners and operators
3. Shipyards
4. IT and solutions providers
5. Classification societies
6. Academia and research organizations
7. Technology and equipment providers
8. Ship design companies
9. R&D projects
10. Startups

Appendix 1 and a list of References for online horizon search sources. References for online horizon search sources summarise data sources used for each group and actor within the group, data collected using BingAI, and a summary with identified main topics for each group. For each of the groups, several primary sources of data were selected. The selection was based on field experience. For example, the most prominent regulators are a few and well-known in the shipbuilding industry. But in some cases, an additional search was performed, for example, to select the biggest shipyards from the list of about 300 total, which would be distributed globally and represent different types of activities preferred. The last two groups – R&D projects and Startups, were handled without identification of the sources, only as a general search through all current projects.

4.2 Data collection

4.2.1 Collecting data using Bing and OpenAI

The data collection and horizon scanning stage was initially planned as manual desk research or an industry survey, requiring considerable effort. However, the approach

changed once Microsoft published the OpenAI-driven search engine – Bing, which can run on ChatGPT-4 (Microsoft Bing Blogs, 2023). A detailed table with the list of all identified groups is collected and presented in Annex A, together with all data collected.

The initial selection of AI-powered tools for data collection seemed like a natural evolution of search engines. Instead of Google searching and scouting the web pages of selected actors, use an engine that can scan the page and search for particular patterns and word combinations. However, the power of linguistic models in ChatGPT-4 added a new dimension to the research. Conversation-based search allows redefining search queries, narrowing down the patterns, and immediately sorting and analyzing these.

From a practical perspective, this allowed for a significant time reduction. Checking every source one by one and scanning it for mentions about future related trends was performed by a search query. The prompts mainly focused on requests to scan the source webpage and other mentions of the actor on the internet and list them in a professional or informative tone, medium-long lists of found mentions about the future, trends, visions, and stated opinions about the future of shipbuilding, long term trend and industry development. Publications describing visions or lists of trends the actor identifies for the future were included in the search. In some cases, when the returned lists were too small or contained completely irrelevant data, additional clarification questions were added to refocus the search or to identify more specific trends. The assumption was that data published on the websites would contain mentions about the actor's aspirations or speculations about the industry's future.

An additional search for wild card events and weak signals was performed as a separate query to make a broad view possible. However, in the analysis stage, it was supplemented with industry observations mentioned separately. Methodological implications of this way of collecting data are discussed in the methodology chapter.

4.2.2 Grouping and analyzing data

In the data collection step, the data was collected for each actor and further summarized for every group of actors, summarized in groups, and grouped and sorted by popularity. The results of this step are presented in Appendix 2.

Three further analysis was made: clustering by topics, grouping by topics, and grouping by relevance. The first two helped to identify the main groups of the topics deriving from the data collected, which were similar in both cases with only minor variations. The last analysis, sorting the signals by relevance, was used for further analysis. It showed how often a particular topic was mentioned and by which group, providing a basis for ranging signals according to their potential magnitude.

This potentially time-consuming operation is enormously simplified by technology. Collected and summarized data was further used for two different paths – for manual analysis and input to request ChatGTP-4, as outlined in the overall design of the research process steps shown in Figure 5.

An additional search was done for weak signals and wild card events using Chat GPT-4, based on the assumption that these trends can appear from any other societal, technological, or other system or industry. Utilization of the ChatGPT-4 linguistic model appears to be especially suitable for this type of task, as it requires analyzing and structuring given input data. It is possible to lift the concern about the correctness of data and its unknown collection mechanisms by using the given input of the data.

4.3 Data analysis

The data analysis was performed in the following steps: analysis and grouping of collected data, scenario building, and CLA analysis.

The collected data was represented in the form of a summary of trends per each actor in every group (Appendix 1), with an exception for R&D projects (group 9) and Startups (group 10). A free search was performed for the last two groups, such as “find all listed R&D projects supported by EU/UN/National institutions and bodies targeting development in shipbuilding” and “list startups companies active in shipbuilding”. Further on, the findings were summarized separately for each group using the ChatGPT-4. For example, the prompts for this analysis were used: “using the data set provided, make a summary of trends mentioned”.

For further analysis, the data from all groups were used in ChatGPT-4 with the following prompts: “Group data by clusters, group data by topics and relevance”. The outcome of this analysis is summarized in Appendix 2. The grouping by relevance presented the most concise summary and was used further as input for building scenarios.

Manual qualitative data analysis was used for building scenarios described in the results section. It was additionally enhanced by testing each scenario against wild card events and by performing CLA analysis for each scenario.

The second arm of the research included using ChatGTP-4 to build scenarios and to make CLA for each scenario as a designed step in the research, presented in Figure 5. Compared to a straightforward methodology based on GFP, this was an additional step to test how well ChatGPT-4 can handle the data and build analysis and prospection based on the given input.

As the technology behind OpenAI is closed, it is impossible to elaborate on how the linguistic model performed the analysis and the possible impact on previously used prompts in the data collection stage.

5 Results

This chapter summarizes the research findings and presents the conclusions drawn. The first section presents the outcomes gathered through the horizon scanning process, which serve as the basis for analysis using the previously described methodology.

The research findings can be segmented into four primary components: a current snapshot of the industry, signals identified, and scenarios derived from analysis, along with their corresponding CLA narratives.

This chapter is followed by a discussion of the findings and the applicability of the results and suggests potential areas for future exploration. The two sets of results are then compared, with the ensuing findings discussed.

5.1 The snapshot of the industry at present

The process of data collection, grounded in the chosen methodology, and the resultant outcomes are outlined in Appendix 1 and 2. Due to the significant amount of data, only the summary trends, categorized by type of trend, are presented in Table 1, which is an overall result of all collected data and preliminary analysis of it to range signals.

Based on the MLP and data collection methods, collected data from selected groups of actors are structured in this summary based on grouping and sorting by the number of reoccurrences. Based on the conceptual framework and methodology, it is assumed that primarily mega trends are mentioned by actors on the landscape level, while weak signals can be found on the niche level of corresponding actors.

The table with data summary represents the shipbuilding industry's current snapshot and perception of the forces shaping the future by its main actors. A significant impact can be expected from the technology (in digital data use, design, and manufacturing), climate change impact, alternative energy, or societal changes on a high level, such as growth orientation or sustainability focus.

Table 1 Summary of driving forces, based on collected data and categorized by scale in preliminary data analysis using ChatGPT-4.

Megatrend	Trend	Weak signal	Wild card
Digitalization AI. New technologies (in IT, design, manufacturing) Climate change Regulations or trade changes Alternative energy	Automation Smart and interconnected shipbuilding and shipping Integration of design, construction and operations Mass customization Cyber governance and security Sustainability of operations and ships Carbon recapture Ammonia, Hydrogen, green fuels (as numerous references and prototypes exist) Renewable energy	Alternative fuels Autonomous technology Digital twins Additive manufacturing Smart ports Trade patterns and routes Cybersecurity shifts in workforce	Large-scale infrastructure failures Major cybersecurity breach Breakthrough in alternative propulsion technology New advanced materials Regulatory shifts Sudden economic crisis or collapse Discovery of new trade routes Significant and sudden climate change Major geopolitical conflict Pandemic or global health crisis

A deeper view into the data unveils expectations from more elaborated trends: digitalization, integration and automation, security impacts, expectations for sustainable building and operations of the vessels, named alternative energy sources, such as ammonia, hydrogen, or similar. Weak signals further identify possible changes and add several new options, such as digital twin technology for automated connection between digital assets (ships, shipyards, ports) and their physical twins, changes in trade patterns and routes, and autonomous technology, such as autonomous shipping and operations or additive manufacturing, entailing cybersecurity shifts. The area of wild cards outlines several ste-

reotypical drastic events – the usual expectations for natural disasters, ecological catastrophes, or other sudden changes. The last two parts: weak signals and wild cards, are discussed further in the following chapters.

5.1.1 Additional data for weak signals

Besides the data obtained from the analysis of the overall data scope, additional data was collected for weak signals by performing a search with prompts: “list weak signals for shipbuilding development in coming 100 years” or “scan all available research papers mentioning the future of shipbuilding and group all developments which are mentioned as emerging”. This search was done without restricting the sources, unlike the data presented in Appendix 1 and Table 1, which was restricted to the sources related to the groups of actors based on the MLP framework classification. The search was performed simultaneously with horizon scanning data collection and possibly can be affected by the previous search prompts. The additional weak signals are shown in Table 2 Weak signals. These trends are relatively small and not visible; however, they have the potential to become significant over time.

Table 2 Weak signals found by Bing search using OpenAI

<p>1. Increasing interest in alternative fuels: The growing focus on alternative fuels such as hydrogen, ammonia, and biofuels suggests a potential shift in the industry's approach to powering ships, which may have significant implications for future ship designs and propulsion systems.</p>
<p>2. Growth in remote and autonomous technologies: The development of remote and autonomous technologies for ships, such as remote monitoring, diagnostics, and autonomous navigation, could potentially reshape the way ships are operated and maintained.</p>
<p>3. Adoption of digital twin technology: The increasing use of digital twins, which are virtual replicas of physical assets, could indicate a shift towards more data-driven decision-making and predictive maintenance in the shipbuilding industry.</p>
<p>4. Expansion of 3D printing and advanced materials: The growing interest in 3D printing and advanced materials for shipbuilding suggests that these technologies could</p>

become increasingly important for the construction and maintenance of ships in the future.
5. Emergence of smart ports: The development of smart port technologies, such as automated container handling and tracking systems, could have implications for ship design and operations, as well as the broader maritime industry.
6. Changes in trade patterns and routes: Shifts in global trade patterns and the opening of new shipping routes, such as the potential melting of Arctic ice, could affect the types of vessels required and the overall demand for new ships.
7. Increased focus on cybersecurity: The growing emphasis on cybersecurity in the maritime industry could suggest that securing vessels and their data will become an increasingly important aspect of shipbuilding and operations.
8. Shifts in the workforce: The increasing need for skilled workers who can adapt to new technologies and processes may indicate a shift in the types of skills and training required in the shipbuilding industry.

Additional weak signals were listed based on the industry observation to make the scope as complete and diverse as possible. The weak signals below complement the ones in Appendix 1 and 2, Tables 1 and 2, and the need to list these additional signals came from the qualitative review of the data obtained in the previous steps. These are based on my experience of systemic changes in the industry and observations of numerous discussions in the shipbuilding forums and conventions, as well as newbuilding project focuses, which are relevant to the future of shipbuilding.

- **Technological synergy:** There is a growing trend to use ready technological units in the design and construction of ships, such as water purification units or storage arrangement units, etc. If it continues to grow and gain momentum, it might become possible to have significantly more synergy between shipbuilding and other industries, such as process plants, logistics, energy production, water treatment etc. Such development would impact shipbuilding from a perspective of more accessible adaptation of new technology and cheaper maintenance, leading to a less unique approach to shipbuilding and making seagoing simpler for society.

- **Immersive technologies:** Due to hardware and software development, current development and adaptation of Virtual/Augmented/Mixed Reality (VR/AR/MR) technologies in design and manufacturing in shipbuilding are low and modest. However, if reaching full potential is possible, these can drastically change the design and digital twin application, providing an immersive virtual environment for engineering and manufacturing and impacting the industry.
- **Diverse floating constructions: airports, energy facilities, living quarters:** Shipbuilding is already now used to develop and construct floating constructions drastically different from typical vessels. These are floating hotels, power plants, liquified gas terminals, and nuclear power plants. It can even become a mainstream phenomenon if this trend gains momentum and demand supported by climate change and population increase processes.
- **Use of biotechnology:** Biotechnology in shipbuilding is limited to searching for ways to fight the elements or bio-organisms. If new synergies are found, it can drastically impact shipbuilding by finding new floating shapes for the vessels or enables for movement and propulsion, such as the one observed in water spiders or magnetic drives, for example. Additional inspiration can originate from biomimicry, nautical observations, and synergies of sea organisms.
- **Arctic Resources and Exploration:** This is not a clear signal for outsiders in the industry, but more and more countries are building arctic fleets and researching the region. Expectations are to get more knowledge, explore potential resources and prepare for a climate change impact that forces human life to migrate away from heated-up areas around the equator where human life is becoming more and more challenging to support. It might be that the impact of climate change will trigger more development in this area, and an increase in arctic exploration and adaptation will become visible.

5.1.2 Additional data for wild cards

Similarly to the weak signals, the wild card events data was done in the following steps: collected from the defined groups of sources for main actors groups using Bing (Appendix 1), summarized by ChatGPT-4 (Appendix 2 and Table 1), complemented by additional free search (Table 3) and by industry observations.

Wild card events, collected additionally for the ones originating from the horizon scanning, are presented in Table 3. These were listed as results of the prompts: “List sudden big changes that might impact the futures of shipbuilding” and “What are the unexpected events that have the potential to make a large impact on shipbuilding in the 22nd century.”

Table 3 Wild card events, based on ChatGPT-4 search

<p>1. Major Geopolitical Conflict: A large-scale military conflict or war could surge demand for naval vessels, significantly impacting the shipbuilding industry.</p>
<p>2. Breakthrough in Alternative Propulsion Technologies: A sudden breakthrough in alternative propulsion systems, such as nuclear fusion or advanced renewable energy solutions, could transform how ships are powered and built, rendering existing technologies obsolete.</p>
<p>3. Significant Climate Change Impact: Drastic changes in the world's climate could lead to rising sea levels, more frequent and severe storms, and alterations to shipping routes. This could require the development of new ship designs to adapt to these changing conditions.</p>
<p>4. Pandemic or Global Health Crisis: A global health crisis, such as a pandemic, could disrupt global supply chains and labor availability, significantly impacting the shipbuilding industry.</p>
<p>5. Major Cybersecurity Breach: A large-scale cyber attack on a prominent shipbuilder or the industry as a whole could lead to significant financial losses, disrupted operations, and reputational damage, potentially altering the competitive landscape.</p>
<p>6. Regulatory Shifts: Sudden changes in international regulations, such as more stringent environmental requirements or new safety standards, could force the shipbuilding industry to adapt quickly or face severe penalties and financial consequences.</p>
<p>7. Discovery of New Trade Routes: The opening of new trade routes, such as the potential melting of Arctic ice or the development of new canals, could change the dynamics of global shipping and the types of vessels needed, impacting shipbuilders.</p>

<p>8. Breakthrough in Advanced Materials: The development of new, revolutionary materials with superior properties could enable the construction of lighter, more durable, and energy-efficient ships, disrupting traditional shipbuilding practices.</p>
<p>9. Large-Scale Infrastructure Failures: Major failures in critical maritime infrastructure, such as ports, canals, or locks, could lead to significant disruption in global shipping, affecting the demand for new vessels.</p>
<p>10. Sudden Economic Crisis or Collapse: A sudden global economic crisis or the collapse of major economies could significantly impact the demand for new ships and the overall health of the shipbuilding industry.</p>

The following observations can be done for several wild cards listed – several appear to be listed as trends (or even megatrends) and, simultaneously, as wild cards. At the megatrends level, climate change is a relatively slow-developing phenomenon, while at the wild card level, it is listed as a significant and sudden high-impact event. The same can be said about new technologies, energy, regulations, or the discovery of new routes. These are the same forces but with different development paths – instead of paced and expected process, these can escalate or make a sudden slowdown as unfolding.

An additional signal was identified for the list, as explained below. This event is external to the shipbuilding industry and can turn the industry around or even eliminate it.

A drastically new and economically feasible method of transportation: new technology enabling transportation or mass or energy to long distances with economically feasible impact. Some steps in this direction are already appearing, for example, quantum teleportation awarded by Nobel Prize in 2022 (The Nobel Prize Foundation, 2022).

5.2 The scenarios for the future of shipbuilding

The data and analysis from the previous step and scenario-building methodology make it possible to create future scenarios. For this purpose, the two main axes represent distinct different development directions. These were selected to be technology development and social development. The middle point is considered a ‘business as usual’ development scenario – this slow unfolding changes, some setbacks, and some breakthroughs. This

space, selected for scenario building, aligns with the described methodology of development pathways and transformational scenarios being a primary target for the exploration research. For technology development, the range goes from setbacks in the use and adaptation of technology to advance disruptive technology with smooth adaptation into the use. For the societal axe, the space ranges from fragmented and profit or growth-oriented to an aligned, conscious, and responsible society.

The four distinctive scenarios were developed using the defined space, as presented in the following chapter.

5.2.1 Scenarios for the futures of shipbuilding

These dimensions and scenarios are presented in Figure 8 Scenarios.

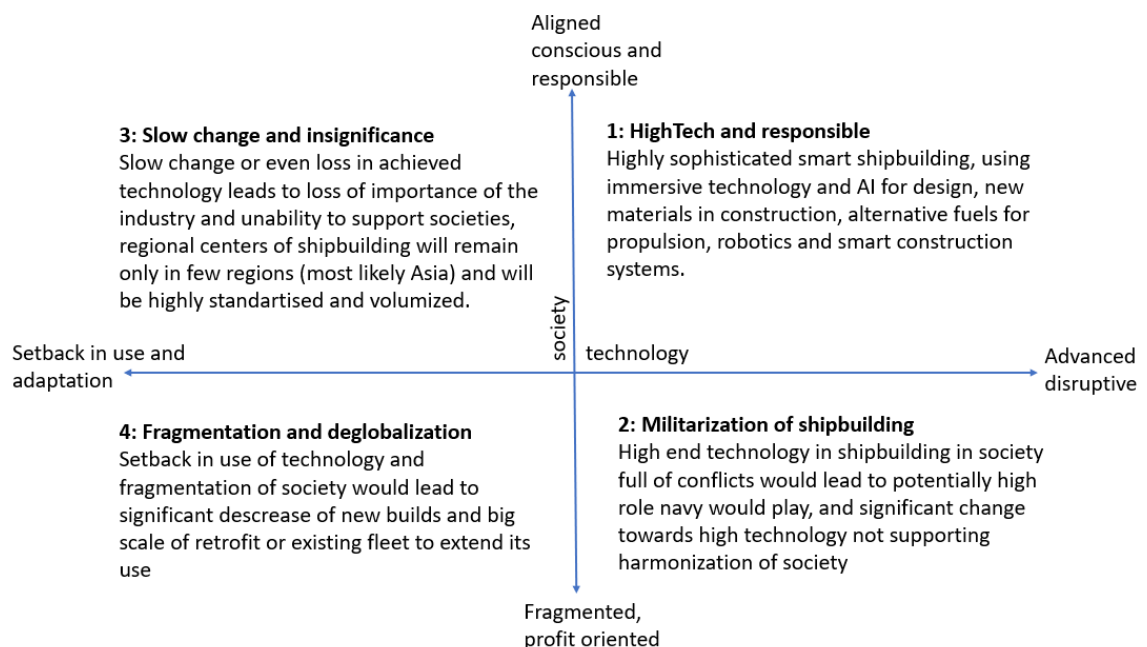


Figure 8 Scenarios summary prepared by analyzing the data

Scenario 1: HighTech and responsible: Highly sophisticated smart shipbuilding, using immersive technology and AI for design, new materials in construction, alternative fuels for propulsion, robotics, and intelligent construction systems.

Accelerated development of technology and sustainable goals of society are favorable conditions for the development of shipbuilding. It enables space for exploration and adaptation of new technology and probably design. Most likely, biotechnology will be used on an increasing scale (adopting ships to co-exist with marine life).

In Scenario 1, the shipbuilding industry is experiencing significant technological advancements and a strong focus on sustainability. With the rapid development of immersive technology and AI, smart shipbuilding has become highly sophisticated. Design processes are now enhanced by virtual simulations and data-driven decision-making, resulting in efficient and optimized ship designs. New materials are being used in ship construction to ensure durability and environmental responsibility. These materials are carefully selected to reduce the industry's ecological footprint and promote sustainability. Additionally, alternative fuels are being embraced for ship propulsion, reducing emissions and contributing to a cleaner environment.

Robotics and intelligent construction systems have revolutionized shipbuilding, allowing for more precise and efficient construction techniques. Automation and advanced systems enable faster assembly and increased productivity while maintaining high-quality standards.

The accelerated development of technology and society's sustainable goals have created favorable conditions for shipbuilding to continuously explore and adapt to new technologies. Biotechnology will likely play a growing role in shipbuilding, enabling the coexistence of ships and marine life. Through biotechnological applications, ships are designed and built to minimize their impact on the marine ecosystem, prioritizing environmental stewardship.

In this scenario, the shipbuilding industry is at the forefront of technological innovation and sustainability, striving to align with societal demands and environmental concerns. The combination of intelligent shipbuilding, immersive technology, AI, alternative fuels, robotics, and biotechnology integration ensures a high-tech and responsible approach to ship construction, contributing to a more sustainable maritime industry.

Scenario 2: Militarization of shipbuilding: High-end technology in shipbuilding in a society full of conflicts would lead to a potentially high role the navy would play and significant change towards high technology not supporting the harmonization of society.

In Scenario 2, the shipbuilding industry is driven by militarization and a society marked by conflicts. High-end technology dominates shipbuilding, fueled by the demands of the Navy and its increasing role in addressing these conflicts. This shift towards militarization brings about significant changes in the industry, with a strong emphasis on advanced technology that mainly focuses on supporting or fighting geopolitical instability.

The need for cutting-edge technology and sophisticated naval vessels drives the shipbuilding sector. The navy's requirements push for continuous advancements in shipbuilding, focusing on advanced weaponry systems, intelligence capabilities, and enhanced performance. This demand drives innovation in the industry, leading to the development of highly specialized and technologically advanced ships. The militarization-focused shipbuilding scenario may result in a divergence from other societal goals and priorities. The focus on high-end technology for military purposes may limit the industry's attention to sustainability and environmental concerns. While technological advancements may occur, the broader harmonization of society, such as environmental sustainability or social equity, might not be prioritized in this scenario.

In this context, the shipbuilding industry plays a crucial role in supplying naval vessels that meet the demands of a conflicted society. The advancements in shipbuilding technology enhance military capabilities, but they may not necessarily contribute to the overall well-being or the collective goals of society outside of the defense sector.

Scenario 3: Slow change and insignificance: Slow change or even loss in achieved technology leads to loss of importance of the industry and inability to support societies, regional centers of shipbuilding will remain only in a few regions (most likely Asia) and will be highly standardized and volumized.

In Scenario 3, the shipbuilding industry experiences slow change or even regression, resulting in a loss of significance and the inability to support societies effectively. This stagnation in technological advancement and industry relevance leads to a concentration of shipbuilding activities in a few regions, with Asia likely being a dominant player. These regions establish themselves as regional centers for shipbuilding, characterized by high standardization and large-scale production, and the current process that can be observed clearly.

In this scenario, the shipbuilding industry faces challenges in keeping up with technological advancements and adapting to changing demands. The lack of innovation and slow progress inhibits the industry's ability to support societal needs effectively. As a result, the industry's importance diminishes, and its contributions to broader economic and social development become limited.

With limited technological advancements, shipbuilding activities became highly standardized and focused on mass production. The emphasis on volume over customization

restricts the industry's ability to cater to specific regional or individual needs. The shipbuilding process becomes more streamlined and less adaptable to unique requirements, reducing the industry's flexibility.

Regional shipbuilding centers, particularly in Asia, maintain their dominance due to their established infrastructure, expertise, and large-scale production capabilities. These regions become the primary suppliers of ships to global markets, leveraging their standardized and efficient manufacturing processes. However, this concentration of shipbuilding activities in a few regions can result in losing diversity and competitive dynamics within the industry.

Scenario 4: Fragmentation and deglobalization: Setbacks in the use of technology and fragmentation of society would lead to a significant decrease in new builds and a big scale of retrofits of existing fleets to extend their use.

In Scenario 4, setbacks in the use of technology and the fragmentation of society contribute to a significant decrease in new shipbuilding projects. Instead, it focuses on retrofitting existing fleets to extend their operational lifespan. This scenario reflects a trend towards deglobalization, where regional or national priorities take precedence over global cooperation and innovation.

The shipbuilding industry experiences setbacks in adopting and utilizing advanced technologies due to various factors, such as economic challenges, political fragmentation, or a lack of collective vision. These setbacks hinder the industry's ability to invest in new builds and lead to a decline in the construction of new vessels.

As a result, the industry shifts its focus toward retrofitting existing fleets. Retrofitting involves upgrading and refurbishing older vessels to enhance their capabilities, improve efficiency, and meet changing regulatory requirements. This approach allows shipowners to extend the useful life of their existing assets rather than invest in new constructions.

The fragmentation of society also plays a role in this scenario. Political, economic, or social divisions lead to declining global cooperation and collaborative efforts in the shipbuilding industry. Countries and regions prioritize their interests, reducing international collaboration and knowledge-sharing.

This scenario highlights a shift away from the globalization of the shipbuilding industry, with a more localized approach taking hold. Regional or national priorities guide decision-making, and shipbuilding activities become more concentrated within specific regions. Innovation and technological advancements become more limited as resources are allocated to retrofitting existing fleets rather than developing new vessels.

The next chapter aims to test each scenario for wild card events and find how these can change the path or impact the development.

5.2.2 Testing scenarios implications

The scenarios defined in the previous step are based on megatrends, trends, and weak signals from the data collected and analyzed. Wild card events represent a separate group that can not be fully accounted for in the scenarios themselves but can change or redirect it. The Table 1 below lists all identified wild card events, including those in the data sample, in the free search, and added from the industry observation. The impact for each scenario is shown as an additional explanation for trajectory change or marked as “X” if it represents the already described path and would only impact the pace of development.

Table 4 Testing scenarios implications against wild card events

Wild card events / Impact on scenarios	1. HighTech and responsible	2. Militari- zation of shipbuilding	3. Slow change and insignifi- cance	4. Fragmen- tation and deglobaliza- tion
1. Major Geopo- litical Conflict	Change of path- way toward sce- nario 2	X	Significant setback on commercial shipbuilding, but push for- ward for navy	X

2. Breakthrough in Alternative Propulsion Technologies	X	X	Change of the path toward Scenario 1	Change of the path toward Scenario 2
3. Significant Climate Change Impact	Acceleration of the development and new tech adoption	Refocusing efforts under pressure and enforced change to scenario 1	Further slowing down and possible disaster scenario of loss of the industry or the opposite, accelerated development and change of path to scenario 1	Similar effect as in scenario 3.
4. Pandemic or Global Health Crisis	Small impact in the form of disruptions of logistic chains and work processes (like what happened during covid) or, if the scale is a drastically bigger – threat to humanity			
5. Major Cyber-security Breach	It would present an obstacle for all scenarios. Depending on the magnitude, it might completely stop the development, slow it down or be something that will not change the pathway.			
6. Regulatory Shifts	The changes in regulations can not significantly affect any of the scenarios, as these are an integral part of society's priorities changes, which are represented in the axes for scenarios.			
7. Discovery of New Trade Routes	Can make shipbuilding more profitable and imposes higher demands on ice-classed vessels, but will not significantly alter any of the scenarios			

8. Breakthrough in Advanced Materials	Will accelerate the building process and conditions, potentially making a high impact and providing a path from the change from inside to encapsulating systems – global trade, transportation and society.
9. Large-Scale Infrastructure Failures	It would present an obstacle for all scenarios. Depending on the magnitude, it might completely stop the development, slow it down or be something that will not change the pathway.
10. Sudden Economic Crisis or Collapse	It would present an obstacle for all scenarios. Depending on the magnitude, it might completely stop the development, slow it down or be something that will not change the pathway.
11. Drastically new and economically feasible way of transportation of goods (teleport)	Can make the whole industry obsolete.

The testing of scenarios provides a possibility to see changes on a described path for each and how, under external influence, these cases be redirected to one another trajectories. It provides a less linear and more holistic view of the futures and accounts for inconsistencies and disturbances that might change the logic of scenarios.

The next step aims to describe each scenario using the CLA method to find underlying causes, views, and metaphors.

5.3 CLA narratives for the scenarios

Each scenario is presented in this part based on four layers of the CLA method, listing litany, systemic causes, worldview, and metaphor narratives separately.

Scenario 1: HighTech and Responsible

- **Litany:** Adopting highly sophisticated technology, immersive technology, AI, and alternative fuels in shipbuilding.

- **Systemic Causes:** The accelerated development of technology and the growing societal focus on sustainability goals create favorable conditions for the shipbuilding industry.
- **Worldview:** Recognition of the potential of advanced technology and sustainable practices to shape the future of shipbuilding, considering environmental stewardship and innovation as integral components.
- **Metaphor:** Harmonious interaction between humans and the environment, reflecting the adoption of responsible practices and the potential for coexistence with marine life through biotechnology.

Scenario 2: Militarization of Shipbuilding

- **Litany:** The militarization of the shipbuilding industry, focusing on high-end technology, sophisticated weaponry systems, and the navy's role.
- **Systemic Causes:** Societal conflicts and tensions drive the demand for advanced military capabilities and technology in shipbuilding.
- **Worldview:** Prioritization of defense and national security, valuing the navy's role and the technological superiority of military vessels, potentially at the expense of broader societal goals and harmonization.
- **Metaphor:** Shipbuilding symbolizes national power, emphasizing the need for strength and superiority in a competitive and conflict-ridden world.

Scenario 3: Slow Change and Insignificance

- **Litany:** The slow change and potential loss of importance in the shipbuilding industry, with little technological advancements and decreased new builds.
- **Systemic Causes:** Economic challenges, lack of collective vision, or external factors hindering shipbuilding's progress and innovation.

- **Worldview:** A pessimistic perspective, perceiving the shipbuilding industry as stagnant and struggling to keep pace with changing demands and technological advancements.
- **Metaphor:** Shipbuilding as an industry caught in a cycle of stagnation and irrelevance, potentially reflecting societal attitudes towards the industry and its perceived significance.

Scenario 4: Fragmentation and Deglobalization

Litany: The fragmentation and deglobalization of the shipbuilding industry, characterized by decreased new builds and a focus on retrofitting existing fleets.

Systemic Causes: Regional or national priorities take precedence over global cooperation, leading to a more fragmented and localized approach to shipbuilding and gradually losing global expertise.

Worldview: A shift towards nationalism and protectionism, emphasizing regional or national interests in shipbuilding and economic activities.

Metaphor: Shipbuilding reflects regional identities and economic self-sufficiency, potentially highlighting the importance of local industries and a sense of autonomy.

This step concludes the analysis of shipbuilding futures based on the research's main branch. The other arm explores a similar process assisted by ChatGPT-4 technology and compares the results in the discussion part.

5.4 Scenarios and CLA generated by ChatGPT-4

The second arm of the research process consisted of building scenarios and CLA for each scenario using the ChatGPT-4. Based on the data collected from the groups of actors, the prompt used was: “*Using the same input and dataset, build distinctively different scenarios for the future of shipbuilding in the 22nd century*” and “*Using the data input and scenarios generated, create CLA analysis for each of the scenarios*”. The results of this process are presented in Tables 5 and 6.

Table 5 Scenarios, generated by ChatGPT-4

Scenario 1: Digital and Green Revolution
In this scenario, the shipbuilding industry fully embraces the digital revolution and green technologies. Ship designs are optimized for energy efficiency, and advanced materials are used to create lightweight, durable vessels. Alternative fuels, such as hydrogen and ammonia, are widely adopted, powering a new generation of zero-emission ships. Digital twins and advanced automation revolutionize shipyards, while AI-driven systems optimize logistics and maintenance. The industry becomes highly sustainable, with minimal environmental impact, and leads the way in addressing climate change.
Scenario 2: Global Cooperation and Standardization
In the 22nd century, global cooperation in the shipbuilding industry results in the creation of a unified regulatory framework and common standards. This facilitates the sharing of best practices, technologies, and resources, fostering innovation and collaboration across borders. The industry benefits from a global workforce, diverse perspectives, and access to cutting-edge technology. Environmental regulations are harmonized, accelerating the adoption of green technologies, alternative fuels, and sustainable practices. This scenario leads to a more competitive, innovative, and sustainable global shipbuilding industry.
Scenario 3: Naval and Defense Dominance
In this scenario, the focus of the shipbuilding industry shifts predominantly towards naval and defense applications. Governments around the world invest heavily in developing advanced maritime capabilities to secure their interests and maintain global stability. As a result, the industry sees a surge in demand for high-tech, specialized naval vessels, leading to rapid advancements in military shipbuilding technology. Although environmental and sustainability concerns remain, the primary driver for innovation is military applications, leading to a more secure but potentially less eco-friendly shipbuilding industry.

Scenario 4: Decentralized and Localized Shipbuilding
<p>The shipbuilding industry of the 22nd century becomes increasingly decentralized and localized, driven by factors such as regionalism, economic shifts, and climate change. Countries and regions focus on developing their own shipbuilding capabilities to address local needs and secure their supply chains. This leads to a diverse ecosystem of small-scale, specialized shipyards, each catering to specific markets and requirements. Innovations in modular and customizable ship designs enable these shipyards to adapt to varying demands. Although this scenario promotes self-reliance and resilience, it may result in slower adoption of global environmental standards and technological advancements.</p>

Table 6 CLA analysis, using ChatGPT-4

	1: Digital and Green Revolution	2: Global Cooperation and Standardization	3: Naval and Defense Dominance	4: Decentralized and Localized Shipbuilding
Litany	The shipbuilding industry is undergoing a major transformation driven by digital technologies and green initiatives.	The shipbuilding industry is moving towards greater cooperation and standardization	The shipbuilding industry is becoming increasingly focused on naval and defense applications	The shipbuilding industry is becoming more decentralized and localized

Systemic changes	Rapid advancements in technology, along with increasing awareness and concern over environmental issues, are driving this transformation	The interconnectedness of global markets, regulatory pressures, and the need for efficient, innovative practices are driving this trend	Rising geopolitical tensions, security concerns, and the strategic importance of maritime defense are driving this focus	Regional economic development, supply chain resilience, and adaptive strategies in response to climate change and global economic shifts are leading to this decentralization
Discourse	There is a global consensus that sustainability and digital innovation are not only necessary but beneficial for the industry, society, and the planet	There is a belief that global collaboration and standardization can foster innovation, competitiveness, and sustainability in the industry	Governments and societies believe in the necessity of strong maritime defense capabilities for national security and global stability	There is a belief in the value of local autonomy, self-reliance, and resilience, coupled with an understanding of the unique needs of local markets and environments
Metaphor	The shipbuilding industry sails into the digital future, pioneering a new era of sustainable and tech-savvy maritime transport	The shipbuilding industry is a united fleet, working together to navigate the waters of global regulations, standards, and sustainability	The shipbuilding industry transforms into a mighty armada, ensuring security and stability in turbulent global waters	The shipbuilding industry is an archipelago of diverse, self-reliant shipyards, each serving its local waters and adapting to the tides of change

These results are further discussed in the next chapter and compared with the conventionally created results from the previous parts.

6 Discussion about the main findings

This chapter describes the discussion about the results listed in the previous chapter. The discussions are structured to start with the main findings, a comparison of manually and automatically obtained findings, limitations originating from the research design and methods, findings for the research questions, and outlining directions for possible future research.

6.1 Discussion about the results

The main results of the research are data from the analysis of horizon scanning, scenarios developed, and CLA narrative to the scenarios.

6.1.1 Summary snapshot for the current state of shipbuilding

Based on the summary of collected data and additional research for weak signals and wild cards, the following snapshot of the shipbuilding industry can be drawn. The shipbuilding is currently in a transformation process. Under economic pressures and technological changes, the number of shipyards globally decreases while building vessels becomes more advanced and automated. This means that the ships built are evolving gradually with a slow expected time from concept development through approval and adaptation to take 10-20 years. The reality of shipbuilding demonstrates that new drastic changes, such as autonomous ships or hydrogen-powered ships, which were enthusiastically presented some 5-10 years ago as concepts, are only expected to be in operation in the coming 5-10 years.

Another area for possible changes can be expected if a breakage of landscape-level and niche innovation in this area are aligned. Two examples of such processes are climate change, new energy sources for propulsion, and digitalization and AI. However, it is impossible to distinguish if the change in landscape causes these innovations and if any of these have high enough potential to break through the regime to become the landscape.

Considering this data from a systems thinking perspective, most of the driving forces come from outside the defined system. It leaves shipbuilding under the influence of external pressures shaping and defining future development paths. A more focused examination reveals smaller magnitude signals coming from within the industry, which have the potential to reshape the industry and impact external systems. These can be smart

technology connecting digital twins, ports infrastructure, and autonomous shipping, and the development of new materials based on shipbuilding needs which might revolutionize other uses for the society – these can be from structural materials, such as graphene, or materials to handle functioning of systems inside the vessels. Biotechnology is a particular case where new developments can bring drastic changes.

6.1.2 Manually developed scenarios and CLA

The four scenarios mentioned above present distinct visions of the future for the shipbuilding industry. While each scenario represents a different trajectory, there are some similarities and differences among them:

Technological Innovation and Sustainability vs. Militarization: Scenario 1 envisions a future where shipbuilding embraces technological innovation and sustainability as key drivers. In contrast, Scenario 2 focuses on the militarization of shipbuilding, prioritizing high-end technology for military purposes. The key difference lies in the industry's emphasis on sustainability and harmonization with society in Scenario 1, while Scenario 2 emphasizes the navy's demands and conflicts, potentially at the expense of broader societal goals.

Technological Stagnation vs. Slow Change and Insignificance: Scenario 3 highlights a scenario of technological stagnation and loss of significance for the shipbuilding industry. In contrast, Scenario 4 depicts a future where setbacks in technology and fragmentation lead to a decrease in new builds, with a focus on retrofitting existing fleets. The main difference is that Scenario 3 portrays a lack of progress and industry decline, while Scenario 4 still sees activity in retrofitting and extending the use of existing vessels.

Globalization vs. Fragmentation and Deglobalization: Scenario 3 and Scenario 4 showcase contrasting trends in terms of globalization. In Scenario 3, the concentration of shipbuilding activities in a few regions (likely Asia) emphasizes the dominance of certain players, potentially suggesting a more globalized industry. However, Scenario 4 focuses on fragmentation and deglobalization, with regional or national priorities taking precedence over global cooperation. This leads to a decrease in new builds and a more localized approach.

Sustainable and Responsible vs. Mixed Environmental Impact: Scenario 1 highlights a focus on sustainability and responsible shipbuilding practices, such as the use of alternative fuels and immersive technology. In contrast, Scenario 2 emphasizes the militarization of shipbuilding, which may have a mixed environmental impact depending on the specific military applications. Scenarios 3 and 4 do not explicitly address sustainability but can be interpreted as having potential implications for environmental impact depending on the extent of technological advancements or retrofits.

The scenarios differ in their visions for the shipbuilding industry, ranging from technological innovation and sustainability to militarization, technological stagnation, or fragmentation. Key factors differentiating the scenarios include the industry's alignment with sustainability goals, the navy's role, technological progress, global or regional focus, and the degree of international cooperation.

6.1.3 Automatically developed scenarios and CLA

The “second arm” of the research, which used the ChatGPT-4 for a complete analysis, was done after the manual work of scenario building and causal layered analysis was done. In bare seconds, using input from the data collection step, it was possible to get a coherent set of analyses according to the correct methodology, which was very close to the results obtained manually.

This exploration triggered literature research about the implications of using AI tools in foresight and clarifying possible pitfalls, as presented in the methodology. It can be noted that results obtained this way could provide significant help and synergy with a traditional, manual way for performing futures studies.

Several observations can be made from the automated scenarios. It is impossible to identify if the logic of the scenarios was similar to the logic of axes in the manual process, but it appears that one dimension was the same – technology development. All four scenarios are optimistic, without the dichotomy of growth/decrease inevitably in the case of scenario axes. From this perspective, the scenarios resemble the stereotypical ones less and are more exciting and provoking. Perhaps these are even closer to the optimistic human nature of thinking about the futures from a positive expectation perspective in general.

6.2 Comparison of manually made analysis and result from ChatGPT-4

A comparison of the obtained analysis - scenarios and CLA, shows that manually created results are more strictly structured and somewhat limited in the growth/decrease dichotomy and quadrant approach. The scenarios appear to fall into stereotypical cases, despite being intentionally focused on transformational pathways. However, these are distinctive, follow a different narrative path, and have a different metaphor level of underlying causes. Automatically created scenarios and CLA are more provoking and less structured, leaving more space for imagination and interpretation. There were no explicitly notable misconceptions or false facts. However, these are impossible to pinpoint for such vaguely defined areas as futures studies.

6.3 Conclusion about the discussion about the futures of shipbuilding

From a simple question about the futures of shipbuilding, the obtained results and analysis provide a clearer image and transformational pathways for the industry. The following external transformations can affect it most significantly: technology, energy, and society.

Technological development can include anything from new technology in robotics to new technology for welding or connecting materials to AI and digital twins development. It seems that the field is vast and primarily external to the industry. It is unlikely to expect significant innovation to originate from the shipbuilding and further make an impact on the broader landscape than the other way around.

The energy transition is already an ongoing transformation under pressure from society's sustainable goals and aspirations. This constitutes new propulsion and alternative fuel uses for shipbuilding, such as ammonia, hydrogen, thorium salts, wind, and solar energy.

Society's development impact shipbuilding in many ways. As the industry is global, it might become under unbearable pressure in case of a trend toward independence and militarization or any change in globalization policies. It affects high levels, such as societies or nations' development, and lower levels, such as a need for highly qualified engineers and workers and an overall ability to have a sufficient workforce.

Any shift in these areas would impact all levels of the MLP framework for shipbuilding and potentially cause breaks in the landscape and the emergence of new niches (application in shipbuilding), which will affect the regime and lead to a new status-quo situation.

Additional weak signals appear to have significant potential for the industry's transformation: biotechnology and new materials. Biotechnology can transform the industry if new ways of interaction between humans and water can be found, such as mimicking the aqua life organisms for the movement on water, a possibility to breathe in the water, or new materials for ships or their internal systems to function in a water environment. The new materials are similar areas but from a chemical or technological perspective, without relation to living organisms. This potentially can be the materials similar to graphene, which can withstand high pressures, be light, and have a small volume. Investigation of these signals further can bring more insights into these areas and potentially trigger faster development and more significant impact.

The next subchapters outline the limitations of the results that originate from the selected concept and methodological frameworks and data collection and analysis methods.

6.4 Limitations originating from research design and methods

Future-oriented research can be beneficial for both industry and society. However, its adoption is often hindered due to the complexity and duration of academic processes. This research demonstrated that a sturdy, simplified methodology guided by industry experts, and possibly assisted by AI tools, is a viable approach. Compared to a social studies approach focusing on multi-actor data collection through interviews, expert-led research, supported by a robust methodology, seems more fitting for the industry. It offers a significantly quicker research preparation time and is less resource-intensive, prioritizing data quality and usefulness for specific objectives.

This research's primary data collection relied on online sources, assuming that the information quality aligns with that obtained from expert opinions or interviews. The justifications for this approach include the long-range future and complex industry setting, where individual opinions or aspirations may not reliably predict transitional change. Instead, institutional visions aggregate and strengthen diverse opinions with organizational influence and are deemed more trustworthy.

Although the selection of sources might be perceived as biased or random, it's based on industry expertise, considering the actor's industry position, history, and location. The chosen method is comparable to interviewing industry experts, which often depends on

the availability and personal connections. Despite the research's limited data due to resource constraints, applying OpenAI technology for data search and summarization mitigated this factor. A more exhaustive data collection approach could yield more comprehensive results, incorporating all visible actors (approximately 300 shipyards and a similar number of other actors worldwide). This extensive data collection, feasible through larger research teams or OpenAI usage, would require a well-defined search methodology.

Systems thinking contributes a complex perspective to scenario development. It considers the subject of research (shipbuilding) as a system within broader systems (e.g., political, economic, technological), influencing scenario-building.

The research scope focusing on one industry also greatly influenced the results. A broader focus, such as "global transportation futures", could have led to less constrained and potentially more interesting findings. Additionally, a narrow research scope than "exploration" would yield different results.

The novelty of this research lies in the use of AI tools for data collection, analysis, and foresight exercise execution. However, the applicability and effectiveness of this technology, such as ChatGPT-4, are yet to be thoroughly evaluated and researched. Key considerations include data reliability, understanding deep learning algorithms, and potential risks associated with data tampering.

6.5 Findings for the research questions and hypotheses

For the research questions identified at the beginning of the research project, the following conclusions can be made:

1. What is the shipbuilding industry's present state from systems thinking perspective?

The present state of shipbuilding is a system with relatively clearly defined borders and defined main groups of actors within the system. The structure of this system fits well with MLP framework layers and the dynamic between the layers. It is a highly developed state, with an established landscape and slow dynamic of appearance and disappearance of new actors or changes in the use of technology. Horizon scanning showed most signals influencing the system from a macro level, and additional analysis was needed to identify the signals that could potentially change the shipbuilding from the inside.

A detailed summary is presented in chapter 5.1 of the results section.

2. What are possible futures scenarios for the industry in a long-range time horizon?

The projected scenarios for the industry were constructed using data gathered through two distinct methods: industry insights, explorative foresight methods, and an automated approach using OpenAI. The manually derived scenarios, based on expert views and foresight methods, are as follows: "High-Tech and Responsible", "Militarization of Shipbuilding", "Slow Change and Insignificance", and "Fragmentation and Deglobalization". These scenarios align with conventional scenario planning as they utilize the growth/decrease dichotomy along selected axes: technological development and societal development.

In contrast, the scenarios generated automatically by OpenAI include "Digital and Green Revolution", "Global Cooperation and Standardization", "Naval and Defense Dominance", and "Decentralized and Localized Shipbuilding". Despite their apparent similarity, these two sets of scenarios show significant differences. The automatically generated scenarios do not strictly adhere to the traditional quadrant-based logic of scenario planning, nor are they confined by the growth/decrease dichotomy. This suggests a more nuanced and complex set of possible futures for the industry, breaking away from the constraints of traditional scenario planning, which comes with considering the use of AI.

3. What are the possible main transformations in shipbuilding, and will a technological breakthrough originate from the industry itself, or will technology have to catch up and adapt to changing external systemic shifts?

The key findings of this research suggest that external forces, including technological, energy, and societal shifts, hold considerable potential to bring about significant changes in the shipbuilding industry. Any substantial or even minor alterations in these global systems could dramatically impact all players within the industry, from landscape-level entities to the regime and niche actors. The emergence of weaker signals inside the industry, such as the potential application of biotechnology and the development of new floating structures, is noteworthy.

Biotechnology in shipbuilding presents an innovative way of interacting with aquatic life. This could involve emulating sea creatures for maritime navigation or developing novel materials that could revolutionize the buoyancy of floating structures. Additionally, the advent of new types of floating constructions could initiate a new era in shipbuilding, fundamentally changing its societal role. Rather than focusing solely on the utilitarian task of creating vessels for sea transportation, the industry could transition into a sector that supports life on the water. These potential developments hint at the exciting possibilities for the future of the shipbuilding industry.

The framework employed in this research offered the advantage of a streamlined, practical structure that facilitated rapid analysis. It alleviated time and effort constraints, allowing for comprehensive desk research, and using OpenAI further boosted time efficiency. However, it also necessitated additional exploration into the applicability of new tools and the careful handling of data and analysis.

There might be a notion that a more extensive application of the manual scenario-building method could have enhanced the accuracy of the results. However, this idea could be misguided, considering that the defined objective of this research was to look at a long-range horizon that inherently holds a high degree of uncertainty.

Interestingly, the utilization of automated analysis produced findings that were thought-provoking and closely aligned with the results obtained manually. This suggests that automated analysis can be a viable and efficient tool for generating meaningful insights in such research contexts.

6.6 Directions for further research

The conclusions drawn from this study highlight several potential areas for extended investigation, as presented below.

- In-depth investigation of identified transformational signals: The research pinpointed two signals that may potentially revolutionize the industry from within. The potential of biotechnology and related innovative materials and various floating constructions in the shipbuilding industry warrants deeper exploration. This could potentially ignite significant advancements and strengthen the industry's progression. Such a study would delve into the specifics of these transformative

signals and their potential impact on the industry, providing further insight into potential disruptive innovations.

- **Implementing regular scenario follow-ups:** The necessity of regular follow-ups on scenario planning at different levels — including policy-making, regulation, and individual actors — was recognized during this research. It is in line with a methodology of scenario approach in futures studies. However, this element fell outside of the scope of this thesis. It is suggested that the industry could greatly benefit from adopting such a practice. Currently, futures studies are not widely used, except for practical strategic foresight or high-level policy-making, leaving substantial room for improvement in the future readiness of organizations at all levels. This follow-up process could involve systematic checks and updates on these scenarios to align them with the ever-evolving industry context. Such task appears feasible for regulating and policy-making bodies in shipbuilding, such as IMO.
- **Creation of an efficient and practical methodology for industry research:** The research underlined the positive impact of increasing futures awareness within organizations. However, traditional academic research methods can be slow and costly, restricting their widespread use in industry settings like commercial shipbuilding. Consequently, a more practical and streamlined methodology would be beneficial. Although this new methodology might provide less precision, it could potentially be more than sufficient for practical application, enhancing future research participation and promoting an increased awareness of future trends in various industries, thus leading to wider societal benefits.
- **Comparative evaluation of expert-led research and traditional data collection:** This research employed an expert-led approach to data collection and analysis, a method that could potentially be prone to bias. Comparing the findings of this research with the results of a study performed with traditional research can provide more reliable information about the applicability of the methods used. It, in turn, can provide a better perspective on the data collection method for futures studies.
- **Scrutinizing the reliability of AI-supported and automated data collection:** The study made use of AI-assisted and automated data collection methods, leading to the need for further scrutiny of their reliability. Given that tools like ChatGPT-4

are relatively new and lack extensive documentation, it is vital to conduct additional investigations to evaluate their efficacy and applicability, especially within the domain of futures studies.

- Utilizing AI assistance for global industrial foresight generation: The research demonstrated that AI assistance could yield promising results. It incorporated the use of AI in a collaborative approach to generate foresight on global industrial topics, applying data collection and analysis frameworks. Future research should further explore the potential of AI in shaping and enhancing foresight in various industries.

7 Conclusions

The futures of shipbuilding in the 22nd century seemed a difficult-to-envision abstract question, which was examined using futures research methods and employing novel OpenAI technology elements. These techniques do not give explicit answers but rather provide structured food for thought with reliability limitations.

The hybrid mode of using OpenAI technology allowed for collecting and analyzing large amounts of data for research input and automated analysis. Each step of the research included an elaboration of applicability for the use of AI and an additional branch of the research path to make AI-generated scenarios and CLA narratives. The overall conclusion is that AI can effectively help in similar research tasks. However, it requires special attention for the methodology and design of the research, as well as close supervision of a specialist to ensure the relevance of the results.

The results generated using AI were compared with those obtained in hybrid mode and it can be concluded that both are relevant and present interesting perspectives for the futures of shipbuilding discussion.

The resulting data, analysis, scenarios, and CLA interpretation show a diversity of possible paths the industry can take—from high-tech and responsible society to fragmentation and deglobalization. The following main changes can be expected from external systems, such as the development of technology, energy sources, and society, and internal for shipbuilding, such as biotechnology use and diversity of floating constructions.

References

- Arrieta, A. B.-R. (2020). Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities, and challenges toward responsible AI. *Information Fusion*, 58, 82-115.
- Bell, W. (2004). *Foundations of futures studies: Human science for a new era*. Transaction Publishers.
- Bengio, Y. C. (2017). Representation Learning: A Review and New Perspectives. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 35(8), 1798-1828.
- Börjeson, L. H. (2006). Scenario types and techniques: towards a user's guide. *Futures*, 38(7), 723-739.
- Bradfield, R. W. (2005). The origins and evolution of scenario techniques in long range business planning. *Futures*, 37(8), 795-812.
- Brown, R. R. (2013). Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. *Global Environmental Change*, 23(4), 701-718.
- Bruce, G. (2021). *Shipbuilding Management*. Singapore: Springer.
- Castelvecchi, D. (2016). Can we open the black box of AI? *Nature*, 538(7623), 20-23.
- Chermack, T. J. (2004). Improving decision-making with scenario planning. *Futures*, 36(3), 295-309.
- Choo, C. W. (2001). Environmental scanning as information seeking and organizational learning. *Information Research*, 7(1), paper 112.
- Cinca, C. S. (2009). Automated environmental scanning with competitive agents. *Foresight*, 11(3), 59-74.
- Clarksons Research. (2022). *World Fleet Monitor*. UK: Clarksons Research.
- Clemen, R. T. (1999). Combining probability distributions from experts in risk analysis. *Risk Analysis*, 19(2), 187-203.
- Crawford, K. &. (2016). There is a blind spot in AI research. *Nature*, 538(7625), 311-313.
- Dator, J. (2009). Alternative Futures at the Manoa School. *Journal of Futures Studies*, 14(2), 1-18.
- Davenport, T. H. (2016). *Only humans need apply: winners and losers in the age of smart machines*. Harper Business.
- Davis, M. &. (2013). *Systems Engineering*.
- Derbyshire, J. (2016). The implications, challenges and benefits of a complexity-orientated Futures Studies. *Futures*, 45-55.
- Encyclopedia Britannica*. (2018, February 20). Retrieved from <https://www.britannica.com/technology/ship-construction>

- Equasis statistic. (2018, April 10). *The world merchant fleet in 2016*. Retrieved from <http://www.equasis.org/Fichiers/Statistique/MOA/Documents%20 disponibles%20on%20statistics%20of%20Equasis/Equasis%20Statistics%20-%20The%20world%20fleet%202016.pdf>
- Floridi, L. C. (2018). AI4People—An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. *Minds and Machines*, 28(4), 689-707.
- Ford, A. (2009). *Modeling the Environment: An Introduction to System Dynamics Modeling of Environmental Systems*. Washington, D.C.: Island Press.
- Forrester, J. W. (1961). *Industrial Dynamics*. Cambridge, MA: MIT Press.
- Future of Life Institute. (2023, April 19). *Future of Life Institute*. Retrieved from Pause Giant AI Experiments: An Open Letter: https://futureoflife.org/wp-content/uploads/2023/04/FLI_Policymaking_In_The_Pause.pdf
- Geels. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. *Research Policy* 31 (8/9), 1257–1274.
- Geels, F. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy* 39, 495-510.
- Geels, F. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, 24-40.
- Geels, F. (2014). Reconceptualising the co-evolution of firms-in-industries and their environments: Developing an inter-disciplinary Triple Embeddedness Framework. *Research Policy* 43, 261-277.
- Geels, F. W. (2005). Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological Forecasting and Social Change*, 72(6), 681-696.
- Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography*, 24, 471-482.
- Geels, F., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, 36(3), 399-417.
- Gilpin, L. H. (2018). Explaining explanations: An overview of interpretability of machine learning. *2018 IEEE 5th International Conference on Data Science and Advanced Analytics (DSAA)* (pp. pp. 80-89). IEEE.
- Goodfellow, I. B. (2016). *Deep learning*. MIT Press.
- Hiltunen, E. (2008). The future sign and its three dimensions. *Futures*, 40(3), 247-260.
- Inayatullah, S. (1998). Causal layered analysis: Poststructuralism as method. *Futures*, 815-829.

- Inayatullah, S. (2004). *The Causal Layered Analysis (CLA) Reader: Theory and Case Studies of an Integrative and Transformative Methodology*. Tamsui, Taiwan: Tamkang University Press.
- Inayatullah, S. (2008). Six pillars: futures thinking for transforming. *Foresight*, 10(1), 4-21.
- Kemp, A. (1994). Technology and the transition to environmental sustainability. The problem of technological shifts. *Futures*(26), 1023-1046.
- Kemp, R. S. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2), 175-198.
- LeCun, Y. B. (2015). Deep learning. *Nature*, 521(7553), 436-444.
- Loorbach, D. (2007). *Transition management: New mode of governance for sustainable development*. Utrecht: International Books.
- Makridakis, S. A. (2018). The accuracy of forecasts for industrial applications: Comparing time series methods and artificial intelligence techniques. *IEEE Engineering Management Review*, 46(1), 34-48.
- Markard, J. R. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, 41(6), 955-967.
- Mason, P. (2015). *PostCapitalism: A Guide to Our Future*. New York, NY: Farrar, Straus and Giroux.
- Meadows, D. H. (2008). *Thinking in Systems: A Primer*. White River Junction. VT: Chelsea: Green Publishing.
- Microsoft Bing Blogs. (2023, March 14). *Confirmed: the new Bing runs on OpenAI's GPT-4*. Retrieved from Bing Blog:
https://blogs.bing.com/search/march_2023/Confirmed-the-new-Bing-runs-on-OpenAI%E2%80%99s-GPT-4
- Miller, R. (2006). Futures literacy: A hybrid strategic scenario method. *Futures*, 38(4), 341-362.
- Mitchell, T. M. (2014). *Machine learning*. McGraw-Hill Science/Engineering/Math.
- Mittelstadt, B. D. (2016). The ethics of algorithms: Mapping the debate. *Big Data & Society*, 3(2), 2053951716679679.
- Moody, J. &. (2010). *The Sixth Wave: How to Succeed in a Resource-Limited World*. Sydney, Australia: Vintage Books.
- Naisbitt, J. &. (1990). *Megatrends 2000: Ten new directions for the 1990s*. New York: William Morrow and Co.
- O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy*. Broadway.
- OpenAI. (2023, March 14). *OpenAI*. Retrieved from GPT-4:
<https://openai.com/research/gpt-4>

- Perez, C. (2002). *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*. Cheltenham, UK: Edward Elgar.
- Perez, C. (2010). Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, 185-202.
- Perez, C. (2015). Capitalism, technology and a green global golden age: the role of history in helping to shape the future. *Political Q.*, 191-217.
- Ramírez, R. &. (2016). *Strategic Reframing: The Oxford Scenario Planning Approach*. Oxford, UK: Oxford University Press.
- Riedy, C. (2008). An integral extension of causal layered analysis. *Futures*, 40(2), 150-159.
- Rip, A., & Kemp, R. (1998). Technological, Change, in Human Choice and Climate Change,. *Battelle Press, Columbus, OH*, 327–399.
- Ritchey, T. (2006). Problem structuring using computer-aided morphological analysis. *Journal of the Operational Research Society*, 57(7), 792-801.
- Rockwell, A. (2017, August 27). *Harvard University, the Graduate School of Arts and Sciences*. Retrieved from Blog, Special Edition on Artificial Intelligence: <https://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/>
- Russell, S. D. (2015). Research Priorities for Robust and Beneficial Artificial Intelligence. *AI Magazine*, 36(4), 105–114.
- Schoemaker, P. J. (2009). How to make sense of weak signals. *MIT Sloan Management Review*, 50(3), 81-89.
- Schot, J., & Kanger, L. (2018). Deep transitions: Emergence, acceleration, stabilization and directionality. *Research Policy*.
- Schwartz, P. (1991). *The Art of the Long View: Planning for the Future in an Uncertain World*. New York: Doubleday.
- Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of The Learning Organization*. New York: Doubleday.
- Smith, A. S. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, 34, 1491–1510.
- Statista. (2021, July). *Statista*. Retrieved January 2022, from [statista.com](https://www.statista.com/statistics/1102252/size-of-the-global-shipbuilding-market/): <https://www.statista.com/statistics/1102252/size-of-the-global-shipbuilding-market/>
- Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston, MA: Irwin McGraw-Hill.
- Suarez, F. F. (2011). Environmental Change and Organizational Transformation. *Industrial and Corporate Change*, 3:1015–1040.
- Sutskever, I. V. (2014). Sequence to sequence learning with neural networks. *Advances in neural information processing systems*, 3104-3112.

- Taleb, N. N. (2007). *The Black Swan: The Impact of the Highly Improbable*. New York: Random House.
- The European Community Shipowners' Associations. (2017). *Shipping and global trade*. Retrieved 01 2022, from ECSA:
<https://www.ecsa.eu/sites/default/files/publications/2017-02-27-ECSA-External-Shipping-Agenda-FINAL.pdf>
- The Nobel Prize Foundation. (2022, October 30). *Pr release: The Nobel Prize in Physics 2022*. Retrieved from Nobel Prizes and Laureats:
<https://www.nobelprize.org/prizes/physics/2022/summary/>
- UTU. (2023, July 5). *Artificial Intelligence In Teaching And Studying*. Retrieved from University of Turku: https://intranet.utu.fi/en/unit/student-affairs/Documents/AI%20in%20teaching%20and%20learning%203_2023.pdf
- UTU. (2023, June 1). *FairUTU*. Retrieved from University of Turku:
<https://www.utu.fi/en/fairutu>
- Vähäkari N., L. V. (2020). The future in sustainability transitions - Interlinkages between the multi-level perspective and futures studies. *Futures*, 123 102597.
- van der Heijden, K. (1996). *Scenarios: The Art of Strategic Conversation*. Chichester, UK: Wiley.
- van der Heijden, K. (2005). *Scenarios: The Art of Strategic Conversation (2nd ed.)*. Chichester, UK: Wiley.
- van Notten, P. W. (2003). An updated scenario typology. *Futures*, 35(5), 423-443.
- Verbong, G. &. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Technological Forecasting and Social Change*, 77(8), 1214-1221.
- Voros, J. (2001). Reframing environmental scanning: An integral approach. *Foresight*, 3(6), 533-552.
- Voros, J. (2003). A Generic Foresight Process Framework. *Foresight (Cambridge)*, 10-21.
- Wilenius, M. (2018). The Sixth Wave of the Kondratiev Cycle and the New Economic Paradigm. *Journal of Future Studies*, 22(3), 99-108.

References for online horizon search sources

3D design & information management software – Cadmatic. (22.03.2023) Retrieved from <https://www.cadmatic.com/>

ABB - Electric, Automated and Digital solutions for the marine industry. (22.03.2023) Retrieved from <https://new.abb.com/marine>

American Bureau of Shipping (ABS) Eagle.org. (22.03.2023) Retrieved from <https://ww2.eagle.org/>

Autodesk | 3D Design, Engineering & Construction Software. (22.03.2023) Retrieved from <https://www.autodesk.com/>

AVEVA - Global Leader in Industrial Software. (22.03.2023) Retrieved from <https://www.aveva.com/>

Caterpillar | Caterpillar. (22.03.2023) Retrieved from <https://www.caterpillar.com/>

China Classification Society (ccs.org.cn). (22.03.2023) Retrieved from <http://www.ccs.org.cn/>

China Shipbuilding Industry Corporation (csic.com.cn). (22.03.2023) Retrieved from <http://www.csic.com.cn/>

C-Job Naval Architects - A Sustainable Maritime Industry Within One Generation. (22.03.2023) Retrieved from <https://www.c-job.com/>

ClassNK. (22.03.2023) Retrieved from <https://www.classnk.com/>

Customized vessel design - KNUD E. HANSEN (knudehansen.com). (22.03.2023) Retrieved from <https://knudehansen.com/>

DNV.com - When trust matters - DNV. (22.03.2023) Retrieved from <https://www.dnv.com/>

Drydocks World. (22.03.2023) Retrieved from <https://drydocks.gov.ae/>

DSME. (22.03.2023) Retrieved from <http://www.dsme.co.kr/>

European Cruises and Ferry Crossings | Passenger Ferries | DFDS. (22.03.2023) Retrieved from <https://www.dfds.com/>

Fincantieri | Home Page. (22.03.2023) Retrieved from <https://www.fincantieri.com/>

Fjord1 - About. (22.03.2023) Retrieved from <https://www.fjord1.no/en/About-Fjord1>

GEA marine and naval solutions. (22.03.2023) Retrieved from <https://www.gea.com/en/applications/marine-and-naval/index.jsp>

Ghenova Ingeniería. (22.03.2023) Retrieved from <https://ghenova.com/>

HD Hyundai Heavy Industries (hhi.co.kr). (22.03.2023) Retrieved from <https://www.hhi.co.kr/>

HD Korea Shipbuilding & Offshore Engineering (ksoe.co.kr). (22.03.2023) Retrieved from <https://www.ksoe.co.kr/>

Hexagon - Empowering an autonomous, sustainable future | Hexagon. (22.03.2023) Retrieved from <https://www.hexagon.com/>

Home – Lamprell Plc. (22.03.2023) Retrieved from <https://www.lamprell.com/>

Home – NAPA. (22.03.2023) Retrieved from <https://www.napa.fi/>

Japan Ship Technology Research Association (jstra.jp). (22.03.2023) Retrieved from <http://www.jstra.jp/>

Kongsberg Digital - Operate your assets smarter, safer and greener. (22.03.2023) Retrieved from <https://www.kongsberg.com/digital/>

Kongsberg Maritime. (22.03.2023) Retrieved from <https://www.kongsberg.com/maritime/>

Korean Register (krs.co.kr). (22.03.2023) Retrieved from <http://www.krs.co.kr/>

Lloyd's Register – classification, training and advisory services (lr.org). (22.03.2023) Retrieved from <https://www.lr.org/>

Main - Tallink & Silja Line. (22.03.2023) Retrieved from <https://www.tallink.com/>

Marine | Rolls-Royce. (22.03.2023) Retrieved from <https://www.rolls-royce.com/products-and-services/marine.aspx>

Maritime Research Institute Netherlands | MARIN. (22.03.2023) Retrieved from <https://www.marin.nl/>

MEYER Group | Three Shipyards | 7,000 Employees (meyerwerft.de). (22.03.2023) Retrieved from <https://www.meyerwerft.de/>

Mitsubishi Heavy Industries, Ltd. Global Website (mhi.com). (22.03.2023) Retrieved from <https://www.mhi.com/>

National Maritime Research Institute (nmri.go.jp). (22.03.2023) Retrieved from <https://www.nmri.go.jp/>

Next Generation Shipping | IMO. (22.03.2023) Retrieved from

Norled - we move people along the coast - Norled. (22.03.2023) Retrieved from <https://www.norled.no/en/>

Norwegian University of Science and Technology - NTNU. (22.03.2023) Retrieved from <https://www.ntnu.edu/>

Safer and Cleaner Shipping - IACS. (22.03.2023) Retrieved from <https://www.iacs.org.uk/>

Salt Ship Design - Home. (22.03.2023) Retrieved from <https://www.saltship.com/>

Samsung Heavy industries. (22.03.2023) Retrieved from <http://www.samsungshi.com/>

Seaspan Corporation - Home. (22.03.2023) Retrieved from <https://www.seaspan-corp.com/>

Siemens. (22.03.2023) Retrieved from <https://www.siemens.com/>

SSI » Empowering the Business of Shipbuilding (ssi-corporate.com). (22.03.2023) Retrieved from <https://www.ssi-corporate.com/>

Sumitomo Heavy Industries, Ltd. (shi.co.jp). (22.03.2023) Retrieved from <https://www.shi.co.jp/>

The global leader in innovative technologies and lifecycle solutions for the marine and energy markets | Wärtsilä (wartsila.com). (22.03.2023) Retrieved from <https://www.wartsila.com/>

Vard Marine Inc. | Naval Architects & Marine Engineers. (22.03.2023) Retrieved from <https://vardmarine.com/>

We are the 3DEXPERIENCE company | Dassault Systèmes (3ds.com). (22.03.2023) Retrieved from <https://www.3ds.com/>

上海船舶研究设计院 (sdari.com.cn). (22.03.2023) Retrieved from <http://www.sdari.com.cn/>

中国船舶工业贸易有限公司 (chinaships.com). (22.03.2023) Retrieved from <http://www.chinaships.com/>

Appendices

Appendix 1. Data collected step in horizon scanning and summary.

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Group 1: Policy and regulations				
IMO	International Maritime Organization (imo.org)	CO2 zero emissions, regulations to achieve carbon neutrality and energy efficiency, multi-point design optimization, alternative fuels, digitalization, autonomy, modularity, market demands, global regulatory network, smart shipping, Shipyard 4.0, new technologies, automation, data exchange, optimization of vessel design and construction	<p>Digitalization: This topic appears several times in the data, indicating its relevance to the maritime industry. It is often associated with other themes such as automation, data exchange, and Shipyard 4.0.</p> <p>Regulations to achieve carbon neutrality and energy efficiency: The maritime industry is under pressure to reduce its carbon footprint, and regulations are being introduced to achieve this. Energy efficiency is also important to reduce operating costs and comply with regulations.</p> <p>Smart shipping: Smart shipping refers to the use of advanced technologies such as sensors, data analytics,</p>	<p>Digitalization</p> <p>Carbon neutrality and energy efficiency regulations</p> <p>Smart shipping</p> <p>New technologies</p> <p>Automation</p> <p>Market demands</p> <p>Regulations</p> <p>European leadership and competitiveness</p> <p>Ocean economy</p> <p>Workforce</p> <p>Renewable energy</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
SEA	Sea Europe - The Shipyards' & Maritime Equipment Association of Europe	European leadership and competitiveness in innovation and digitalization, green and smart ships, renewable energy, maritime defence and security, cooperation, workforce	<p>and automation to improve efficiency, safety, and sustainability in the maritime industry.</p> <p>New technologies: The maritime industry is constantly evolving, and new technologies are being introduced to improve efficiency and reduce emissions. Examples include wind-assisted propulsion, hybrid propulsion, and multi-point design optimization.</p>	<p>Maritime defence and security</p> <p>Mass customization</p> <p>Ship finance</p> <p>Offshore activities</p> <p>Developing navy</p> <p>Biotechnology</p>
OECD	Home page - OECD	Cooperation and information exchange in industry, market demands, governments regulations, ocean economy, safety and environment regulations, technology uptake, ship finance, competitiveness	<p>Automation: Automation is another topic that appears frequently in the data. It is often associated with digitalization and smart shipping, and can improve efficiency, safety, and productivity.</p> <p>Market demands: The maritime industry is influenced by market demands, such as the need for eco-friendly and energy-efficient ships. This drives innovation and new technologies.</p>	
ASA	Asian Shipowners' Association	Net-zero emissions industry transition, smart shipping, shift from mass production to mass customization, digi-	<p>Regulations: Regulations are a key driver of change in the maritime industry, particularly in relation to emissions and safety.</p> <p>European leadership and competitiveness in innovation</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		talization, automation, enhanced productivity and safety	and digitalization: The European Union is promoting leadership and competitiveness in innovation and digitalization to improve the maritime industry's efficiency, safety, and sustainability.	
SAJ	The Ship-builders' Association of Japan (sajn.or.jp)	eco-friendly, energy efficient ships, hybrid propulsion, autonomous ships, digitalization, wind-assisted propulsion, new technologies, regulations, enhancing engineering capabilities, diversifying types	Ocean economy: The ocean economy is a growing sector, and the maritime industry plays a key role in this. Cooperation and information exchange between industry, governments, and other stakeholders is important to promote sustainable growth. Workforce: The maritime industry requires a skilled workforce to operate and maintain ships, and there is a need to attract and retain talent in the sector.	
Ko-shipa	KOSHIPA - The Korea Offshore & Shipbuilding Association	lower emission ships, climate change, automation, data integration, smart shipping, cyber governance, security, adapt to changed market and regulations, strong regional dominance	Renewable energy: Renewable energy is becoming more important in the maritime industry, with a focus on wind, solar, and other sources of clean energy. Maritime defence and security: Maritime defence and security are important issues, particularly in relation to piracy and terrorism.	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		by Asian shipbuilding, government support, lined industries	Shift from mass production to mass customization: The maritime industry is moving towards mass customization to meet the diverse needs of customers. Ship finance: Ship finance is an important aspect of the maritime industry, and there is a need for innovative financing models to support investment in new technologies and infrastructure.	
CANSI	China International Marine, Port & Shipbuilding Fair (china-ship.com)	High-end ships, LNG, developing navy, subsidies to support shipbuilding	Offshore: Offshore activities such as oil and gas exploration and renewable energy production are important to the maritime industry.	
CSIC	China Shipbuilding Industry Corporation (csic.com.cn)	Developing non marine products, technological development, offshore, renewable energy, biotechnology	Developing navy: The development of naval vessels is an important aspect of the maritime industry, particularly for countries with strategic interests in the sea. Biotechnology: Biotechnology has potential applications in the maritime industry, such as in aquaculture and the development of new materials.	
Group 2: Shipowners/operators				
AP Moller-Maersk	About A.P. Moller - Maersk Maersk	Global integration of logistics, digital twin technology, global flow of goods	Sustainability: Sustainability appears several times in the data, indicating its importance to the logistics and	Sustainability Digitalization Innovation and new technologies

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
MSC	Global Container Shipping Company MSC	New design and technology, diversification for big and smaller shipyards and ships, sustainability, low carbon emissions	shipping industry. This includes efforts to reduce carbon emissions and adopt eco-friendly technologies. Digitalization: Digitalization is also a key topic in the logistics and shipping industry. This includes the use of advanced technologies such as IoT, AI, and block chain to improve efficiency and sustainability.	Automation Climate change Green solutions LNG Globalization
COSCO O	COSCO SHIPPING Lines	Advanced technologies, automation, lower emissions, climate change, large scale globalization	Innovation and new technologies: The logistics and shipping industry is constantly evolving, and new technologies are being introduced to improve efficiency and reduce environmental impact. This includes digital twins, 3D printing, and hybrid propulsion.	Sustainability challenges Personalization of services Green fleet Renewable fuels
CMA CGM Group	CMA CGM A global player in sea, land, air, and logistics solutions. (cma-cgm.com)	Logistics solutions, solutions to respect people and the planet, liquefied natural gas, biomethane, biofuel, acceleration innovation and digitalization, IoT, AI, block chain technology	Automation: Automation is another topic that appears frequently in the data. This includes the use of advanced technologies to improve efficiency and reduce human error. Climate change: Climate change is a major challenge for the logistics and shipping industry, and efforts are being made to reduce emissions and adopt sustainable practices.	Cyber governance and security Market fluctuations Uncertainty in regulations Shipyard 4.0 Low carbon emissions Diversification Smart and connected ships
Hapag- Lloyd	Our Company - Hapag-Lloyd	Sustainability		

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
ONE - Ocean Network Express	Home ONE (one-line.com)	Climate change, smart shipping, 3D printing, cyber governance and security, integration of advanced technologies, automation	Green solutions: Green solutions refer to efforts to reduce the environmental impact of the logistics and shipping industry, including the use of alternative fuels and electrification. LNG: LNG is a specific type of alternative fuel that is becoming more common in the shipping industry due to its lower emissions.	
Evergreen Line	EVER-GREEN LINE (evergreen-line.com)	Digitalization, decarbonization, globalization	Globalization: The logistics and shipping industry is highly globalized, with goods and services flowing across borders. This presents both opportunities and challenges for the industry.	
HMM	HMM (hmm21.com)	Eco-friendly technology, digital twins platform, innovation	Sustainability challenges: Sustainability challenges refer to the specific issues that the logistics and shipping industry must address in order to reduce its environmental impact. This includes reducing emissions, improving fuel efficiency, and adopting sustainable practices.	
Carnival Corporation	Home Carnival Corporation & plc	Sustainability, eco-friendly, energy-saving technology	Personalization of services: Personalization of services refers to efforts to tailor logistics and shipping services	
Royal Caribbean Group	Home - Royal Caribbean Group	Climate neutrality, LNG, innovation		

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
NCLH _Norwegian	Norwegian Cruise Line Holdings Ltd. (NCLH) (nclhltd.com)	Sustainability, innovation, new technologies, automation, hybrid propulsion, fuel cells, global presence, personalization of services, environment challenges	to the needs of individual customers, improving efficiency and reducing waste. Green fleet: The green fleet refers to a fleet of ships that are designed to be eco-friendly, using sustainable fuels and technologies. Renewable fuels: Renewable fuels, such as biomethane and biofuel, are becoming more common in the logistics and shipping industry as a way to reduce emissions.	
DFDS Sea-ways	European Cruises and Ferry Crossings Passenger Ferries DFDS	Green fleet, alternative fuels, reduce carbon footprint, sty, logistics, new technologies, green fuels, smart and connected ships, automation, data exchange, shipyard 4.0	Cyber governance and security: Cyber governance and security are important issues for the logistics and shipping industry, particularly as more advanced technologies are introduced.	
Tal-linkSilja Line	Main - Tallink & Silja Line	Renewable fuels, uncertainty in regulations, market fluctuations, technology development	Market fluctuations: Market fluctuations are a challenge for the logistics and shipping industry, as changes in demand and supply can affect profitability. Uncertainty in regulations: Regulations related to sustainability and emissions are constantly evolving, cre-	
Norled AS	Norled - we move people along the	Green solutions, hydrogen		

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
	coast - Norled		ating uncertainty for the logistics and shipping industry.	
Fjord1	About Fjord1 - Fjord1	Green solutions, electrification	<p>Sty: STY refers to Shipyard 4.0, an approach to shipbuilding that uses advanced technologies such as digital twins and automation.</p> <p>Low carbon emissions: Low carbon emissions are a key goal for the logistics and shipping industry, with a focus on adopting sustainable technologies and fuels.</p> <p>Diversification: Diversification refers to efforts to expand the types of ships and services offered by the logistics and shipping industry, improving efficiency and reducing environmental impact.</p> <p>Smart and connected ships: Smart and connected ships use advanced technologies to improve efficiency and safety, such as sensors and data analytics.</p>	
Group 3: Shipyards				
China Ship-build-	China Shipbuilding Industry Corporation	Market distortions, excess capacity, green growth, global value chain and ship	Sustainability: Sustainability is a key topic in the shipping industry, with a focus on reducing greenhouse	Sustainability Innovation and advanced technologies

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
ing corporation	csic.com.cn	finance practices, 3D printing technology	emissions and adopting environmentally friendly practices. Innovation and advanced technologies: The shipping industry is constantly evolving, and new technologies are being introduced to improve efficiency and reduce environmental impact. This includes 3D printing technology, autonomous navigation, and virtual twin technology.	Decarbonization Smart shipping Digitalization
Mitsubishi Heavy Industries	Mitsubishi Heavy Industries Global Website (mhi.com)	Climate change, smart shipping, ocean economy, safety regulations, technology uptake, ship finance, new design and manufacturing technology, innovation, performance, variety of type of vessels, navy ships	Decarbonization: Decarbonization is a major challenge for the shipping industry, and efforts are being made to reduce emissions and adopt sustainable practices. This includes the use of ammonia fuel, energy-efficient ships, and data analytics and AI.	Navy ships Global value chain and ship finance practices Environmental regulations Excess capacity Green growth Ocean economy Technological synergy
Hyundai Heavy Industries	Welcome to HD Hyundai Heavy Industries (hhi.co.kr)	New value for humankind, sustainability, smart shipbuilding, inclusive, innovative technologies, autonomous navigation, liquid hydrogen, intelligent robotics and solutions, self-driving massive-scale transoceanic voyage, incorporating the	Smart shipping: Smart shipping refers to the use of advanced technologies such as sensors, data analytics, and automation to improve efficiency, safety, and sustainability in the shipping industry. Digitalization: Digitalization is also a key topic in the shipping industry. This includes the use of advanced technologies to improve efficiency and reduce human	Ammonia fuel Supply chain disruptions Renewable energy Conversion projects Complex offshore structures

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		technology of the 4th industrial revolution I4, cost and revenue performance, advanced technology, automation, greener vessels, infrastructure, navy ships contracts with government support	<p>error, such as digital shipyards and virtual twin technology.</p> <p>Navy ships: Navy ships are an important aspect of the shipping industry, particularly for countries with strategic interests in the sea.</p> <p>Global value chain and ship finance practices: The shipping industry is highly globalized, with complex value chains and finance practices. This presents both opportunities and challenges for the industry.</p>	
China State Shipbuilding Corporation	中国船舶工业贸易有限公司 (chinaships.com)	Advanced technologies and automation, new ship designs, LNG carriers, large containers, icebreakers, environmental regulations, supply chain disruptions	<p>Environmental regulations: Environmental regulations related to emissions and sustainability are constantly evolving, creating uncertainty for the shipping industry.</p> <p>Excess capacity: Excess capacity is a challenge for the shipping industry, as it can lead to market distortions and reduced profitability.</p>	
DSME	DSME	Technological synergy, global network, new shipbuilding materials, ammonia fuel, reducing greenhouse emissions, climate change,	<p>Green growth: Green growth refers to efforts to promote economic growth while reducing environmental impact, including in the shipping industry.</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		smart shipping, connected and optimized design and manufacturing, data exchange	Ocean economy: The ocean economy is a growing sector, and the shipping industry plays a key role in this. Technological synergy: Technological synergy refers to the integration of different technologies to improve efficiency and reduce environmental impact in the shipping industry.	
Sam-sung Heavy Industries	Welcome To Samsung Heavy industries. (samsungshi.com)	Digital shipyard, smart yard, digital transformation, virtual twin technology, model-based systems, efficiency,	Ammonia fuel: Ammonia fuel is becoming more common in the shipping industry as a way to reduce emissions.	
Sumitomo Heavy Industries	Sumitomo Heavy Industries, Ltd. (shi.co.jp)	Decarbonization, ammonia-fueled vessels, sustainability, energy-efficient and environmentally friendly, digital technologies, automation, advanced design, optimization of ship performance, reduce emissions, data analytics and AI, collaboration of stakeholders	Supply chain disruptions: Supply chain disruptions can affect the shipping industry, particularly during times of crisis or economic uncertainty. Renewable energy: Renewable energy is becoming more important in the shipping industry, with a focus on wind, solar, and other sources of clean energy. Conversions projects: Conversion projects refer to efforts to retrofit existing ships with new technologies to improve efficiency and reduce emissions.	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Fin-cantieri Group	Fincantieri Home Page	Digitalization of production, innovation, sustainability, increase in Navy in West Europe and Asia-Pacific	Complex offshore structures: Complex offshore structures are an important aspect of the shipping industry, particularly in relation to oil and gas exploration and renewable energy production.	
Meyer Group	MEYER Group Three Shipyards 7,000 Employees (meyer-werft.de)	Innovation, sustainable ships, Digital, Green, Collaborative		
Van-couver shipyards	Home - Seaspan	Innovation, sustainability, environmental footprint, complexity, variety of vessels, conversions projects		
Dry Docks World	Drydocks World	Decarbonization, innovation, sustainability, complex offshore structures, green and smart ships		
Lam-prell	Home – Lamprell Plc	renewable energy		

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Group 4: IT/Solutions providers				
Siemens	Siemens	Shipyards 4.0, digitalization, automation, data exchange, paperless	Digitalization: Digitalization is a key topic in the shipbuilding industry, with a focus on using advanced technologies to improve efficiency, reduce costs, and improve environmental sustainability.	Digitalization Shipyards 4.0 Automation
Dassault Systèmes	We are the 3DEXPERIENCE company Dassault Systèmes (3ds.com)	Digital transformation, collaborative business, connection in value chain, innovation, standardization, modularity, low-impact design	Shipyards 4.0: Shipyards 4.0 refers to the use of advanced technologies such as digital twins, automation, and data exchange to improve efficiency and reduce costs in the shipbuilding industry.	Data exchange Advanced technology Digital transformation Collaborative business Environment regulations
Aveva	AVEVA - Global Leader in Industrial Software	Advanced technology, robotics, immersive technology, additive manufacturing, AI, environment regulations, fuel efficiency	Automation: Automation is a key aspect of Shipyards 4.0, allowing for improved efficiency and reduced costs. Data exchange: Data exchange is an important aspect of Shipyards 4.0, allowing for the sharing of information between different stakeholders in the shipbuilding process.	Fuel efficiency Data-driven solutions Digital twins Immersive technology Additive manufacturing Advanced materials
SSI	SSI » Empowering the Business of Shipbuilding (ssi-corporate.com)	quick ROI, integration, collaboration, reuse of data, secure flexible connection, adaptive scalable platforms,	Advanced technology: Advanced technology such as robotics, immersive technology, and additive manufacturing are being used in the shipbuilding industry to	Operational agility Modularity Paperless

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		digital transformation, empowering with new software and expertise	improve efficiency and reduce costs. Digital transformation: Digital transformation refers to the process of using digital technologies to transform business processes, improve efficiency, and reduce costs.	
Cadmatic	3D design & information management software – Cadmatic	Data-driven, digital twins, automation, networked operating model, AI, machine learning, technology	Collaborative business: Collaborative business refers to the use of partnerships and collaboration to improve efficiency and reduce costs in the shipbuilding industry.	
Napa	Home – NAPA	Data-led solutions, efficiency, voyage monitoring, safety, fuel efficiency, analysis platforms	Environment regulations: Environment regulations related to emissions and sustainability are a key concern for the shipbuilding industry.	
Hexagon	Hexagon - Empowering an autonomous, sustainable future Hexagon	Digital transformation, data-driven performance and integration, digital twins for design and execution, operational agility, environmental stability	Fuel efficiency: Fuel efficiency is an important aspect of the shipbuilding industry, as it can help reduce operating costs and improve environmental sustainability. Data-driven solutions: Data-driven solutions are being used in the shipbuilding industry to improve efficiency, monitor voyages, and analyze performance.	
Kongsberg digital	Kongsberg Digital - Operate your assets	Digital solutions, unlock values of data, vessel-to-cloud data infrastructure,	Digital twins: Digital twins are digital models of physical assets that are used in the shipbuilding industry to	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
	smarter, safer and greener	advanced simulation, digitalization	<p>improve design and execution.</p> <p>Immersive technology: Immersive technology, such as virtual design and simulation, is being used in the shipbuilding industry to improve performance and efficiency.</p>	
Auto-desk	Autodesk 3D Design, Engineering & Construction Software	Advanced robotics, immersive technology for virtual design and simulation, design optimization, improved performance and efficiency, green ships, reducing emissions, additive manufacturing, advanced materials	<p>Additive manufacturing: Additive manufacturing, or 3D printing, is being used in the shipbuilding industry to improve efficiency and reduce costs.</p> <p>Advanced materials: Advanced materials are being used in the shipbuilding industry to improve performance, reduce emissions, and improve environmental sustainability.</p> <p>Operational agility: Operational agility refers to the ability of shipbuilders to quickly adapt to changes in the market, technology, and regulations.</p> <p>Modularity: Modularity refers to the use of standardized, interchangeable components in the shipbuilding process, allowing for greater efficiency and flexibility.</p> <p>Paperless: Paperless refers to the move towards digital record-keeping and communication in the shipbuilding</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			industry, allowing for greater efficiency and reduced costs.	
Group 5: Classification societies				
Association of Classification Societies (IACS)	Safer and Cleaner Shipping - IACS	Harmonization of certification and regulation, digitalization, decarbonization, innovation	<p>Decarbonization: Decarbonization is a key topic in the maritime industry, with a focus on reducing greenhouse gas emissions through the use of alternative fuels and digital technologies.</p> <p>Digitalization: Digitalization is also a key topic, with a focus on using advanced technologies such as AI and data-driven solutions to improve efficiency and reduce costs.</p>	<p>Decarbonization</p> <p>Digitalization</p> <p>Innovation</p> <p>Alternative fuels</p> <p>Multi-point optimization of design</p> <p>Enhanced safety</p> <p>Development of naval vessels</p>
DNV	DNV.com - When trust matters - DNV	Multi-point optimization of design, lower emissions, alternative fuels, digitalization, automation, AI, smarter operations, enhanced safety, development of naval vessels, security challenges	<p>Innovation: Innovation is a driving force in the maritime industry, with a focus on developing new technologies and processes to improve efficiency and reduce environmental impact.</p> <p>Alternative fuels: Alternative fuels such as biofuels, ammonia, and LNG are being explored as ways to reduce emissions in the maritime industry.</p>	<p>Digital platform for ship design and classification</p> <p>Offshore wind industry</p> <p>Dredging</p> <p>Reducing CO2 emissions</p> <p>Smart logistics</p> <p>Carbon capture technology</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
LR	Lloyd's Register – classification, training and advisory services (lr.org)	Zero-carbon fuel, decarbonization, data-driven technology, efficiency, innovation	<p>Multi-point optimization of design: Multi-point optimization of design refers to the use of advanced technologies to optimize vessel design, reducing emissions and improving efficiency.</p> <p>Enhanced safety: Safety is a top priority in the maritime industry, and new technologies such as automation and AI are being used to improve safety and reduce the risk of accidents.</p>	<p>Remote surveying</p> <p>Green technology</p>
ABS	American Bureau of Shipping (ABS) Eagle.org	Offshore wind industry, dredging, coastal and waterway, digitalization and decarbonization, digital technology adoption, reducing greenhouse emissions	<p>Development of naval vessels: The development of naval vessels is an important aspect of the maritime industry, with a focus on using advanced technologies to improve performance and reduce environmental impact.</p>	
Bureau Veritas	Home Bureau Veritas	Biofuels, digital platform for ship design and classification, energy efficiency, smart ships, digitalization, connectivity, alternative fuels	<p>Digital platform for ship design and classification: Digital platforms are being developed to improve ship design and classification, using advanced technologies such as AI and data analytics.</p>	
ClassNK	ClassNK	reducing CO2 emissions, evolution of ocean-related	<p>Offshore wind industry: The offshore wind industry is a growing sector, and the maritime industry plays a key role in supporting it.</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		business, smart logistics, digital technology, data dt	Dredging: Dredging is an important aspect of the maritime industry, with a focus on improving navigability and reducing the risk of accidents.	
China Classification Society	China Classification Society (ccs.org.cn)	LNG as a transitional fuel for decarbonization, Ammonia, carbon capture technology, remote surveying, digitalization, offshore constructions, data services	Reducing CO2 emissions: Reducing CO2 emissions is a key goal of the maritime industry, with a focus on using advanced technologies and alternative fuels to achieve this. Smart logistics: Smart logistics refers to the use of advanced technologies to optimize the movement of goods and reduce waste in the maritime industry.	
Korean Register	Korean Register (krs.co.kr)	Ammonia, green fuels, green technology, digitalization	Carbon capture technology: Carbon capture technology is being explored as a way to reduce emissions in the maritime industry. Remote surveying: Remote surveying allows for the inspection of ships and offshore structures without the need for physical presence, improving efficiency and reducing costs. Green technology: Green technology refers to the use of environmentally friendly technologies to reduce	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			emissions and improve sustainability in the maritime industry.	
Group 6: Academia and research organizations				
NTNU	Norwegian University of Science and Technology - NTNU	Industry 4.0, sustainability, efficiency of supply chains, standardization, modularization engineer-to-order, flexibility, innovation, customized solutions, automation, digitalization, integration of design, p, production after-sales service, supply chain management	<p>Sustainability and Environment: This theme covers research in areas like alternative fuels, emission reduction, energy-saving, and sustainable use of the sea, indicating a trend toward mitigating the environmental impact of maritime operations.</p> <p>Digitalization and Advanced Technologies: Research in the use of digital twins, cloud computing, ICT integration, smart ship technologies, and digital operation support underscores an industry-wide shift towards leveraging digital technology for efficiency and optimization.</p>	<p>Sustainability</p> <p>Digitalization</p> <p>Innovation</p> <p>Alternative fuels</p> <p>Automation</p> <p>Integration of design, production, and after-sales service</p> <p>Cloud computing and data sharing platforms</p> <p>Standardization and modularization</p>
NMRI	National Maritime Research Institute (nmri.go.jp)	Optimal design and performance, alternative fuels, international collaboration, risk assessment for maritime scenarios, cloud computing, data sharing platforms, open innovation, cooperation	<p>Autonomous and Intelligent Systems: The focus on autonomous surface ship systems, intelligent upgrades, and safety enhancements through advanced tech falls under this theme. It underlines the continuous pursuit of increased automation and intelligence in maritime systems for improved safety and efficiency.</p>	<p>Autonomous surface ships systems and business models</p> <p>Risk assessment for maritime scenarios</p> <p>Open innovation and cooperation</p> <p>Clean, smart, and safe shipping</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Japan Ship Technology Research association	Japan Ship Technology Research Association (jstra.jp)	Autonomous surface ships systems and business models, digital twins, advanced technologies adaptation from other sectors, sophisticated production management, ICT, cloud services, safety and environment regulations	<p>Innovative Engineering and Design: This encompasses optimal design and performance, exploration of various types of ships, and modularization engineer-to-order. It showcases a focus on innovation in design and production to create superior maritime vessels and systems.</p> <p>Efficiency and Supply Chain Management: This theme includes sophisticated production management, efficient supply chain management, and various operational improvements, indicating an ongoing push towards improving operational efficiency within the shipbuilding industry.</p>	<p>Energy islands and floating air-ports</p> <p>Labor shortage and competition with China</p> <p>Technology development and intelligence upgrade</p>
MARI N	Maritime Research Institute Netherlands MARIN	Clean, smart and safe shipping, sustainable use of sea, floating airports, energy islands	<p>Education and Professional Training: This involves preparing future professionals for the emerging trends and technologies in the shipbuilding industry, an essential focus for academic institutions.</p>	
KSOE	HD Korea Shipbuilding & Offshore Engineering (ksoe.co.kr)	net-zero carbon emissions, eco-friendly ships, smart ship technology, hydrogen energy, offshore wind power, labor shortage, competition with China, environmental regulations	<p>Collaboration and Standardization: The potential drive for international collaboration and standardization, in-</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
SDARI	上海船舶研究设计院 (sdari.com.cn)	technology development, various types of ships, intelligence upgrade, energy saving, emission reduction, smart ship innovation, new energy technology, digital operations support, ammonia, low-carbon	tegral to the implementation of new technologies, enables shared growth, development, and uniformity within the industry.	
Group 7: Technology and equipment providers				
ABB	Electric, Automated and Digital solutions for the marine industry ABB	sustainable shipping, electric propulsion, data-driven, integrated solutions, offshore wind installations, autonomous and cooperative operations, hydrogen based shore power systems, CO2 capture	<p>Sustainable shipping: Sustainable shipping is a key topic in the maritime industry, with a focus on reducing environmental impact and improving the sustainable use of resources.</p> <p>Electric propulsion: Electric propulsion is a growing area in the maritime industry, with a focus on reducing emissions and improving efficiency.</p>	Sustainable shipping Electric propulsion Data-driven and integrated solutions Offshore wind installations Autonomous and cooperative operations

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Wärt-silä	The global leader in innovative technologies and lifecycle solutions for the marine and energy markets Wärtsilä (wart-sila.com)	Electric shipping, hybrid ships, autonomy solutions, fleet optimization, decarbonization, sustainable fuels, simulation, training	<p>Data-driven and integrated solutions: Data-driven and integrated solutions are being used in the maritime industry to improve efficiency and reduce costs.</p> <p>Offshore wind installations: Offshore wind installations are a growing sector in the maritime industry, with a focus on supporting renewable energy.</p> <p>Autonomous and cooperative operations: Autonomous and cooperative operations are being explored as a way to improve efficiency and reduce the risk of accidents in the maritime industry.</p>	<p>Hydrogen-based shore power systems</p> <p>CO2 capture</p> <p>Hybrid ships</p> <p>Fleet optimization</p> <p>Decarbonization</p> <p>Integration of advanced technologies</p> <p>Sustainable materials</p> <p>Advanced propulsion systems and marine engines</p>
GEA	GEA marine and naval solutions	Increase of demand for naval vessels, transition from mission-specific platforms to multirole functionality for surface and subsurface vessels, environmentally friendly power, electric propulsion, integration of ad-	<p>Hydrogen-based shore power systems: Hydrogen-based shore power systems are being explored as a way to reduce emissions in the maritime industry.</p>	<p>Net-zero carbon solutions</p> <p>Fuel alternatives and reduced fuel use</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		vanced technologies, AI, robotics, digitalization in design and operations, emergin markets in middle east and Africa	<p>CO2 capture: CO2 capture is being explored as a way to reduce emissions in the maritime industry.</p> <p>Hybrid ships: Hybrid ships are being explored as a way to reduce emissions and improve efficiency in the maritime industry.</p>	
Kongsberg Maritime	Kongsberg Maritime	integrated systems for energy and operations, unique vessel concepts for different types of vessels, fuel transition, fuel alternatives, reduced fuel use, platform for enabling vessels optimal operations	<p>Fleet optimization: Fleet optimization is a key aspect of the maritime industry, with a focus on improving efficiency and reducing costs.</p> <p>Decarbonization: Decarbonization is a key goal in the maritime industry, with a focus on reducing greenhouse gas emissions through the use of alternative fuels and advanced technologies.</p>	
Caterpillar	Caterpillar Caterpillar	Sustainable materials, environmental impact, recuced and renewable materials, hybrid and electric propulsion, robotics, automation	<p>Integration of advanced technologies: The integration of advanced technologies such as AI, robotics, and</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
Rolls Royce marine	Marine Rolls-Royce	Advanced propulsion systems and marine engines, autonomous shipping, net-zero carbon solutions, sustainable fuels	<p>digitalization is being explored as a way to improve efficiency and reduce costs in the maritime industry.</p> <p>Sustainable materials: Sustainable materials such as recycled and renewable materials are being explored as a way to reduce environmental impact in the maritime industry.</p> <p>Advanced propulsion systems and marine engines: Advanced propulsion systems and marine engines are being explored as a way to improve efficiency and reduce emissions in the maritime industry.</p> <p>Net-zero carbon solutions: Net-zero carbon solutions are being explored as a way to reduce emissions and improve sustainability in the maritime industry.</p> <p>Fuel alternatives and reduced fuel use: Fuel alternatives and reduced fuel use are being explored as ways</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			to reduce emissions and improve efficiency in the maritime industry.	
Group 8: Ship design companies				
Salt Ship Design	Salt Ship Design - Home	innovation, advanced maritime technology, offshore wind, flexibility, collaboration in shipbuilding, zero emissions, alternative fuels, digitalization, big data analytics, optimization of ship design and operations	<p>Innovation: Innovation is a key aspect of the maritime industry, with a focus on developing new technologies and processes to improve performance and reduce environmental impact.</p> <p>Advanced maritime technology: Advanced maritime technology is being explored as a way to improve efficiency and reduce environmental impact in the maritime industry.</p>	<p>Innovation</p> <p>Advanced maritime technology</p> <p>Offshore wind</p> <p>Flexibility</p> <p>Collaboration in shipbuilding</p> <p>Zero emissions</p> <p>Alternative fuels</p> <p>Digitalization</p>
Ghenova	Ghenova Ingeniería – GHENOVA es una empresa de ingeniería que trabaja tanto a nivel nacional	increasing demand for naval vessels, from mission-specific to multirole, dominance of Asian shipbuilding	<p>Offshore wind: Offshore wind is a growing sector in the maritime industry, with a focus on supporting renewable energy.</p> <p>Flexibility: Flexibility is an important aspect of the maritime industry, particularly in relation to adapting to changing regulations and market demands.</p> <p>Collaboration in shipbuilding: Collaboration between different stakeholders in the shipbuilding industry is</p>	<p>Optimization of performance and safety</p> <p>Increasing demand for naval vessels</p> <p>Energy efficiency</p> <p>Environmentally friendly ships</p> <p>Eco-friendly ships</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
	como internacional ofreciendo servicios multidisciplinarios de ingeniería y consultoría.		<p>being explored as a way to improve efficiency and reduce costs.</p> <p>Zero emissions: Zero emissions is a key goal in the maritime industry, with a focus on reducing environmental impact through the use of alternative fuels and advanced technologies.</p> <p>Alternative fuels: Alternative fuels such as hydrogen and ammonia are being explored as ways to reduce emissions and improve sustainability in the maritime industry.</p>	<p>Sustainability</p> <p>Specialized vessels</p>
Knud E. Hansen	Customized vessel design - KNUD E. HANSEN (knudehansen.com)	energy efficiency, environment friendly, adaptable to changing regulations and markets, offshore wind, digital technologies, data analytics, optimized performance, safety, collaboration, expertise	<p>Digitalization: Digitalization is being used in the maritime industry to improve efficiency and reduce costs through the use of big data analytics and optimization of ship design and operations.</p> <p>Optimization of performance and safety: Optimization of performance and safety is a key focus in the maritime industry, particularly in relation to improving efficiency and reducing the risk of accidents.</p>	
VARD Marine	Vard Marine Inc. Naval Architects & Marine Engineers	Zero emissions, smart vessels, autonomous systems, digitalization, data analytics,	<p>Increasing demand for naval vessels: There is an increasing demand for naval vessels, particularly with a</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		optimization of performance, safety, specialized vessels	transition from mission-specific to multirole functionality and a dominance of Asian shipbuilding. Energy efficiency: Energy efficiency is a key focus in the maritime industry, particularly in relation to reducing greenhouse gas emissions and improving sustainability.	
C-Job	A Sustainable Maritime Industry Within One Generation - C-Job Naval Architects	Sustainability, greenhouse emissions, energy efficiency, robotics, automation, eco-friendly ships, innovation, increase of demand for navy vessels	<p>Environmentally friendly ships: Environmentally friendly ships are being explored as a way to reduce environmental impact in the maritime industry through the use of robotics, automation, and innovation.</p> <p>Eco-friendly ships: Eco-friendly ships are being explored as a way to reduce environmental impact in the maritime industry through the use of innovation and advanced technologies.</p> <p>Sustainability: Sustainability is a key focus in the maritime industry, with a focus on reducing environmental impact and improving the sustainable use of resources.</p> <p>Specialized vessels: Specialized vessels are being ex-</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			plored as a way to improve efficiency and reduce environmental impact in the maritime industry through the use of advanced technologies and innovation.	
Group 9: R&D projects				
	https://nextgen.imo.org/	<p>Developing low-carbon or zero-carbon fuels and propulsion systems</p> <p>Improving energy efficiency and reducing emissions from existing ships</p> <p>Enhancing port infrastructure and logistics to support green shipping</p>	<p>Green Technologies: Developing and implementing clean technologies for ships, including alternative fuels, energy-efficient ship designs, and green propulsion systems to reduce greenhouse gas emissions and other pollutants.</p> <p>Energy Efficiency: Promoting energy-efficient practices across the maritime industry, such as optimizing ship operations, improving vessel routing, and using advanced materials to reduce weight and fuel consumption.</p> <p>Digitalization and Innovation: Encouraging the adoption of digital technologies, such as IoT, AI, and data analytics, to improve ship performance, optimize maintenance, and enhance safety.</p> <p>Sustainable Ports and Infrastructure: Promoting the de-</p>	<p>Green Technologies</p> <p>Energy Efficiency</p> <p>Digitalization and Innovation</p> <p>Sustainable ports and architecture</p> <p>Regulatory Framework</p> <p>Collaboration and knowledge sharing</p> <p>Education and capacity building</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			<p>velopment of sustainable port infrastructure and operations, including the use of renewable energy sources, waste management, and improved port logistics.</p> <p>Regulatory Framework: Supporting the development of a comprehensive regulatory framework that encourages sustainable shipping practices and addresses the environmental challenges faced by the maritime industry.</p> <p>Collaboration and Knowledge Sharing: Facilitating collaboration and knowledge exchange among stakeholders, including governments, shipping companies, technology providers, and research institutions, to accelerate the transition towards a sustainable maritime industry.</p> <p>Education and Capacity Building: Enhancing the skills and expertise of maritime professionals to better address the challenges of sustainable shipping, through education and training programs, as well as sharing best practices and innovative solutions.</p>	
Group 10: Startups				

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
		<p>Building capacity and raising awareness on maritime decarbonisation</p> <p>autonomous vessels</p> <p>green technologies</p> <p>digital platforms</p> <p>modular design</p> <p>smart maintenance</p>	<p>Green Technologies: Many startups are concentrating on developing environmentally-friendly technologies for the maritime sector. This includes alternative fuels, such as biofuels, hydrogen, and ammonia, as well as hybrid and electric propulsion systems, to reduce emissions and minimize environmental impact.</p> <p>Autonomous Vessels: Startups are exploring autonomous navigation technologies, which can lead to the development of self-navigating ships. These technologies involve advanced sensors, AI, and communication systems that allow vessels to operate without human intervention, improving efficiency and safety.</p> <p>Digitalization and IoT: Digitalization is a key focus for startups in the shipbuilding industry. They are developing solutions that integrate IoT devices, data analytics, and machine learning to optimize ship design, maintenance, and operations. This helps in monitoring vessel performance in real-time, enhancing decision-making, and reducing costs.</p> <p>Advanced Materials and 3D Printing: Startups are</p>	<p>Green Technologies</p> <p>Autonomous vessels</p> <p>Digitalization and IoT</p> <p>Advanced materials and 3D printing</p> <p>Robotics and automation</p> <p>Cybersecurity</p> <p>Virtual reality</p> <p>Port and supply chain optimization</p>

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			<p>working on new materials and 3D printing techniques to improve ship design and construction. Advanced materials, such as composites and lightweight alloys, can reduce weight and improve fuel efficiency, while 3D printing can be used to manufacture complex components faster and more cost-effectively.</p> <p>Robotics and Automation: The application of robotics and automation is another focus area for startups in shipbuilding. They are developing solutions that automate various stages of ship construction, inspection, and maintenance, leading to increased efficiency, reduced labor costs, and improved safety.</p> <p>Cybersecurity: As ships become more connected and reliant on digital technologies, startups are developing innovative cybersecurity solutions to protect vessels and their critical systems from cyber threats.</p> <p>Virtual Reality (VR) and Augmented Reality (AR): Some startups are focusing on the use of VR and AR in shipbuilding for design, training, and maintenance</p>	

Source	Website	Signals	Summary by ChatGPT4	Summary of main topics by ChatGPT4 for the group
			<p>purposes. These technologies can help visualize complex ship designs, train employees on new processes, and provide remote assistance during maintenance activities.</p> <p>Port and Supply Chain Optimization: Startups are working on solutions to optimize port operations and global supply chains. This includes technologies for smart ports, such as automated container handling and tracking systems, as well as tools for better planning and routing of maritime transportation.</p>	

Appendix 2. Data grouped by clusters, topics and relevance.

Clusters approach	Grouping by topics	Grouping by relevance
Cluster 1: Digitalization and Technology	Group 1: Digitalization and Innovation	Group 1: Highly Relevant
Digitalization	Digitalization	Digitalization
Smart shipping	Smart shipping	Sustainability
New technologies	New technologies	Decarbonization
Automation	Automation	Climate change
Digital transformation	Advanced technology	Alternative fuels
Data-driven solutions	Digital transformation	Automation
Digital platform for ship design and classification	Shipyard 4.0	Environmental regulations
Digital twins	Data-driven solutions	New technologies
Shipyard 4.0	Digital twins	Renewable energy
Advanced technology	Immersive technology	Smart shipping
Additive manufacturing	Additive manufacturing	Market demands
Immersive technology	Cloud computing and data sharing platforms	
Integration of design, production, and after-sales service	Integration of design, production, and after-sales service	Group 2: Moderately Relevant
	Advanced materials	

Clusters approach	Grouping by topics	Grouping by relevance
Cluster 2: Sustainability and Environmental Regulations	Operational agility	Integration of design, production, and after-sales service
	Modularity	Shipyard 4.0
Sustainability	Paperless	Ocean economy
Carbon neutrality and energy efficiency regulations	Technology development and intelligence upgrade	Workforce
Decarbonization		Regulations
Climate change	Group 2: Sustainability and Environment	Advanced materials
Green solutions		Mass customization
Renewable energy	Carbon neutrality and energy efficiency regulations	Maritime defense and security
Environmental regulations	Sustainability	Developing navy
Green growth	Decarbonization	Offshore activities
Reducing CO2 emissions	Climate change	Supply chain disruptions
Carbon capture technology	Green solutions	Cyber governance and security
Sustainable shipping	Renewable energy	Risk assessment for maritime scenarios
Sustainable materials	Environmental regulations	
Environmentally friendly ships	Green growth	Group 3: Emerging or Niche Relevance

Clusters approach	Grouping by topics	Grouping by relevance
Eco-friendly ships	Low carbon emissions	
	Diversification	Biotechnology
Cluster 3: Alternative Fuels and Energy Sources	Reducing CO2 emissions	Technological synergy
	Carbon capture technology	Digital twins
Alternative fuels	Sustainable shipping	Immersive technology
LNG	Sustainable materials	Additive manufacturing
Renewable fuels	Environmentally friendly ships	Autonomous surface ships systems and business models
Ammonia fuel	Eco-friendly ships	Open innovation and cooperation
Hydrogen-based shore power systems	Energy efficiency	Energy islands and floating airports
Offshore wind installations		Remote surveying
Offshore wind industry	Group 3: Alternative Fuels and Energy Sources	Carbon capture technology
Offshore activities		Sustainable materials
Energy islands and floating airports	LNG	Hydrogen-based shore power systems
	Renewable fuels	Net-zero carbon solutions
Cluster 4: Maritime Industry Challenges	Ammonia fuel	Specialized vessels
	Offshore wind industry	
Market demands	Offshore activities	

Clusters approach	Grouping by topics	Grouping by relevance
Regulations	Offshore wind installations	
Globalization	Hydrogen-based shore power systems	
Sustainability challenges	Energy islands and floating airports	
Personalization of services		
Green fleet	Group 4: Market and Business Factors	
Market fluctuations		
Uncertainty in regulations	Market demands	
Excess capacity	Regulations	
Supply chain disruptions	European leadership and competitiveness	
Conversion projects	Ocean economy	
Complex offshore structures	Workforce	
Labor shortage and competition with China	Global value chain and ship finance practices	
	Mass customization	
Cluster 5: Naval and Defense	Ship finance	
	Supply chain disruptions	
Maritime defence and security	Conversion projects	
Developing navy	Complex offshore structures	
Development of naval vessels	Labor shortage and competition with China	

Clusters approach	Grouping by topics	Grouping by relevance
Navy ships		
Increasing demand for naval vessels	Group 5: Naval and Defense	
Cluster 6: Cooperation and Business Models	Maritime defence and security	
	Developing navy	
European leadership and competitiveness	Navy ships	
Ocean economy	Development of naval vessels	
Workforce	Increasing demand for naval vessels	
Ship finance		
Global value chain and ship finance practices	Group 6: Cooperation, Security, and Risk Management	
Mass customization		
Open innovation and cooperation	Cyber governance and security	
Collaborative business	Risk assessment for maritime scenarios	
Autonomous surface ships systems and business models	Remote surveying	
	Collaborative business	
Cluster 7: Security and Risk Management	Autonomous surface ships systems and business models	
	Open innovation and cooperation	
Cyber governance and security		

Clusters approach	Grouping by topics	Grouping by relevance
Risk assessment for maritime scenarios	Group 7: Specialized Technologies and Solutions	
Remote surveying		
	Biotechnology	
Cluster 8: Innovative Solutions and Concepts	Technological synergy	
	Advanced maritime technology	
Innovation	Smart logistics	
Biotechnology	Green technology	
Technological synergy	Enhanced safety	
Advanced maritime technology	Fleet optimization	
Shipyards 4.0	Electric propulsion	
Advanced materials	Net-zero carbon solutions	
Operational agility	Fuel alternatives and reduced fuel use	
Modularity	Specialized vessels	
Paperless		
Enhanced safety		
Smart logistics		
Green technology		
Clean, smart, and safe shipping		
Specialized vessels		